21st CENTURY SCIENCE & TECHNOLOGY

SPRING 1997

$3.50/IN CANADA $4.50

INSIDE FRENCH GREENPEACE, p. 74

Eurasia's Technology Bridge To the 21st Century

- New Harmonies in Planetary Orbits
- Ice Core Data Show No CO_2 Increase
- 'Mars Direct'—Low Fare, Buyer Beware

71>
0 74470 74216 6

Reach for the stars with

21st CENTURY
SCIENCE & TECHNOLOGY

SUBSCRIPTIONS

U.S.—6 issues for $25
Foreign—6 issues for $50

BOOKS

The Holes in the Ozone Scare: The Scientific Evidence That the Sky Isn't Falling
by Rogelio A. Maduro and Ralf Schauerhammer
$15 each, plus $3 shipping OR $10 postpaid with a subscription

How We Got to the Moon: The Story of the German Space Pioneers
by Marsha Freeman
$15 each, plus $3 shipping OR $10 postpaid with a subscription

Global Warming: The Rest of the Story
by Dr. Gerd Weber
$11 each, postpaid OR $8 postpaid with a subscription

Hermann Oberth: The Father of Space Flight
by Boris V. Rauschenbach
$15 each, plus $3 shipping OR $12 postpaid with a subscription

Video on the ozone hoax
"Fair Skin—Stay In"
1-hour documentary produced by the Belgian television network BRTN. VHS, English narration, some subtitles.
$20 each, plus $3 shipping

Special offer: Get a subscription to *21st Century Science & Technology* magazine and save up to $8 per book!

Give *21st Century* subscriptions and gifts

ORDER FORM

Enclosed is $_____for:

_____6 issues/ U.S.— $25
_____12 issues/ U.S.—$48
_____6 issues/ foreign airmail—$50
_____12 issues/ foreign—$98

_____$10 for *The Holes in the Ozone Scare* with a subscription
_____$18 postpaid for *The Holes in the Ozone Scare*
_____$10 for *How We Got to the Moon* with a subscription
_____$18 postpaid for *How We Got to the Moon*
_____$8 for *Global Warming* with a subscription
_____$11 postpaid for *Global Warming*
_____$12 for *Hermann Oberth* with a subscription
_____$18 postpaid for *Hermann Oberth*
_____$23 postpaid for ozone video

Please print or type name and address of gift recipients on a separate paper. Gift cards are available.
Note: Back issues are available at $5 each ($6 foreign)

Name _____

Address _____

City _____ State _____ Zip _____

Daytime telephone (_____)_____

Send check or money order (U.S. currency only) to:
21st Century, P.O. Box 16285, Washington, D.C. 20041.

21st CENTURY
SCIENCE & TECHNOLOGY

Vol. 10, No. 1 Spring 1997

Features

Thomas Jukes reviews the history of pesticide scares and muses on the "idyllic" past when insects and disease ruled daily life (page 7).

News

Departments

On the cover: The Yangpu Bridge across the Yangtze River, one of the world's longest suspension bridges. Photo by Teng Jinfu, Shanghai Foundation Engineering Company. Cover design by Rosemary Moak.

21st Century Science & Technology (ISSN 0895-6820) is published 4 times a year in 1996, every third month, by 21st Century Science Associates, 60 Sycolin Road, Suite 203, Leesburg, Va. 20175. Tel. (703) 777-7473.

Address all correspondence to **21st Century**, P.O. Box 16285, Washington, D.C. 20041.

Second-class postage is paid at Leesburg, Va. and additional mailing offices.

Dedicated to providing accurate and comprehensive information on advanced technologies and science policy, **21st Century** is committed to restoring American scientific and technological leadership. **21st Century** covers the frontiers of science, focusing on the self-developing qualities of the physical universe in such areas as plasma physics—the basis for fusion power—as well as biology and microphysics, and including groundbreaking studies of the historical development of science and technology. Opinions expressed in articles are not necessarily those of 21st Century Science Associates or the scientific advisory board.

Subscriptions by mail are $25 for 6 issues or $48 for 12 issues in the USA and Canada. Airmail subscriptions to other countries are $50 for 6 issues. Back issues are $5 each ($6 foreign). Payments must be in U.S. currency.

POSTMASTER: Send address changes to 21st Century, P.O. Box 16285, Washington, D.C. 20041-0285.

Printed in the USA ISSN 0895-6820

Global Warming, Globaloney, And Global Development

Over the next few months, representatives of 150 nations will be meeting in Bonn, Germany, to work out the final wording of regulations intended to deindustrialize and depopulate the world—in the name of protecting the planet from industrial carbon dioxide emissions, which supposedly cause global warming. The final, binding climate treaty regulations will be determined in December 1997 in Kyoto, Japan.

There is no scientific basis for the global warming scare, as we have documented. Climate change is driven by the long-term astronomical cycles that are determined by the periodicities in the eccentricity, tilt, and precession of the Earth's orbit. Such cycles are measured in tens or hundreds of thousands of years. In this perspective, which corresponds to reality, the daily or yearly, or decade-long fluctuations in temperature are not of importance. The reality is that the planet is leaving the warmer interglacial period and entering, or may have already entered, a New Ice Age.[1]

Given this reality, proposals for curtailing carbon dioxide emissions have no bearing on climate; the intended effect of the so-called remediation is social and economic, as the proponents of such globaloney admit. Yet, even those who attack the treaty for its bogus science fall into the globaloney trap.

The position of the AFL-CIO illustrates this point. The union issued a statement Feb. 20 noting, correctly, that "carbon taxes or equivalent carbon emission trading programs, will raise significantly electricity and other energy prices to consumers." But the statement begins from the position that developing nations must not be exempt from the emission reduction requirements. In other words, the unnecessary pain must be shared "fairly."

Enter the Land-Bridge

The global warming scare scenario must be opposed, not with rhetoric or proposals to mitigate the alleged worst effects, but with a bold counter-proposal for global development. The key to this, as we move into the 21st century, is the Eurasian Land-Bridge, a Great Project to lift the 4.5 billion people who live on the Eurasian landmass out of poverty—and in the process, to bring life to the dying industrial economies of the West.

The Land-Bridge—a continent-wide rail link that spans Eurasia, from the port of Lianyungang on China's east coast, to the port of Rotterdam in Western Europe—has already captured the imagination of the Chinese and other Eurasian governments, who see it as the only alternative to poverty and endless conflict in the region. As we have reported,[2] the new industrial corridors envisioned along the Old Silk Road will be the cities and industrial centers of tomorrow, bringing this three-quarters of the world's population out of the so-called Third World and into the 21st century. For the United States, this could be a bonanza of technology development and trade, that would raise our post-industrial economy out of the dumps.

There is a rich history behind the Eurasian Land-Bridge idea. In the 1860s, the American System economists associated with President Lincoln, planned continent-spanning railroads, in alliance with Germany, Russia, and China, for the purpose of developing the landlocked, resource-rich interior of Eurasia. Later, just after World War I, Dr. Sun Yat-sen, the first President of the Republic of China, circulated *The International Development of China,* in which he laid out a bold program for rail transport, waterways, and industrial development, that would have integrated an industrialized China into a community of sovereign nations throughout Eurasia.

Dr. Sun was linked in his ideas to the American System, through his study of Friedrich List's *National System of Political Economy,* which he translated

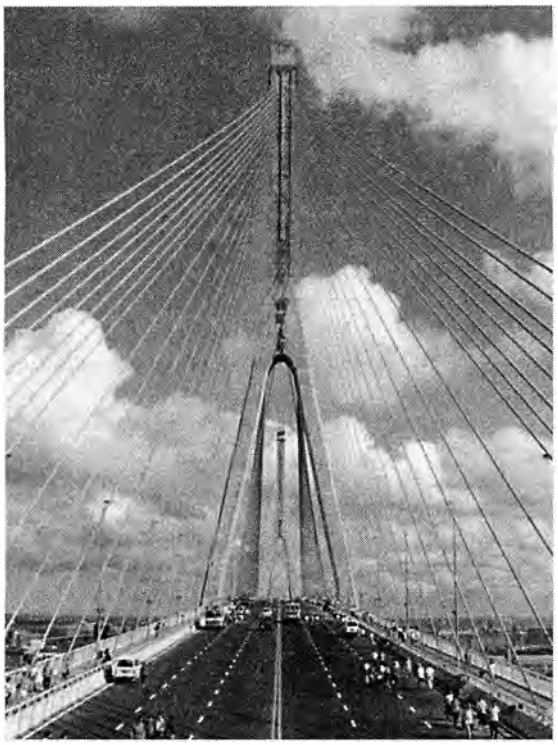
into Chinese.[3] List had worked closely with his American co-thinkers, the Hamiltonian faction, Mathew and Henry Carey, and others who were associated with Lincoln's program for industrialization.

In turn, this faction was based on the 17th century work of scientist-philosopher Gottfried Wilhelm Leibniz. Leibniz saw the importance of including China as an active member of the community of nations, based on the congruence between China's Confucian philosophy and Christianity. In the preface to his 1697 work, *Novissima Sinica,* Leibniz wrote: "Through a unique combination of destiny, it has occurred that the highest cultural goods of the human species are today located on the two extreme poles of our continent, that is, Europe and China. . . . And, furthermore, the highest Providence has caused, through a fortunate turn, that, in stretching out the arms to each other, the most highly educated and at the same time most distant people eventually bring everything, which lies in between them, to a way of life which is more in correspondence to reason."

Most recently, in this tradition, economist Lyndon LaRouche proposed in 1989, in view of the imminent collapse of the economies of the Soviet bloc, an industrial development project for what he called the "Productive Triangle," bounded by Vienna, Berlin, and Paris. His idea was to make this region, with its density of industrial, scientific, and technological resources, into an "engine" for the industrial development of the collapsed East, corridors of infrastructure, energy, and transportation— development arms—that would stretch out in all directions, to mobilize the economic potential of this densely populated area. Later, LaRouche expanded the Triangle proposal to include an integrated development program for Eurasia, with "development arms" reaching to the Americas and Africa. The idea then took on a life of its own.

The Geopolitical Enemy

The Land-Bridge proponents today face the same enemy that stopped the alliance of the Leibnizians and Confucians, stopped the Berlin-Baghdad railroad, and stopped Dr. Sun's "Grand Design": the European oligarchy, which preferred to embroil the Eurasian nations in wars, thereby preventing any challenge to their control of the world economy. For the colonialists, the idea of an integrated *industrial* economy in Eurasia has been a nightmare for centuries. Dr. Sun very accurately characterized the geopolitical strategy of the British Empire at the time of World War I.



"The key policy of England," Sun wrote, "is to attack the strongest country with the help of the weaker countries, and join the weakened enemy in checking the growth of a third country. This British foreign policy has remained essentially unchanged for two centuries. When England befriends another country, the purpose is not to maintain a cordial friendship for the sake of friendship, but to utilized that country as a tool to fight a third country. When an enemy has been shorn of his power, he turns into a friend, and the friend who has become strong, into an enemy. England always remains in a commanding position; she makes other countries fight her wars and she herself reaps the fruits of victory. She has been doing so for hundreds of years. . . ."

That Empire geopolitics succeeded in sabotaging previous plans for Eurasian development, especially since World War I, has meant nothing but misery—disease, poverty, starvation, war, and terrorism—for three-quarters of the world's population. Today, the people and nations who would gain most from the Land-Bridge project are under attack. Tribal and ethnic conflicts, border disputes, environmentalist agitation against development projects, the strangling economic reforms of the International Monetary Fund, are just some of the operations unleashed to try to prevent the Land-Bridge from becoming a reality.

Yet, just as the Berlin Wall tumbled down in 1989, when many had thought it to be impossible, so it is possible to begin to institutionalize the Eurasian Land-Bridge. Indeed, led by China, whose development conference on the Land-Bridge we reported on in Winter 1997-1998 issue, several nations of the region have already signed or expressed interest in agreements to complete sections of the project, and many more support the development principle behind it. Early this year, several developing nations met in Istanbul and agreed to create a new economic and political union to promote development, known as the Developing 8 or D-8, for example.

In the coming period of unprecedented economic and financial crises, as old alliances founder and crumble, there is a wonderful, exciting alternative to devolution and destruction: Embark on the Great Projects of the 21st century—the Eurasian Land-Bridge and the colonization of Mars.

Notes

1. See, for example, Hugh Ellsaesser, "Setting the 10,000-Year Climate Record Straight," *21st Century*, Winter 1991, p. 52; Laurence Hecht, "The Coming or Present Ice Age," *21st Century*, Winter 1993-1994, p. 22; Robert Stevenson, "An Oceanographer Looks at the Non-Science of Global Warming," *21st Century*, Winter 1996-1997, p. 51; and this issue's feature by Zbigniew Jaworowski, p. 42.
2. See Jonathan Tennenbaum, "China Says 'Yes!' to Progress" and "High-Tech Development Corridors: Locomotive for Eurasian Development," *21st Century*, Winter 1996-1997, pp. 7-15.
3. List's *Outlines of American Political Economy*, written in 1827, was republished in English in 1996 by Böttiger Verlags-GmbH, Wiesbaden, Germany (349 pp., paperback $19.20).

Letters

Ionizing Radiation When Life Began

To the Editor:

Dr. T.D. Luckey more than many others contributed to the recent acceptance of radiation hormesis as scientific fact, and he ought to be congratulated for the excellent paper in *21st Century* (Fall 1996, p. 12).

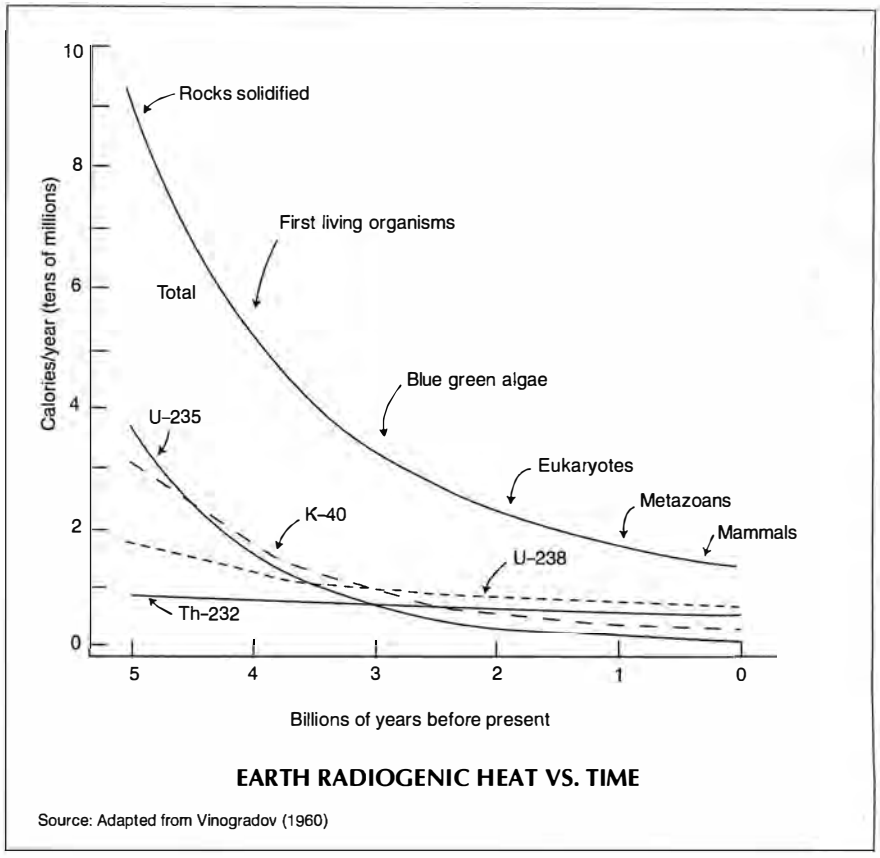
A minor problem in this paper needs elucidation. When life began some 3.5 billion years ago, the average level of ionizing radiation was probably not 10 times the current level, but only about 3 times higher. The radiation background is composed of cosmic and terrestrial components. Cosmic radiation and radiation from cosmogenic radionuclides are rather stable, but terrestrial radiation is slowly decreasing, due to decay of natural radionuclides.

This can be seen in the table below, in which, as an example, are given present average natural doses to man, which include both external and internal irradiation. The source for the tables is UNSCEAR (United Nations Scientific Commission on the Effects of Atmospheric Radiation), 1982 and 1993.

From the table it appears that, for example, U-238 accounted for less than 30 percent of the 2.89-fold higher than now radiation 3.5 billion years ago. For radiation to be 10-fold higher than it is now, as assumed by Dr. Luckey, U-238 would contribute only 8.3 percent. Recent estimates of radiogenic heat show that 1 square meter of the surface of the primitive Earth received from decaying natural radionuclides 117 kilojoules per year, which is about 3.5 times more than the corresponding value of 33.4 kilojoules per year for the present-day Earth (I.G. Draganić et al., *Radiation and Radioactivity on Earth and Beyond,* CRC Press, Boca Raton, 1993).

Today, as billions of years ago, there were places in the land and sea with much higher than average radiation. One type of such places in the past were the environments of the natural nuclear reactors, like those found in 1972 in Oklo (Gabon, Africa). About 2 billion years ago, at least six nuclear reactors were in operation at this site for about a million years. The radiation dose rate at such reactors was calculated to be more than 47 grays per hour (Draganić et al., 1993). It was estimated that about 100 million natural reactor sites of the Oklo type have been active in the past history of our planet. They might perhaps have contributed to the dawn of life.

Prof. Zbigniew Jaworowski
Central Laboratory for Radiological Protection, Warsaw, Poland



EARTH RADIOGENIC HEAT VS. TIME

Source: Adapted from Vinogradov (1960)

Source of radiation	Half-life	Present dose Microsieverts	Present dose %	% of present dose, 3.5 billion years ago
Cosmic radiation and cosmogenic radionuclides		316	15.5	15.5
K-40	1.3×10^9 years	300	14.7	89.1
Rb-87	47×10^9 years	6	0.3	~0.3
Th-232 series	14×10^9 years	326	15.9	18.2
U-238 series	4.5×10^9 years	1,044	51.0	82.9
U-235 series	0.7×10^9 years	53	2.6	83.2
Total		2,045	100	289

Author Luckey Replies

The comment of Dr. Jaworowski is correct for five radionuclides. His data agree with my calculations following the original suggestion of Vinogradov in 1960. (See figure above.) However, there

are 10 to 15 more radionuclides which may have contributed to background radiation when life began about 4 billion years ago. Hopefully, these will be evaluated before the 21st century.

The comment did note the probable increased concentration of U-235 in the crust of the early Earth. This would account for much of the increase toward a 10-fold increased background radiation 4 billion years ago.

T.D. Luckey

Greetings from Göttingen On Gauss-Weber Article

To the Editor:

With this letter I wish to convey my best wishes to the author of the article on the "1845 Gauss-Weber correspondence in the Fall 1996 issue of *21st Century*. Mr. Laurence Hecht has written a very instructive and for me almost unimaginably precisely assembled report about the former director of our institute. Perhaps he might be interested in the article about the Weber law by Prof. A. Pinski in Moscow, which to my knowledge has not been published. I would be very interested to know what Mr. Hecht thinks about this exposition. . . . Yesterday I received a copy of the book by Andre Koch Torres Assis (Kluwer Academic Publishers, 1994) on Weber's electrodynamics.

I am extremely happy about the interest in our great forefathers.

With friendly greetings, especially to Mr. Hecht!

Prof. Dr. Gustav Beuermann
First Physical Institute
Göttingen University

Ambartsumian and Tectonics

To the Editor:

In your memorial to astronomer Victor Ambartsumian, David Cherry reported (Fall 1996, p. 51) that Ambartsumian was critical of the "Cambridge School," led by Sir James Jeans, Sir Arthur Eddington, and others, because they maintain (as I understand it) Earth maintains thermal equilibrium, and Earth is running down.

I am greatly interested in the comment, because, in geology, plate tectonics proponents hold that seafloor subsidence takes place owing to lithospheric (thermal) cooling. I do not really believe lithospheric cooling is the correct explanation. For one thing, the seafloor often is uplifted, and cooling does not explain this, or other, tectonic vertical movements. The originator of the lithospheric cooling explanation is from England, so he probably is part of the Cambridge School, as are most English geologists.

Can you provide me with additional information on how the same criticism might be applied to geology (plate tectonics)?

Richard D. Terry, Ph.D.
San Clemente, Calif.

The Author Replies

The school of astrophysical thought emanating from Cambridge University maintains that the *universe* is running down to thermal equilibrium. It does not assert that the Earth maintains thermal equilibrium or that the Earth is running down. And Ambartsumian, for his part, did not discuss the evolution of the Earth, as far as I know.

I was recently surprised to discover that, for decades, there has been a minority of geologists—scattered over three continents—who marshal evidence in favor of the idea that the Earth is expanding. If it were expanding unevenly, might this not cause tectonic vertical movements?

There are a dozen papers on the expansion thesis in *Frontiers of Fundamental Physics,* edited by Michele Barone and Franco Selleri (New York: Plenum Press, 1994). If read critically, they might be of some help.

A First-hand Report On Antarctica

To the Editor:

In November and December 1996, I travelled to Chilean and Argentinian Patagonia and Tierra del Fuego. I explored the forest around Ushuaia (the southernmost city in the world), the environment in Parque Nacional Los Glaciares, and those near Punta Arenas, at the southern tip of Chile.

I was interested in investigating the

Courtesy of J. Gordon Edwards

Mt. FitzRoy in Glacier National Park, Patagonia, Argentina.

allegations that have been published by pseudo-environmentalists, specifically their claim that because of a "hole" in the Antarctic ozone layer, there has been such a great increase in the amount of ultraviolet (UV) light reaching the Earth in Patagonia that: (1) skin cancer has recently become a more common ailment there, especially among sun-bathers; (2) great numbers of sheep have been blinded; and (3) entire forests are being killed.

Almost everyone I saw down there was wearing woolen clothing beneath their parkas, and nobody was sunbathing. An earlier Reuter wire service story reported an Argentine government advisory against sunbathing between 10:00 A.M. and 4:00 P.M., but Willy Rudloff's 1992 article in *World Climates* stated that the October average during the sun-tanning period of the day is approximately 46 degrees, and that with average winds of 15 mph, the normal wind-chill factor is 26 degrees Fahrenheit.

When I spoke with residents and doctors, I found no confirmation that UV has caused skin cancer of the curable type *or* the potentially deadly melanoma.

When I questioned "natives" regarding Al Gore's frightening statement about the widespread blinding of sheep by UV down there (in his *Earth in the Balance* book), they did not know about any such cases. We saw hundreds of healthy, active sheep along the roads, and all of them ran much faster than they could have if they were suffering from the alleged impaired vision.

North of Puerto Natales, in Chile, we saw many dead trees along the road, but they were the remains of very old trees, and were most noticeable in areas where water was at or near the surface of the soil. These trees are notoriously sensitive to excess water around their roots. Many hillside trees that were still alive were heavily invested with parasitic plants, especially *Usnia* lichens and *Myzodendron* foliage, both of which are known causes of tree deaths. Very few of the younger trees bore any of those parasitic growths.

Further south, much closer to the famous "hole in the ozone layer," it was rare to see recently killed trees. From the mountains and ridges near Ushuaia I photographed great expanses of healthy forests below me. I also walked through the forests for many hours without finding any trees that had recently died. My conclusion is that the pseudo-environmentalists misspoke about the alleged effects of ultraviolet light on the southern forests.

Incidently, there are only five species of trees in those southern forests, and three of them are kinds of beech. The Evergreen Beech or Cihue *(Nothofagus betuloides)* are the largest. The Lenga, or High Beech *(Nothofagus pumilio)* inhabit valley floors and relatively warm sea coasts. The Antarctic Beech or Nire *(Nothofagus antarcticus)* are widespread deciduous trees that thrive in the valleys, but also form short dense thickets high on the mountainsides. The Cinnamon Tree or Canelo *(Drimus winter)* was named for John Winter, Drake's captain in 1578. When they entered the Straits of Magellan, Winter urged the sailors to chew the bark or make it into tea, which helped prevent scurvy. The Pickwood, or Lena dura *(Maytenus magellanica)* are fragile, not over 10 feet tall, and were primarily used for firewood by the native Indians.

Dr. J. Gordon Edwards
Professor Emeritus
Biology Department
San Jose State University
San Jose, Calif.

Guaranteeing a Future By Colonizing Space

To the Editor:

Lyndon H. LaRouche, Jr., a scientist and economist, and I, a retired machinist, sure come from very different directions, but end up with pretty much the same conclusions. One is that Malthusianism is one of the most dangerous ideas. . . .

Only harnessing fusion and colonizing space will guarantee a future for humanity and will make any war look ridiculous. Why would anybody want to fight, if there is enough of everything for everybody? Also, colonizing space is a big enough undertaking for everybody to pitch in.

Continued on page 9

The Truth About Pesticides, or How to Survive the Perils of Living

by Thomas H. Jukes, Ph.D.

The science of toxicology was described succinctly in 1564 by Paracelsus, who said: "All things are poisonous, yet nothing is poisonous. The dose alone determines the poison." Failure to grasp this elementary principle leads to public fear of pesticide residues.

The current fear of pesticide residues in foods started in November 1959, and I was present at its creation. The leading publicist was Arthur Flemming, then Secretary of Health, Education, and Welfare, who had vice-presidential ambitions, but who settled for the presidency of University of Oregon. Mr. Flemming went on the radio to warn the public that if they ate cranberries at Thanksgiving, they were risking cancer. The "risk," he warned, was cancer of the thyroid, allegedly caused by the use of the chemical aminotriazole on the cranberries.

The origin of Mr. Flemming's fears was this: In 1959, scientists at American Cyanamid, led by Dr. Boyd Shaffer, found that a weed killer, aminotriazole, was a goitrogen—a substance that inhibits the entrance of iodine into the thyroid, thus causing its enlargement. If thyroid enlargement is acute and prolonged, it can lead to thyroid cancer in rats. (Goitrogens are present in many common foods, especially cabbage, soybeans, and turnips, but not in sufficient quantities to cause thyroid enlargement in human beings.)

When aminotriazole was fed at high levels to rats, the rats developed thyroid cancer. The scientists published these findings, and notified the U.S. government. Aminotriazole was used as a weed killer on several food crops and under strict regulations, including that its use should be stopped well before harvest, so that the residues would disappear. One of the crops was cranberries. A few growers disobeyed the rules, and traces of aminotriazole were detected in a few batches of cranberries.

Despite the fact that the experimental rats had received aminotriazole for many months, while human beings would be eating cranberries only at Thanksgiving time, Mr. Flemming saw his chance. He went on the radio in November 1959, warning the public not to eat Thanksgiving cranberries. There was a general panic. The cranberry growers dumped their product into trash pits. Refrigerated storehouses of cranberries were thrown open, and the fruit was thrown out.

There were no reported incidents of anyone being harmed by eating cranberries. The amounts of aminotriazole were very small, equivalent in effect to no more than that naturally found in cole slaw, and were present in only 0.34 percent of the crop. Nevertheless, the idea started that pesticide residues could cause cancer, and this idea has persisted ever since.

Capitalizing on Cranberries

An author of nature stories saw her opportunity to capitalize on the cranberry scare. Rachel Carson published an article called "Silent Spring" in *The New Yorker* magazine in 1962. This subsequently became her famous book.Carson's target was DDT, the substance that has saved more lives and prevented more diseases than any chemical in history, except perhaps the antibiotics.

Here is how Rachel Carson described the effects of DDT:

"A strange blight crept over the area and everything began to change. Some evil spell had settled on the community: mysterious maladies swept the flocks of chickens; the cattle and sheep sickened and died. Everywhere was a shadow of death. The farmers spoke of much illness among their families. In the town the doctors had become more and more puzzled by new kinds of sickness appearing among their patients. There had been several sudden and unexplained deaths, not only among adults but even among children, who would be stricken suddenly while at play and die within a few hours.

"There was a strange stillness. The few birds seen anywhere were moribund; they trembled violently and could not fly. It was a spring without voices. On the mornings that had once throbbed with the dawn chorus of robins, catbirds, doves, jays, wrens and scores of other bird voices there was now no sound, only silence lay over the fields and woods and marsh.

"In the gutters under the eaves and between the shingles of the roofs, a white granular powder still showed a few patches; some weeks before it had fallen like snow upon the roofs and the lawns, the fields and streams."

The white powder was, of course, DDT.

DDT—A Great Life-Saver

But Carson's eloquent words were lies. The fact is that for human beings, DDT, rather than killing children at play, was a major contributor to the population explosion by preventing malaria in infants.

Silent Spring says (page 118) that the American robin "seems to be on the verge of extinction." In 1963, one year after *Silent Spring,* Roger Tory Peterson said that the American robin is probably North America's number one bird. "Found from coast to coast it inhabits cities and forests alike and is one of the most abundant birds in the vast 3,000-mile belt of conifers stretching across Canada to Alaska."

The counts of most wild birds increased during the usage of DDT, and

---

Dr. Jukes is a professor at the Space Sciences Laboratory, the University of California, Berkeley.

one species, the red-winged blackbird, underwent a population explosion, perhaps because of the effects of DDT on avian malaria. Honeybees are resistant to DDT, but are rapidly killed by substitute insecticides such as parathion and carbaryl. Many fish are so tolerant of DDT that they develop enormously high tissue levels with no apparent ill effect, as in the case of Triana, Alabama, where DDT from a chemical production plant got into the river.

Furthermore, laying hens are resistant to DDT, and the hatchability of their eggs is unaffected when the hens receive 100 ppm (parts per million) DDT in their diet. Cattle and sheep are protected by DDT against disease-bearing lice, ticks, fleas, and blowflies. There is no record of pigs being harmed by DDT.

"For the first time in the history of the world," says *Silent Spring* (page 15), "every human being is now subjected to contact with dangerous chemicals, from the moment of conception until death."

This is *not* true. Every chemical is dangerous if the concentration is too high. Moreover, 99.9 percent of the chemicals humans ingest are natural. For example, 99.9 percent of the pesticides humans eat are natural pesticides produced by plants to kill off predators. About half of all natural chemicals tested at high dose, including natural pesticides, cause cancer in rodents. Risk assessment methods build in huge safety factors for synthetic chemicals, while natural chemicals are ignored. Current policy diverts enormous resources from important to unimportant risks. Yet, in spite of these lies, Rachel Carson is revered. It is a strange phenomenon that *Silent Spring* is accepted as gospel, without a critical reading. Apparently, many people are hypnotized by Rachel Carson's prose.

What Carson Deliberately Ignored

Raising the level of health through the use of DDT has resulted in better agricultural and industrial production. Much land has been reclaimed, new factories have been built, and more goods produced. There has been a significant decrease in workers' absences in countries where malaria has been controlled, and this has enabled higher earnings, with an increase in economic well-being for both individuals and the community.

In some countries, Madagascar, for example, the population has doubled since 1947, although it had been practically stationary for years previously. A DDT malaria campaign was initiated in Madagascar in 1949, and is largely credited with the population increase. This is no isolated phenomenon and the full social significance of this trend will be much greater than is at present anticipated.

In 1959, Dr. S.W. Simmons of the U.S. Public Health Service made the following statement about DDT:

"The total value of DDT to mankind is inestimable, and is comprised of health, economic, and social benefits. Health benefits are both direct and indirect and fall into three principal categories: (1) direct control of vector-borne diseases such as malaria, typhus, etc., and of insect pests, by the use of DDT for destroying the insects concerned; (2) use of DDT in agriculture for crop pest control, resulting in an increased food supply, often where malnutrition is the principal health problem; and (3) an increase in resistance to non-vector-borne diseases through better health as a result of freedom from malaria and other vector-borne diseases and malnutrition. As Sir Malcolm Watson has stated, when malaria was cleared out of the Malay States, dysentery wards were closed. If data were available, it is predicted that they would show a decrease in tuberculosis and some other diseases in areas where malaria and malnutrition, particularly, have been largely conquered by the use of DDT."

It was estimated in 1953 that no less than 5 million lives had been saved and no less than 100 million illnesses pre-

Rachel Carson's Myth

Rachel Carson was an eloquent writer. *Silent Spring* starts with the following beautiful and nostalgic prose passage:

"There was once a town in the heart of America where all life seemed to live in harmony with its surroundings. The town lay in the midst of a checkerboard of prosperous farms, with fields of grain and hillsides of orchards where, in spring, white clouds of bloom drifted above the green fields. In autumn, oak and maple and birch set up a blaze of color that flamed and flickered across a backdrop of pines. Then foxes barked in the hills and deer silently crossed the fields, half hidden in the mists of the fall mornings."

How could we have been so heedless as to lose these wonderful surroundings? More important, did they ever exist? I thought not, so I wrote the following:

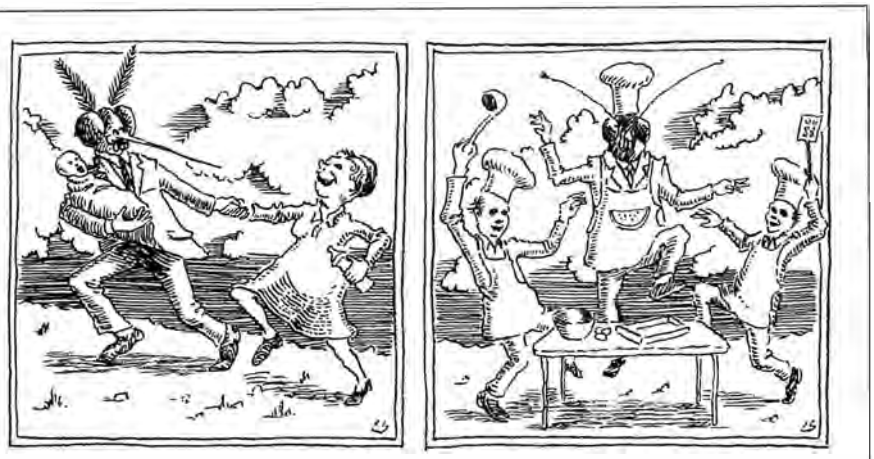
"The harmony of all life in this idyllic town followed a biological balance in Nature, a balance which man had not yet learned to disturb by drastic intervention on his own behalf.

"As the sun went down, the buzzing of mosquitoes could be heard in the town; the malaria parasites in the mosquitoes' salivary glands were about to continue their life cycle in the red blood cells of human victims.

"The last slanting rays of the sun lingered on the small headstones in the town graveyards. Here slept the children who had perished from diphtheria, scarlet fever, and whooping cough. Beside them were those who had lived and died in harmony with proliferant typhoid germs. These bacteria, uninjured by chlorine or antibiotics, teemed in the limpid stream that ran at the edge of town.

"It had been a warm afternoon, and a hush had settled on the grocery store. Faint sounds could be heard; a friendly rat gnawing in the cellar; the rustle of weevils in the cracker barrel; the high-pitched buzz of flies that were struggling in the sticky festoons hanging from the ceiling, and the stealthy patter of cockroaches that darted across the floor."

—Tom Jukes



vented through the use of DDT for controlling malaria, typhus, dysentery, and other arthropod-borne diseases, since DDT became available in about 1942. These figures have now increased. In a complete treatise on the value of DDT to the public health, it would be necessary to consider the entire group of chlorinated hydrocarbon insecticides in order to give full credit to this parent compound.

This information was available to Rachel Carson, but she ignored it.

Some recent writers have claimed that there is a widespread decline in fertility in human males, and that small traces of DDT were to blame. This is difficult to believe in view of the record at the DDT manufacturing plant in Torrance, California, when it was in operation. Married male workers averaged 4 children per family. The largest families had as many as 13 children and the male supervisor had 8 children. The workers had high levels of DDT in their blood serum and body fat. These results come from a sample of 63 human males with a median of 15 years of exposure to DDT.

An experiment on exposing human beings to high levels of DDT was carried out inadvertently in Triana, Alabama. The riverbed contained large amounts of DDT remaining from a former DDT manufacturing plant. The fish in the river became very high in DDT, up to 627,000 parts per billion. Many of the people of Triana ate the fish, and the only effect detected was an increase in a blood enzyme, gamma glutamyl transpeptidase. The U.S. Public Health Service stated "the effect is small and probably has no effect on well-being."

Combatting Tropical Diseases

Pesticides have rescued people from terrible diseases in the tropics. One such disease is onchocerciasis, or river blindness, caused by a parasite that is transmitted by the bites of blackflies, the larvae of which live in swiftly running streams in Africa and tropical America. The parasite migrates to the eyes and causes blindness. In some villages, the adult humans are blind and are led around by children who themselves will later become blind. An incident occurred in which a donkey carrying a load of DDT slipped and fell while crossing a stream. As a result, the blackfly larvae were killed, even though DDT is only slightly soluble in water, and river blindness stopped in villages downstream.

Another insecticide, Abate, is now used. Abate is of great value in controlling another parasite, the guinea worm, which is transmitted to humans when they drink contaminated water from ponds and cisterns. It is found in India, Pakistan, and 17 African countries, and cripples 10 million people each year. It is a horrible parasite that grows to a length of several feet in the human body. Sometimes the victims try to pull out the worm by winding it on a twig, but the worm usually breaks.

Natural Pesticides

Plants make toxic substances that protect them against insects and animals. These toxins have been studied by Dr. Bruce Ames at the University of California, Berkeley. He concludes that more than 99 percent of the toxins in crops that are used for human food are

Continued on page 63

Letters

Continued from page 6

I admit, for me space is much more interesting than fusion; since I was a child, long before Sputnik, or before I knew anything about fusion, I dreamed of going to Mars. But harnessing fusion is even more urgent. If we had the energy fusion could give us, everything else would be so much easier.

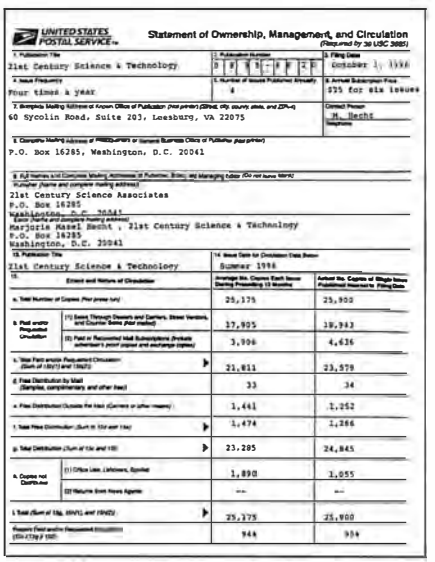
I cannot understand why so little money is given to research on fusion. Of course, that so few people see the importance of space is hard to understand too. Just for rekindling a pioneer spirit, colonizing space would be worthwhile. It hurts to see our youth so hopeless in a time when they have so much reason to be enthusiastic.

Your winter 1996-1997 issue was one of the most interesting yet. Keep up the good work, but do not fight all the environmentalists. Most of them are interested in the future and mean well; they are only misled in some ways by the extremists.

Hans Petri
Wood Dale, Ill.

Correction

The obituary for Victor Ambartsumian (Fall, 1996, p. 51) stated that he was accorded a state funeral. Although a state funeral was initially planned, the funeral was private. Ambartsumian was buried at Byurakan, near the observatory he had founded.



UNITED STATES POSTAL SERVICE — Statement of Ownership, Management, and Circulation (Required by 39 USC 3685)

1. Publication Title: 21st Century Science & Technology	2. Publication Number: 0 8 9 5 - 8 2 2 X
3. Issue Frequency: Four times a year	4. Number of Issues Published Annually: 4
5. Annual Subscription Price: $75 for six issues	
7. Complete Mailing Address of Known Office of Publication (Not printer): 60 Sycolin Road, Suite 203, Leesburg, VA 22075	Contact Person: M. Hecht
8. Complete Mailing Address of Headquarters or General Business Office of Publisher (Not printer): P.O. Box 16285, Washington, D.C. 20041	
9. Full Names and Complete Mailing Addresses of Publisher, Editor, and Managing Editor (Do not leave blank): Publisher (Name and complete mailing address): 21st Century Science Associates, P.O. Box 16285, Washington, D.C. 20041	
Editor (Name and complete mailing address): Marjorie Hazel Hecht, 21st Century Science & Technology, P.O. Box 16285, Washington, D.C. 20041	
Managing Editor (Name and complete mailing address):	
10. Owner (If owned by a corporation, give the name and address of the corporation immediately followed by the names and addresses of all stockholders owning or holding 1 percent or more of the total amount of stock. If not owned by a corporation, give the names and addresses of the individual owners. If owned by a partnership or other unincorporated firm, give its name and address as well as those of each individual owner. If the publication is published by a nonprofit organization, give its name and address.): 21st Century Science Associates, P.O. Box 16285, Washington, D.C. 20041	
11. Known Bondholders, Mortgagees, and Other Security Holders Owning or Holding 1 Percent or More of Total Amount of Bonds, Mortgages or Other Securities. If none, check box: None	
12. Tax Status (For completion by nonprofit organizations authorized to mail at nonprofit rates) (Check one): The purpose, function, and nonprofit status of this organization and the exempt status for federal income tax purposes: Has Not Changed During Preceding 12 Months	
13. Publication Title: 21st Century Science & Technology	14. Issue Date for Circulation Data Below: Summer 1996

15. Extent and Nature of Circulation	Average No. Copies Each Issue During Preceding 12 Months	Actual No. Copies of Single Issue Published Nearest to Filing Date
a. Total Number of Copies (Net press run)	25,175	25,900
b. Paid and/or Requested Circulation (1) Sales Through Dealers and Carriers, Street Vendors, and Counter Sales (Not mailed)	17,905	18,943
(2) Paid or Requested Mail Subscriptions (Include advertiser's proof copies and exchange copies)	3,906	4,636
c. Total Paid and/or Requested Circulation (Sum of 15b(1) and 15b(2))	21,811	23,579
d. Free Distribution by Mail (Samples, complimentary, and other free)	33	34
e. Free Distribution Outside the Mail (Carriers or other means)	1,441	1,252
f. Total Free Distribution (Sum of 15d and 15e)	1,474	1,286
g. Total Distribution (Sum of 15c and 15f)	23,285	24,865
h. Copies not Distributed (1) Office Use, Leftovers, Spoiled	1,890	1,035
(2) Returns from News Agents	---	---
i. Total (Sum of 15g, 15h(1), and 15h(2))	25,175	25,900
Percent Paid and/or Requested Circulation (15c/15g x 100)	94%	95%

Charles Hughes/EIRNS

Helga Zepp LaRouche speaking at a Schiller Institute forum on the Land-Bridge at Riverside Church in New York City. The banner reads, "We warmly welcome 'The Silk Road Lady.'"

'SILK ROAD LADY,' HELGA LAROUCHE, TAKES LAND-BRIDGE TO NEW YORK

Helga Zepp LaRouche, the founder of the Schiller Institute, held seminars in New York City on Feb. 27-28 to discuss the 290-page report she co-authored, titled "The Eurasian Land-Bridge: The 'New Silk Road'—Locomotive for Worldwide Economic Development." The Land-Bridge is a plan for rapidly industrializing the world, based on Great Projects of transportation, communications, energy, and water infrastructure, to be situated along rail lines that link Eurasia from East to West, and tying in all the nations in between. LaRouche's Feb. 28 briefing to representatives from 26 nations and many members of the international press, was reported on in both mainland China and Taiwan through television and radio, and in major Chinese-language press outlets in the United States. The report is published in English and German by *Executive Intelligence Review.* See p. 12 for details.

IHARA AFFIRMS JAPAN'S COMMITMENT TO PLUTONIUM FUEL CYCLE

Japan is firmly committed to the utilization of nuclear energy based on the plutonium fuel cycle, Dr. Yoshinori Ihara, vice chairman of the Atomic Energy Commission of Japan, told the Washington, D.C., chapter of the American Nuclear Society March 20. This commitment is being maintained, he stated, despite the spate of media scare stories about a recent incident at the Tokaimura nuclear fuel processing facility. Japan is developing nuclear energy not just for itself, but for the world, Ihara said: "Our essential concerns are to be how can we establish and transfer a wealthy and advanced society to the next generations" and "what can nuclear energy contribute to these efforts." He stressed that as one of the advanced countries in the field of the peaceful uses of nuclear energy, "we consider it important to respond appropriately to the growing world's energy demands."

PREMATURE OBITUARY FOR ITER CRAFTED BY *SCIENCE* MAGAZINE

New calculations of plasma behavior by William Dorland and Michael Kotschenreuther (Institute for Fusion Studies, University of Texas at Austin) were reported in *Science* magazine Dec. 6, 1996. According to author James Glanz, their work shows that ITER, the International Tokamak Experimental Reactor, "will fizzle." Although their recent theorizing on how turbulence relates to heat loss has been at issue among fusion scientists for months, *Science* issued a press release based on Glanz's article, crowing that ITER will not work, and the national media then picked up the story.

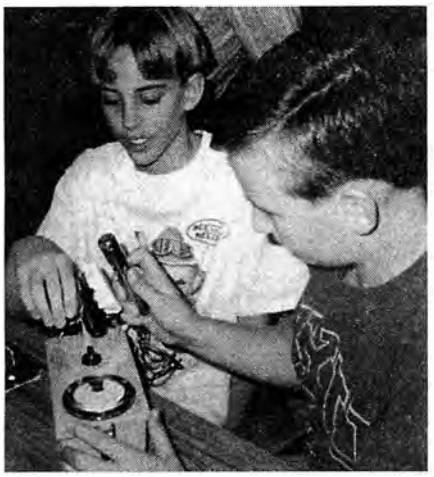
Dorland and Kotschenreuther attempted to derive the heat loss from turbulence directly from physics principles, while other models are, in part, based on actual data. Using certain assumptions regarding ITER's operating conditions, they say ITER's plasma will be too large and turbulent to become hot enough for sustained fusion. Their tokamak performance model is one of several and is not known to be superior to the others. The purpose of building ITER is to go beyond the parameters of past tokamak experiments, probably leading to the scrapping of most or all of the models.

2,000 ECONOMISTS BUY AND SELL GLOBALONEY ON GLOBAL WARMING

With much fanfare, 2,000 economists issued a statement Feb. 13, urging the United States to take measures to slow climate change, by means such as carbon taxes and "trading of marketable emissions permits." This would not harm U.S. living standards, the economists claimed. Their policy is based on the Intergovernmental Panel on Climate Change's deliberately false report that "the balance of evidence suggests a discernible human influence on global climate." The economists' effort was led by Nobel Prize winner Kenneth J. Arrow; for more on Arrow, et al., see "Kenneth Arrow Runs Out of Ideas, But Not Words," by Lyndon H. LaRouche, *21st Century,* Fall 1995, p. 34.

FEMA HAS A LARGE SUPPLY OF SURPLUS GEIGER COUNTERS TO GIVE AWAY

Steve Jones, a Utah house painter with an electronics hobby, has alerted *21st Century* that FEMA, the Federal Emergency Management Agency, has a large supply of Geiger counters that it plans to junk this summer. Geiger counters detect ionizing radiation. Jones obtained 4,000 of them for use in the Utah schools, and has been working with the Health Physics Society in Salt Lake City to obtain 15,000 more for delivery to the National Science Teachers Association Convention in New Orleans April 3-6. The instruments were originally for use in the event of nuclear war, but can be adapted to other uses. To request one or more counters, write to the Federal Emergency Management Agency, 500 C Street, S.W., Washington, D.C. 20472.



Steve Jones

Eighth-graders exploring the uses of a Geiger counter, thanks to the efforts of Steve Jones. Here students are measuring an air sample from the school basement to check on radon.

FIRST 8-METER MIRROR IS CAST FOR LARGE BINOCULAR TELESCOPE

The largest monolith mirror in the world, the first of two 8.4-meter mirrors for the Mt. Graham telescope, was cast in January at the University of Arizona's Steward Observatory Mirror Laboratory. After loading 20 tons of borosilicate glass blocks into the mold, the temperature was ramped up to 2,200°F and the rotating mold was set in motion Jan. 18 and 19. The mirror has now cooled to less than 800°F; the furnace can be opened in early April. Buddy Powell, Associate Director of the Steward Observatory, told *21st Century* the rule of thumb is to expect success in two out of every three castings. Construction of the housing on Mt. Graham will resume in early April.

Ohio State University and a consortium of German institutes (the Astrophysikalisches Institut in Potsdam and three Max Planck institutes) have reached final agreement to become partners in the telescope, it was announced Feb. 24. The homepage for the Large Binocular Telescope includes updates on the project (http://medusa.as.arizona.edu/lbtwww/lbt.html).

GREENPEACE BOOK CREDITS *21ST CENTURY,* LAROUCHE AGAINST GREENS

Green Backlash by A. Rowell, published by Routledge (London) and funded by Greenpeace, attacks both *21st Century* and economist Lyndon H. LaRouche, Jr., for making life difficult for the greens. Rowell accuses LaRouche of "vehemently promoting nuclear power and advanced technology" and having a worldwide intelligence operation that exchanges information with many governments, making it a special danger to Greenpeace. Rowell identifies *21st Century* and its associate editor Roger Maduro as the key force that stopped adoption of the 1994 biodiversity treaty. The book consists chiefly of diatribes against the enemies of environmentalism, including Dixy Lee Ray, Hugh Ellsaesser, Magnus Gudmundsson, and Barry Clausen, all contributors to *21st Century*.

SPACE COMMUNITY LOSES ONE OF ITS BEST HISTORIANS: MITCHELL SHARPE

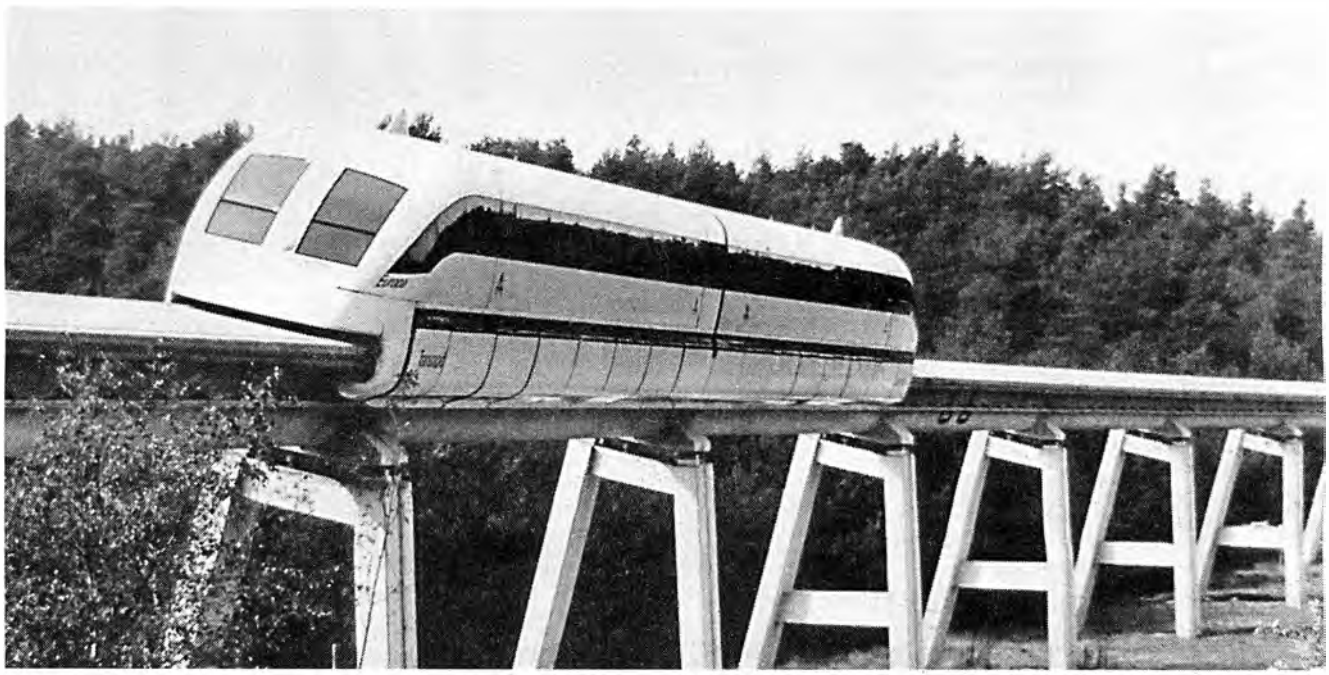
Mitch Sharpe, a talented writer, historian, and friend of *21st Century,* passed away Jan. 6, at age 72. After a career in the Army, Sharpe followed the rocket team centered on Wernher von Braun to the NASA Marshall Space Flight Center in 1960, where he worked in the public affairs and history offices. In 1976, he co-authored with Frederick Ordway *The Rocket Team,* the definitive work on the von Braun group. Throughout his more than 30-year career at Marshall, he wrote books and articles and even ghost-wrote some pieces. Through his work in the history office of the U.S. Space and Rocket Center in Huntsville, and after retirement, he was a tireless adviser to many new writers in space history, and was one of the editors of *How We Got to the Moon,* published by *21st Century*. Sharpe leaves a legacy of younger space history researchers and writers who greatly benefitted from his encouragement and advice.

Mitchell Sharpe (1924-1996)

HIGH-TECH DEVELOPMENT CORRIDORS

Motor for Eurasian Development

by Jonathan Tennenbaum



The transport system of the future: the Transrapid maglev train.

EDITOR'S NOTE

The Eurasian Land-Bridge, a 10,000-mile-long transcontinental railroad line linking China's east coast to the ports of Western Europe, and lined with new cities and industrial centers, is the development policy adopted by China and now gaining support among the nations of Eurasia.

This ambitious mega-development project is conceived not only as the way to lift the population of the Eurasian land mass out of poverty and into the 21st century, but as the answer to the austerity demands of the International Monetary Fund and other supranational bodies, and the solution to the long-time colonial ploy of stirring up ethnic and tribal warfare in the area. (See Editorial, p. 2.)

Specific projects as part of the Land-Bridge plan are now being discussed by Iran, India, Turkey, Georgia, Armenia, Kazakhstan, Uzbekistan, and the Foreign Ministry of Russia, among others.

This article is part 2 of an excerpt from the book-length report on the Eurasian Land-Bridge, published by Executive Intelligence Review *in German and English.* Part 1 appeared in the Winter 1996-1997 issue of* 21st Century *and covered the historical background and conceptual basis for the industrial development corridors and new cities along the Land-Bridge. Part 2 deals with the crucial technologies for these industrial corridors.*

The criteria for choosing the technologies, as discussed in Part 1, include bringing the average per capita and per square kilometer parameters of infrastructure performance in the interior Eurasian regions up to—and later, beyond—those of Japan prior to the present economic crisis. In addition, the technologies must provide the highest density of performance per unit of land area, per employed worker, and per unit of other resources consumed by the infrastructural system.

Jonathan Tennenbaum heads the Fusion Energy Foundation in Europe and has worked closely with the Schiller Institute on the Land-Bridge project.

Notes

* The 290-page English-language report, *The Eurasian Land-Bridge: The 'New Silk Road'—Locomotive for Eurasian Economic Development*, is available from Executive Intelligence Review at $200. Write EIR News Service, P.O. Box 17390, Washington, D.C. 20041-0390.

Rail and Maglev Transport

Obviously, any efficient modern transport system for Eurasia, must combine all major modes of transport: water, highway, railway, and air, with an emphasis on containerized freight. There exist, however, strong reasons that railroad transport (gradually supplemented by magnetic levitation systems) must play the central role in development of the Eurasian infrastructure corridors. These reasons are connected with the following observations:

(1) For freight transport between fixed points, rail transport on the average requires much less energy and less labor, per ton-kilometer and value-ton-kilometer transported, than transport by truck, while providing equal or higher speeds.

(2) The land area used by a railroad line is much smaller than that occupied by highways with a comparable transport capacity.

(3) Although transport by ship is even more efficient (from the standpoint of energy and labor) than either rail or highway, the construction of waterways for transport in the vast hinterlands of Eurasia, is very much restricted by geographical and other constraints. Furthermore, with present-day technologies, shipping times are often too long for passengers and certain high-value goods.

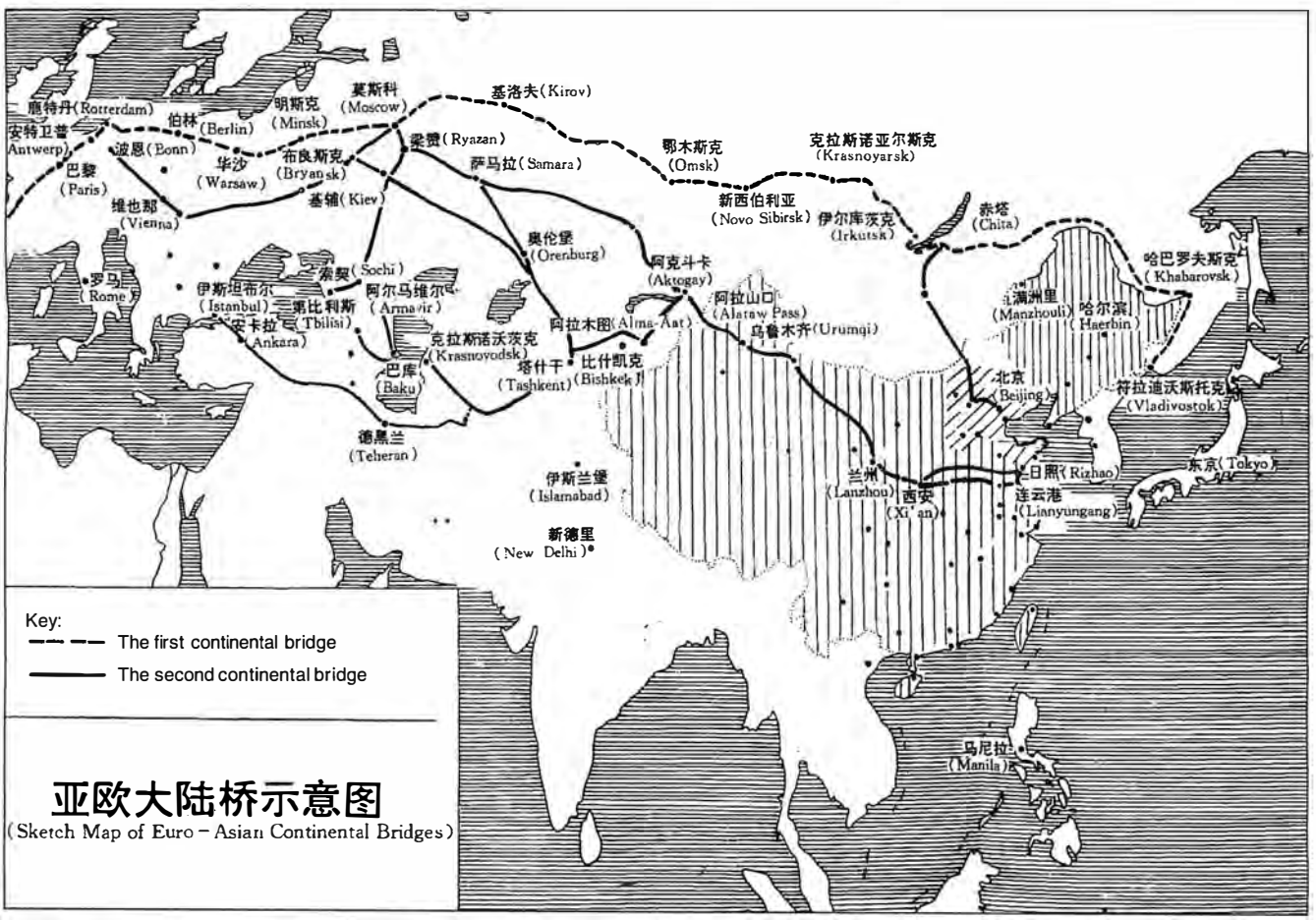
(4) Railroad transport is generally much less affected by climate and weather, than transport by road or ship. This is crucial for many areas in the hinterlands of Eurasia which have extremes of climate.

(5) Modern improvements of rail technology have greatly increased the speeds which can be used in rail transport, to more than 300 km per hour for passengers (French TGV) and to 150 km per hour or more for new high-speed freight lines. At the same time, advances in computer control and signalling technology can multiply the daily transport capacities of any given line, by several times in the future.

(6) The advantages of railroad transport are particularly significant in the case of a corridor geometry of development; that is, where the population and economic activity are highly concentrated along, or not far from, major axes of transport. Any point within a typical 100-km-wide development corridor can easily be reached, either directly by railroad side lines, or by the combination of long-haul rail and short-haul trucking, particularly when realized in the form of container freight assisted by computerized intermodal transfer systems.

Breakthroughs in Intermodal Transport

The main technical bottleneck standing in the way of realizing ultra-efficient, containerized high-speed transport systems that combine railroad, highway,



THE MAIN CONNECTIONS OF THE EURASIAN CONTINENTAL BRIDGE

The Land Bridge or Continental Bridge refers to the 10,000-km-long transcontinental railroad line, which runs from China's Eastern harbor city of Lianyungang, to the Europort at Rotterdam. Part 1 of this special report reviewed China's diplomatic initiative to make the Land Bridge an axis of economic development for the entire Eurasian land mass.

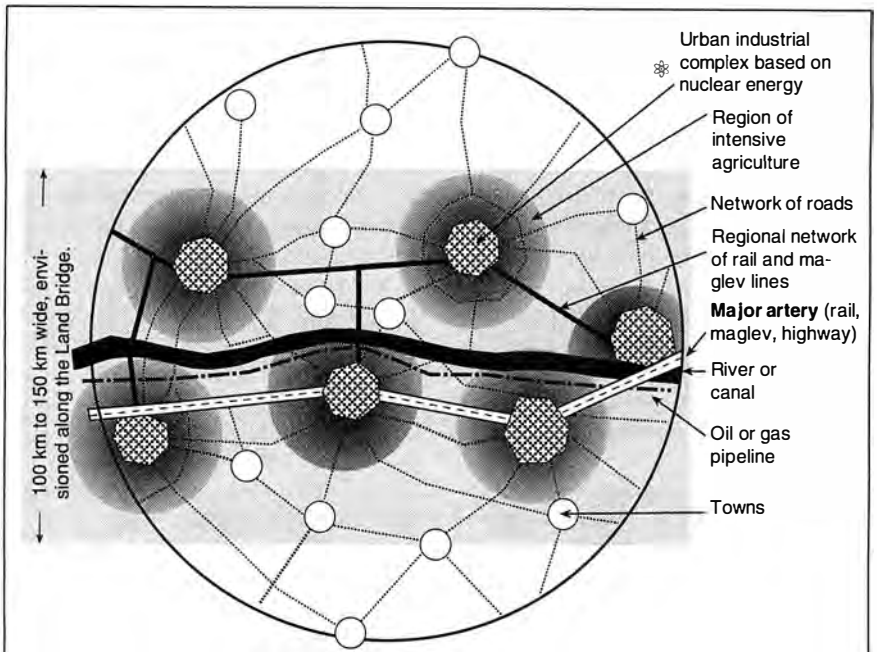


Figure 1
SEGMENT OF A DEVELOPMENT CORRIDOR
A schematic view of a typical development corridor.

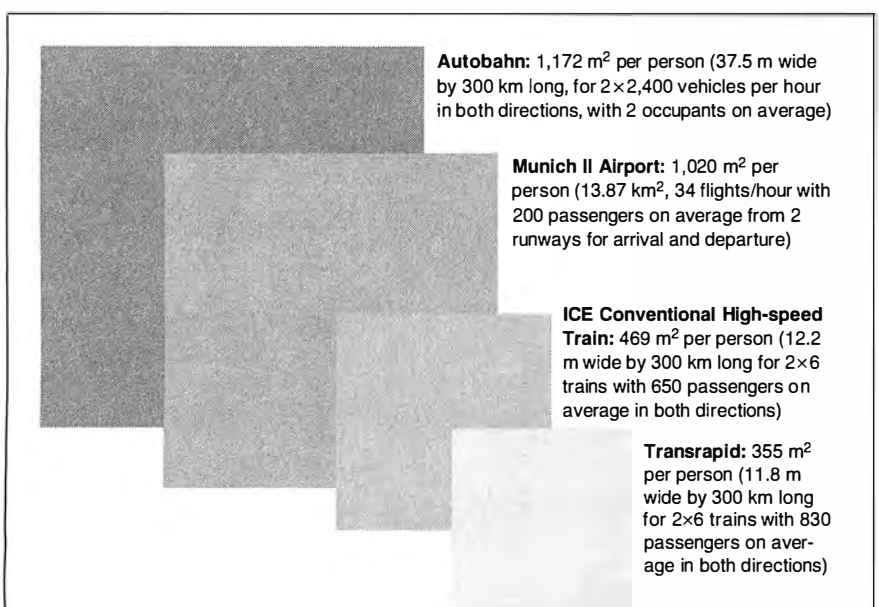


Figure 2
SURFACE AREA USED BY VARIOUS TRANSPORT MODES

and water transport, arises at the points of transfer of freight from one transport mode to the other. At present, the overall efficiency of multimode (combined) transport is still much constrained by difficulties of logistical coordination, together with lack of development of rapid, automated techniques for loading, unloading, and warehousing the various types and sizes of containers—leading to costly losses of time. Given the projected, dramatic increase in global demand for multimode transport in the coming period, considerable efforts have been invested in recent years, to overcome the mentioned bottlenecks. Already, a number of alternative engineering designs for fully automated freight transfer stations ("combi-terminals") exist on the drawing boards and in computer simulations, and full-fledged pilot-project facilities are under development. In France, a first-generation rapid transfer system is already in operation, the so-called Commutor facility in Trappes, near Paris.

Typical of the state-of-the-art for existing, conventional systems is the use of portal-cranes which run along 700-meter-long tracks, parallel with the train tracks. To unload a typical container train (600 m long, and carrying 40 containers), such a crane requires at least 70 minutes. With the first new generation of automated, rapid-transfer systems, it would take 15 minutes or less.

An example of such a system is the Krupp Fast Freight Transfer Facility (KSU), developed by the famous German company Krupp. The KSU consists of four basic elements: (1) Separate, automatic loading and unloading machines for the rail cars and for the trucks; (2) A modular storage system, located between the rail yard and the road terminal, for sorting-out and temporary storage of containers; (3) An intermediate transporter system, which moves containers between the loading and unloading points and the storage area; (4) A hierarchically organized computer-control system.

In the Krupp system, the trains move continuously, at walking pace, through the loading/unloading area. The containers and their destinations are identified electronically. Moving synchronously with the train, the mobile unloading machine grasps each container individually, and places it on the intermediate transporter system. Depending on orders from the central processor, the intermediate transporter either brings the containers directly to the truck loading positions, or places them in the storage system.

The KSU system is already in the component-testing stage.

Another promising concept has been developed by the Thyssen company. The Thyssen system is based on an overhead monorail transporter for heavy loads, which is manufactured by that company and already used for transport of materials on construction sites. In the Thyssen concept, the containers are grasped and lifted from above by automatic carrier vehicles suspended from monorails running directly above the

train tracks. The monorail system can transport the containers either to a storage area, or directly to the truck loading area, where the containers are lowered from above onto waiting trucks (or vice-versa from truck to rail car). The use of monorail transport gives the system a considerable degree of flexibility, permitting the truck-loading area, the storage areas and the railroad terminal to be separated from each other at any convenient distance.

Later versions of these sorts of systems will doubtless make use of magnetic levitation technologies (see below) for highly flexible, virtually frictionless handling of containers.

Automatic transfer systems, of the sort described here, will be absolutely necessary to handle the enormous freight flows on the main lines of the Eurasian infrastructure corridors. Conversely, the high density of traffic in the Eurasian corridors provides the most favorable conditions for economic use of such highly capital-intensive systems.

The Maglev Revolution

Although the present Eurasian landbridges are based on classical railroad technology, the revolutionary technology of magnetically levitated ground transport is destined to play a decisive role in the future development of the Eurasian infrastructure corridors.

In fact, the maglev revolution has already begun, with the creation of first fully operational magnetic levitation transport system, the German Transrapid. The Transrapid, which is designed for passenger transport at maximum speeds of 450 to 500 km per hour, will begin commercial operation between Hamburg and Berlin in 2005. Interest is building up on many sides, to extend the Hamburg-Berlin line in various directions, into a European network. Japan is only slightly behind Germany in developing a somewhat different type of system for high-speed passenger transport, and numerous other countries, including China, are actively working on maglev technology.

The key feature of magnetic levitation systems is that they eliminate the mechanical contact between vehicle and track, replacing the classical relationship between wheel and track/roadway by a magnetic (or electromagnetic) interaction, operating at a distance. Thereby, the major source of vibration, friction, and wear on the vehicle and track, which affects all traditional modes of railroad and road transport, is eliminated. At the same time, magnetically levitated transport systems permit revolutionary new methods of locomotion and control of moving vehicles. Unlike the frictional traction used by wheel and track systems, the magnetic/electromagnetic interactions in maglev systems can be regulated at will by electric currents supplied to linear motors and positioning devices which control the entire movement of the magnetically suspended vehicle. These characteristics have a number of decisive consequences for the future of ground transport, including the following:

First, magnetically levitated trains are capable of routine operation at much higher speeds than are technically or economically feasible for classical wheel and rail or road transport systems. Germany's commercial maglev system, the Transrapid, can operate routinely at speeds of 450 to 500 km per hour, thereby comparing favorably, even in point-to-point transport times, with passenger airline transport for distances up to 1,500 km (this includes the advantage of being able to run directly between city centers, without need for airport transfer). There is no essential obstacle to much higher maximum speeds, except the increase in aerodynamic resistance, and concern for the comfort of passengers when moving over curves and inclines. In the future, magnetically levitated vehicles, operating in underground, evacuated tunnels could traverse long distances at *supersonic speeds*. Transcontinental systems of the latter type are already being studied.

Second, magnetic levitation trains are capable of much higher rates of acceleration and deceleration, than are feasible in classical wheel and rail systems. For example: In routine operation, Transrapid takes only 1 minute and a track length of only 3 km to reach a speed of 300 km per hour. In comparison, conventional high-speed trains such as the French TGV and German ICE, require several minutes and 30 km of track to reach the same speed. This high acceleration capacity means that maglev trains can make relatively frequent stops, without losing the advantages of high speed. This makes them particularly suited for operation in dense corridors, where major cities may occur every 100 km or less.

Third, magnetic levitation trains can operate with much steeper inclines and tighter curves for any given speed, than conventional trains. This gives magnetic levitation systems an intrinsic advantage in hilly or mountainous terrain.

Fourth, magnetic levitation technology is ideally suited to the creation of fully automated, conveyor-belt-like transport systems with extremely high performance-densities. In this case, the speeds would be moderate (probably less than 200 km per hour), but the amount of freight that could be carried by a single line, would be an order of magnitude or more larger than present

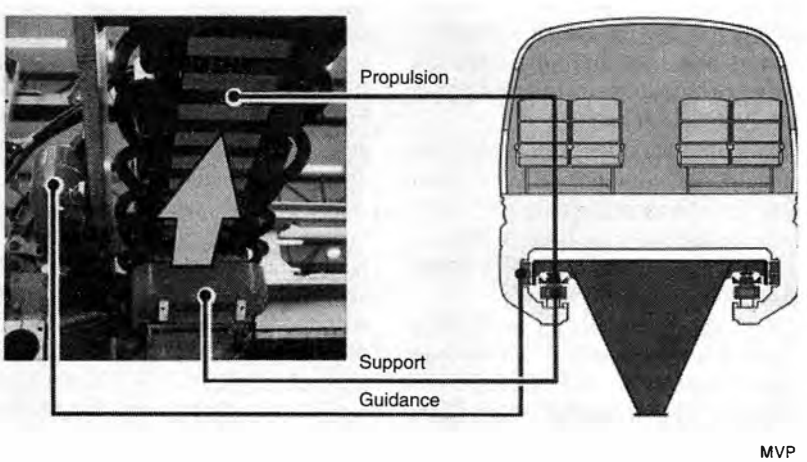


Figure 3
DESIGN OF THE TRANSRAPID MAGLEV TRAIN

railroads. In a hypothetical system of this type, the individual vehicles, which might take the form of pallets carrying containerized freight, would travel along the track with minimal spacing between them; the entire flow of vehicles would be controlled through the track, which contains the essential power and locomotion systems. At nodal points of the transport network, these vehicles would be sorted out according to their destination, by computer-controlled electromagnetic switches.

Although a magnetic levitation system of this sort has not yet been built, the basic technologies required—including the automatic management of streams of vehicles transported by a linear motor—have already been demonstrated. An example is the technology for the projected tunnel through the Alps in Austria, where cars and trucks would be carried by an automatic conveyor system on special platforms propelled by a linear motor.

Maglev for the Land Bridge

The common objection to a broad use of magnetic levitation systems on a continent-wide scale, is that they are allegedly too expensive. It is true that maglev systems (at least of the type of the German Transrapid) are more capital intensive than traditional railroads. That increased capital cost, however, can be more than compensated for by the higher performance-density of maglev systems, provided that the capabilities of these systems are exploited by intensive use. But that is exactly the situation which is created by the concentration of population and economic activity in dense infrastructure corridors. In fact, the emergence of the Eurasian infrastructure corridors provides the most favorable context for the large-scale introduction of magnetic levitation systems.

Taking into account the present state of maglev development, as well as the potentials summarized in the four points above, the evolution of these systems in the Eurasian corridors might be conservatively projected as follows:

Over the next five to ten years, high-speed maglev lines for mainly passenger transport should be built up in the regions of most developed portions of the Eurasian corridors. This includes the main corridors of the Productive Triangle in Europe (Vienna-Paris-Berlin), and some key corridors in the Pacific region, particularly in Japan, Korea, eastern China (for example, Beijing-Shanghai-Hongkong) and possibly Indonesia. The major economic belts of the United States, of course, will be another key area for initial maglev development. In these areas, high-speed maglev systems will be able to take over an increasing portion of short- and medium-range passenger air traffic, which has already reached a saturation level in a number of cases, and is intrinsically more costly.

At the same time, the construction and modernization (including multiple-tracking) of railroad lines should be completed throughout the Eurasian corridors, according to Western European standards.

As the density of population and economic activity in the trans-Eurasian corridors increases, the maglev lines should be progressively extended, until they finally meet up to form a Eurasian maglev network suitable for high-speed passenger transport as well as transport of high-value freight (including post) of the sort normally sent by air. An increasing portion of passenger traffic will be transferred to these maglev lines, while the use of conventional railroads becomes more and more exclusively concentrated on containerized freight transport. At the same time, maglev conveyor-belt systems should be installed in the regions of heaviest freight transport flows (2005-2015).

In the final phase (2015-2030), maglev conveyor belt systems are extended to the entire corridor network, as well as in many branches. By this time, a portion of the transcontinental air traffic may be taken over by maglev trains running in evacuated tunnels at supersonic speeds. Conventional rail will probably still be used for lower-value goods and for some passenger and freight traffic to areas still not covered by the growing array of infrastructure corridors.

The total investment cost to build a maglev system of the Transrapid type within the main Eurasian development corridors (total length 60,000 km to 100,000 km), will be on the order of $1 trillion. At first glance, that might appear a very large figure, but it corresponds to a total expenditure only about $220 per capita of the Eurasian population, spread out over a period of 10 to 15 years. That would mean spending about 1 percent of the GNP of the Eurasian nations each year, during 10 years, for the construction of a transcontinental maglev network. For such a (mainly) passenger network, it is not necessary to decide on a single maglev technology; on the contrary, different systems could be used on the various major lines, in such a way that the investment in a Eurasian maglev network would greatly stimulate the development of maglev and related technologies.

The same kind of electronically controlled magnetic levitation system, as used in the Transrapid, has important applications in other domains of technology, too. For example, magnetic levitation systems are being developed as precision platforms to hold the workpieces in machine tools. Another use is in *electronically controlled magnetic bearings,* which are finding increasingly wide use in turbines and other rotating machinery.

Water Transport

At present, a very large proportion of international trade is carried by ship. With the development of the Eurasian land-bridges, however, transport by railroad will become a strong competitor to the sea routes between Europe, southern Asia, and eastern Asia. Already, transit times for rail between Rotterdam and Vladivostok are less than half that for the sea route; with ongoing improvements in the logistical organization of transcontinental rail, this time advantage will increase much more. With the progress of magnetic levitation systems, ground transport will gain an even larger advantage in speed, competing even with air freight for certain high-value goods. The economic development of Eurasia's hinterlands, which are mostly accessible only over land, is another factor which will tend to strengthen the relative weight of rail transport in international trade. The completion of land connections from the Eurasian mainland to Japan, and even over the Bering Strait from Asia to North America, would open up enormous possibilities to all-rail transport between Japan, Europe, and America.

Does all this mean that transport by sea is bound to become marginalized in the future? By no means!

First, it should be noted that water transport remains by far the most efficient means of transport for bulk goods and other goods, for which time-of-de-

livery is not a critical factor. Hand in hand with the large-scale development and industrialization of formerly backward areas of Asia, Africa, and South America, the worldwide traffic in ores and other raw materials, semi-finished products, fuels, fertilizers, and other chemicals, cereals, heavy machinery, and so forth, will expand *many times,* compared with present levels. In fact, it is exactly the development of rail transport in the interior of Eurasia, which will lead to the fastest growth in the demand for water transport! The expansion of harbor facilities and, above all, *major improvements in inland waterways,* including *large-scale construction of new inland shipping canals,* is one of the most urgent tasks in Eurasian and world development. The great navigable rivers and canals of Eurasia will retain and expand their historical role, together with the new land-bridges, as the primary infrastructure development corridors for Eurasia.

Second, technological advances—including some which can be termed revolutionary-—open entirely new possibilities for water-borne transport, transforming once again the relationship between land, water, and air. We shall limit ourselves here to a few brief examples.

High-speed Catamarans

Potentially revolutionary breakthroughs have been made, in recent years, in the development of large *high-speed, gas turbine-powered catamarans* which can transport passengers and cargo routinely at *twice the speed* of the most modern, conventionally built ferry-boats.

The HSS-1500, built by the Stena Company of Sweden, carries 100 cars and 50 large trucks, together with up to 1,500 passengers, at speeds of up to 40 knots—about 74 km per hour (Figure 5)! Instead of conventional propellers, the HSS-1500 uses four high-speed water jets, whose outlets can be swivelled over a wide angle. The water jets are powered by four compact gas turbines, somewhat similar to the turbines of jumbo aircraft, which provide a total of up to 100,000 horsepower (73 megawatts).

The entire power and propulsion system is nearly vibrationless. The command bridge, manned only by the captain, navigator, and chief engineer, and filled with the most advanced instrumentation ever used in civilian ships, resembles the cockpit of an airliner. The ship is provided with advanced fire-protection and evacuation systems. The design of the ship is based on the double-hull catamaran principle, emphasizing light-weight aluminum construction. The enormous width of 40 meters, and the distribution of weight over the two catamaran hulls, make the ship extraordinarily stable and safe. High-speed catamarans of this type are going into service soon in the waters of northern Europe, and will probably find wide application in other areas of the world.

MHD Propulsion Systems

A further revolution, already on the horizon, is magnetohydrodynamic (MHD) propulsion systems for high-speed ships. This system has no mechanical moving parts at all; instead of a propeller or turbine pump, it uses *electromagnetic* forces to directly accelerate water into a jet, exploiting the fact that seawater is an electrical conductor. The MHD propulsion system employs a set of electrodes to send electric current through water which is passing through a cylindrical chamber; this current interacts with a powerful magnetic field created by a set of magnets surrounding the chamber, thereby exerting a force which propels the water down the tube.

Although MHD ship propulsion was patented, as a concept, by the American W.A. Rice in 1961, its use first became feasible with the development of high-intensity superconducting magnets. Originally, military applications provided a

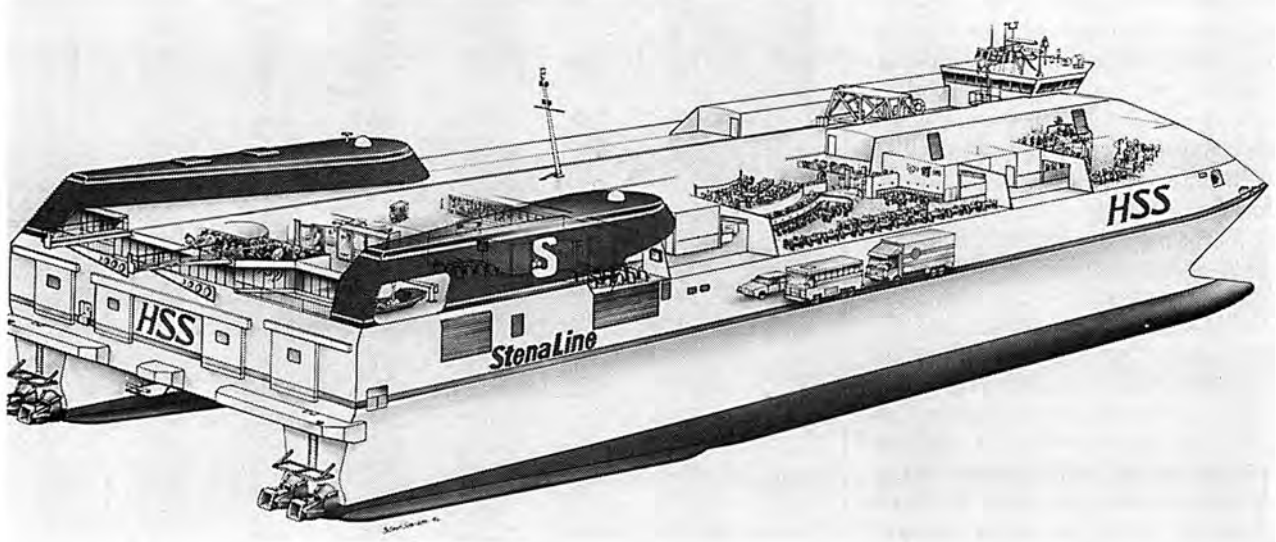


Figure 4
HIGH-SPEED CATAMARAN
The new high-speed catamaran of the Stena Line.

Source: Stena Line

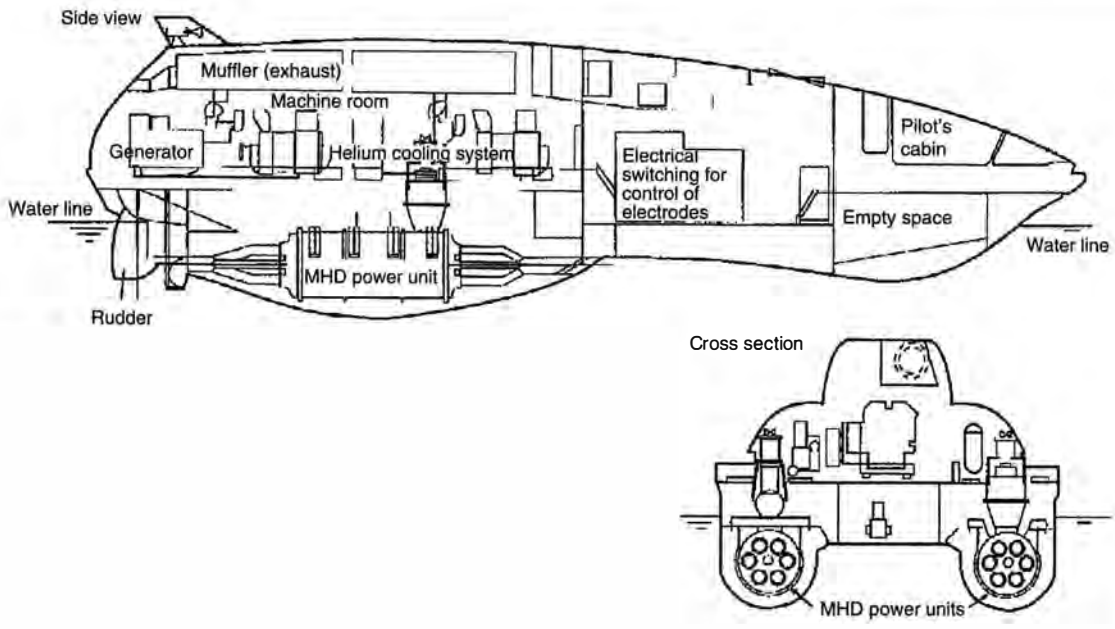


Figure 5
SCHEMATIC OF AN MHD SHIP

Yamato 1, the Japanese MHD ship, is 30 meters long, weighs 280 tons, and requires a crew of 10. The prototype is designed for a speed of 8 knots. Later, MHD-driven vessels will travel at 200 km/hr.

strong impetus to development of MHD propulsion, because it offered a possibility of reducing the noise generated by submarines in motion. In 1985, however, the Ship and Ocean Foundation in Japan set up a project to develop MHD systems for commercial shipping. A small experimental vehicle, the Yamoto-1, has already operated successfully (Figure 5). In principle, MHD provides a means for overcoming the strict limitations imposed by turbulence and cavitation in all marine propulsion systems that are based on the mechanical action of propellers or turbines. Large, MHD-propelled ships may one day be able to operate at speeds of 50-100 knots—or 95-190 km per hour!

Russian Ekranoplane

Still another potential revolution in the speed of sea transport has been opened up by Russia's development of the ekranoplane (Figure 6). A military prototype version of this remarkable vehicle became famous among Western observers of Soviet military technology, as the "Caspian Sea monster." In the 1980s, Western military satellites photographed what appeared to be a gigantic airplane, operating at very low altitudes over the Caspian Sea. In reality, the ekranoplane is a winged vehicle which exploits the "ground effect"—the aerodynamic interaction which occurs when flying very close to a water or ground surface—to increase its lift. In this way, ekranoplanes have a much lower fuel consumption to carry heavy cargo, than ordinary transport aircraft. While its speeds are somewhat lower

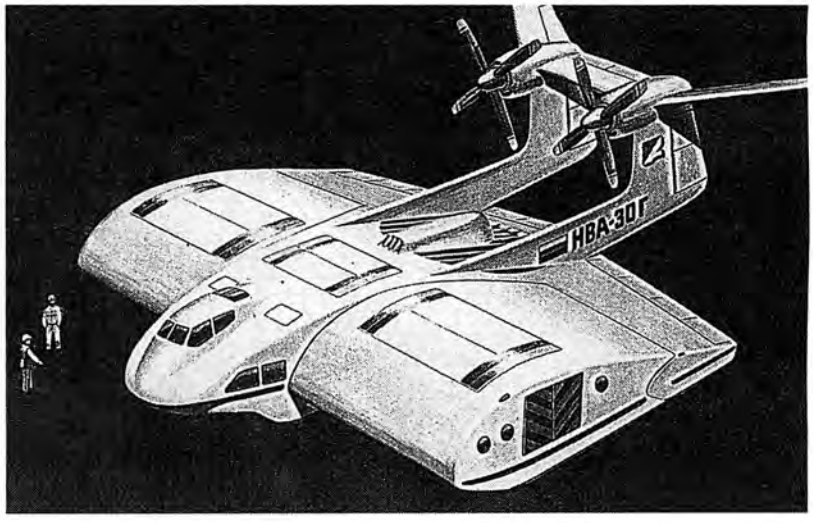
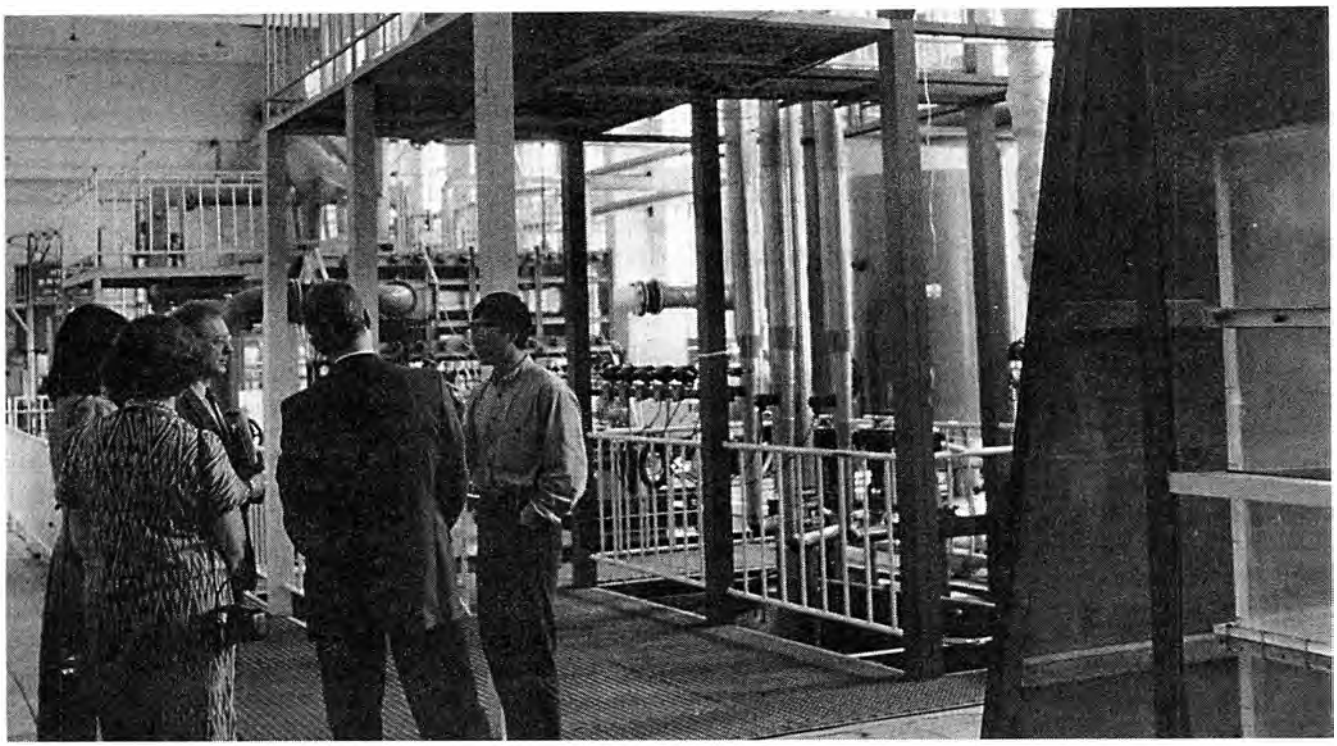


Figure 6
RUSSIA'S EKRANOPLANE DESIGN

This Russian design of an amphibious very-low-altitude air vehicle is its cargo version, Wig GAAV-30C, using the ground-effect principle of the ekranoplane.

Source: Amphicon Ltd.



Schiller Institute

The author (third from left) visiting the Chinese research center that is testing technologies for the high-temperature reactor now under construction.

than ordinary air transport—typically 300 km per hour—the ekranoplane is still much faster than ships. When developed for commercial use, it could become an important means of transport, both on the oceans and seas, and in some sparsely inhabited, remote land regions. At present, this technology is also being developed in Germany.

Nuclear Shipping

Besides the increase in speed and efficiency of propulsion, another important factor in the future of sea transport will be the use of nuclear energy. Although small nuclear reactors have been employed as power sources in hundreds of nuclear submarines, aircraft carriers, and other military ships—as well as the famous nuclear ice-breakers developed in the Soviet Union—until now only the first steps have been made to open up the era of nuclear-powered commercial shipping. The technical and economic feasibility of nuclear-powered freight vessels was fully demonstrated, in several years of successful commercial operation, by the German-built *Otto Hahn,* as well as experience with the American *Savannah.* The crucial advantage, which becomes economically quite significant for larger ships, is the extremely low fuel consumption, permitting a nuclear-powered ship to operate for a year or more without refueling. The *Otto Hahn* sailed 600,000 nautical miles or about 20 times around the Earth, consuming a mere 55 kilograms of enriched uranium fuel! Only the manipulated, irrational opposition to nuclear energy, and the post-1970s depression in the shipbuilding sector, has so far prevented the large-scale introduction of nuclear power in commercial shipping.

The Energy-Intensive Economy

Contrary to the delusional fantasy of a "post-industrial information society," the world economy of the future will be *far more energy-intensive* than at any earlier period. (See Figure 7.) In order merely to survive, countries such as China will have to rapidly raise the level of per capita energy consumption by an order of magnitude, and then beyond that, in the early decades of next century. As the demand for high-quality metals and other new and old materials increases sharply, the economic exploitation of mineral resources in Siberia and other areas of Eurasia, will require the use of extremely energy intensive technologies, such as plasma processing. At the same time, providing water for the large-scale development of desert regions of the Near and Middle East, Central Asia, and China, will require enormous amounts of energy for pumping, reprocessing, and desalination of water. Furthermore,

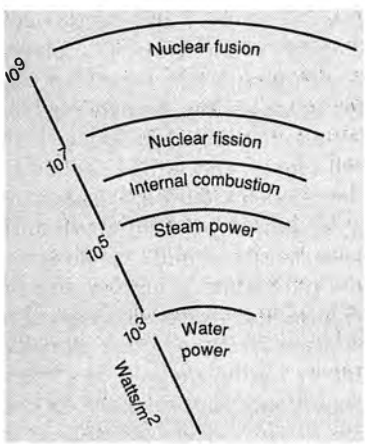


Figure 7
GROWTH OF ENERGY FLUX DENSITY

The energy flux density of power-generating technologies has grown historically in successive jumps of one to two orders of magnitude.

once the process of true scientific and technological revolutions is resumed on a world scale, new types of physical processes will be discovered, including on the subnuclear scale, whose technological mastery will increase the per capita energy consumption by further orders of magnitude.

For the immediate future, the key to efficient development of the Eurasian infrastructure corridors is, above all, to provide large amounts of *cheap electricity*. Electricity represents today the highest *technological quality* of energy which we can produce and distribute on a large scale. (Some time in the future, we expect, more concentrated, coherent forms of energy will emerge to play the leading role, in place of present-day electricity. Perhaps the transmission of high-density electric current in superconductors constitutes an intermediate step.)

In addition to electricity, of course, we require large amounts of industrial process heat, heat for buildings, and fuels for internal combustion engines and other applications.

Nuclear Technologies

Although Eurasia has enormous reserves of fossil fuels, the decisive role in the energy economy must be played by the technology which has the *highest energy-flux-density,* namely nuclear fission, and later, nuclear fusion. Nuclear fission fuel is more than 50,000 times more concentrated than fossil fuels, in energy output per unit mass, and the power density of nuclear reactors is an order of magnitude higher, than in the combustion chamber of a typical fossil fuel plant. These and other properties of nuclear fission mean a qualitatively higher "performance density" of nuclear energy, as a system, compared to all available "alternatives."

This does not mean that chemical combustion processes will be eliminated from energy production, but only that the potentials of nuclear energy will determine the role to be played by other technologies. This includes such things as the future application of nuclear reactors for the extraction and processing of hydrocarbon raw materials into high-grade fuels and chemical products.

Seen from any rational standpoint, the endless debate about "whether or not nuclear energy is safe," is totally absurd. Like every other physical process, nuclear energy in itself is neither safe nor unsafe; everything depends upon *how it is used*. So, the only *rational* issue for Eurasian development, is to determine *which* nuclear technologies are the most suitable for the problems which must be solved. That includes, naturally, the provision of safety features which makes a serious accident, having consequences outside the reactor building itself, virtually impossible.

In fact, the use of nuclear energy is certain to expand extremely rapidly in Asia during the coming decades. Japan and South Korea, of course, already have large nuclear energy programs. The case of North Korea is well known. China is carefully building up its base for building and operating nuclear plants, with construction of four large units to begin in the near future. Recently, Vietnam announced that it is making plans for a first nuclear power station, to be built in the middle coastal region of the country. Indonesia also appears to have decided to go nuclear in the coming years. In western Asia, Iran is completing the nuclear plants, begun by Siemens, on the Persian Gulf, and has also ordered two nuclear plants to be built by Russia in the north of the country. Turkey has called for construction bids on its first nuclear plant, and plans to build at least eight plants in the future. India will almost certainly be forced, by its own growth rate, to accelerate its nuclear power program, which includes the full capability to manufacture its own plants.

LWR and High Temperature Reactors

Of the forms of nuclear fission reactors presently available, there are essentially two which are immediately suitable for use in the Eurasian development corridors.

One is the large unit-size (1,000 megawatts and more) light water reactor (LWR) technology used in many industrial nations. In France, for example, whose nuclear program has been particularly strong and successful, more than 80 percent of the national electricity consumption is now provided by such reactors. These reactors exploit economies of scale to generate large quantities of electricity at low cost, but are not suited for other applications, such as production of industrial process heat. Another limitation is the lack of flexibility inherent in the very large unit size.

The other major option is the helium-cooled high-temperature reactor (HTR), developed by R. Schulten and his collaborators in Germany, as well as, in a slightly different form, in Japan and the United States. HTRs operate at a much higher temperature than the LWR reactors—up to 950° Celsius—which means a higher efficiency in electricity production, as well as the ability to provide process heat for a variety of industrial processes, and low-temperature heat for the heating of buildings, desalination, and other applications. If desired, electricity production, high-temperature process heat, and low-temperature heat applications can be combined in a single, multipurpose unit.

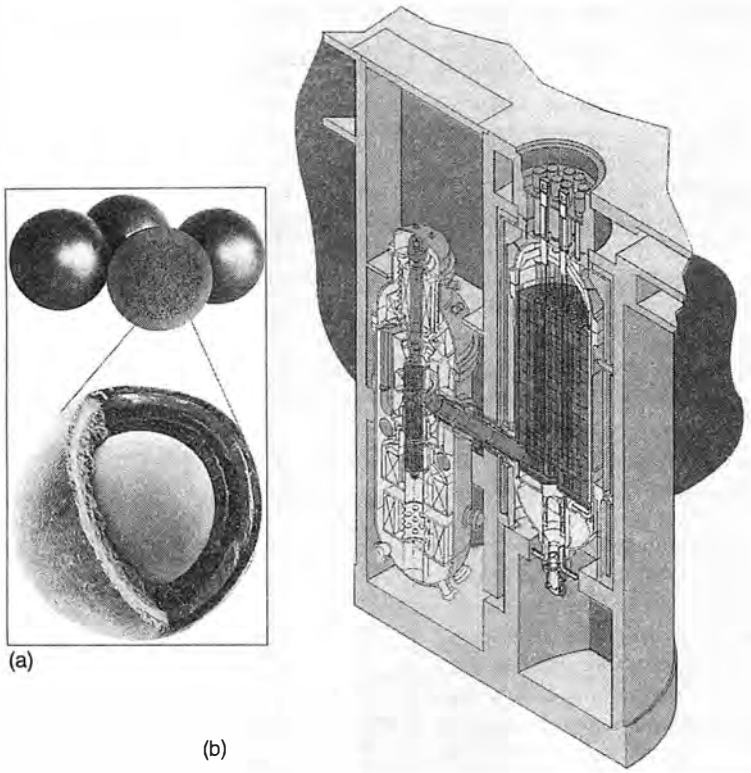
With the projected development of a helium turbine, operating directly in the primary coolant loop of an HTR reactor, the efficiency of electricity generation will be raised even further, eliminating the costly steam generators in LWR power plants. Such turbines will be extremely compact, having a much higher power density than traditional steam turbines.

The HTR technology is particularly well suited to the construction of standardized modular reactors with powers ranging from 50 to 250 MW thermal output, which can be mass-produced at low cost and combined to reach any designed total output. The cost reduction through manufacture in series, is sufficient to make modular HTRs competitive with the large LWR reactors, even for electricity production alone. On the other hand, the HTRs are equally suited for the production of heat, which is an even larger market in quantitative terms.

An additional, particular advantage of HTR modules lies in their *inherent safety properties;* they can be designed in such a way, that the possibility of serious accident—a "runaway" reaction, "melt-down," or major release of radioactivity—is ruled out by physical mechanisms alone, without any complex safety systems and independent of human intervention. In particular, the encapsulization of the nuclear fuel within multiple layers of special high-temperature ceramics (Siamant) prevents the release of radioactive fission products even under the most extreme conditions (Figure 8). This results in an inexpensive, robust system, which is simple to operate and safe enough to be

Figure 8
(a) HTR FUEL ELEMENTS
Fuel elements for the German-designed high-temperature reactor are shown with a cross-section image of a pellet, produced by a scanning electron microscope. The fuel core of 0.4 mm diameter is surrounded by a protective coating.

(b) SCHEMATIC OF A GAS-TURBINE MODULAR HELIUM REACTOR
This General Atomics design for a modular high-temperature reactor is the design under way in a collaborative program with Russia. The reactor is on the right, and the gas turbine on the left. By eliminating the extensive equipment required for the steam cycle, the gas turbine system reduces the capital and operating costs of the plant and increases plant efficiency.



installed without danger in areas of high population density.

HTR reactors also have the advantage of being ideally suited to convert thorium—a plentiful resource in India and some other countries—into fissionable fuel.

The HTR technology for modular use was developed and proven in the uniquely successful AVR reactor at Jülich, Germany (Figure 9). It is typical of the recent, self-destructive policy in the West, that the "live" HTR programs are in Asia at present, while Germany and the United States have all but dismantled their HTR efforts. China has the world's only project for an HTR of the Jülich design, while Japan is building an HTR with a different form of fuel element.

The HTR technology appears predestined by its advantageous properties, to be the main "work horse" in the development of the Eurasian infrastructure corridor regions. The HTR is ideally suited to supply power to cities and large towns, integrated agro-industrial complexes (so-called nuplexes) and *in situ* extraction and processing of certain raw materials. The components of smaller-sized HTR plants could be transported by rail and assembled at suitable sites

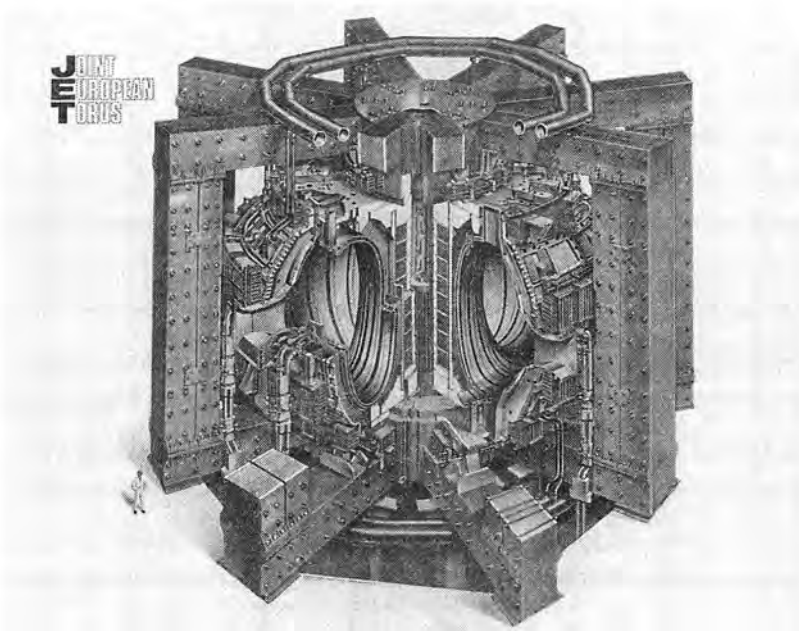


Figure 9
JOINT EUROPEAN TORUS
The Joint European Torus (JET), a thermonuclear fusion experiment in England. This European fusion project has produced several megawatts of power.

Source: JET

along the Eurasian rail lines. All necessary services, including supply of fuel, transport of spent fuel, spare parts delivery, inspection and so forth, could be provided via the rail system in a highly efficient, centralized manner. As the power consumption grows, more modules are simply added.

The use of such systems is particularly attractive for underdeveloped areas of Eurasia, where abundant energy is a precondition for overcoming the disadvantages of difficult climate and other natural conditions. With plentiful energy, we can populate the coldest regions of northern Siberia, or—through large-scale desalination, pumping, and recycling of water—the driest desert regions of Central Asia and the Middle East.

Other Fission Reactor Types

Besides the LWR and HTR technologies, several other fission reactor types deserve mention. China, for example, has developed a specialized reactor type for low-temperature heat production, which is cooled by the natural heat convection motion of coolant water and has a very high intrinsic safety and simplicity of operation. This type of reactor is well suited to space heating in cities, and as a heat source for desalination. Combined with a heat pump, the same reactor can provide air-conditioning for large building complexes in summer. Sweden and Russia also have developed heating reactor designs, to heat towns in remote northern areas.

A very different direction of development is the fast breeder reactor. Besides producing thermal energy, this reactor can convert the abundant, but non-fissionable uranium isotope U-238 into fissionable plutonium for fueling further reactors. By this procedure, the energy extractable from any given amount of raw uranium ore can by increased many times over. Fast breeders have far higher power densities, in their cores, than either HTR or LWR reactors. Unfortunately, technical characteristics of the existing systems, and certain problems of safety, have so far made it impossible to exploit the economic advantages which might otherwise be derived from such higher density.

Controlled Nuclear Fusion

In the future, however, the leading role of nuclear fission (at least in the forms known at present) will doubtless be superseded by controlled nuclear fusion. The first generation of experimental fusion reactors use a mixture of the hydrogen isotopes deuterium (D) and tritium (T) as "fuel." To obtain an economically useful rate of reactions between D and T nuclei, the fuel mixture must be raised to the equivalent of temperatures of more than 100 million degrees, creating a special form of matter known as a hot plasma.

The first successful large-scale release of energy from fusion reactions created by man occurred when the first hydrogen bomb was tested by the United States. In that case, a nuclear fission bomb was used as a trigger. The crucial problem for civilian, commercial exploitation of fusion reactions, is how to achieve such reactions on a smaller scale and in a controlled manner. For this purpose, two basic families of experimental fusion reactors have been developed. The first, "magnetic confinement fusion," employs powerful magnetic fields to hold the fusion plasma in the middle of a suitable container. The plasma is initially created by an electric discharge, and then heated by microwaves and particle beams.

The large European experimental fusion reactor, the Joint European Torus (JET), is based on this principle (Figure 10). Although it was not designed as a net generator of power, it has produced several megawatts of power from fusion reactions in experiments in 1995. Similar results have been produced in the TFTR reactor in the United States.

The second family of fusion reactors employs a different principle, inertial confinement fusion. In this case, the fuel is initially contained in a tiny pellet approximately the size of a grain of sand. By means of a sudden, powerful pulse of coherent light radiation or particle beams, the fuel is compressed to enormous densities and heated to the ignition temperature. The result is a miniature H-bomb explosion, whose energy release can be contained within a specially de-

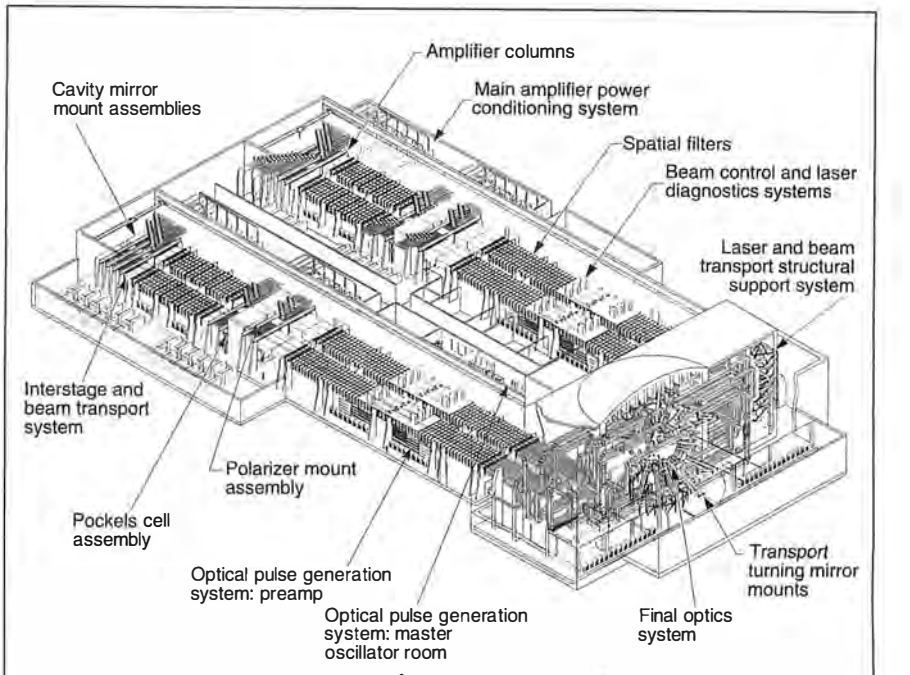


Figure 10
THE NATIONAL IGNITION FACILITY

A diagram of the gigantic laser fusion experimental installation, the National Ignition Facility, being planned at Lawrence Livermore National Laboratory in California. The installation will generate—with 192 parallel linear laser amplifiers—a single, short, but extremely powerful, pulse of about 500 terawatts, which can be used in various experiments for ignition of fusion fuel. The microexplosions produced in this way are expected to release up to 45 megajoules per shot.

Source: LLNL

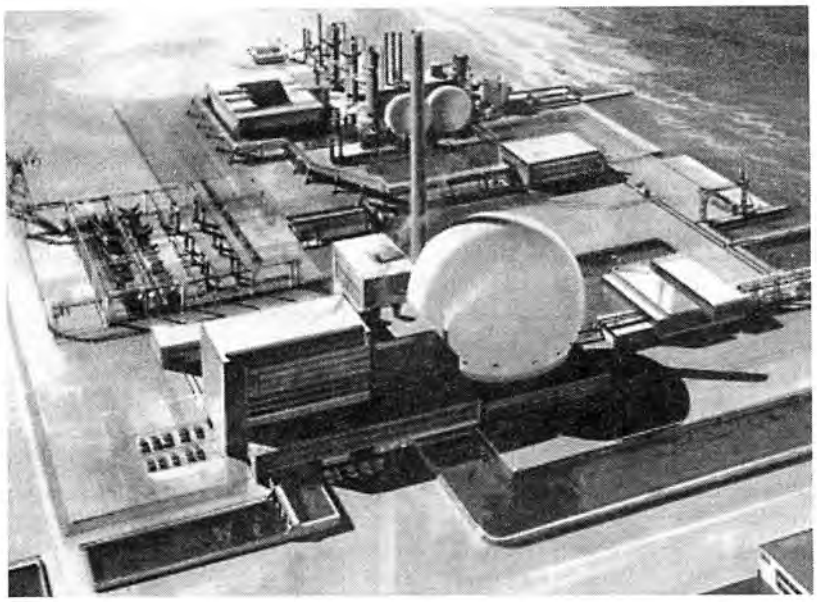


Figure 11
A NUPLEX DESALINATION PLANT
This nuplex plan from the 1960s, located on a coast, was designed to provide the nuclear-powered water desalination to make large-scale irrigation possible.

signed explosion chamber. Such fusion microexplosions have been produced in a number of laboratories, particularly the Lawrence Livermore National Laboratory in the United States, using powerful lasers. To achieve this form of fusion for commercial purposes, however, it is necessary to greatly increase the fusion output, compared to the power needed to generate the laser pulse.

A workable method for doing this was demonstrated in underground tests, carried out by the Livermore Laboratory in the mid-1980s, which used a small nuclear fission device to generate the pulse of radiation, instead of a laser. A new laser facility is now planned, and should demonstrate the performance parameters needed for a commercial laser fusion power plant (Figure 11).

When controlled nuclear fusion reactors will become commercially available, is mostly a question of political will. We would almost certainly already have power-generating, commercial prototypes operating today, if the development of science and technology had not been sabotaged by anti-progress, "post-industrial" policies introduced from the mid-1960s on. With a renewed international commitment to progress in the context of full-scale development of the Eurasian infrastructure corridors, the first commercial fusion reactors will surely be in operation by 2015-2020 at the latest, and possibly before.

This does not mean, of course, that nuclear fission reactors will go out of use. Most likely, the world economy in the first half of the next century will be based on a combination of fission and fusion, making the best use of both. For example, it is likely that fission reactors will continue to be used as industrial heat sources at temperatures up to about 1,000° Celsius, while fusion reactors will be used for much higher-density, more coherent forms of power output.

The Fusion Revolution

Twenty to thirty years is not a long time for planning long-term infrastructure investments. As a result, energy policy for the Eurasian corridor development must already take account of the coming fusion revolution.

An important probable feature of the coming era of fusion energy, will be the increasingly large-scale production and use of *hydrogen,* both as a fuel for aircraft, space vehicles, and (possibly) ships and cars, and as an industrial fuel. Contrary to some myths spread nowadays, production of hydrogen using solar energy would be far too expensive for most uses. What is required for really efficient hydrogen production is, first of all, a highly concentrated source of energy, which primarily means nuclear energy and especially certain types of fusion reactors which might be developed in the future for that purpose.

The development of a Eurasian pipeline network for natural gas and oil today, should be seen as laying the groundwork for a future transport network for hydrogen, synthetic liquid fuels, and other chemical products. In fact, there should be a policy of shifting away from combustion of oil, gas, and coal as simple fuels, toward their dramatically increased usage as raw material feedstocks for the production of hydrogen and other high-value chemical products. Nuclear energy will play an important role in that process.

Nuclear Excavation

Thanks to the general atmosphere of hysteria surrounding the topic of nuclear energy, and nuclear weapons in particular, nowadays, very few people realize that there are extremely important civilian applications of nuclear explosions. One of the most obvious applications is for scientific research, where underground nuclear explosions provide a unique possibility to study phenomena at the extreme ranges of pressure, temperature, and energy density. For example, the so-called Halite Centurion program, carried out by the U.S. Lawrence Livermore National Laboratory in the mid-1980s, used underground nuclear explosions as a source of intense radiation, in order to investigate the optimum conditions for realizing "inertial confinement" nuclear fusion as a civilian power source in the future.

The other obvious potential use of nuclear explosions is for large-scale excavation work, such as the digging of canals, reservoirs, tunnels, for the recovery of oil and natural gas, and so forth. Such applications were extensively investigated by the United States ("Project Plowshare") and the Soviet Union in the 1960s and 1970s, and also by other countries. It was demonstrated that, under appropriate natural conditions, and, given careful planning and execution, nuclear explosives could be safely used for a variety of earth-moving and mining applications.

Real-life tests, as well as extensive simulations and other studies, showed that undesirable side-effects from underground nuclear charges, including possi-

ble release of radioactive materials into the human environment, could be reduced to an acceptable minimum. It was demonstrated, that, in many cases, the use of nuclear explosives could provide an enormous saving in cost and time, compared to conventional methods. In the future, improvements in nuclear device uses, including possible development of low-radiation fusion charges with non-nuclear triggers, would further increase the advantages of nuclear excavation techniques.

A concrete example of the saving involved is the long-discussed Kra Canal project in Thailand, which would drastically shorten the sea route between the South China Sea and the Indian Ocean, while alleviating the bottleneck at the Straits of Malacca. The plan is to build a sea-level canal approximately 120 km long across the narrow section of the peninsula of Thailand, just north of the border with Malaysia. In the most attractive version of the project, the canal would have two lanes, one in each direction, capable of carrying ships up to 500,000 cwt. In addition to the canal itself, a major harbor ("Asiaport") and transshipment facility could be built up at Songkhla, as well as industrial development zones along the canal route. A feasibility study, carried out by two American engineering companies in cooperation with the Lawrence Livermore National Laboratory in the 1970s, demonstrated that the use of nuclear explosions for part of the excavation work would reduce the overall cost of the canal by at least 40 percent, while cutting the construction time nearly in half, to between six and seven years. Although the decision to build the canal has been delayed for political and financial reasons, the recent growth of trade in Asia makes its construction a more and more attractive proposition.

Development of Water Resources

Water plays a crucial role in Eurasian development, no less decisive than energy or transport. Water supply and distribution systems, sanitation and wastewater treatment, irrigation and drainage systems for agriculture, river and flood control, and so on, belong to the category of essential infrastructure, which are the absolute basis for any healthy economy.

Most of Eurasia still lacks even the minimum level of per capita and per hectare water infrastructure, necessary to sustain a modern economy. Particularly in large parts of Asia, existing conditions require a much larger per capita and per hectare investment, than in central Europe, for example. On the one hand, this applies to vast areas of low rainfall, including parts of the Near and Middle East, the huge arid regions of Kazakhstan and Central Asia, the deserts and other dry areas of northern China, as well as some parts of India. On the other hand, we have major problems of river and flood control in the monsoon regions such as India, Bangladesh, Thailand, and so forth, and the age-old legendary problems of the Huang He (Yellow) and Chang Jiang (Yang Tze) rivers of China. Added to this is the challenge of overcoming ecological disasters connected with large-scale pollution and with the drying-up of rivers and lakes such as the Aral Sea.

All these problems are in principle solvable. The question is only one of adequate investment, and of building up an economic and technological base capable of sustaining the required levels of investment. The giant water diversion projects, dam projects, and flood control projects in China today are a very good example of what can be done, especially when modern, capital-intensive construction techniques are employed.

The use of nuclear energy for large-scale pumping of water, and for desalination, and the use of nuclear explosives to speed up and cheapen large-scale excavation for canals and other projects (see below), are examples of the impact of advanced technology on the economy of water supply.

It has become popular to dismiss large water projects as "threats to the environment"—as if it were a good thing to protect deserts from being turned into gardens, or to defend natural disasters as "good" because they were made by nature, instead of man! In fact, in nearly all of the cases of disastrous negative effects, connected with water infrastructure projects, the cause was not the project itself, but wrong or inadequate economic policies. A typical case is the destruction of the Aral Sea.

In fact, it is entirely possible:

(1) To move large flows of water, equivalent to major rivers, by man-made canals, aqueducts, tunnels, and so on, over distances of hundreds or thousands of kilometers. So, China is moving water from the wet south to the relatively dry north of the country.

(2) To pump large amounts of water over natural barriers, such as differences of elevation, or even mountain ranges.

(3) To control the waters of mighty rivers, whose flooding has cost millions of lives in the past.

(4) To desalinate, recycle, and remove arbitrary impurities from water on a large scale, even to the point of creating "artificial rivers" by desalination of seawater or saline underground water.

The last example is of particular importance, since many people are accustomed to considering freshwater resources as something intrinsically limited, to some supposedly absolute amounts.

Potential of Large-scale Desalination

The production of fresh, drinkable water from seawater in large quantities by desalination, is a well-established industrial process today. At present, desalination plants around the world produce about 15 million cubic meters of fresh water per day (5.7 billion cubic meters per year)—which corresponds, for example, to twice the total water consumption of the Jordan Valley nations, including Israel, Jordan, and the West Bank. The total power consumption of the world's desalination plants (including older, less efficient ones) is between 5 and 7 gigawatts (GW). Desalination capacities are projected to grow dramatically in the future.

Since the amount of water in the world's oceans is practically infinite, from the standpoint of man's foreseeable requirements, the only limitation to the potential supply of fresh water by this method, is the investment cost for transport of water, for desalination facilities, and the cost to supply the required energy inputs, which are on the order of approximately 7 kilowatt-hours per cubic meter of desalinated water.

At present, there are two main types of processes used for large-scale desalination. One, which uses heat as the main energy input, is based on *multiple-stage evaporation,* with recovery of some of the heat during condensation of the water. The other main type of process is based on *reverse osmosis (RO),* and involves pumping water through special

membranes; here, energy is supplied mainly in the form of electricity for the pumps. Taking RO as an example, RO desalination plants can be built up from standard modules, each producing 24,000 cubic meters of water per day. In continuous operation, each such module requires approximately 7.2 MW of electric power.

By building up such facilities on a very large scale, it would be possible even today to literally create "artificial rivers" by desalination of sea water. To take an extreme hypothetical example: 10,000 RO modules of the type just described, would produce very roughly the equivalent of the water flow of Germany's Rhine River! The electricity input required would be about 72 GW, which is of course very large, but not beyond the range of what would be conceivable, even today, for a modern industrial nation. (The present electricity generation capacity of Germany is 123 GW.)

More significant than such a thought experiment is the order of magnitude of cost for desalinated water. Taking into account the investment and operating requirements, and the lifetime of modern desalination plants and electric power plants (for example nuclear plants), the production cost in a large-scale, nuclear-powered desalination plant will be less than 65 cents per cubic meter of desalinated sea water. (This assumes zero rate of interest; for present market rates, the price would approximately double.)

To get a sense of what this means: A typical household at European living standards has a water consumption of about 50 cubic meters per person per year. If this were all provided by desalination, that would mean a per-person cost of about $33 to $66 per year, hardly a major burden in the developed countries. In fact, many areas of Germany now pay more for their water.

Taking a more extreme case, suppose the entire water consumption for agriculture had to be supplied using desalination. It is estimated, that approximately 1,200 cubic meters of water are needed in modern agriculture, to produce the food to feed one adult person for one year. The cost to supply that water by desalination would be $800 to $1,600, which is a significant cost, but still a small fraction of the average per capita income in advanced sector nations.

All this means, simply, is that it is entirely feasible, at modern industrial standards of economic productivity, for a nation to supply virtually its entire water requirements—including agriculture!—by desalination of seawater. In practice, of course, there are nearly always natural sources of water, and desalination is used as a supplement, particularly for high-grade uses such as drinking water.

With future advances in desalination and energy technology, the costs will naturally be reduced.

Of course, for the more underdeveloped areas, such as much of the Near and Middle East, the cited costs would appear prohibitively high. The problem here, however, is not that the desalinated water is intrinsically too expensive, but that the level of industrial productivity of these nations and areas is too low. The general answer to the problem is rapid economic development on the basis of long-term, low-interest credits, and the use of infrastructure development corridors to dramatically increase the productivity of the economy.

It should be noted, that China has developed a special heat-producing nuclear reactor, with high safety characteristics, for use in desalination as well as urban heating. One of the projects now under consideration, is to build a nuclear-powered desalination plant to supply fresh water to the northern coastal city of Dalian.

TELECOMMUNICATIONS TECHNOLOGY

Given the great emphasis placed on the information revolution in the industrial nations nowadays, communication-related technology has advanced relatively rapidly. Thanks especially to laser, optronic, optical fiber, and satellite technologies, the goal of providing telephone service to *every household* in Eurasia within the next 25 years is entirely realistic. While today in Sweden there are 68 telephones per 100 inhabitants, and in Germany 44 telephones per 100 inhabitants, in China the figure is only 1 per 100. Naturally, provision must be made for the fact that an increasing proportion of households will require not only voice communication, but also the capability for data links of various sorts.

The Trans-Asia-European fiber-optical cable . . . points in the right direction. Installing high-capacity optical fiber trunk lines and other communications network equipment (for example, wireless [cellular] digital telephones) along the Eurasian infrastructure corridors, provides the most efficient means of expanding communication services throughout the vast area of the supercontinent. Because of the high density, users within the 100-km-wide band of the corridors are accessible, and provide a high rate of return on investment; the remaining areas are most efficiently reached through the growing network of infrastructure capillaries extending outward from the main corridors.

The fiber-optical communications network, running parallel to lines of rail and maglev transport, will also handle the increasing data-flows connected with the logistics of intermodal freight (including postal) transport throughout Eurasia.

By means of such a coherent, coordinated approach, oriented to the entire Eurasian landmass and employing the most advanced technologies, the *per capita and per square kilometer* costs of supplying postal and telecommunication services, could be drastically reduced, compared to the present.

Besides providing universal telephone services, high-capacity computer data links for relevant institutions, firms, and households throughout Eurasia, and so forth, perhaps the most important priority for telecommunications technology for the development of Eurasia, will be the establishment of a *universal library system* encompassing all the world's books and periodical publications, past and present. Such a system would operate like a computer data bank, which would download the content of any desired book or periodical as a graphics file (that is, in facsimile form) to any user on request. Advances in technology are making it feasible to carry out a digital scanning of the entirety of existing stocks of books in the world's libraries, in all languages, for storage in a universal library. The implications for general education, and for a renaissance of culture, would be immense. Perhaps the establishment of such a universal library system, available to every citizen, would partly compensate for the enormous damage, that Hollywood, the corrupt mass media, and the epidemic of mind-destroying "computer games" have done to the minds of young people all over the planet.

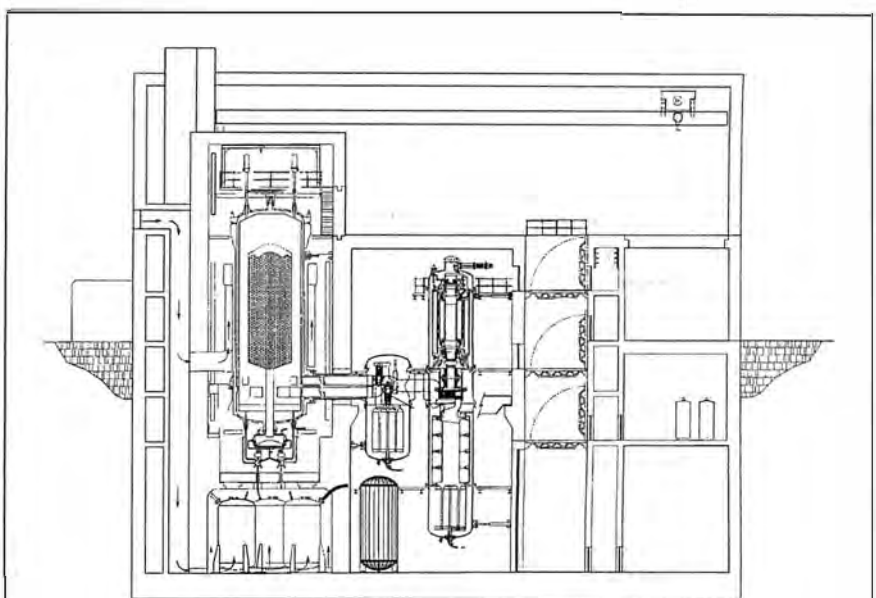
INTERVIEW WITH DAVID NICHOLLS

South Africa Plans Advanced High-temperature Nuclear Reactor

David Nicholls is a member of the Technology Group of Eskom, the national utility of South Africa, where he is a project manager for Eskom's current investigations into high-temperature gas-cooled reactor technology.

Eskom, the fifth largest electric utility in the world, generates more than 95 percent of South Africa's electricity and more than half the total electricity consumed on the African continent. Its goal is to electrify another 450,000 homes a year; currently only 40 percent of the nation's housing receives electricity. Eskom is a profitable company and boasts one of the lowest costs of electricity in the world.

Nicholls was interviewed by Benoit Chalifoux, of the French-language Fusion *magazine.*



ESKOM'S PEBBLE BED MODULAR NUCLEAR REACTOR DESIGN
This inherently safe, modular, high-temperature reactor uses helium as the working fluid, 60-mm fuel pellets, and a closed-cycle gas turbine system in place of the conventional steam cycle. The closed cyle permits higher inlet and outlet temperatures, with reactor core powers at 200 to 250 MW. The overall efficiency is 45 to 50 percent, yielding an electrical power output of about 110 MW.

Question: Can you tell us about the modular high-temperature gas-cooled reactor project at Eskom?

Eskom is undertaking a number of technical-economic evaluations of new generating options to meet the possible need for new generating capacity in the first of the next century. Among these investigations is one for a high-temperature gas-cooled reactor, based on earlier German developments.

This study is aimed at a closed-cycle gas turbine system using helium as the working fluid. The system, called the Pebble Bed Modular Reactor, or PBMR, appears to hold the potential for inherent safety coupled with excellent economy. This is based on the work done for the Interatom Modul and the IIRB-100 designs in the 1980s.

The major change from these designs is the use of a closed-cycle gas turbine system in place of the steam cycle. This has led to higher core inlet (604° C) and outlet temperatures (900° C), with similar core powers. With the thermal power of the core limited to 200 to 250 MW, this leads to a post-accident core temperature below the point of fuel damage, avoiding the need for any safety systems.

The overall cycle efficiency is 45 to 50 percent, giving an electrical power output of about 110 MW, on the current calculations. The turbine machinery is configured as two turbo compressors and a power turbine for each 110-MW module. There is active stator position control on each of these machines, allowing a very wide range of operating conditions. Specific targets include a ramp rate of 10 percent of full power per minute, and full load rejection with reactor scram [sudden shutdown].

The plant is intended to operate at full efficiency down to 20 percent power, and to be able to sustain any power level (zero to 100 percent) on a continuous basis. In order to respond to changes in grid capacity, a construction

period of 24 months is intended. (Unit 1 is expected to take 36 months). To be competitive with Eskom's coal-based options, a capital cost of under $1,000 per kW is the target.

The study currently under way involves a number of local and overseas companies and institutions and, while it is not yet complete, the early indications are that the targets mentioned above are achievable.

Question: Why are you interested in a 100-MW reactor? Why not a 300-MW unit like the General Atomics project?

At present, the aim is to achieve the maximum power from the outline design without adding complexity. The present indications are that this combination will lead to a better cost-versus-risk than will larger units. Power stations would consist of multiple modules, with further modules being added in response to load growth.

The German-designed fuel used by the pebble bed modular reactor consists of coated particle kernels embedded in 60-mm graphite spheres, compared with the prismatic block fuel used by the General Atomics MHTGR [modular high-temperature gas-cooled reactor] design. The use of the fuel balls is thought to have a number of advantages over the block type. These include a lower fuel operating temperature and the possibility of on-load fueling/defueling.

One of the limitations is that the core geometry limits power output of this "pebble bed" configuration, if inherent safety is to be achieved, unless complex (and untested) layouts are used. This limitation on unit size is seen to have advantages, however. It leads to shorter construction periods and to a lower "entry" cost for the program. It also allows for a greater use of mass production techniques.

Question: Are you planning to use these high temperature reactors only for electricity or also for heat?

The current investigations are based on electric power generation only. It is accepted that there is potential for process heat applications, but that is not included in the commercial evaluation being done, as this is very site-specific.

The one application which has been considered, briefly, is desalination. This could use the normal waste heat from the pre-cooler, which could be up to 100°C, without impacting the overall electrical efficiency.

Question: What are the prospects for growth in energy consumption for the next 10 years—in the residential sector and in the industrial sector?

In the last 10 years (1986-1996), the peak power demand on the Eskom system has gone from 18,278 MW to 27,967 MW, more than 50 percent. The forecasts for the next 10 years vary considerably. The country has a very large electrification program (450,000 households per year) in the previously disadvantaged community, and is also encouraging energy-intensive industries. These industries include an 850-MW "green field" aluminum smelter that was commissioned in 1996. These are, in large part, economically viable due to Eskom's very low electricity cost, which averages approximately 2 cents (U.S.) per kilowatt/hour.

The future is not certain but there is a significant potential for growth in the electricity sector.

Question: Many experts believe South Africa has a lot of cheap, high quality coal, and has the means to import oil. Why then would you go nuclear?

Eskom is a predominantly coal-based utility with over 90 percent of its capacity in this form. The low cost of these units is, in part, due to their being pit-head plants of large size (typically 6 units of 650 MW). These coal fields are all in the northeast of South Africa, where water supplies for cooling are limited. The cost of oil fuel makes oil-based generation exorbitantly expensive, and there is very limited hydroelectric potential capacity in the country (600 MW total, installed).

It was for these reasons that Koeberg, Eskom's current nuclear station, which consists of two 922-MW Framatome-built units, is based near Cape Town, 1,000 miles from the next power station. There is, therefore, the scope for small, flexible, stations to support the end of the grid system. If the target costs are met for the PBMR design, it could be considered for inclusion in a future construction program.

ESKOM INSTALLED CAPACITY (GROSS, 1996)

Coal	34,125 MW
Gas Turbine	342 MW
Hydro	600 MW
Pumped Storage	1,400 MW
Nuclear	1,930 MW

ESKOM PEAK DEMANDS (1986-1996)

1986	18,278 MW
1987	20,001 MW
1988	20,587 MW
1989	21,871 MW
1990	21,863 MW
1991	22,342 MW
1992	22,460 MW
1993	23,169 MW
1994	24,789 MW
1995	25,133 MW
1996	27,967 MW

The total electrical power delivered is 36,543 MW, of which 4,531 MW is in reserve storage because of lower-than-expected growth rate during the 1980s. There is a six-unit 4,000-MW coal-fired station under construction, with one unit commissioned in 1996 and further units coming on stream at yearly intervals. Work is ongoing on returning the units in reserve storage to power operation as the load increases over the next few years.

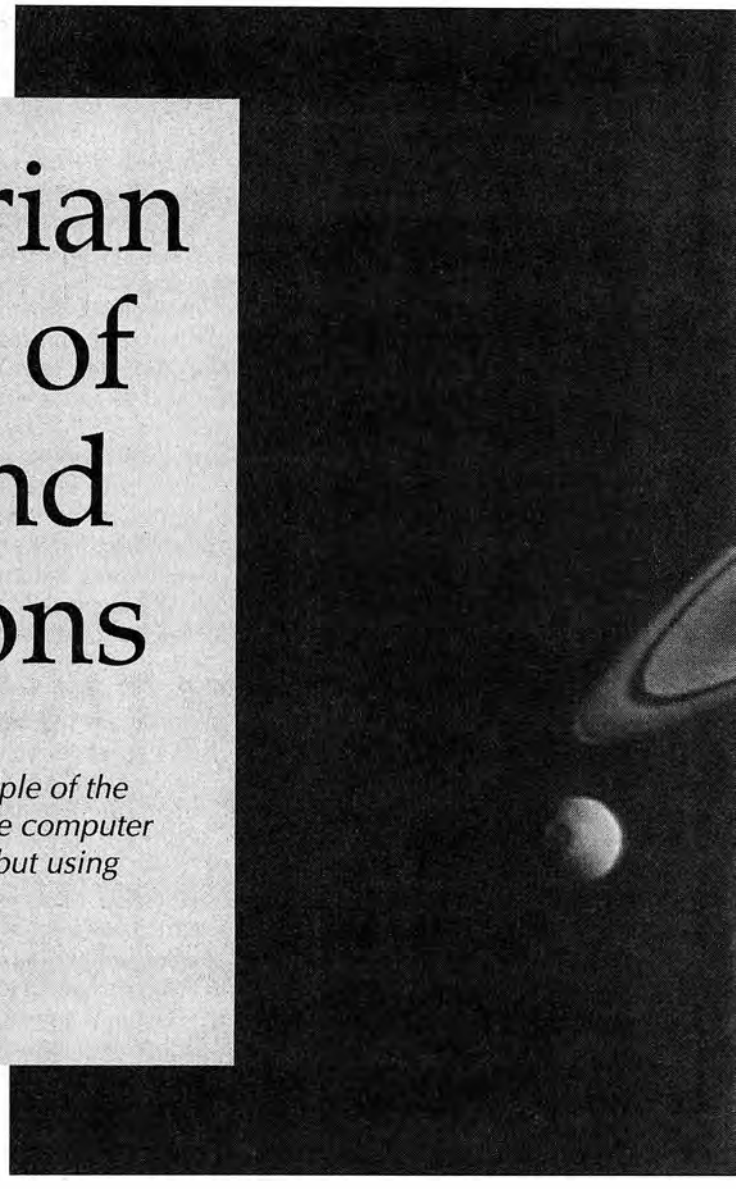
Question: Does Eskom have targets in terms of the percentage of nuclear-generated electricity it would like to achieve?

No. We don't have any specific policy. Our decisions will be principally made on a commercial basis only.

Question: What are the prospects for exporting MHTGRs?

The studies Eskom is currently undertaking are based on the generating needs of the company itself. While it is accepted that there could be a potential for export at some point, the possibility is not currently being included in the studies.

The Keplerian Harmony of Planets and Their Moons



The author discovers the ordering principle of the moons orbiting the planets, not with sterile computer modelling or Newton's so-called laws, but using a lively Keplerian imagination.

by Lothar Komp

Astrophysics is in turmoil. Research budgets are being cut back worldwide, NASA is only a shadow of its former self, and the golden age of Voyager planetary flybys is past. Yet, those great astronomical projects that have remained—such as the Hubble Space Telescope and the orbiting X-ray telescope ROSAT—have recently produced enough contradictions to standard physics, that entire domains of supposedly securely held science have disintegrated.

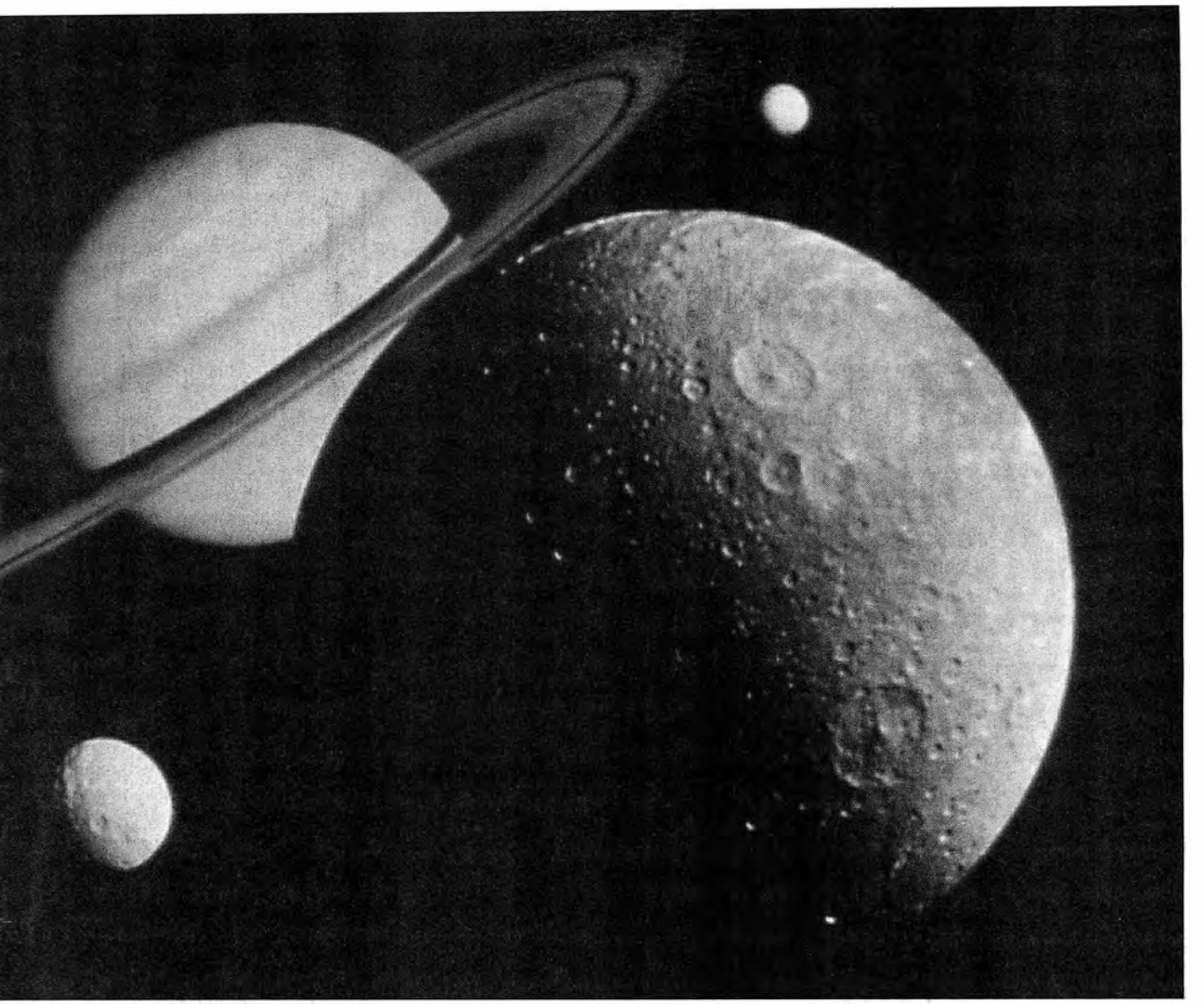
Some examples:

- Most of the stars in globular clusters seem to be at least 5 billion years older than the Big Bang.
- The observation of "naked" quasars has shaken the interpretation of quasars as merely the nuclei of distant galaxies.
- The cold-dark-matter model for the origin of galaxies has been shipwrecked on the rocks of a surprisingly high degree of order, of even extremely old galaxy clusters.
- There are new indications of a quantization of the red shift.
- It is still true that spiral galaxies are rotating much faster than is allowed by the law of gravitation.

Yet, aside from these extragalactic subtleties, even right here, at our very doorstep, there is enough to be disturbed about.

Whenever you pick up a physics book today to learn about lawful motion within the solar system, it is beaten into you that, although Johannes Kepler discovered the laws of planetary motion, this did not result in progress until Isaac Newton put these laws into a formula. Indeed, Kepler's laws are supposed to be the same as Newton's laws of gravitation, in the case of two bodies, such as the Sun and Mars, but only Newton's formulation is supposed to permit the exact calculation of motion of an arbitrary number of bodies, under mutual attraction, in space.

Furthermore, we are taught that Kepler's laws of motion are supposedly embedded in mystical, world-harmonic speculations, while Newton's *hypotheses non fingo* (I make no hypotheses) marked the definitive break with the medieval way of thinking.



NASA

Kepler's central hypothesis of a principle of harmony that underlies the solar system, contrasts starkly with the entropic notions of modern physical theories. Here, a composite of four of Saturn's moons.

However, Newton himself was much more skeptical than this, because even then a general solution to the three-body problem had already turned out to be impossible. Thus, Newton believed that he could bring the present ordering of the solar system into coherence with the long-term consequences of his gravitational laws, only through occasional divine intervention, to counteract a general decay. Since Newton's time, we have developed computers good enough to calculate, step by step, the mutual attraction of the Sun, the planets and their moons, and, presumably, the future of the solar system, based on the laws of gravitation. Yet, here also, certain principled limits have been known for quite some time.

Is it not true that the quantities input into the computers, such as the mass and the position of the planets, are known only to a certain degree of approximation? And even independent of that, the computer itself, with each step of calculation, produces an additional uncertainty, because of an inevitable rounding off. That is why computer simulations of the solar system, including the planets' mutual disturbances of each other's orbits, reach their predictive limits after only a few hundred thousand years. Indeed, even the simple question, whether the solar system will be stable in the long term, cannot be unambiguously answered using the laws of gravitation, supported by the most modern computer techniques, and hundreds of years of mathematical efforts.

With significant mathematical fanfare, it has been shown that parameters such as the mean distance of a planet from the Sun, or the eccentricity of a planet's orbit, in first approximation, oscillate periodically around a mean value; however, after looking at closer approximations, time and again, ugly

"divergences" make their appearance. Whether, for example, in the distant future, one of the planets might not "escape" from the solar system, is not possible to predict, or contradict, from such computer simulations.

Thus, the simulation of the solar system became the playground for the "chaos" theorists, who, although they could not shed any light here, did bring to the public their pretty mathematics, and their appealing computer graphics, thereby promoting the market for high-resolution color computer screens.

Let us leave the calculator alone for a while, and without prejudice, let us look at the characteristics of the ordering of the solar system, along with the history of their discovery.

Quantized Orbits

According to the Newtonian doctrine, all the orbits which a planet might take around the Sun, or a moon around a planet, have equal rights. Even a quick glance at the paths of the planets and moons known today, shows that the truth starkly contradicts this idea: The solar system is ordered to a high degree. The fact that the orbital planes of the larger planets coincide very closely, and that the planets all move in the same direction around the Sun, is ascribed to the special relations that existed while the solar system was being formed. The same reason is given for the eccentricities of the planetary orbital ellipses, which, in contrast to the orbits of the comets and asteroids, are nearly all very slight. Yet, the mean distances of the planets from the Sun—or what amounts to the same thing according to the laws of Kepler, their periods—should be entirely arbitrary, and hence the ordering of the orbits is supposed to be a mere accident. Somehow, however, the planets do not seem to have understood this.

TABLE 1
THE TITIUS-BODE RULE

Planet	*n*	2^n	*d* (from the rule)	*d* (observed)
Mercury	$-\infty$	0	0.4 + 0 = 0.4	0.39
Venus	0	1	0.4 + 0.3 = 0.7	0.72
Earth	1	2	0.4 + 0.6 = 1.0	1.00
Mars	2	4	0.4 + 1.2 = 1.6	1.52
Ceres	3	8	0.4 + 2.4 = 2.8	2.77
Jupiter	4	16	0.4 + 4.8 = 5.2	5.20
Saturn	5	32	0.4 + 9.6 = 10.0	9.55
Uranus	6	64	0.4 + 19.2 = 19.6	19.22
Neptune	7	128	0.4 + 38.4 = 38.8	30.11
Pluto	7	128	0.4 + 38.4 = 38.8	39.44

A Wittenberg theology professor, Johann Daniel Titius, first conceived of the following rule that appears to order the spacing of the planets:

$$d = 0.4 + 0.3 \times 2^n,$$

where d *is the distance of the planet from the Sun, given in multiples of the Sun-Earth distance (that is, astronomical units or AU), and* n *is the next whole number.*

The agreement with the true distance of the planets from the Sun is striking. Only Neptune breaks the pattern. The similarity to the quantization of electron orbits in the hydrogen atom, cannot be ignored. There has been no scarcity of attempts to explain the Titius-Bode rule, or the divergences from it, through mechanisms of gravitation or electromagnetism. Yet, these explanations are both very complicated and little convincing.

In his early work, *Mysterium Cosmographicum,* Kepler developed his geometric model of nested Platonic solids, which not only gave Earth's approximate distance from the Sun, but also, the distance of the six then-known planets. Kepler understood this as a first approximation of the geometry of the solar system, with the exact eccentricities and the distances determined by the harmonic lawfulness of the motions of the planets at perihelion and aphelion, their closest and farthest distances from the Sun, respectively.

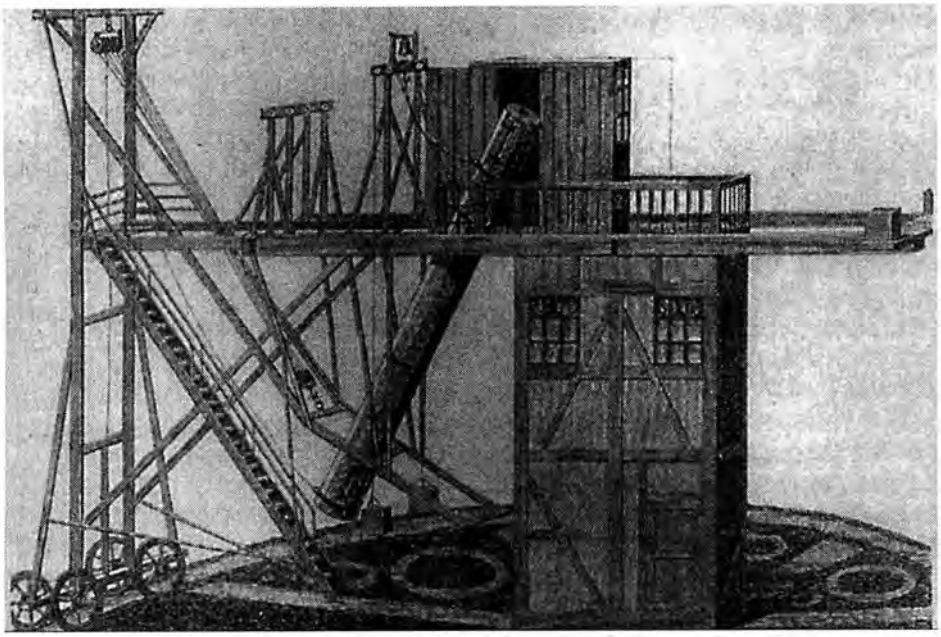
Further along, we will return to the Keplerian harmonies in the light of the plethora of astronomical data available today. For now, we must keep in mind Kepler's central hypothesis, that there is a principle of harmony that underlies the solar system, in stark contrast to the entropic notions of modern physical theories.

It was in no way a dogma for Kepler, that there were only six planets, in contrast to the case, about 200 years later, of the philosopher Hegel, who toward the end of the 18th century drew up a treatise presenting the *a priori* argument, that there can only be exactly six planets—hence no one should bother getting it into his head to point a telescope at the heavens to look for a new planet. Kepler, on the other hand, in the introduction to his *Mysterium Cosmographicum,* offered his suspicion that between Mars and Jupiter, there might well be another planet. He did not base this surmise merely on the great distance between the orbits of Mars and Jupiter. In the *Harmonices Mundi,* after examining the harmonic proportions of the movement of the planets, he comes to the following conclusion:

> These therefore are the harmonies which are shared by each pair of planets. In their main relationships (that is, in the relationship between the motions at the convergent and divergent extremes [perihelion and aphelion, respectively]), there is no pair of planets that would not come so close to a harmony, that the ear, were strings tuned in a corresponding manner, could not easily distinguish the imperfection, except for that difference between Jupiter and Mars.

These considerations of Kepler were given an added impetus by Johann Daniel Titius's devising a geometric array, which fairly closely gave the average distance from the Sun of all the six known planets. Titius, a theology professor from Wittenberg, in a flagrant abuse of his assigned task as translator, simply inserted the following passage describing his discovery into the middle of the text of his 1766 translation into German of the *Contemplation de la Nature* by Charles Bonnet:

> Let us consider for a moment, the relative spacing of the planets, and take note that virtually all of them are distant from each other in a proportion which increases



The observatory of J.H. Schröter in Lilienthal near Bremen. This was the site of the astronomy "conspiracy" in 1800, which founded the United Astronomical Society with the goal of discovering a possible planet between Mars and Jupiter. The reflecting telescope in the middle has an aperture of 50 cm and a focal length of 9 meters.

with their physical size. Take the distance between the Sun and Saturn as 100 units; then the distance between the Sun and Mercury, is 4 such units; Venus, 4 + 3 = 7 units; Earth, 4 + 6 = 10; Mars, 4 + 12 = 16. But note that the distance between Mars and Jupiter would appear to diverge from this very precise progression. Moving outwards from Mars, there is a place at 4 + 24 = 28 such units, at which today there is no major planet or moon to be seen. And the Architect is supposed to have left this place empty? Never, nevermore! Let us make the confident assumption, that this place, without doubt, belongs to the companions of Mars, till now undiscovered, and let us add that Jupiter may perhaps have a few accompanying it as well, which have not yet been seen with a telescope. Beyond this unknown orbit arises Jupiter's locus at 4 + 48 = 52; and Saturn's, at 4 + 96 = 100 such units. What a wonderful relationship!

It was not until the second printing of his Bonnet translation, that Titius resolved to lay claim to this observation as his own. However, in the world of professional astronomy, Titius's discovery was first made public under the name of Johann Elert Bode, the director of the Berlin Observatory, in his 1772 book, *Anleitung zur Kenntnis des gestirnten Himmels* [Introduction to the science of the starry heavens], because Bode could not bring himself to credit, as the source of his own wisdom, a mere translator from Wittenberg.

To posterity, this geometric progression of the distances of the planets from the Sun, has been passed on as the "Titius-Bode rule" (Table 1). Its relevance was brilliantly confirmed by the 1781 discovery of the planet Uranus, whose distance from the Sun, in the above units, was found to be almost exactly 4 + 192 = 196. Still and all, something was missing.

The Gap between Mars and Jupiter

In the fall of 1800, in Lilienthal near Bremen, a "conspiracy" was hatched involving six astronomers. Those present included the "comet astronomer" Heinrich Wilhelm Olbers; the director of the Seeberg (Gotha) Observatory, Franz Xaver von Zach; the owner of the private observatory in Lilienthal, Johann Hieronymus Schröter; Schröter's student Karl Ludwig Harding; and, finally, the astronomers Gildmeister and F.A. Ende. They decided to found the United Astronomical Society, which set itself the goal, in the middle of the Napoleonic wars, to bring together an international host of astronomers, through a joint "great project" of astronomical research: the discovery of a possible planet between Mars and Jupiter. To this end, each of the members of the society should dedicate himself to the goal, "that the heavens visible in middle Europe, should be divided into regions according to the zodiac, and each member should systematically search a region, and make precise notes . . . keeping up a lively exchange of letters with each other; and that in their work, they should always keep in mind, the goal of the research of the group as a whole," in order so to feel and act as "a part of the whole."

The zodiac, the projection of the Sun's path onto the heavens as seen from Earth, is divided into 24 zones of 15 degrees, and each of these zones should be adopted by an astronomer of this international search commando. The astronomers chosen for this task also included Giuseppe Piazzi, professor of mathematics and director of the observatory at the Norman castle in Palermo, Sicily, with whom Bode was in contact. Yet, while the letter to Piazzi was still on its way from Berlin, Piazzi had already acted. Piazzi possessed at the time one of the best instruments for measuring the positions of stars, part of which he had built himself, the so-called universal instrument. With its help, he compiled a star catalogue which gave uncommonly precise positions for 8,000 stars.

On New Year's Eve, 1800, Piazzi observed a faint star in Taurus, whose position, relative to the stars already in his catalogue, had changed only two days later! Was this a new comet? Night after night during January 1801, Piazzi measured the position of the wandering star. Then his observations were

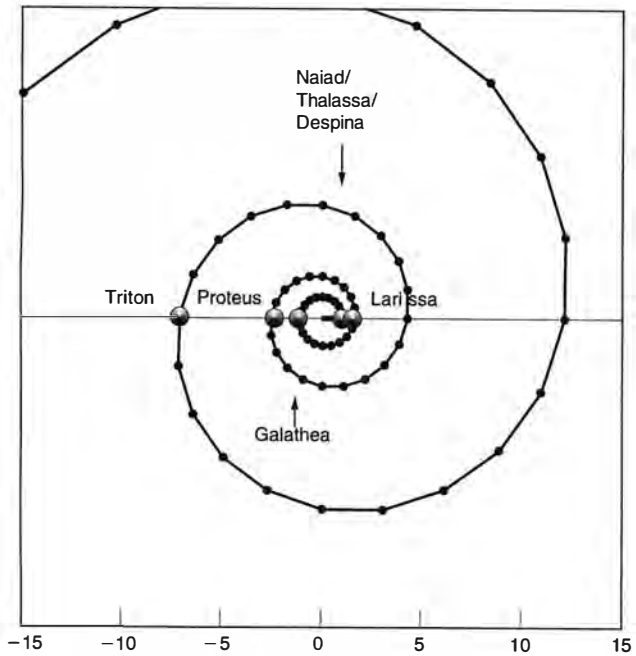


Figure 1
THE MOONS OF NEPTUNE
Distances in diameters of the planet
Barred spiral (c = 1.700)

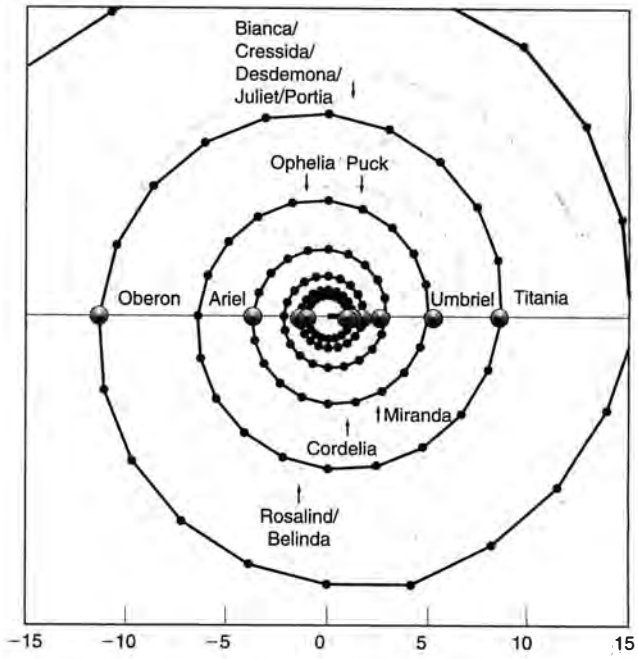


Figure 2
THE MOONS OF URANUS
Distances in diameters of the planet
Barred spiral (c = 1.328)

The planetary diameter or "bar," from which the spiral begins, is extended outward to intersect the spiral's turns. The intersections define the distances of the moons to very close approximations.

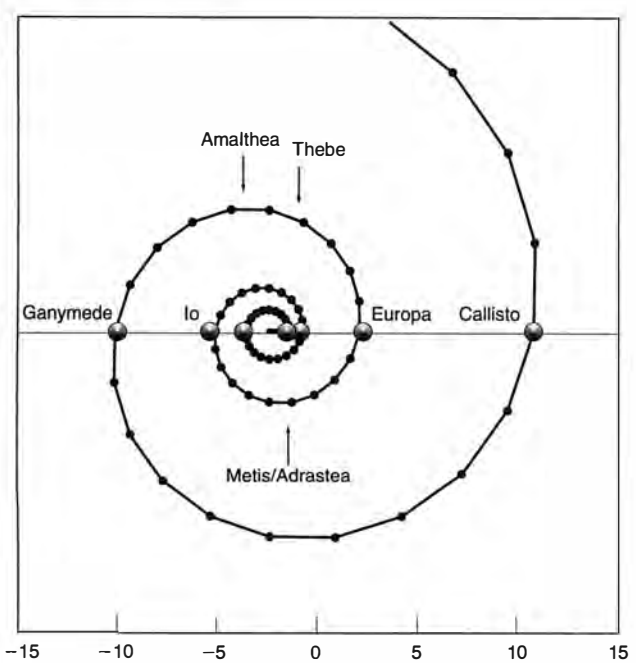


Figure 4
THE MOONS OF JUPITER
Distances in diameters of the planet
Barred spiral (c = 1.725)

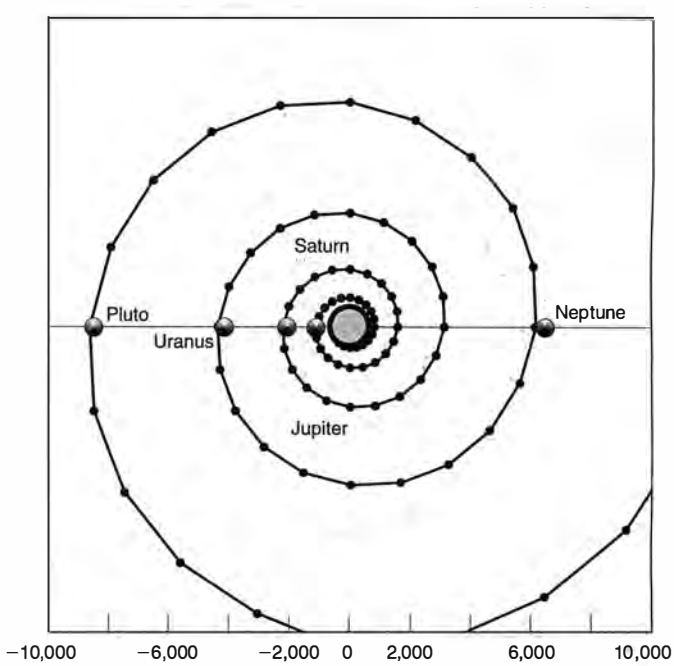


Figure 5
THE OUTER PLANETS
Distances in solar diameters
Barred spiral (c = 1.405)

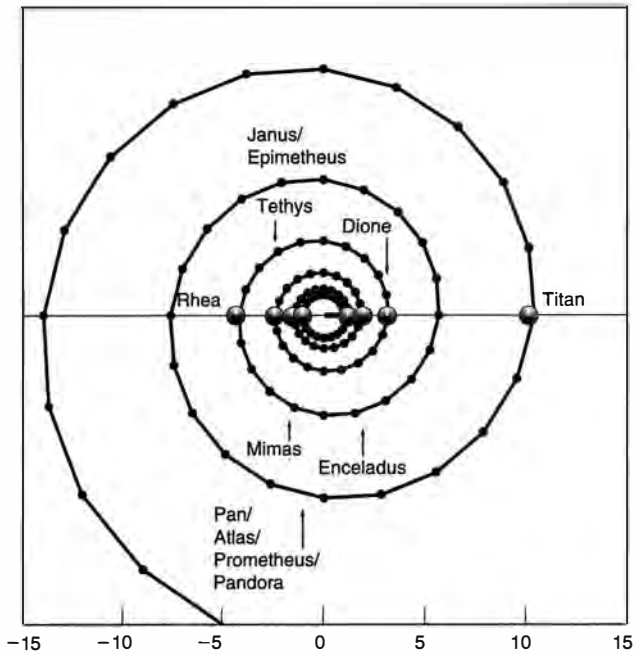


FIGURE 3
THE MOONS OF SATURN
Distances in diameters of the planet
Barred spiral (c = 1.353)

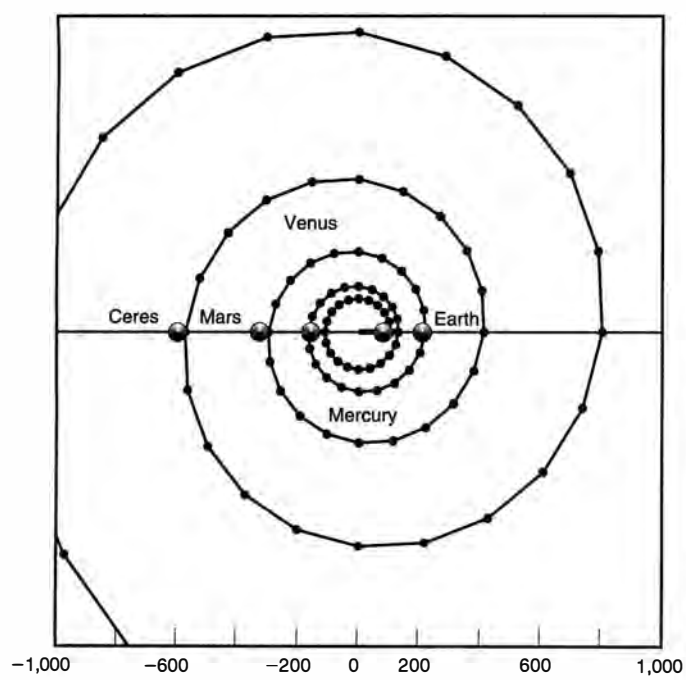


Figure 6
THE INNER PLANETS
Distances in solar diameters
Barred spiral (c = 1.405)

interrupted by bad weather, and when the weather cleared, the star was no longer to be found. Besides, the Sun had now come so much closer to that part of the heavens, that continued observation became impossible for another six months. His last sighting was on Feb. 11.

Piazzi wrote in a letter to Bode in Berlin, that he thought he might have seen the missing planet between Mars and Jupiter. Piazzi's "star" was named after the goddess-protectress of Sicily, Ceres. In June 1801, Zach and Olbers also found what Piazzi had seen. Olbers was at the time the leading expert in the calculation of parabolic comet paths. Yet, in spite of all his efforts, Olbers was not successful, using Piazzi's data and the method available to him, in deciphering the orbit of Ceres. There was only one man capable of doing that: the 24-year-old Carl Friedrich Gauss.

In the summer of 1801, Gauss's *Disquisitiones Arithmeticae* had appeared. At this point in his life, Gauss was turning to new fields of endeavor such as astronomy. First he concerned himself with the unsolved problem of the motion of the Moon. But an event occurred of such pitch and moment, that it changed the course of his life, when "Piazzi's observations became known to the public, and I was pulled in a completely different direction," as Gauss later wrote in a letter to the astronomer H.C. Schumacher. In October 1801, he received from a friend the September issue of the magazine published by von Zach, *Monthly Correspondence for Promoting the Knowledge of the Earth and the Heavens,* which contained Piazzi's observations. Gauss's mathematical diary, in which he had entered every one of his mathematical triumphs since March 1796, suddenly breaks off.

For the next four years, Gauss was in the grip of an astronomical discovery program. In a few weeks, he developed a new mathematical theory which enabled him, proceeding from only three complete observations, to determine the form, the size, and the spatial orientation of a Keplerian orbit. To be precise, it was a question of determining a conic section in space, knowing initially only one of its focal points, namely, the position of the Sun. Then the desired conic section must cut three known lines in space, which are themselves to be found on the path of another conic section, namely, the Earth's orbit. Finally, the path defined by the three points of intersection, must be coherent with Kepler's laws.

After finishing this task, Gauss immediately solved the problem of the determination of a conic section, given only four incomplete observations. He applied the method he had developed—but not published—many years before, the method of least squares. It was still late autumn of 1801, when Gauss sent news to Zach telling him where Ceres would be found on certain nights. And, in fact, a little later, Ceres was found, once again on a New Year's Eve, precisely in the position calculated by Gauss. The next night, Wilhelm Olbers in Bremen also sighted it. Von Zach wrote to Olbers:

> With joy you will have noticed, how precisely Dr. Gauss's ellipse coincides with the observations of Ceres. Please announce this to the worthy scholars, along with a profession of my quite extraordinarily high regard. Without his toilsome research on the elliptical elements of this planet, we should probably not have recovered it.

Now it was clear: Ceres was the sought-for planet between Mars and Jupiter, whose mean distance from the Sun almost exactly corresponded to the expectations of the Titius-Bode rule. This event, Gauss reported later, made him into an astronomer. Thenceforth he maintained a close friendship with Olbers in Bremen. Over the course of 1803, with Zach at the observatory in Gotha, he received a thorough grounding in practical astronomy. At the time, new asteroids were being discovered at a great rate, and Gauss functioned as a "calculation center," for determining the path of each new one. Careful coordination by Olbers ensured that all the observational data found their way to Gauss. Using his revolutionary method, Gauss would then find the future positions of the asteroids.

On March 28, 1802, Olbers discovered the asteroid Pallas, which was shown to have a similar distance from the Sun as Ceres. Olbers expressed the suspicion that Ceres and Pallas might be fragments of a large planet, which he called Phaeton. On Sept. 1, 1804, there followed the discovery of Juno by Karl Ludwig Harding in Lilienthal, and on March 29, 1807, finally, the discovery of Vesta, again by Olbers. The asteroid discoveries then ceased, at least for some decades.

In July 1807, Gauss went to Göttingen as professor of astronomy, and at the same time he became director of the Göttingen observatory. There he drafted, and published in 1809, his "Theory of the Movement of Heavenly Bodies, which Orbit the Sun in Conic Sections," which followed from his somewhat earlier "Theory on the Motion of the Heavenly Bodies, according to Kepler's Laws." Unfortunately, in 1813, Schröter's private observatory in Lilienthal, the launching pad for the asteroid "conspiracy," was completely destroyed by the invading French troops.

Systems of Planets and Moons as 'Barred Spirals'

Gauss first called the Titius-Bode rule a "play of the imagination," but then saw it confirmed by the discovery of the asteroids. Yet, something gnawed away at him as much as before, namely, the empty space between Mercury ($n = -\infty$) and Venus ($n = 0$), in that, according to Titius-Bode, an unending multitude of additional planets with negative "quantum numbers" n might go around the Sun. Yet, these orbits are not occupied, at least according to knowledge then and now.

Another uncomfortable aspect of the Titius-Bode rule results from the natural attempts today to apply it to the moon systems of the planets. In fact, the distances of the moons from their planets do point to unmistakable traces of a geometric progression. Just in the manner of Titius-Bode, one could put forward the rule for their distances in the following form:

$$d = a + (b \times c^n) \qquad (n = 0, 1, 2, 3, \ldots).$$

However, here, in contrast to the distances of the planets, one must abandon the whole number 2 as the basis for the geometric progression c^n. In every system of moons, a, b, and c are independent parameters. Because no choice of a, b, and c will give us their distances in quite so satisfying a way as Titius-Bode does for the planets, there have been attempts in recent times to apply broader, more generalized versions of the Titius-Bode rule, such as the so-called Blagg-Richardson formulation. Without getting into the details here, suffice it to say that with this formulation, one can admittedly get good agreement with the actual orbits of the moons. To do that, however, the number of free parameters, which can be added after the fact, until "it fits," is even greater than the number of epicycles in the Ptolemaic theory of the planets.

Here, we wish to take another path. The most evident departure of the moons' distances from a geometric progression consists in the fact that, with small distances of the moons from the planet, they are also more and more squeezed together in logarithmic scale. In other words, while in a strict geometric progression, the distance from the center should always grow by the same factor, this only holds for the moons that are at greater distances from their planets. With the inner moons, this factor decreases constantly, and approaches the value 1, so that two moons next to each other should have practically the same distance from their planet.

Such a relationship, however, has been familiar in the world of astronomical forms for some time—namely, in spiral galaxies. Many spiral galaxies have the form of a perfect logarithmic spiral. If one puts a straight line through the nucleus, and considers the intersections of the spiral and the straight line, the sequence of distances from the center will form a geometric progression. The angle at which such a straight line cuts the spiral, the so-called opening angle, is always the same.

However, there is a related type of spiral galaxy, the so-called barred spiral, which occurs not infrequently. A straight bar runs through the nucleus of such a galaxy, and the spiral arms begin at the ends of the bar and, indeed, always at a right angle (an opening angle of 90°). Near the bar, the spiral arms are nearly circular in form; they eventually change their shape as they go out, to approach asymptotically the form of a logarithmic spiral. At the simplest, the resulting rule of distance can be expressed as a hyperbolic cosine (abbreviated cosh), a close relative of the exponential function:

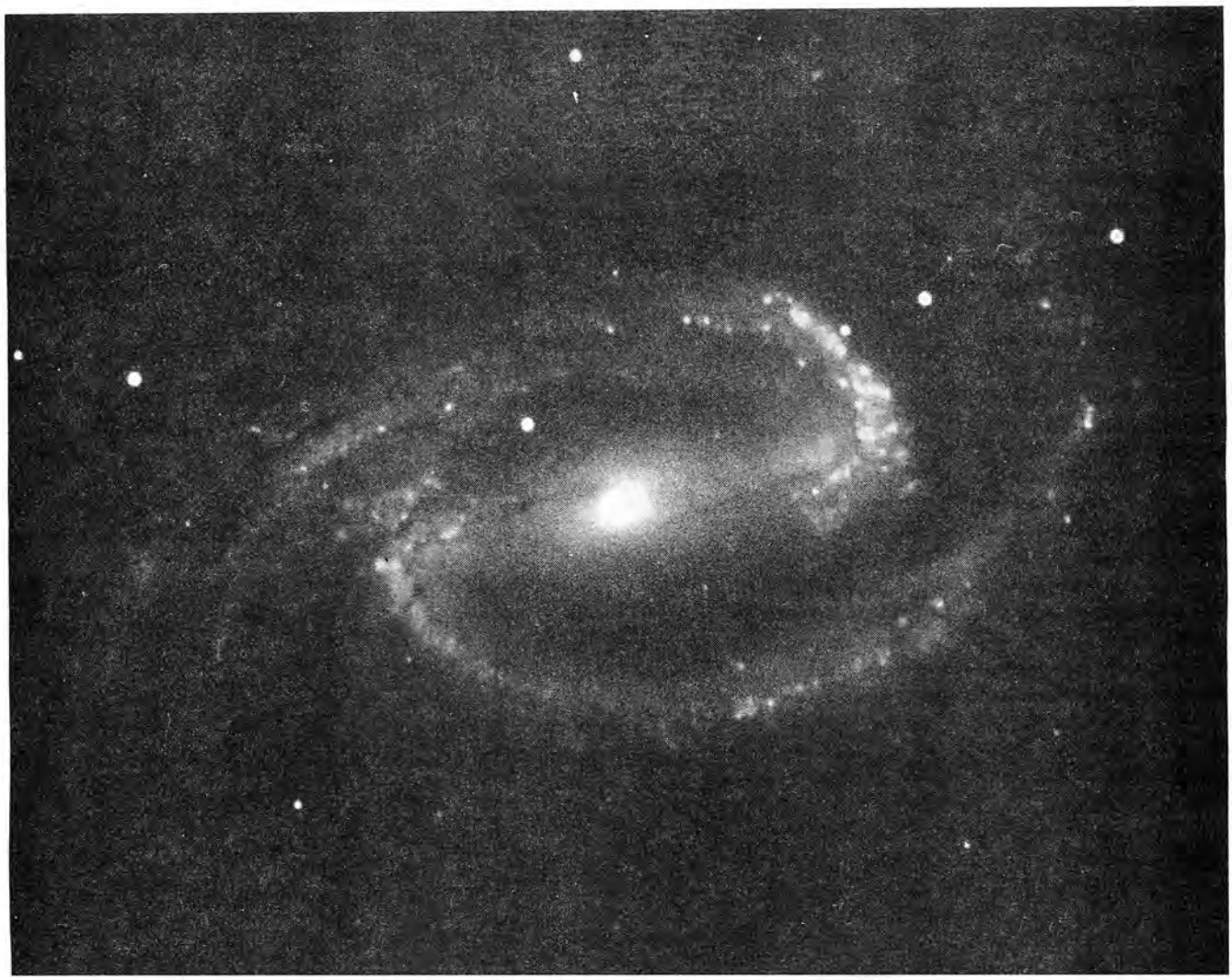
$$d = a \times \cosh (c \times n) \qquad (n = 0, 1, 2, 3, \ldots).$$

For every system of moons, there are then only two parameters, a and c, that remain arbitrary. The length of the bar of a barred spiral galaxy, corresponds to a, while c defines an asymptotic rate of growth outward. It turns out that the orbits of the moons of a planet can be precisely mapped onto a barred spiral, when the length of the bar corresponds to the diameter of the planet to which they belong.

Figures 1 to 4 show a striking agreement with the true lunar paths, even though there is only one independent variable available. In these graphics, we are considering all those moons which are at a distance of less than 15 planetary diameters, with the exception of Hyperion, the irregular moon of Saturn. Figures 5 and 6 show the barred spiral system of the planets, in which now—in contrast to the Titius-Bode rule—the planets Neptune and Pluto also fit. Here the bar length is, to be sure, about 50 times the diameter of the Sun. (In comparison with barred spiral galaxies, it must naturally be kept in mind that these galaxies possess two spiral arms.)

Harmonies and Resonances

Let us remember Kepler's words in the *Harmonices Mundi:* admittedly, when we ponder the planetary distances, that "is



Hale Observatories

A barred spiral galaxy, NGC 1300. A straight bar runs through the nucleus, and the spiral arms begin at the ends of the bar. The spacings of the moons of planets follow a barred spiral geometry, not the Titius-Bode Law.

the first shimmering of a harmony," and "an allurement, to continue our search." But the deeper causes of the architecture of the solar system, are to be found primarily in the periods of rotation and their harmonies:

> Indeed, when we think about these things more closely, it seems very unlikely, that the all-wise Creator should have been merely concerned with having harmonious relations respecting the paths of the planets. For if the proportions of their paths are in harmony, then all the particulars which the planets have of themselves, ought to necessarily derive from these paths, and there should be no more possibility, that harmonies might be created in other positions. But what about the harmonies between the paths? Who will perceive these harmonies? Two things there are in nature, which allow us to perceive the harmonies of nature, light and sound. The former is perceived through the eyes, or through the hidden sense organs corresponding to the eyes, the latter through the ear. When our minds perceive the latter species, we distinguish the melodic and the unmelodic, be it purely instinctively (with which we have dealt at sufficient length in Book IV), or through astronomical or harmonic consideration. However, there are no tones in the heavens, nor are the motions there so violent, that through friction of the heavenly air, a buzzing or a piping should ensue. That leaves light. If light should teach us about the paths of the planets, then it should teach either through the eyes or a similar sense organ, that has a very specific location. . . . Because I comprehended all of this under one point of view, I rightly reached the conclusion, that one would have to abandon the perceived paths of the planets in space, and turn our eyes to their constructed daily arcs, and indeed, to the constructed magnitudes taken together, seen from one specific, superb place in the world, that is, from the body of the Sun, which is the wellspring of the motion of all the planets.

Thus, Kepler turns to the angular velocity of the planets, and certainly not from the standpoint of the empty middle of the ellipse, but rather from its focal point, which he marks as the position of the Sun. Now, the angular velocities vary with the distances of the planets from the Sun, so that the radius vector of the planet always covers an equal area within the ellipse per unit of time. Kepler himself had established this in the *Astronomia Nova*.

Consequently, he took up the question of the extreme values of these angular velocities: first at the closest approach to the Sun, the perihelion, and then at the farthest point, the aphelion. Finally, for each pair of neighboring planets, he took the relationship between the motion of one at aphelion, with the motion at perihelion of the other.

Astonishing musical harmonies emerged from this, with the exception of the Mars-Jupiter proportions. However, as shown in Table 2, that gap in Kepler's system is most dramatically filled by the asteroid Ceres, long after Kepler's death. The convergent Ceres-Jupiter proportion—that is, the relationship of the motion at aphelion of Ceres, to the motion at perihelion of Jupiter—is precisely an octave. The error is less than 1/10th of 1 percent. Their divergent proportion—that is, the motion at perihelion of Ceres to the motion at aphelion of Jupiter—is, with like precision, an octave increased by the proportion 5:3. The relationship between the motions at perihelion of Ceres and Mars, corresponds to a major third, while that at aphelion, corresponds to a minor third. The precision with which these values are approached, lies in the range of 1/100th of a percent.

The Orbit Determines the Mass

The orbits of the moons and the planets thus seem to obey certain quantization rules, and manifest harmonic proportions in relation to each other. Still, that is not enough. The sizes of the moons and planets are by no means arbitrarily distributed, but have instead a clear and active underlying ordering principle. At first glance, it strikes us that the orbits of the planets close to the Sun—Mercury, Venus, Earth, and Mars, all with relatively small diameters of about 5,000 to 13,000 km—have only a few or no moons, and a high specific gravity, between 3.9 and 5.5.

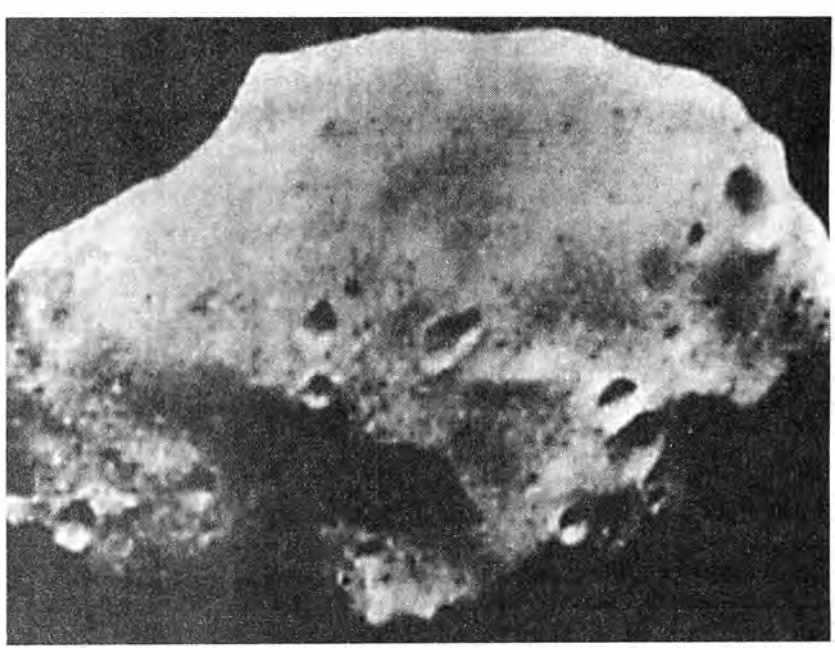
In contrast, the outer planets—Jupiter, Saturn, Uranus, and Neptune—have diameters of about 50,000 to 140,000 km, numerous moons, more or less complex ring systems, and, finally, specific gravities of about 1.7. They consist for the most part of gas. Moreover, the chemical composition of the atmospheres of the Earth-like planets, on the one hand, and the gaseous giants, on the other, is clearly different. Even from the scarce data available to Kepler about the nature of the planets, he concluded that there was a close coherence between their orbits and their sizes. In the *Harmonices Mundi* he says:

> Now it is a very probable supposition (supported by geometric proof, and the theory of the causes of planetary motion presented in the work on Mars), that the volumes of the planetary bodies are related to their periods, so that the sphere of Saturn is about thirty times as big, Jupiter twelve times, Mars somewhat less than twice, as the sphere of the Earth, and Earth one-and-a-half times as large as Venus, and four times as large as Mercury.

Obviously, Kepler has in mind here precisely the relationship of their periods (Mercury, 0.24 years; Venus, 0.62 years; Earth, 1 year; Mars 1.9 years; Jupiter 12 years;, and Saturn 29 years). If we plot a diagram of the periods of the

Table 2
APHELION-PERIHELION HARMONIES
Proportions of angular velocities (A = aphelion, P = perihelion)

Proportion		Interval	Corresponds to	Measured
P (Venus)	: A (Mercury)	Two octaves	4.000	4.015
A (Earth)	: A (Venus)	Minor sixth	1.587	1.593
A (Mars)	: P (Earth)	Fifth	1.498	1.502
A (Ceres)	: A (Mars)	Octave & major third	2.520	2.521
P (Ceres)	: P (Mars)	Octave & minor third	2.378	2.379
A (Jupiter)	: P (Ceres)	Octave	2.000	2.001
P (Saturn)	: P (Jupiter)	Octave & major third	2.520	2.518
A (Neptune)	: A (Uranus)	Octave & half tone	2.119	2.121
A (Neptune)	: A (Pluto)	Whole tone	1.122	1.122



NASA

Phobos, a moon of Mars, taken by the Mariner 9 probe.

planets against their diameters, then the first thing that strikes us is what Kepler suspected, the increase of the size of the planets with the increase of their periods (Figure 7).

However, at Jupiter a maximum diameter is reached, and the planets farther out become increasingly small. Because of the small number of planets, it is difficult to draw sweeping conclusions here. But are there not a great number of moons, which, thanks to Voyager, might be able to give us some answers in this regard? Taking separately and in turn the 16 moons of Jupiter, then the 18 Saturn moons, the 15 of Uranus, and, finally, the 8 moons of Neptune, each time we get the same ordering that we already know from the planets: With increasing distance from the planets, the periods of the moons also increase, and the diameters of the moons increase and reach a maximum; and with further distance from the planet, the diameters of the moons again begin to decrease.

Now, one might assume, that this dependency of the size of the moons on the periods has as its cause, the particular conditions that held while the solar system was being formed. Here the astrophysicists consider certain hydrodynamic regularities, which determine the behavior of a gas cloud collapsing under its own gravity. While the cloud of gas is condensing into the Sun and the planets, there might be accidental increases in density, caused by gravity, in parts of these gas envelopes of the planets, which would gradually develop into moons. But could one imagine, with such a complicated process, that each time the end result would be the relationship of period to diameter described above?

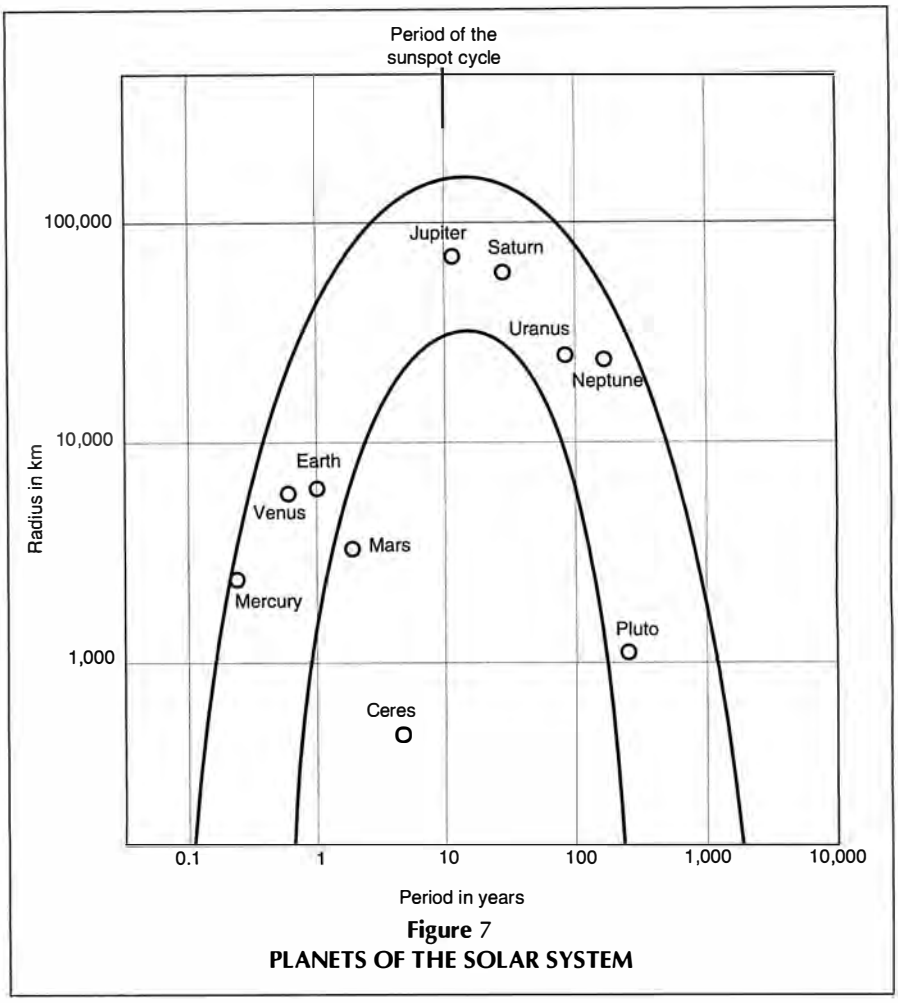


Figure 7
PLANETS OF THE SOLAR SYSTEM

But careful: The masses of the giant planets are quite distinct. Jupiter for example, has a mass some 20 times greater than Neptune and Uranus. According to the law of gravity, therefore, the characteristic time scale in the Jupiter system should be much smaller than for Neptune and Uranus. Figure 8 proves the contrary. All the moons in the solar system fit into one and the same period-diameter diagram, and thereby show that they don't give a hoot about the masses of their planets.

If the particles of planetary rings be considered, which are not taken into account here—and they would be found several orders of magnitude deeper within the hyperbolic band—then all the planetary "satellites," taken together, fall into four categories or "registers", clearly distinguished one from another. First, with periods of up to five hours, there begins the zone of the planetary rings. When the period reaches seven hours up to about one day, in part overlapping with the ring zone, there are numerous small moons to be found, whose paths around their planets are virtually perfect circles, precisely in the equatorial plane. Moreover, the rotation of each of these inner, small moons, is said to be synchronous, that is, its orbital period around its planet, and its rotation upon its axis, are exactly equal. The latter characteristic is also true for the large, regularly formed moons, which have periods from one day to one month.

The highest point of the hyperbola is located at around 20 days; in other words, the nearer a moon's period is to the range of 15 to 25 days, the larger in size must that moon be. Dwarf moons of diameter 100 km or less, are not tolerated here. Finally, very far away—with periods of some hundreds of days—there are sundry smaller, irregularly formed moons, in eccentric orbits, whose orbital axes point all over the heavens. One assumes that these outer moons, and perhaps one or two of the smaller, inner moons, represent captured asteroids.

Admittedly, there are a couple of exceptions, and these are especially interesting: First, all the moons that significantly depart from the mean period-diameter scheme, are bound by resonances to another moon (denoted by a dotted line in the figures). Thus the periods of Io and Europa are related precisely as 1:2, Phobos and Deimos 1:4, and Titan and Hyperion, 3:4.

It would be useful to take a closer look at these peculiarities. Jupiter's moon Io, which, relative to its period, has much too great a diameter, is a sulphur-spitting monster, whose vol-

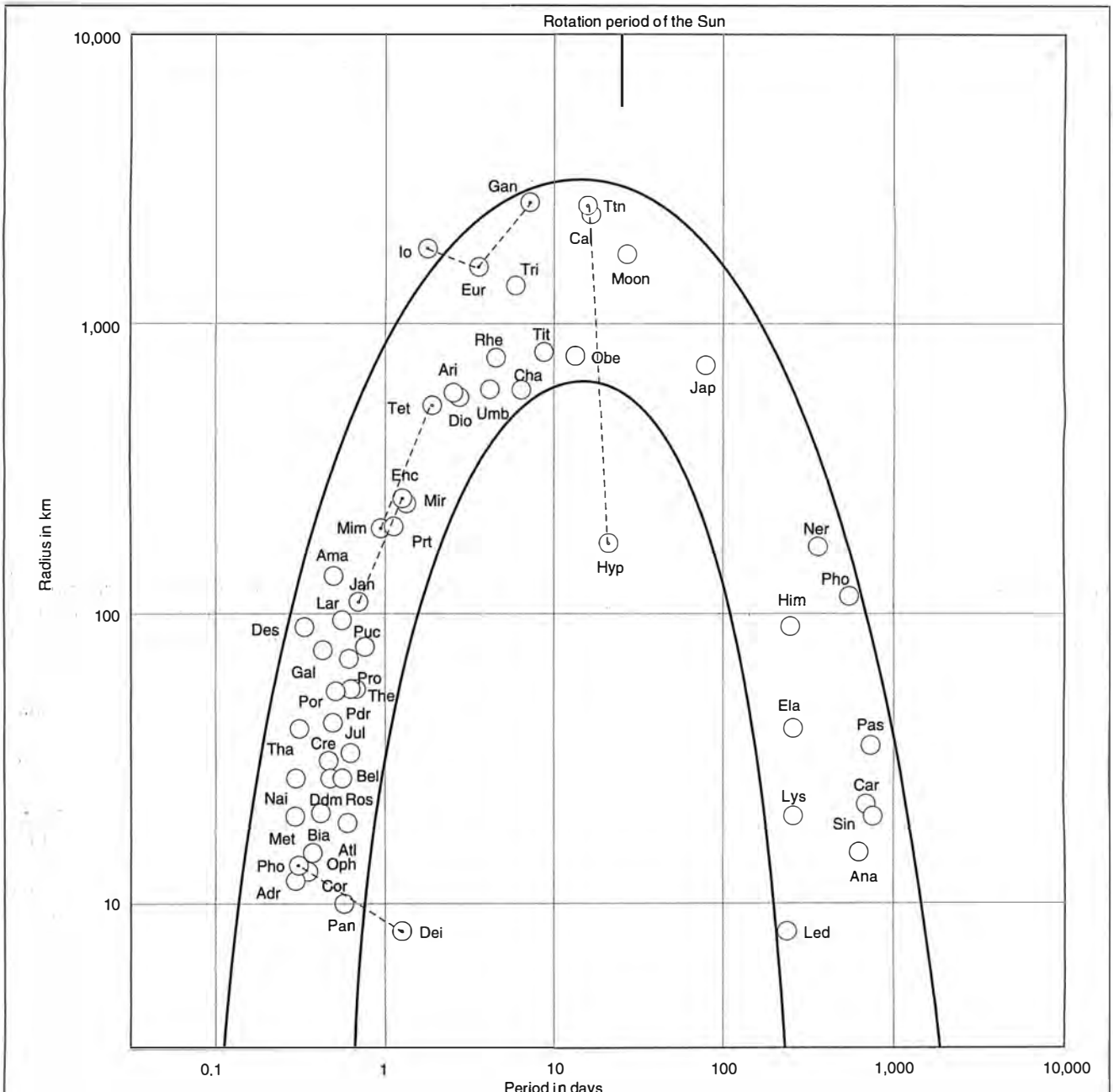


Figure 8
MOONS OF THE SOLAR SYSTEM

Abbreviation	Name	Planet
Moon	Moon	Earth
Dei	Deimos	Mars
Pho	Phobos	
Adr	Adrastea	Jupiter
Ama	Amalthea	
Ana	Ananke	
Car	Carme	
Ela	Elara	
Eur	Europa	
Gan	Ganymede	
Him	Himalia	
Io	Io	
Cal	Callisto	
Led	Leda	
Lys	Lysithea	
Met	Metis	
Pas	Pasiphae	
Sin	Sinope	
The	Thebe	
Atl	Atlas	Saturn
Dio	Dione	
Enc	Enceladus	
Epi	Epimetheus	
Hyp	Hyperion	
Jan	Janus	
Jap	Japetus	
Mim	Mimas	
Pan	Pan	
Pdr	Pandora	
Pho	Phoebe	
Pro	Prometheus	
Rhe	Rhea	
Tet	Tethys	
Ttn	Titan	
Ari	Ariel	Uranus
Bel	Belinda	
Bia	Bianca	
Cor	Cordelia	
Cre	Cressida	
Ddm	Desdemona	
Jul	Juliet	
Mir	Miranda	
Obe	Oberon	
Oph	Ophelia	
Por	Portia	
Puc	Puck	
Ros	Rosalind	
Tit	Titania	
Umb	Umbriel	
Des	Despina	Neptune
Gal	Galathea	
Lar	Larissa	
Nai	Naiad	
Ner	Nereid	
Prt	Proteus	
Tha	Thalassa	
Tri	Triton	
Cha	Charon	Pluto

The only moons that are not on the diagram are the three small moons of Saturn, Teleso and Calypso (both co-orbital with Tethys), and Helene (co-orbital with Dione): When there is more than one occupant of the same orbit, only the largest representative has been considered.

canic activity is greater than that of all the other planets and moons of the solar system. This is commonly explained by the strong tides resulting from Jupiter's powerful gravitational field. And Hyperion is the only known moon of the solar system, which trundles around its planet in a chaotic manner, that is, continuously alters its period of rotation, and also the direction of its axis, and on top of that, seems to be shaped like a peanut. It is generally assumed that Saturn's moon Hyperion represents the remains of a destroyed moon. We shouldn't wonder, therefore, that a moon such as that, does not quite fit into the schema.

Then there is Deimos, the small moon of Mars, which for its size, has an orbit of much too great a diameter. Phobos and Deimos, because of their uncommonly dark surfaces, would seem to be unusually promising candidates for the category of captured asteroids.

All in all, we might say, that a moon of a certain size can only go around its planet in such a path, that would give it a period in one of two ranges. If you will, there are for each moon, depending on its size, two orbital sectors, comparable to two possible directions of spin for an electron.

Let us look, for example, at Saturn's moon Phoebe. It has a radius of somewhat more than 100 km, and a period of 550 days. According to our period-diameter diagram, relative to its size, it could also exist as an inner moon, with a period of from a few hours to maximally one or two days. Now Phoebe has an axial rotation, which is not synchronous with its orbit around Saturn, and this period fits—at 9.4 days—in fact in the middle of this range. In other words, based on its rotation, Phoebe is still at the same height, but this time exactly within the left limb of the hyperbola, just above Neptune's moon Galatea (Gal).

Now another interesting question arises in this connection. For the moons of the solar system, there is one, and only one, characteristic time scale of about 20 days. Any moon that has a period in the neighborhood of this value, will be among the larger ones, quite independently of which planet it orbits. Since captured moons are also configured into this ordering, this should mean that here we are dealing with an ordering principle, that not only corresponds to the conditions that held during the formation of the solar system, some billions of years ago, but whose efficacy is still present today.

For the orbits of the planets around the Sun, there is another characteristic time scale, this one about 10 years. But our Sun also has two striking periodic values: It turns upon its own axis in about 25 days, and the sunspot cycle repeats itself every 11 years! Might this, in a surprising way, confirm Kepler's physical conjecture in the *Astronomia Nova,* according to which the rotation of the Sun, in concert with its magnetic characteristics, determines the course of the planets?

Figure 9
PLANETARY RESONANCES

1. The system of the inner planets

$S_{Mercury}$ —2:1— $O_{Mercury}$ —3:2— $R_{Mercury}$ —2:1 — S_{Venus} —5:1 — $S_{Venus, Earth}$

8:5

R_{Venus} —3:2— O_{Earth} —13:8— O_{Venus} —3:1— O_{Mars}

2. The Jupiter-Saturn system

$O_{Jupiter}$ —5:3— $S_{Jupiter, Saturn}$ —13:8 —O_{Saturn}

3. The system of the outer planets

O_{Uranus} —2:1— $O_{Neptune}$ —3:2— O_{Pluto} 2:1 —$S_{Neptune, Pluto}$

The relationships shown here are between synodic periods (S), orbital periods (O), and axial rotation periods (R). The synodic period is with respect to the Sun unless otherwise indicated.

All relationships are formed from members of the Fibonacci series:

1, 1, 2, 3, 5, 8, 13, 21, . . .

The sum of each adjacent pair defines the succeeding member. The ratios of neighboring members draw closer and closer to the Golden Section ratio, as the series proceeds.

Resonances and the Fibonacci Series

A striking peculiarity in the motions of known solar system bodies—whether planets, moons, asteroids, or rings—is the surprising abundance of resonances. This is shown, for example, in the 1:1 resonance between orbital period and rotation time of the great majority of the 61 known solar system moons. From their corresponding planets, one would always see the same side of the satellite, just in the way we always see the same side of the Moon.

Then there is a series of pairs of neighboring moons, whose orbital periods form a ratio of exactly 2:1—for example, Ganymede-Europa, Europa-Io, Dione-Enceladus, Enceladus-Janus, Tethys-Mimas, Proteus-Larissa. Other neighboring moons have orbital period ratios of 3:2, 4:3, 5:3, or even 4:1, such as the two moons of Mars, Deimos and Phobos. The number of resonances is so great, that no one seriously claims it as a simple game of chance anymore. It is thought to be understandable in some degree with the help of gravitational effects. But in the individual case, it is as hard as ever to explain why the Jupiter resonances in the asteroid belt induce significant gaps, while some resonances of the moon Mimas in the rings of Saturn lead to amplifications.

Not less interesting are the resonances of the planets. Consider Mercury. It possesses a property that is closely related to the synchronous rotation of moons that are near their planets. The period of its orbit around the Sun is 87,969 days; the time of one axial rotation, only 58,646 days. As in the case of synchronous moons, we are concerned here also with a perfect tuning between orbital and rotational periods, only this time not of 1:1, but a resonance of 3:2. When Mercury has turned three times on its own axis, it has orbited the Sun exactly twice.

To understand the mutual tunings of the forms of motion of Mercury, Venus, Earth and Mars, an additional periodicity is of course necessary, the synodic period, along with time of rotation and orbital period. The synodic period is the apparent rotational or orbital time from the relative standpoint of

The Discovery of Neptune

Exactly 150 years ago, on Sept. 23, 1846, Johann Gottfried Galle and a student, Heinrich Ludwig d'Arrest, working at the Fraunhofer refractor of the Berlin Observatory, discovered a major new planet, Neptune. It was the 55th birthday of the observatory director, Johann Franz Encke. In the morning, a letter had been received from the French astronomer Jean-Joseph Leverrier, asking if "the indefatigable observer" Galle would devote "a few moments to a search of a region of the heavens . . . where there is a possibility of discovering a planet. It is the theory of Uranus that has led me to this conclusion."

Leverrier supposed that the influence of a transuranian planet lay behind the long-observed deviations in Uranus's orbit. While the Paris Academy did not think much of such speculations, Galle and D'Arrest took it upon themselves to scour the indicated part of the sky for an uncatalogued object. In this search, they obtained decisive help from the Berlin Academy Star Charts, a mapping of the heavens directed by the Berlin Observatory and executed with international collaboration. It was significantly superior to all previous maps, in that it included stars down to a fainter limiting magnitude.

The Role of Alexander von Humboldt

The outstanding position of Berlin in the astronomy of the mid-19th century was above all the work of Alexander von Humboldt. In the spring of 1827, he returned to Berlin, the city of his birth, after a stay of nearly 20 years in Paris.

According to his program: "Berlin, in time, should have the leading observatory, the leading institute of chemistry, the leading botanical garden, the leading school for transcendental mathematics. That is the object of my labors and the unifying thread of my exertions."

Provoked by the discovery of Neptune, Humboldt, in letters to the Königsberg mathematician Carl Gustav Jacob Jacobi, posed the "question, what necessary preconditions had to have been achieved in the realm of the mind, such that in 1846 it was possible to determine the position of the transuranian planet?" He was interested in the "gentle influence of the germination of that train of thought, without which the laws of motion of the heavenly bodies—whether in the hypothesis of epicycles or in that of the mutual attraction of masses—could not have been established."

another rotating or orbiting system. The length of a day on the surface of a planet is an example.

In the case of slowly rotating planets, it just so happens that the length of the day is sometimes very markedly different from its time of rotation. When, for example, Mercury completes a full 360° rotation on it own axis in 58,646 days, it has, in the same time, traversed two-thirds of its course around the Sun, hence an angle of 240°. From the standpoint of an inhabitant of Mercury, the Sun has then advanced in Mercury's sky only 360° −240° = 120°. One "Mercury day" has thus not elapsed, but only one-third of a day. The synodic rotation (S) or short day of Mercury is thus 3 times greater than its time of rotation (R) and that is just double the time of its orbit around the Sun (O), hence:

$$S_{Mercury} : O_{Mercury} = 2:1$$
and
$$O_{Mercury} : R_{Mercury} = 3:2.$$

Now to Venus. Here the resonances are somewhat subtler, but all the more impressive. First, the orbit of Venus around the Sun requires 224.701 days. But what is the relation of this to Venus's rotation around its axis? Indeed, Mercury turns very slowly (58.65 days), in comparison to all the planets, moons, and asteroids of the solar system. But Venus allows itself all of 243.16 days to complete a single turn on its axis. When a planet turns so slowly, one might think that in such a case, there might be very little wind there. Completely wrong: the dense atmosphere of Venus has a velocity 50 times greater than the surface. But that's not all: Venus has a false rotation. It turns in the opposite direction of all the other planets. On top of that, Venus's rotation time is exactly tuned with an orbit around the Sun, but for a change, not its own, but the period of its neighboring planet. For, indeed, the Earth year (365.256 days) and the rotation of Venus, form a 3:2 resonance.

When we look at the orbital periods of the Earth and Venus, and then compare them to the synodic periods of the two—that is, the time between two moments of closest approach between Venus and Earth—then the following relationships obtain, to a high degree of approximation:

$$S_{Venus,Earth} : O_{Earth} = 8:5$$
and
$$O_{Earth} : O_{Venus} = 13:8.$$

If we investigate neighboring planets Jupiter and Saturn in the same way, the result is:

$$S_{Jupiter,Saturn} : O_{Saturn} = 3:2$$
and
$$O_{Jupiter} : S_{Jupiter,Saturn} = 5:3.$$

Some additional resonances between the periods and the rotational times of the planets are identified in Figure 9.

Taken together, these resonance proportions have one characteristic that immediately strikes the eye of anyone who is intimately acquainted with Renaissance painting, the construction of the Platonic solids, or with the typical geometry of nu-

merous plant and animal forms. And yes, it is a question of proportions derived from the Fibonacci series, in which the sum of two neighboring elements always yields the element that follows:

1, 1, 2, 3, 5, 8, 13, 21, . . .

The proportion of each successive pair of neighboring elements of the Fibonacci series approaches ever nearer to the Golden Section.

Gulliver's Travels and the Two Moons of Mars

When Jonathan Swift's fictional character reached the land of Laputa, he made the acquaintance of a special people. They were all astronomers, and they behaved in a somewhat strange manner. Instead of conversing about the weather, their first question in every conversation concerned the state of the Sun. Whether all was well with the Sun, or whether it might well be about to explode. The denizens of Laputa had had their ears so tuned, that they could hear the planetary music of the spheres, which they would sometimes accompany on their musical instruments. In any case, Gulliver found that they were very able astronomers. Be that as it may, they were said to have discovered, in fact,

> two lesser stars, or 'satellites,' which revolve about Mars, whereof the innermost is distant from the center of the primary planet exactly three of his diameters, and the outermost five; the former revolves in the space of ten hours, and the latter in twenty-one and an half; so that the squares of their periodical times are very near in the same proportion with the cubes of their distance from the center of Mars. . . .

Swift wrote this story in 1726, obviously under the influence of Kepler's work. Some 150 years later, the U.S. astronomer Asaph Hall in Washington discovered that Mars has two moons, later named Phobos and Deimos, and these did not have—as in the case of Earth's Moon, or as one could conceive for the large moons of Jupiter—periods of several weeks, but rather a mere 8 hours for Phobos and 30 hours for Deimos.

A coincidence? After Hall's discovery, this was bitterly contested. In any case, Swift's description of the moons of Mars was in all probability rooted in Kepler. And for him, the existence of moons could not simply be attributed to the play of chance, but rather must arise, in one way or another, from the harmonic composition of the solar system.

After obtaining Galileo's *Starry Messenger,* Kepler wrote in 1610 in his *Conversation with the Sidereal Messenger:*

> I should rather wish that I now had a telescope at hand, with which I might anticipate you in discovering two moons of Mars (as the relationship seems to me to require) and six or eight moons of Saturn, with one each perhaps for Venus and Mercury.
>
> For this search, so far as Mars is concerned, the most propitious time will be next October, which will show Mars in opposition to the Sun and (except for the year 1608) nearest to the Earth. . . .

Kepler supposed that the size of the planets, as well as the number of their moons, increased in a lawful way in relation to their distance from the Sun, perhaps in the manner of a geometric series (Earth 1, Mars 2, Jupiter 4, Saturn 8). Naturally, the moons had to be relatively small compared with Jupiter's moons, or they would long ago have been detected.

Now Kepler had already suspected, as shown above in the case of the planets, that there must be a relationship between the size and the period of any moon. The periods of the moons of Mars should accordingly be small.

As Immanuel Kant circulated his *General Natural History and Theory of the Heavens* in 1755, as a contribution to a breakthrough for the Newtonian worldview on the Continent, he summarily cleared up all of these speculations on the moons of Mars. Kant declared unequivocally, harmonies or no harmonies, Mars could in no wise have a moon, according to the law of gravitation:

> Therefore, only the planets of larger mass and greater distance are endowed with companions. Jupiter and Saturn, the two largest and also most distant of the planets, have the largest number of moons. The Earth, which is much smaller than they, is only a fraction thereof; and Mars, which, because of its distance is due some share in this privilege, goes wanting, because its mass is so small.

Here again, Kant has run right off the rails.

Obviously the solar system is no collection of self-evident point masses, that respond to the blind play of pairwise interactions in an absolute space of Kant's coinage. In opposition to that conception, the hypothesis of the existence of harmonic compositional principles has been shown, again and again, to be the most fruitful. For the clues to such ordering principles that have been presented here, Kepler's observation is naturally valid:

> With this example, however, I would like to summon all of you experts in mathematics and experienced friends of the highest philosophy, that you get down to the reading of this book. Now then! Be bold! Overturn but a single one of the harmonies that I have everywhere established, replace it with a different one, and test whether you come as close to the conclusions of astronomical research cited in Chapter 4. Search for grounds on which you could construct a system that better corresponds to the motions of the heavens and could partly or completely demolish the ordering I have erected. Whatever serves the eternal glory of the Creator, our Lord, for that you may use this, my book. To this hour, I have assumed for my own self the liberty to change things here and there, when I had to recognize that the day before, I had wrongly considered, as a result of indolence or excessive zeal.

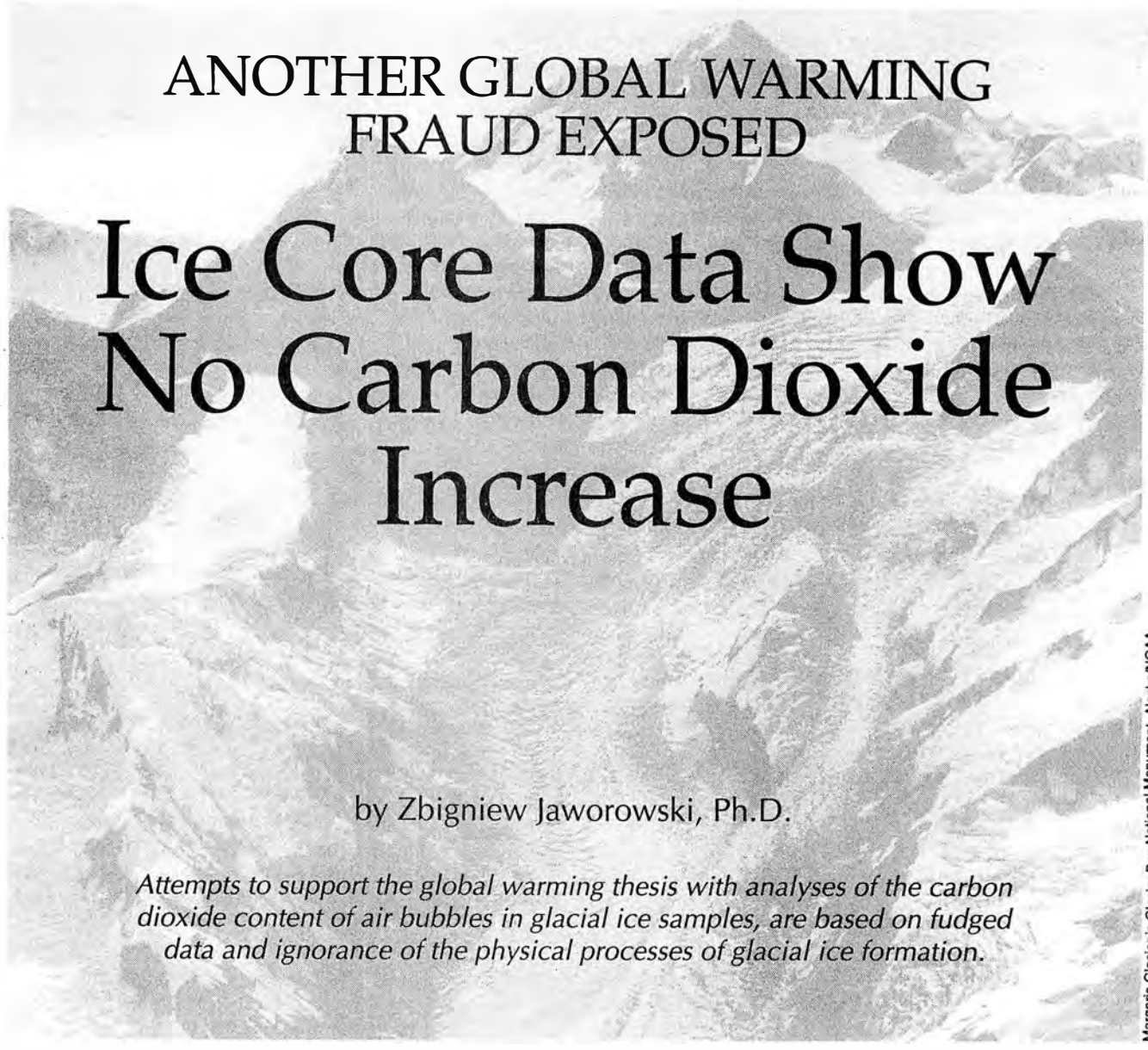
Lothar Komp is on the editorial staff of the German-language magazine Fusion. *His article appeared in* Fusion*'s April-May-June 1996 issue, and was translated by Rick Sanders and David Cherry.*

ANOTHER GLOBAL WARMING FRAUD EXPOSED

Ice Core Data Show No Carbon Dioxide Increase

by Zbigniew Jaworowski, Ph.D.

Attempts to support the global warming thesis with analyses of the carbon dioxide content of air bubbles in glacial ice samples, are based on fudged data and ignorance of the physical processes of glacial ice formation.



Margerie Glacier in Glacier Bay National Monument, Alaska/NOAA

EDITOR'S NOTE

When climate science was not driven by ideology, it was generally assumed that long-term astronomical cycles—those measured in tens or hundreds of thousands of years—were the way in which climate had to be situated. The long 100,000-year cycles of Ice Ages are determined by the periodicities in the eccentricity, tilt, and precession of the Earth's orbit; in between Ice Ages, there are roughly 10,000-year periods known as interglacials, when relatively milder climates prevail. Right now, the Earth is at the tail end of an interglacial and probably already entering a period of glacial advance.

The Ice Ages of the past and the coming Ice Age have a timetable of their own, quite independent of man's industrial output of carbon dioxide. No scientist who knew these astronomical cycles could possibly be trapped into worrying about the ups and downs of local or global temperatures in time spans of years or even decades, or seriously be concerned with short-term computer modelling and associated scare stories about global warming.

The times have changed, and so has environmental ideology—but the long-range climate cycles have not changed. This means, that based on the last several million years of history, the world is inexorably moving into another Ice Age, no matter how much propaganda is generated about global warming. The global warming hypothesis and the many research artifacts it has generated can be dissected and disproved one by one; but the fact remains that the overall question of climate must be situated in a long view of history, not the short term.

This article examines one of the main pillars of the global warming thesis: the assertion that ice core data—analyses of gas bubbles trapped in glacial ice—prove that atmospheric carbon dioxide, CO_2, has increased since the pre-industrial era as a result of fossil-fuel burning and other human activities.

From its very beginning, the hypothesis on anthropogenic greenhouse warming was tainted with a biased selection of data, ad hoc assumptions that were not verified experimentally, and one-sided interpretations. Such symptoms of affliction, which Irving Langmuir called "pathological science,"[1] are evident in the publications of G.S. Callendar, who truly can be regarded as the father of the modern "man-made climatic warming" hypothesis. In 1938, Callendar revived Svante Arrhenius's idea of man-made climatic warming, now 100 years old.[2] Callendar claimed that because of fossil fuel burning, the average atmospheric concentration of CO_2 had increased from the 19th century value of 274 parts per million volume (ppmv) to 325 ppmv in 1935, that is, by 18.6 percent; and that between 1880 and 1935, this caused an increase in the global surface temperature of 0.33°C.[3-5] However, the *measured* 19th century CO_2 concentrations in the atmosphere ranged from about 250 to 550 ppmv (Figure 1), and the average concentration estimated from these values was 335 ppmv.[6]

A nonsignificant decreasing trend of values in Figure 1, between 1860 and 1900, when CO_2 emissions from fossil fuel burning increased from 91.5 to 485.6 million tons of carbon was similar to a decrease in global surface air temperature in this period.[7] This may reflect lower CO_2 degassing from colder oceans, the result of natural climatic fluctuation.[8]

To reach the low 19th century CO_2 concentration, the cornerstone of his hypothesis, Callendar used a biased selection method. From a set of 26 19th century averages, Callendar rejected 16 that were higher than his assumed low global average, and 2 that were lower. Callendar's paper of 1938, presented at a meeting of the Royal Meteorological Society, was criticized by its members, who asked a dozen fundamental questions (for example, the validity of the estimate of CO_2 average concentrations, the basics of the carbon cycle, and the balance between radiation and atmospheric temperature distribution), which, after half a century, have remained unanswered and are still the subject of ardent discussions (for example, see Reference 9).

Because of uncertainties in 19th century air measurements, studies of greenhouse gases in glacier ice are often regarded—incorrectly—as the most reliable estimates of CO_2, CH_4 (methane), and N_2O (nitrous oxide) concentrations in the pre-industrial atmosphere. The results of ice core analyses are supposed to be "the only possible validation of models that were set up to describe future climatic changes caused by anthropogenic emissions."[10] On the basis of these analyses, the Intergovernmental Panel on Climate Change[11] declared that the pre-industrial concentration of CO_2 in the atmosphere was 26 percent lower than the current level. The IPCC also declared that the pre-industrial concentration of N_2O was 19 percent lower, and that CH_4 was 215 percent lower than current levels. However, no study has yet demonstrated that the content of greenhouse trace gases in old ice, or even in the interstitial air from recent snow, represents the atmospheric composition.

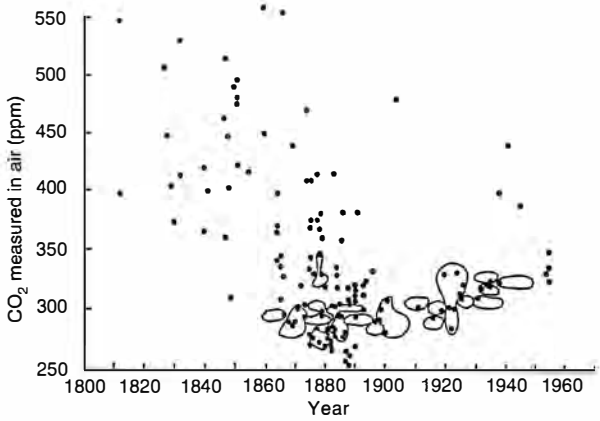


Figure 1
AVERAGE ATMOSPHERIC CO_2 CONCENTRATIONS MEASURED IN THE 19TH AND 20TH CENTURIES
The values that G.S. Callendar chose to use are shown encircled. He rejected both higher and lower values, to arrive at a figure that backed up his hypothesis.

Source: Adapted from S. Fonselius, et al., 1956. *Tellus*, Vol. 8, p. 176

Ice Core Data Unreliable

The ice core data from various polar sites are not consistent with each another, and there is a discrepancy between these data and geological climatic evidence.[12] One such example is the discrepancy between the classic Antarctic Byrd and Vostok ice cores, where an important decrease in the CO_2 content in the air bubbles occurred at the same depth of about 500 meters, but at which the ice age differed by about 16,000 years. In an approximately 14,000-year-old part of the Byrd core, a drop in the CO_2 concentration of 50 ppmv was observed, but in similarly old ice from the Vostok core, an increase of 60 ppmv was found. In about ~6,000-year-old ice from Camp Century, Greenland, the CO_2 concentration in air bubbles was 420 ppmv, but it was 270 ppmv in similarly old ice from Byrd, Antarctica.

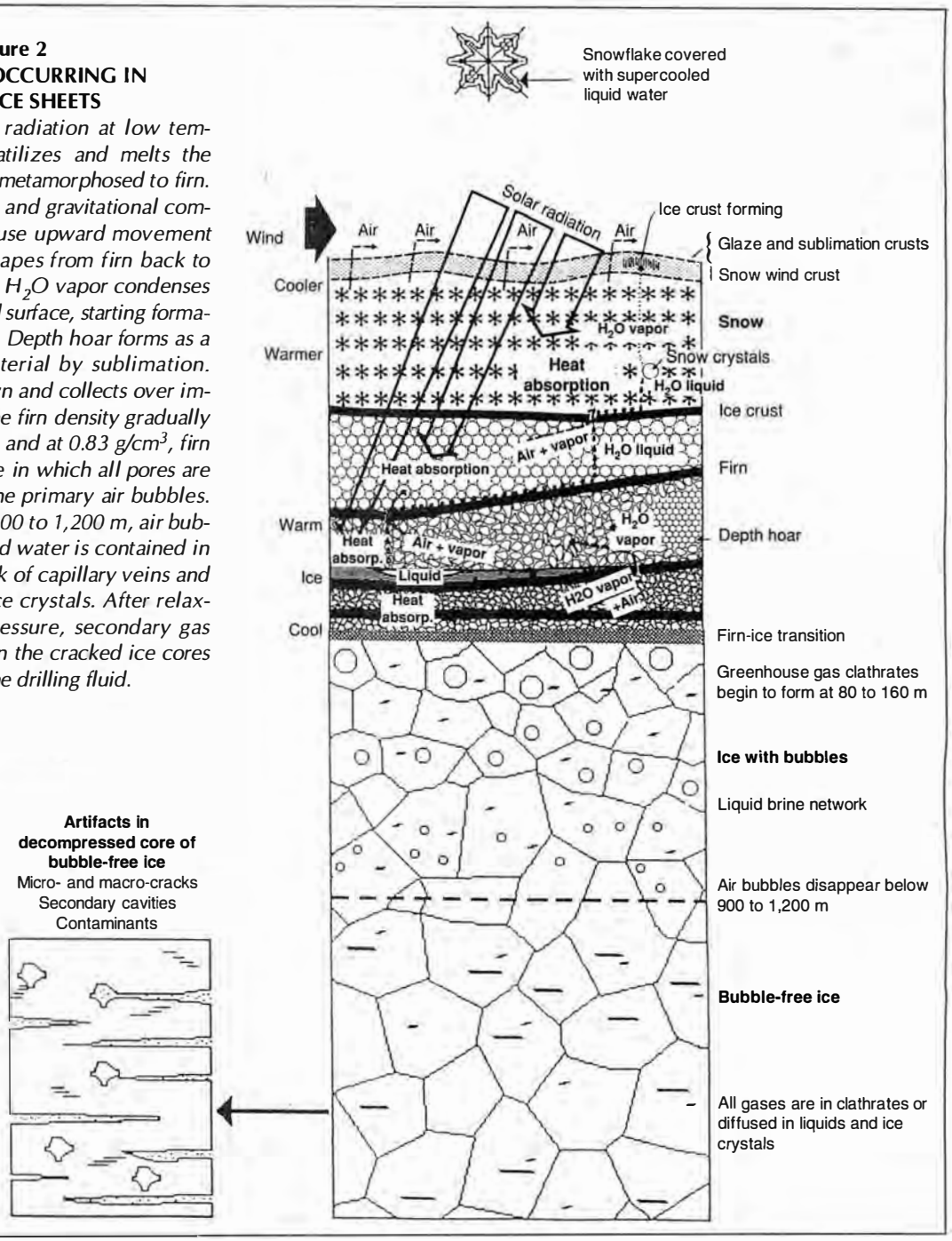
H. Oeschger, et al. made an ad hoc attempt to explain some of these discrepancies as (1) "a process which has not yet been identified," (2) wrong modelling, and (3) "not overlapping time intervals," but these explained nothing.[13] The failure to resolve the notorious problem of why about 30 percent of man-made CO_2 is missing in the global carbon cycle, based on CO_2 ice core measurements, suggests a systematic bias in ice core data.[14] It is not possible to explain the ice core CO_2 record in terms of a system with time-invariant processes perturbed by a combination of fossil fuel carbon release, CO_2-enhanced biotic growth, and deforestation.[15]

Dating of such important climatic events as the termination of the Younger Dryas period based on dendrochronology (examination of tree ring growth) and lake sediments, differs from recent ice core data from Greenland by up to about 900 years.[16] The short-term peaks of $\delta^{18}O$ in the ice sheets have been ascribed to annual summer/winter layering of snow

Zbigniew Jaworowski, M.D., Ph.D., and D.Sc., a multidisciplinary scientist, is a professor at the Central Laboratory for Radiological Protection, Warsaw, Poland. He has served as the chairman of the United Nations Scientific Committee on the Effects of Atomic Radiation, and has studied glacier ice samples from around the world, analyzing traces of heavy metals and radionuclides.

Figure 2
PROCESSES OCCURRING IN POLAR ICE SHEETS

Absorption of solar radiation at low temperature partly volatilizes and melts the snowflakes. Snow is metamorphosed to firn. The thermal gradient and gravitational compression of snow cause upward movement of gas. Some air escapes from firn back to the atmosphere, and H_2O vapor condenses near the wind-cooled surface, starting formation of the ice crusts. Depth hoar forms as a result of loss of material by sublimation. Meltwater seeps down and collects over impermeable layers. The firn density gradually increases with depth, and at 0.83 g/cm^3, firn changes into solid ice in which all pores are occluded, forming the primary air bubbles. Between a depth of 900 to 1,200 m, air bubbles disappear. Liquid water is contained in quasi-infinite network of capillary veins and films between the ice crystals. After relaxation of the load pressure, secondary gas cavities are formed in the cracked ice cores contaminated with the drilling fluid.



formed at higher and lower air temperatures. These peaks have been used for dating the glacier ice, assuming that the sample increments of ice cores represent the original mean isotopic composition of precipitation, and that the increments are in a steady-state closed system.[17,18]

Experimental evidence, however, suggests that this assumption is not valid, because of dramatic metamorphosis of snow and ice in the ice sheets as a result of changing temperature and pressure. At very cold Antarctic sites, the temperature gradients were found to reach 500°C/m, because of subsurface absorption of Sun radiation.[19] Radiational subsurface melting is common in Antarctica at locations with summer temperatures below −20°C, leading to formation of ponds of liquid water, at a depth of about 1 m below the surface.[12] Other mechanisms are responsible for the existence of liquid water deep in the cold Antarctic ice, which leads to the presence of vast sub-sheet lakes of liquid water, covering an area of about 8,000 square kilometers in inland eastern Antarctica and near Vostok Station, at near basal temperatures of −4 to −26.2°C.[12] The sub-surface recrystallization, sublimation, and formation of liquid water and vapor disturb the original isotopic composition of snow and ice (Figure 2).

Important isotopic changes were found experimentally in firn (partially compacted granular snow that forms the glacier

surface) exposed to even 10 times lower thermal gradients.[19] Such changes, which may occur several times in a year, reflecting sunny and overcast periods, would lead to false age estimates of ice. It is not possible to synchronize the events in the Northern and Southern Hemispheres, such as, for example, CO_2 concentrations in Antarctic and Greenland ice. This is, in part the result of ascribing short-term stable isotope peaks of hydrogen and oxygen to annual summer/winter layering of ice and using them for dating.[17]

New light was shed on the validity of the dating of recent ice strata when six U.S. Lightning fighter planes and two B 17 Flying Fortresses from World War II were found buried in 1942 ice, about 200 km south from a classic Greenland site at Dye 3, where they had made an emergency landing. The planes were found 47 years later at a depth of 78 m, and not at the 12-m depth that had been estimated by glaciologists using oxygen isotope dating.[20]

In the air from firn and ice at Summit, Greenland, deposited during the past ~200 years, the CO_2 concentration ranged from 243.3 ppmv to 641.4 ppmv.[21] Such a wide range reflects artifacts caused by sampling, or natural processes in the ice sheet, rather than the variations of CO_2 concentration in the atmosphere. Similar or greater range was observed in other studies of greenhouse gases in polar ice. (See reviews in References 12 and 22.)

Fudging the CO_2 Data

Until 1985, the published CO_2 readings from air bubbles in pre-industrial ice ranged from 160 to about 700 ppmv, and occasionally even up to 2,450 ppmv. After 1985, high readings disappeared from the publications! To fit such a wide range of results to the anthropogenic climatic warming theory, which was based on low pre-industrial CO_2 levels, three methods were used: (1) rejection of high readings from sets of pre-industrial samples, based on the credo: "The lowest CO_2 values best represent the CO_2 concentrations in the originally trapped ice";[23] (2) rejection of low readings from sets of 20th century samples; and (3) interpretation of the high readings from pre-industrial samples as representing the contemporary atmosphere rather than the pre-industrial one.

Publications on greenhouse gases in ice often exhibit similar symptoms to those of G.S. Callendar, cited above. But the most important deficiency of these studies is the ice matrix itself, which does not fulfill the absolutely essential closed-system criterion. This is because liquid water is present in ice even at very low temperatures, and because many chemical and physical processes occur, in situ, in ice sheets and in recovered ice cores. These factors, discussed in References 8, 12, 22, and 24-28, change the original composition of air entrapped in ice, making the ice core results unrepresentative of the original chemical composition of the ancient atmosphere.

Here are some typical examples of how the estimates of pre-industrial atmospheric levels of greenhouse gases were determined. These results were then taken as a basis for estimation of the man-made climatic warming.[11]

- Neftel, et al. reported in 1982 rather high median CO_2 concentrations in the preindustrial ice core from Byrd, Antarctica, of about 330 and 415 ppmv, with maximum value reaching 500 ppmv.[23] However, in 1988, in the second publication on the same core, Neftel et al. did not show these high readings; the highest concentration reported was 290 ppmv, in agreement with the global warming theory[29] (Figure 3).

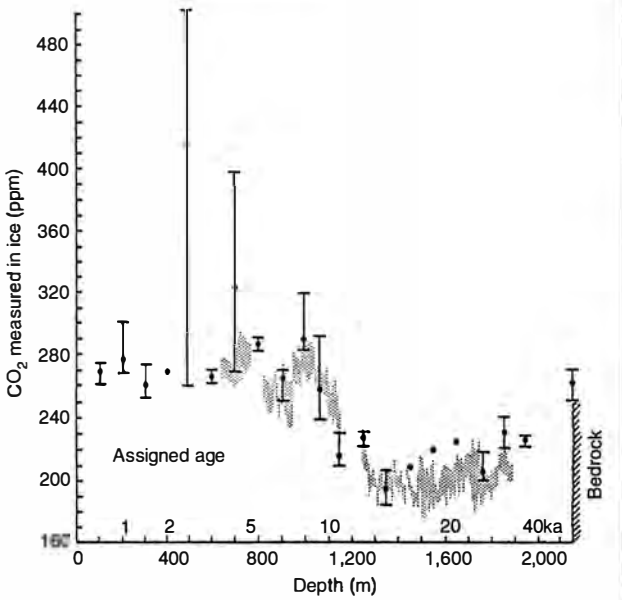


Figure 3
HOW SELECTION OF ICE CORE DATA SKEWS RESULTS TO MATCH THE GLOBAL WARMING THEORY

In presenting measurements of CO_2 concentrations in the pre-industrial ice core from Byrd Antarctica, Neftel, et al., in 1982 showed maximum values up to 500 ppmv (dots and bars). In 1988, the same authors published measurements for the same section of the Byrd ice core (gray areas), but left off the high readings published previously, reporting a highest concentration of 290 ppmv, in agreement with the global warming theory.

- Pearman, et al. "on examination of the data," rejected 43 percent of the CO_2 readings from Law Dome, Antarctica core, 39 percent of the CH_4 readings, and 43 percent of the N_2O readings, because they were higher or lower than the assumed "correct" values.[30] Thus, they concluded a value of 281 ppmv CO_2 for the pre-industrial atmosphere, and increases from the year 1600 of 90 percent and 8 percent of CH_4 and N_2O, respectively.
- Leuenberger and Siegenthaler claimed that their data from a Greenland ice core demonstrate that the present level of N_2O in the atmosphere, 310 ppbv, is an effect of a recent 19 percent increase caused by industrial activity.[31] To reach this conclusion, they rejected 27 percent of the samples with N_2O readings deemed to be "too high" for pre-industrial ice. After this "correction," the average pre-industrial atmospheric concentration of N_2O was declared to be 260 ppmv, although their value for ice from the year 1822 was 296.1 ppmv. Their results from a shallow Dye 3, Greenland core show a random N_2O distribution. Nevertheless, the authors formed an increasing temporal trend by rejecting the "incorrect" high readings.
- Etheridge, et al. claimed that their ice core results show a pre-industrial N_2O concentration of 285 ppbv.[32] This value

was calculated after rejection of 44 percent of their measurements! From the remaining analyses, the high readings from 16th and 17th century ice (328.3 and 329.8 ppbv), which were higher than in the 20th century samples (285.7 and 322.9 ppmv), were again eliminated without explanation.

- Zardini, et al. rejected a low N_2O reading of 240 ppbv in the youngest part of an Antarctic core from the year 1919.[33] From the several-thousand-year-old part of the core, they did not reject an even lower value of 217 ppbv, but they eliminated the high values of 310, 354, 359, and 362 ppbv. After these "improvements," Zardini, et al. concluded that the pre-industrial N_2O level in the atmosphere was 270 ppbv, and that in the present atmosphere N_2O increased "due to fossil fuel burning."

Some False Assumptions

For climatic interpretation of the ice core data the following assumptions are used:

(1) The entrapment of air in the ice is essentially a mechanical process, which occurs with no fractionation of the gas components;[34] the original composition of trapped air is believed to be permanently preserved in the polar ice sheets and in the collected ice cores. This means that the ice, with its included air bubbles, should remain a closed system during tens or hundreds of thousands of years in the ice sheets, and that this system is not disturbed during the core drilling or its transportation to the laboratory and its storage.

(2) No liquid phase occurs in firn and ice at average annual air temperatures of −24°C or less.[35]

(3) The gas inclusions are 80 to 2,800 years younger than the age of the ice in which they are entrapped. (See, for example, Reference 36.) This assumption is needed to accommodate the data from the shallow ice cores, which show that air entrapped in 19th century ice, or earlier, exhibits levels of CO_2, CH_4, and N_2O similar to present atmospheric concentrations.

It has been pointed out that these assumptions are incorrect, and thus that the conclusions on low pre-industrial levels of atmospheric greenhouse gases are wrong. (See, for example, References 12, 22, 24-28.) However, this criticism was largely ignored by greenhouse gases glaciologists, who offered no convincing arguments to refute this criticism in the one and only paper that it provoked.[37]

In addition to this biased selection of experimental evidence, there are many technical aspects to the science of glacial ice analysis that are ignored by the global warming enthusiasts in their desire to bolster their arguments with glacial data. Presented here are some of the scientific points eliminated by the global warming advocates.

Chemical Fractionation

A striking feature of the ice core arguments that there is a recent man-made increase of atmospheric CO_2, CH_4, and N_2O, is that all the ice core data are from ice deposited not in the last few decades, but in the 19th century or earlier. No information is presented on the recent concentrations of greenhouse gases in firn and ice deposited in the 20th century. Instead, the concentrations of greenhouse gases found in the pre-industrial ice are compared with the concentration of these gases in the contemporary free atmosphere.[12]

To justify such comparisons, an assumption is required that the entrapment of air in ice does not involve any chemical fractionation of gases. However, there are more than 20 chemical and physical processes that change the original chemical and isotopic composition of ice and of gas inclusions recovered from the ice cores.[12] Even the composition of air from near-surface snow in Antarctica is different from that of the atmosphere; the surface snow air was found to be depleted in CO_2 by 20 to 50 percent. (See references in Reference 12.)

"No study has yet demonstrated that the content of greenhouse trace gases in old ice, or even in the interstitial air from recent snow, represents the atmospheric composition."

Chemical and isotopic fractionation of gases occurs at the occlusion of air in snowflakes, in interstitial air in near-surface snow (effects of insolation), deep in the firn and ice, and in the ice cores. In the upper snow and firn strata, fractionation occurs on a time scale of days and of a few years; but deep in the ice, it occurs on a scale of up to hundreds of thousands of years. Fractionation is caused by the differences in solubility in cold water of air components, chemical reactions, formation of gas clathrates and gravitational thermal effects.[12] (Clathrates are compounds formed by the inclusion of one type of molecule in the cavities of the crystal lattice of another.) In firn, fractionation is related to subsurface melting of ice crystals, evaporation of water, transport of vapor in firn pores along the thermal gradient, liquefaction of vapor, formation of ice layers and depth hoar (Figure 2).

Most of these processes are related to liquid water, which is present in the cold snow and ice down to the temperature of −73°C,[38] to pressure and temperature changes, and to metamorphosis of snow crystals.[12] The fractionation of gases as a result of their various solubilities in water (CH_4 is 2.8 times more soluble than N_2 in water at 0°C; N_2O, 55 times; and CO_2, 73 times), starts from the formation of snowflakes, which are covered with a film of supercooled liquid.[22] Gases dissolved first in liquid water are then equilibrated with air trapped in the firn pores and in the air bubbles of the solid ice.

Carbonates and other impurities present in the ice sheet—such as the reactive species HNO_3 (nitric acid), HCl (hydrochloric acid), H_2O_2 (hydrogen peroxide), SO_2 (sulfur dioxide), and O_3 (ozone), as well as catalysts such as copper, iron, manganese, or particulate matter—are dissolved or suspended in the liquids present at the surface of snow and ice grains, and can react with themselves (for example, producing or consuming CO_2), or with the greenhouse gases. Oxidation or reduction processes occur not only in the upper firn part of the ice sheet, where solar radiation penetrates, but also in the deep, dark parts. This is indicated by sharp decreases in H_2O_2 concentration profiles observed deep in the ice sheet, and also by the systematic decrease of its concentration with depth (for references, see Reference 22).

Another important process is differential formation and dissociation of pure and mixed clathrates (hydrates) of green-

house gases and of major components of air. Dissociation pressures are much lower for greenhouse gases than for oxygen and nitrogen. At −20°C, these pressures are only 4, 5, and 13.5 bars, for N_2O, CO_2, and CH_4, respectively; but these pressures are 120 bars for N_2, and 160 for O_2. At −20°C in the ice sheet, CO_2 gas begins to change into the CO_2 clathrate (a white solid discovered in 1882 by Zygmunt F. Wróblewski, a physicist who first liquefied air,[39,40]), and to disappear from the gas in the air bubbles, at a depth of about 70 m, where the load pressure increases to 5 bars.

On the other hand, O_2 and N_2 change into clathrate crystals at much greater depth of about 900 to 1,200 m, where all gases finally enter the clathrate form, or diffuse into liquids and ice crystals. Therefore, at this depth, all air bubbles disappear completely from the ice. Now, what happens when ice cores are decompressed and recovered at the surface of the ice sheet: In the bubble-free ice, new artificially created gas cavities are formed from the clathrate crystals dissociating at the lower pressure (Figure 2). This dramatic phenomenon is played down, (for example, see Reference 41), or ignored, in publications on greenhouse gases.

It was found experimentally that the partial pressure of the gas is not a determining factor for the dissociation pressure of clathrates, which become enriched in components that form clathrates readily. In contrast, the free-gas phase becomes enriched with components that do not easily form clathrates.[42] The occurrence of clathrates causes depletion of greenhouse gases in two stages: (1) during clathrate formation in the ice sheet, when greenhouse gases enter the clathrate form and leave the air bubbles earlier than N_2 and O_2; and (2) in the ice cores after relaxation of the load pressure, when N_2 and O_2 clathrates dissociate long before the greenhouse gases, forming secondary gas cavities in the ice.

This latter phenomenon is associated with micro-explosive changes in the core structure[43] (Figure 2), and formation of micro- and macro-cracks, which, together with the stress fracturing of ice, leads to molecular and isotopic fractionation of gases.[44]

As mentioned above, in some gas inclusions from pre-industrial ice, concentrations of greenhouse gases were found similar to, or much higher than, those of the present atmosphere. In some gas inclusions, changes in CO_2 concentrations of up to 50 ppmv have been measured over distances of only 2.5 cm in the cores.[45] Such inhomogeneous distribution of CO_2 concentrations obviously does not reflect the changes in the composition of the atmosphere, but is the result of the random character of fractionation processes.

However, as discussed in References 12 and 22, the prevalent effect of fractionation of gases in the ice sheets, and in the recovered ice cores, is the preferential depletion of greenhouse gases in the air bubbles, and in the secondary gas cavities. For this reason, most gas samples recovered from polar ice cores had concentrations of trace gases that were much lower than those of the present atmosphere, even in ice dating from periods when the global surface temperature was higher than the present by 0.5 to 1.3°C—for example, during the Eemian interglacial period, 125,000 to 130,000 years ago; in the mid-Holocene, 5,000 to 6,000 years ago; or during the Medieval warm period, 1,200 years ago.[11]

The CO_2 concentrations in air bubbles in ice from the years 1000 to 1800, remained remarkable stable: 270 to 290 ppmv, even though during the Little Ice Age of the 16th to 19th century, the global temperature decreased about 1°C. Such a long-term drop in global temperature should be reflected as a decrease in the CO_2 content in the atmosphere, because of higher CO_2 solubility in the colder oceanic water, and reduced oxidation processes on land and sea (see discussion below).

The lack of this effect in the air bubbles in ice seemed "surprising" for the authors of the Intergovernmental Panel on Cli-

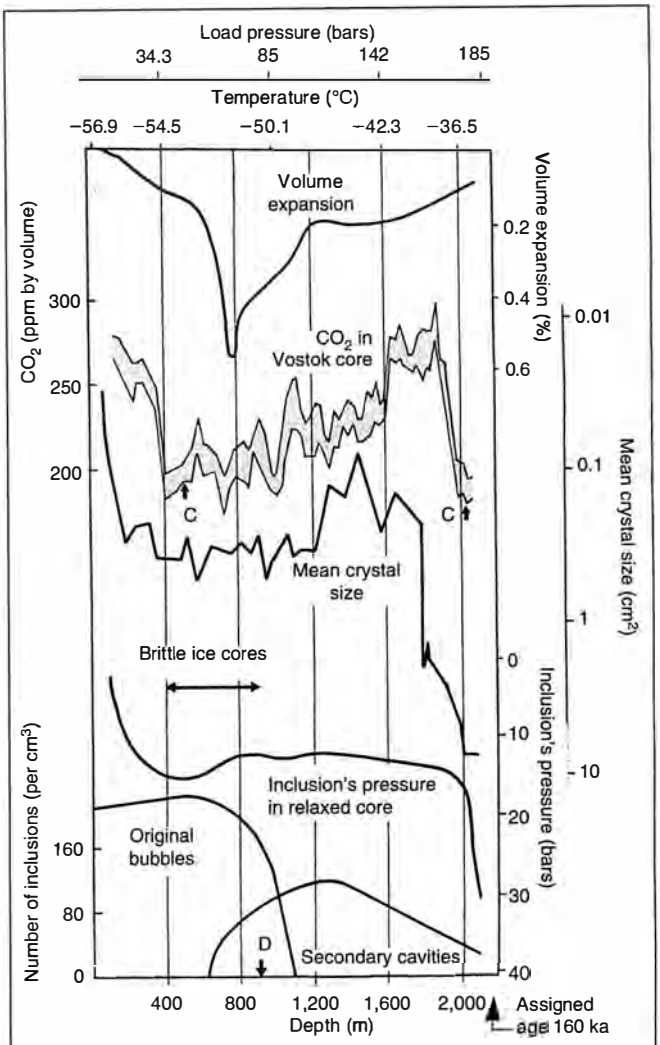


Figure 4
PROCESSES CAUSING CONTAMINATION OF ANTARCTIC ICE CORE SAMPLES

Shown here are the many processes that influence the chemical and isotopic composition of air inclusions in ice sheets and in the ice cores, based on the data from the Vostok and Byrd stations, Antarctica. The vertical arrow D (at bottom) indicates the total disappearance of air bubbles in the Vostok core. The vertical arrows C (at middle, left and right) indicate the sites of highest contamination of the inner parts of the Vostok core with lead, zinc, aluminum, and sodium from drilling fluid.

Source: Adapted from Jaworowski et al., 1992

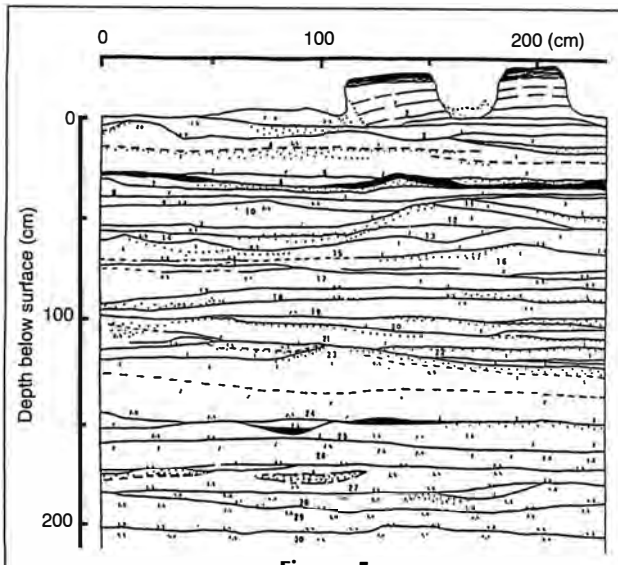


Figure 5
ICE SHEET STRUCTURE BARS AIR PENETRATION INTO FIRN

The ice crust evidence indicates that high density ice strata form a multilayer structure that separates the firn into horizontal pockets, a structure that prevents air penetration into the firn. Thus assumptions that air and ice ages are different, used to bolster the global warming theory, are not correct. Shown here is firn stratigraphy in a pit at Mizuho Plateau (East Antarctica), where the mean annual temperature is −51°C. The solid lines indicate the ice crusts.

Source: Adapted from Watanabe 1977

mate Change report in 1990, who deduced from it that the sensitivity of atmospheric CO_2 to such climatic fluctuations is small. However, the CO_2 atmospheric content is *very* sensitive even to short-term and much smaller changes of global temperature, as will be shown below. It is much more plausible that the long-term changes of concentration of greenhouse gases in the gas inclusions from ice sheets represent the cumulative effect of the interplay of many processes occurring in the ice sheet and in the ice cores, rather than composition of the ancient atmosphere (Figure 4).

The Age of Air in Bubbles

An ad hoc, speculative assumption that the air in bubbles in ice is 90 to 200 years younger than the ice in which the bubbles are entrapped, was posed at a time when the concentrations of greenhouse gases in air bubbles from ice deposited in the 18th and 19th century were found to be similar to those of the present atmosphere.[46, 47]

No experimental evidence was offered in support of this assumption. Instead, Craig et al. offered the circular-logic argument that this speculation must be correct, because the ice core data for a greenhouse gas with the ages corrected in this way "lead rather precisely into the recent atmospheric measurements"![47] Later, the assumption for the difference between the age of the air and the age of the ice was theoretically, but not experimentally, elaborated, with estimations of this difference for various polar sites ranging between 90 and 2,800 years.[36] These estimations were simply based on the age of the firn/ice transition. It was supposed that in the Greenland and Antarctic sites, where the mean annual temperature is −24°C or less, the whole column of firn was devoid of ice layers that were impermeable to atmospheric air. Further, it was believed that this air can freely penetrate into the ice sheet, down to the

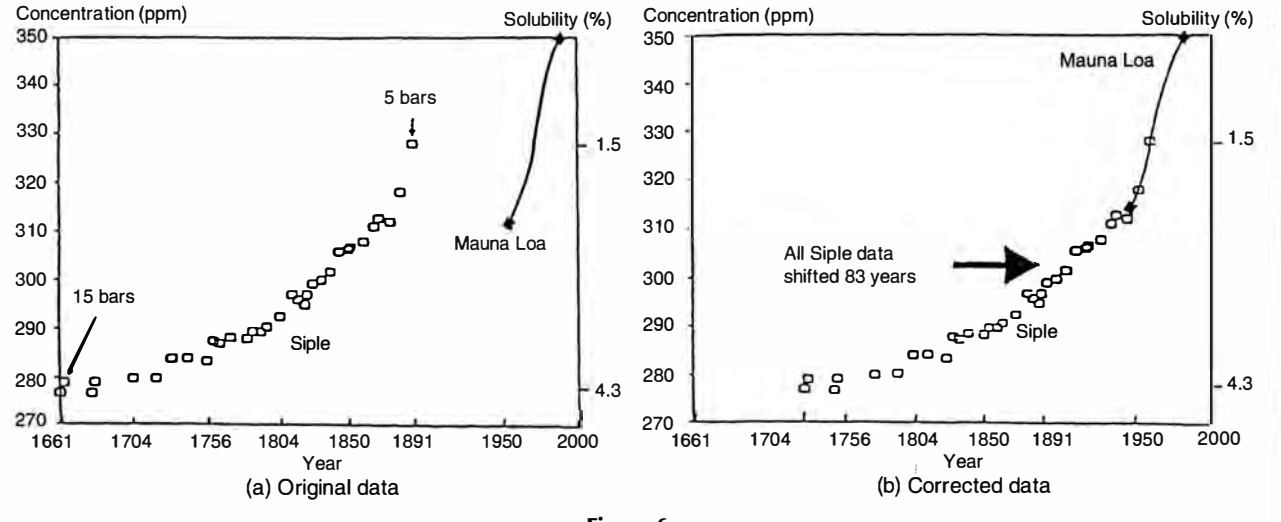


Figure 6
CORRECTING THE CO_2 ICE DATA TO FIT THE THEORY: AN EXAMPLE FROM SIPLE, ANTARCTICA

The figures here show measurements of CO_2 in pre-industrial ice (open squares) and CO_2 as measured in the atmosphere at Mauna Loa, Hawaii (solid line). The original data are shown in (a). The same data appear in (b) after an arbitrary "correction" of 83 years in the age of the air, to make the data accord with the global warming theory. Using the real age of the air, could indicate that the CO_2 concentrations in the latter 19th century were the same as those in the 1970s. The "corrected" data were published by Neftel et al. 1985; Friedli, et al. 1986; and IPCC, 1990.

firn/ice transition at about 40 to 120 m depth, where final occlusion of the firn pores occurs.

However, as discussed in Reference 12, the formation of ice crusts has been recorded at many sites with mean annual surface air temperature reaching −57°C. Numerous Japanese, Russian, and Norwegian stratigraphic studies have demonstrated that such high density ice strata (layers) are ubiquitous in the Antarctic ice sheet, where they form a multilayer structure (1 to 15 strata per meter depth), separating firn into horizontal pockets (Figure 5). This structure acts as a barrier to the free penetration of air into firn. The chemical and stable isotope fractionation of CO_2, CH_4, N_2, and O_2 occurring in the air trapped in the porous Greenland firn, indicates that this air in firn is isolated from the atmosphere.[47] On this basis, Craig et al. revoked their earlier estimate of a difference between age of air and ice.[48]

Thirteen years after the age assumption was postulated, and it was accepted on this basis that the level of greenhouse gases was lower in the pre-industrial atmosphere than now, an attempt was made to prove its validity in an experiment carried out in a borehole at Summit, Greenland.[21] At this site, the authors estimated the air/ice age difference as 210 years. As was indicated in Reference 22, the interpretation of the results in this experiment ignored Darcy's law on flow in porous media. CO_2 concentration measured in air from about 214-year-old firn ranged from 242.3 to 435.7 ppmv; and from 50-year-old firn, it ranged from 347 to 641.4 ppmv. Such concentrations do not represent the composition of atmospheric air, but rather the fractionation processes in the ice sheets, and experimental artifacts.

The consequence of the assumption that the air in bubbles is younger than the ice in which the bubbles are found, is evident in Figure 6(b), which is widely accepted as a "proof" that the level of CO_2 in the atmosphere has been increased by man's activities.[11] The same erroneous procedure was also used for other greenhouse gases. In the case of CO_2, the data from the 19th century ice collected at Siple, Antarctica, were made to overlay exactly the present atmospheric CO_2 concentrations measured at an active and CO_2-emitting volcano, Mauna Loa, Hawaii—by assuming, arbitrarily, that the occluded air is 83 years younger than the ice.

Without this "correction," and using the real age of ice, the Siple and Mauna Loa curves do *not* correspond, and could indicate that CO_2 atmospheric concentration was the same in the latter part of the 19th century as in the 1970s. One can also note that the CO_2 concentration in the air bubbles decreases with the depth of the ice for the entire period between the years 1891 and 1661, not because of any changes in the atmosphere, but along the increasing pressure gradient, which is probably the result of clathrate formation, and the fact that the solubility of CO_2 increases with depth.[12]

Cracked and Contaminated Ice Cores

Another area ignored by the global warming advocates concerns the condition of the ice core samples, as a result of the sampling procedure. Drilling the ice cores is a brutal procedure, subjecting the ice to mechanical and thermal stress, drastic decompression, and pollution. These factors cause micro- and macro-cracking of the ice, opening the original air bubbles and forming artificially created secondary air cavities in the bubble-free, deep ice, and causing internal contamination of cores.

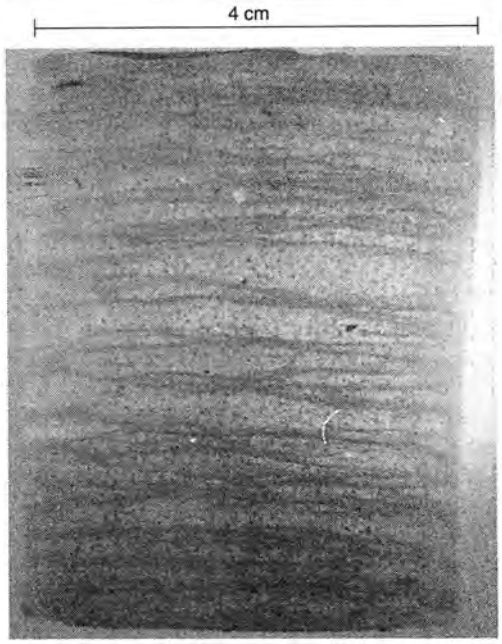


Figure 7
CRACKING IN ICE CORE SAMPLES AS A RESULT OF DRILLING AND TRANSPORTATION UPWARDS
A photograph in transmitted light of the inner part of an ice core from the Mizuho Plateau (East Antarctica), at a depth of 356 m. Note a dense structure of "healed" macro-cracks, which do not disturb the mechanical integrity of the core. Before "healing," the cracks were open to migration of gases and pollutants, which affect the measurements of greenhouse gases.

A dense network of horizontal fractures is created in the ice cores by a sheeting phenomenon that occurs as the result of elastic relaxation of load pressure of more than about 8 bars; that is, in cores at a depth below 110 meters. The cracking occurs during the drilling and upward transportation of the core in the borehole, which is filled with a wall-retaining drilling fluid. The small cracks are soon healed by regelation, and their remnants are visible as horizontal stratification of the cores. The effects of this sheeting phenomenon, well known to geologists and glaciologists, are demonstrated in Figure 7. The same horizontal cracking is visible in a similar photograph of Vostok core.[49]

Drilling fluid (diesel oil, jet fuel, and so on, with aggressive organic substances added for density regulation and antifreeze purposes) enters the cracks and penetrates into the central parts of the cores, and into the air bubbles and secondary gas cavities formed by dissociating clathrates. In the classic papers on greenhouse gases in polar ice, the reader is not informed about the method of drilling, or about the use of a drilling fluid (for example, see Reference 50). The gases released by decomposition of clathrates can escape into the drilling fluid before the cracks are healed at the surface of the ice sheet. As suggested by Craig et al., the molecular and isotopic fractionation of gases may occur during this process.[48]

Numerous studies on radial distribution of metals in the cores (for example, Reference 51) reveal an excessive contamination of their internal parts by the metals present in the drilling fluid. In these parts of cores from the deep Antarctic, ice concentrations of zinc and lead were higher by a factor of tens or hundreds of thousands, than in the contemporary snow at the surface of the ice sheet (Figure 8). This demonstrates that the ice cores are not a closed system; the heavy metals from the drilling fluid penetrate into the cores via micro- and macro-cracks during the drilling and the transportation of the cores to the surface.

During this drilling process, the ice cores become porous and open to both inflow and outflow of gases and liquids. The sheeting phenomenon, and about 20 physical and chemical processes that occur in the ice sheets and in the ice cores, make the ice and its gas inclusions an improper material for reconstruction of the levels of greenhouse gases in the ancient atmosphere.[12]

It is astonishing how credulously the scientific community and the public have accepted the clearly flawed interpretations of glacier studies as evidence of anthropogenic increase of greenhouse gases in the atmosphere. Future historians can use this case as a warning about how politics can negatively influence science.

Using Carbon Isotope Evidence for CO_2

Analysis of glacier ice is not the only way to estimate the anthropogenic contribution to the current CO_2 content in the atmosphere. Carbon present in CO_2 is composed of two stable isotopes, carbon-12 and carbon-13. Their ratio is commonly expressed as the $\delta^{13}C$ (delta carbon-13) value. This value differs in various components of the environment. For average crustal carbon, it is −7 per mill;[52] for atmospheric CO_2 in isotopic equilibrium with marine HCO_3^- and $CaCO_3$ (calcium carbonate), it has been estimated to be about −7 per mill;[53] measured in atmospheric CO_2 in 1956, it was −7.00 per mill;[54] and in 1988, −7.807 per mill;[55] and for fossil fuel and biogenic carbon it is −26 per mill.[56] Such great differences in the isotopic signature of fossil fuel and biogenic carbon make possible the estimation of the current and past contributions from this source to the atmosphere, because mixing even relatively small amounts of CO_2 with so low a $\delta^{13}C$ value should change the average natural $\delta^{13}C$ of atmospheric CO_2.

This estimation can be made by carbon isotope mass balance calculations. For example, between 1956 and 1988, the CO_2 concentration in the atmosphere changed from 315.6 ppmv to 351.2 ppmv;[7] that is, by 10.14 percent. If this change were caused solely by anthropogenic emissions of CO_2 with $\delta^{13}C$ of −26 per mill, then in 1988, the average atmospheric $\delta^{13}C$ should be

$$(-7 \text{ per mill} \cdot 0.8989) + (-26 \text{ per mill} \cdot 0.1014) = -8.927 \text{ per mill}$$

and not −7.807 per mill, as measured by Keeling et al. at Mauna Loa, Hawaii.[55] With a 21 percent increase in atmospheric CO_2 caused by human activities, as claimed by the IPCC on the basis of glacier studies,[11] and with a preindustrial $\delta^{13}C$ value of −7 per mill, the current $\delta^{13}C$ of airborne CO_2 should decrease to about −11 per mill. Such a low value was never determined

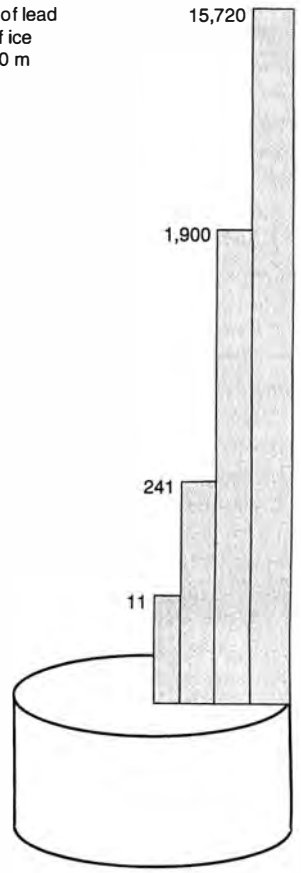


Figure 8
CONTAMINATION OF ICE CORE SAMPLES BY DRILLING FLUIDS

A radial distribution of lead pollution in the Vostok core, at a depth of 1,850 m, shows values of lead per gram of ice that are factors of tens to hundreds of thousands higher than lead concentrations measured in nearby recent surface snow in Antarctica, which range from 2.3 to 7.4 picograms of lead per gram of ice.

Source: Adapted from Boutron, et al. 1990.

Such data conflict with the whole structure of the greenhouse warming hypothesis and, in particular, these data conflict with the unrealistically long atmospheric lifetime of CO_2 of up to 200 years assumed by the IPCC.[11] This assumption allows the accumulation of a rather small annual fossil-fuel and land-use increment of about 6 gigatons of carbon (GtC) per year, to about the 150 GtC assumed atmospheric increase between 1869 and 1990. The $\delta^{13}C$ value measured in 1988, which is much higher than the result of isotopic mass balance calculation, suggests that in 1988, anthropogenic sources contributed only a small fraction to the total of atmospheric CO_2. This fraction can be quantified in the following way:[57]

In 1991, the author, together with Tom V. Segalstad from Oslo University, calculated the isotopic composition of the December 1988 atmospheric total CO_2 pool of 748 GtC reported by the IPCC in 1990, in which Keeling et al. (1989) measured a

$\delta^{13}C$ of −7.807 per mill. We made these calculations for three components of the CO_2 pool: (1) the fraction of natural CO_2 with $\delta^{13}C$ of −7 per mill remaining from the pre-industrial atmosphere (pre-1750); (2) the fraction of natural CO_2 with $\delta^{13}C$ of −7 per mill remaining from the period 1750-1988; and (3) the cumulative CO_2 fraction remaining from each annual emission of fossil-fuel CO_2 from 1860 to 1988, with a $\delta^{13}C$ of −26 per mill.

For various atmospheric lifetimes of CO_2, we calculated the mass N of each component remaining in 1988 from particular years, using the equation

$$N = N_0 e^{-\lambda t}$$

where N_0 is the annual injection of CO_2 (in GtC) at a time t (in years) before the end of December 1988 from natural sources or fossil fuel burning, and λ is the removal constant (reciprocal lifetime) for various atmospheric CO_2 lifetimes between 2 and 200 years. The isotopic mass balance calculations demonstrated that the lifetime fitting the 1988 criteria of $\delta^{13}C$ of −7.807 per mill, and of the mass of atmospheric CO_2 of 748 GtC, is only 5 years. Neither longer nor shorter lifetimes give realistic isotopic mass balance results.

The atmospheric CO_2 lifetime of about 5 years agrees with numerous estimates based on measurements of atmospheric carbon-14 from natural sources and nuclear tests.[58,59] Significant amounts of carbon-14 from nuclear tests penetrated deep into the ocean, in a relatively short time; 10 years after the most intensive test in 1962, carbon-14 was found at a depth of 5,000 m in the North Atlantic.[60] A similar CO_2 atmospheric lifetime was also estimated by Starr from the seasonal atmospheric CO_2 variations.[61] The implication of the 5-year lifetime, is that about 18 percent—that is, 135 GtC, of the atmospheric CO_2 pool—is exchanged each year. An anthropogenic contribution of about 6 GtC per year pales in comparison with this vast natural flux.

The results of our calculations also indicate that the mass of CO_2 from all past fossil-fuel emissions remaining in the December 1988 atmosphere was about 30 GtC—that is, about 4 percent (and not 21 percent) of the 1988 atmospheric CO_2 pool, corresponding to an atmospheric CO_2 concentration of about 14 ppmv. The content of non-fossil-fuel and non-biogenic CO_2 with $\delta^{13}C$ of −7 per mill in the December 1988 atmosphere was about 718 GtC. This corresponds to a pre-industrial atmospheric CO_2 concentration of about 339 ppmv. The fossil-fuel component would be less if emissions from terrestrial biota (with similar $\delta^{13}C$ to that of fossil fuel) were included in the calculation. The estimate by Guthrie and Smith[62] of 35 GtC remaining from 1860 to 1990 in fossil-fuel CO_2 emissions, based on (non-isotope) mass balance calculations and a 5.1 year atmospheric lifetime of CO_2, is close to our result.

The current atmospheric CO_2 pool is dominated by the natural CO_2 with $\delta^{13}C$ of −7 per mill degassed from the ocean. The 4 percent anthropogenic contribution to this pool is probably smaller than the variations of CO_2 flux from natural sources caused by climatic instabilities.

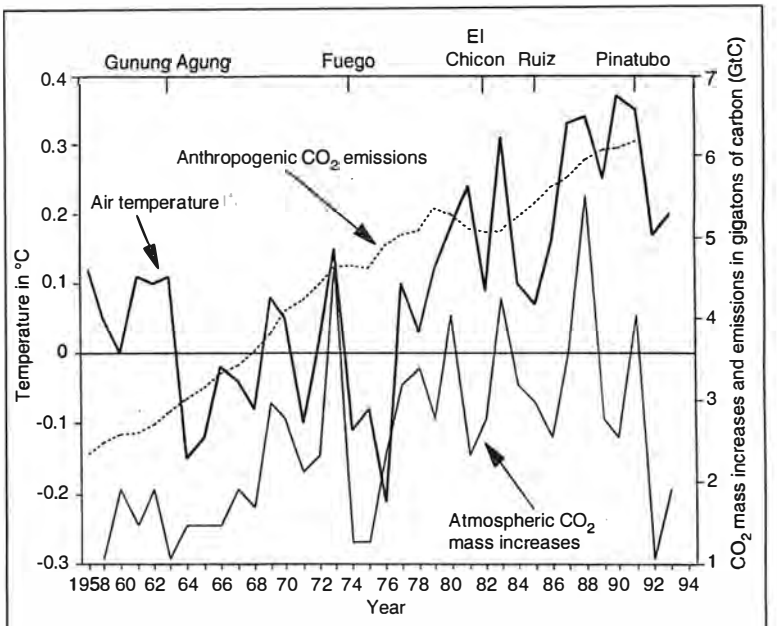


Figure 9
ANNUAL CHANGES IN ATMOSPHERIC CO_2 FOLLOW TEMPERATURE CHANGES, NOT MAN-MADE EMISSIONS

The increases in man-made emissions of CO_2 (dotted line) are not coupled to the fluctuations in the atmospheric CO_2 (thin solid line). Instead, zig-zags of changes in atmospheric CO_2, seem to closely follow changes in temperature (heavy solid line). The largest decreases in CO_2 occur after volcanic eruptions reach the stratosphere. Volcanic eruptions are noted at top.

The source of temporal trends in anthropogenic CO_2 emissions from fossil fuel burning and cement production is taken from Boden, et al., 1990; Andres, et al., 1993. The data for atmospheric CO_2 mass increases are calculated from CO_2 air concentrations measured at Mauna Loa, Hawaii, and are taken from Boden, et al., 1990; Keeling, et al., 1995. The global surface air temperature is taken from Boden, et al., 1990; Keeling, et al., 1995.

CO_2 Increases Not the Result of Human Activity

Atmospheric CO_2 concentration increased from 315.6 ppmv in 1958, to 359 ppmv in 1994.[7,63] As these concentrations correspond to an atmospheric CO_2 mass of 669 GtC and 761 GtC, respectively, the cumulative increase during 37 years was 92 GtC; that is, about 14 percent of the 1958 atmospheric mass of CO_2. The average annual increase in this period was then about 2.5 GtC.

Each year about 12 percent (that is, 92 GtC) of the total atmospheric mass of CO_2 exchanges with the ocean, and about 13 percent (102 GtC) with the land biota (IPCC 1990). It is possible that the observed CO_2 increase is the result of a small change in this annual natural CO_2 flux, caused by increased degassing from the warmer ocean, and increased oxidation processes at land and sea, resulting from natural climatic fluctuation. This possibility was not discussed in the IPCC's 1990 document.

The IPCC estimated that the temperature of the surface waters increased between 1910 and 1988 by about 0.6°C. A similar increase was observed in the surface air temperature in this period. Increasing the average temperature of the surface of

the oceanic waters (15°C) by 0.6°C, would decrease the solubility of CO_2 in these waters (0.1970 g CO_2 per 100 g) by about 2 percent. The CO_2 flux from the ocean to the atmosphere should be increased by the same factor; that is, by about 1.9 GtC/year. This is similar to the observed average increase of atmospheric CO_2 in the years 1958 to 1968, of 0.73 ppmv/year,[7] which corresponds to 1.6 GtC/year. The measured annual atmospheric CO_2 increases were higher in the next two decades (2.5 GtC/year and 3.4 GtC/year),[7] which indicates that changes in CO_2 solubility in oceanic water were responsible only for a part of observed CO_2 increases. Inorganic processes on land and changes in marine and terrestrial biota could also contribute to these increases.

The atmospheric air and sea surface temperatures did not increase smoothly during this period, but were rather irregular, zig-zagging from year to year (Figure 9). The annual changes in atmospheric CO_2 mass closely followed the temperature changes. This was probably the result of rapid equilibration between CO_2 concentration in the atmosphere, and the dissolved inorganic carbon in the sea in about three quarters of a year.[64]

The greatest cooling and largest decreases in the rate of atmospheric CO_2 increase occurred after volcanic eruptions which reached the stratosphere, characterized by high dust veil index: Gunung Agung in 1963, Fuego in 1974, El Chichon in 1982, Nevado del Ruiz in 1985, and Pinatubo in 1991.

On the other hand, the smoothly and steadily growing annual increases in anthropogenic emissions of CO_2 from fossil-fuel burning and cement production, do not match the atmospheric CO_2 fluctuations. Since 1988, these sharply growing anthropogenic emissions have not been associated with decreasing values of $\delta^{13}C$ of atmospheric CO_2;[63] for 7 years between 1988 and 1994, this latter value remained remarkably stable. If the observed changes in CO_2 concentration were man-made, a decrease in $\delta^{13}C$ should be observed.

During the famous "energy crisis" in 1974-1975, there was practically no decrease in anthropogenic CO_2 emissions, but there was a dramatic drop in annual mass increase of atmospheric CO_2 associated with atmospheric cooling; in 1983, the decreasing anthropogenic CO_2 emission rate was associated with a peak in the rate of atmospheric CO_2 mass increase, preceded by a cooler air temperature in 1982; in 1992, the highest rate of anthropogenic CO_2 emission was associated with one of the deepest drops in atmospheric CO_2 mass increase, and air cooling.

The data in Figure 9 suggest that CO_2 atmospheric mass increases were *not* related to man-made emissions of this gas, but rather that these increases depended on volcanic eruptions and other causes of natural climatic fluctuations.

Notes

1. I. Langmuir, 1989. *Phys. Today*, October, p. 36.
2. S. Arrhenius, 1896. *Philos. Mag. J. Sci.*, Ser. 5, Vol. 41, p. 237.
3. G.S. Callendar, 1938. *Q.J.R. Meteorol. Soc.*, Vol. 64, p. 223.
4. ——, 1940. *Q.J.R. Meteorol. Soc.*, Vol. 66, p. 395.
5. ——, 1958. *Tellus*, Vol. 10, p. 243.
6. G. Slocum, 1955. *Mon. Weather Rev.*, (October), p. 225.
7. T.A. Boden, et al., 1990. *Trends '90*, Report ORNL/CDIAC-36, p. 257.
8. Z. Jaworowski, et al., 1992. "Atmospheric CO_2 and Global Warming: A Critical Review, Norwegian Polar Institute, Oslo, *Meddelelser*, Vol. 19, No. 1, p. 76.
9. J. Emsley, ed., 1996. *The Global Warming Debate* (London: European Science and Environment Forum), p. 288.
10. "International Commission Report of the Workshop on Snow and Ice," held March 6-7, 1992, at the University of New Hampshire, p. 17.
11. Intergovernmental Panel on Climate Change, 1990. "Climate Change: The Intergovernmental Panel on Climate Change Scientific Assessment," p. 365
12. Z. Jaworowski, et al., 1992. *The Sci. Tot. Environ.*, Vol. 114, p. 227.
13. H. Oeschger, et al., 1988. *Ann. Glaciol.*, Vol. 10, p. 215.
14. I.G. Enting, 1992. *Tellus*, Vol. 44B, p. 23.
15. I.G. Enting, et al., 1987. *Tellus*, Vol. 39B, p. 318.
16. G. Landmann, et al., 1996. *Palaeogeogr. Palaeoclimat. Palaeoecol.*, Vol. 122, p. 107.
17. W. Dansgaard, 1954. *Geochim. Cosmochim. Acta*, Vol. 6, p. 436.
18. ——, 1977. IAHS Publication No. 118, p. 401.
19. K. Satow, et al., 1985. *Ann. Glaciol.*, Vol. 6, p. 256.
20. G. Heinsohn, 1994. *Vorzeit-Frühzeit-Gegenwart*, Vol. 4, p. 76.
21. J. Schwander, et al., 1993. *J. Geophys. Res.*, Vol. 98, p. 2831.
22. Z. Jaworowski, 1994. *Environ. Sci. & Pollut. Res.*, Vol. I, p. 162.
23. A. Neftel, et al., 1982. *Nature*, Vol. 295, p. 220.
24. H.-E. Heyke, 1992. *Erdöl und Kohle-Erdgas-Petrochemie*, Vol. 45, p. 360.
25. H.-E. Heyke, 1992. *Fusion*, No. L3, p. 32.
26. Z. Jaworowski, 1996. "Reliability of Ice Core Records for Climatic Projections," In *The Global Warming Debate* (London: European Science and Environment Forum), p. 95.
27. Z. Jaworowski, et al., 1991. *Atmospheric CO_2 and Global Warming: A Critical Review* (Oslo: Norsk Polarinstitutt, Rapportserie No. 59), pp. 1-75.
28. Z. Jaworowski, et al., 1992. *Atmospheric CO_2 and Global Warming: A Critical Review* (Oslo: Norsk Polarinstitutt, second revised edition), *Meddelelser*, No. 119, pp. 1-76
29. A. Neftel, et al., 1988. *Nature*, Vol. 331, p. 609.
30. G.I. Pearman, et al., 1986. *Nature*, Vol. 320, p. 248.
31. M. Leuenberger, et al., 1992. *Nature*, Vol. 360, p. 449.
32. D.M. Etheridge, et al., 1988. *Ann. Glaciol.*, Vol. 10, p. 1.
33. D. Zardini, et al., 1989. *J. Atmos. Chem.*, Vol. 8, p. 189.
34. H. Oeschger, et al., 1985. *Geophysical Monographs*, Vol. 32, p. 132.
35. D. Raynaud, et al., 1985. *Nature*, Vol. 315, p. 309.
36. J. Schwander, et al., 1984. *Nature*, Vol. 311, p. 45.
37. D. Raynaud, et al., 1993. *Science*, Vol. 259, p. 926.
38. R. Mulvaney, et al., 1988. *Nature*, Vol. 33l, p. 247.
39. S. Wróblewski, 1882. *Compt. Rend.* Vol. 24, p. 212.
40. ——, 1882. *Compt. Rend.* Vol. 24, p. 954.
41. A. Neftel, et al., 1983. *J. Phys. Chem.*, Vol. 87, No. 4l, p. 16.
42. Y.F. Makagon, 1974. *Gidraty Prirodnikh Gazov* (Moscow), p. 208.
43. H. Shoji, et al., 1982. *Nature*, Vol. 298, p. 548.
44. H. Craig, et al., 1988. *Science*, Vol. 242, p. 1535.
45. A. Neftel, 1991. *Seasonal Snowpacks* (Berlin), p. 386.
46. W. Berner, et al., 1980. *Radiocarbon*, Vol. 22, p. 227.
47. H. Craig, et al., 1982. *Geophys. Res. Lett.*, Vol. 2, p. 1221.
48. H. Craig, et al., 1988. *Science*, Vol. 242, p. 1535.
49. S. H. Schneider, 1989. *Sci. Am.*, Vol. 261, p. 38.
50. J.M. Barnola, et al., 1987. *Nature*, Vol. 329, p. 408.
51. C.F. Boutron, et al., 1990. *Earth Planet. Sci. Lett.*, Vol. 101, p. 248.
52. A.N. Fuex and D.R. Baker, 1973. *Geochim. Cosmochim. Acta*, Vol. 37, pp. 2509-2521.
53. H. Ohmoto, 1986. *MSA Rev. Mineral.*, Vol. 16, pp. 491-559.
54. C.D. Keeling, W.G. Mook, and P.P. Tans, 1979. *Nature*, Vol. 277, pp. 121-123.
55. C.D. Keeling, R.B. Bacastow, A.F. Carter, S.C. Piper, T.P. Whorf, M. Heimann, W.G. Mook, and H. Roeloffzen, 1989. *Geophys. Mono.*, Vol. 55, pp. 165-236.
56. P. Tans, 1981. "Carbon Cycle Modelling, SCOPE 16" (Chichester: John Wiley & Sons), pp. 127-129.
57. T.V. Segalstad and Z. Jaworowski, 1991. "Carbon Isotope Mass Balance of Atmospheric CO_2," University of Oslo, unpublished.
58. UNSCEAR, 1977. "Sources and Effects of Ionizing Radiation." United Nations Scientific Committee on the Effects of Atomic Radiation, report to the General Assembly (New York: United Nations), p.725.
59. E.T. Sundquist, 1985. "Geological Perspectives on Carbon Dioxide and the Carbon Cycle," in E.T. Sunquist and W.S. Broecker (eds.), *The Carbon Cycle and Atmospheric CO_2: Natural Variations Archean to Present*, AGU Geophysical Monograph, Vol. 32, pp. 5-60.
60. B. Bolin, 1989. "How Much CO_2 Will Remain in the Atmosphere?" *SCOPE 29* (Chichester: John Wiley & Sons), pp. 93-155.
61. C. Starr, 1993. *Energy*, Vol. 18, pp. 1297-1310.
62. M.B. Guthrie and S.P. Smith, 1993. Appendix in Starr (see Reference 61).
63. C.D. Keeling, T.P. Whorf, M. Wahlen and J. vander Plicht, 1995. *Nature*, Vol. 375, pp. 666-670.
64. B. Bolin, 1982. "Changing Global Biogeochemistry." In P.G. Brewer (ed.) *Oceanography: The Present and Future* (New York: Springer Verlag), pp. 306-326.
65. O. Watanabe, 1977. JARE Data Reports No. 36 (Glaciology), (Tokyo: National Institute of Polar Research), pp. 61-138.

The Battle Over The Laws of Electrodynamics

by Dr. Rémi Saumont

A French physicist reviews the experiments designed to prove the existence of the Ampère longitudinal force

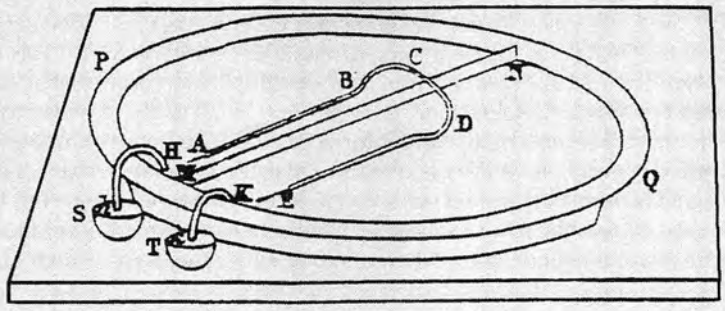


Figure 1

The figure is Ampere's hairpin experiment. Above: André-Marie Ampère (1775-1836).

In the 170 years that have passed since Oersted discovered electromagnetism, Ampère's Law, at least in the first 70 years, was universally recognized. This law has to do with the force effects of the parts of an electrical current in a conductor upon each other, and with the existence of longitudinal forces of repulsion between the "current elements."

In the 20th century, countless experiments were conducted in order to prove the existence of longitudinal Ampère forces. They were the subject of intense discussion and controversy. Most of these attempts applied strong currents of over 100 amperes (A), and even up to 100,000 A. In order to prevent heat effects, in my own experiments on the Ampère force, I have used only weak currents of up to 16 A and measured the resulting force effects by means of a mechanical-optical coupling.

Ampère's Hairpin Experiment

At the beginning of the 19th century, Ampère had come to the view that all the theoretical and experimental results assembled by him and other scientists underscored the existence of longitudinal forces. He was thus of the opinion that this state of affairs had been sufficiently explained. Yet, during a visit to his colleague De la Rive, he consented to conduct one last experiment in order to confirm the assumption of longitudinal forces. What is known as the "Ampère Hairpin Experiment" was in fact initiated by De la Rive, as Peter Graneau shows in his book *Ampère-Neumann Electrodynamics of Metals*.[1]

A copper wire in the form of a bent hairpin was floated in a dish filled with mercury (Figure 1). The dish was separated into two halves by an insulating divider. A source of current, with a switch, was placed between two conductors dipping into the mercury. The hairpin floated freely on the mercury. Its top, connecting the two parallel prongs, spanned the divider. When the current was applied, Ampère observed that the floating wire moved away from the fixed conductors. This, he thought, proved that in any interaction between current in mercury and current in copper, a longitudinal force was active.[2]

According to Ampère's own law, the electrical circuit would have to exert a small force of repulsion on the hairpin. But the prongs of the hairpin were long enough to ensure that the transverse force of repulsion on the bent part of the hairpin was negligible.

Long before Lorentz put forth a new theory of electrodynamics in 1890, scientists believed that this experiment by Ampère and De la Rive represented the main proof of the existence of a longitudinal force. Maxwell mentioned that this experiment was sometimes cited to prove that Ampère's formula was more correct than that of von Grassmann. He explained: "We find it

hard to believe that Ampère actually discovered the force law with the help of the experiments that he describes."

With regard to research of this kind, this verdict still holds, because the strength of the current was not known. Unfortunately, these and other experiments can only be considered to provide qualitative evidence.

Toward the end of the1 9th century, a new form of electrical current was discovered—the electron flow in a vacuum. This discovery raised a problem which prompted Lorentz to present his new theory of electrodynamics. For most physicists, this new theory rendered untenable the hypothesis of longitudinal forces, because, given an electron beam in a vacuum, longitudinal forces would interrupt the flow of electrons; thus Lorentz saw no reason not to formulate a law that excluded longitudinal forces.

This was the start of a long controversy. Some physicists declared that there exists a fundamental difference between an electron beam in a vacuum tube and an electrical current in a metallic conductor. The electron, which moves through the metal, is exposed to far more complex forces than a free electron in the vacuum of a cathode ray tube.

The most interesting among the numerous experiments conducted in this field at the beginning of the 20th century was Carl Hering's in 1922,[3] which was later described and commented upon by L.A. Robertson.[4]

A rectangular electrical conductor *ABCDEFG* was constructed (Figure 2), in which the element *DE* could be rotated horizontally. It rotated around point *E,* and its bent-under endpoint was submerged in an oval vat *M,* filled with mercury and electrically connected to *C.* When a strong current was applied between *A* and *G,* it was observed that segment *DE* swung inward of its own impetus from its initial position in the circuit, instead of being pushed outward, as would have to be the case according to the classical laws of electrodynamics.

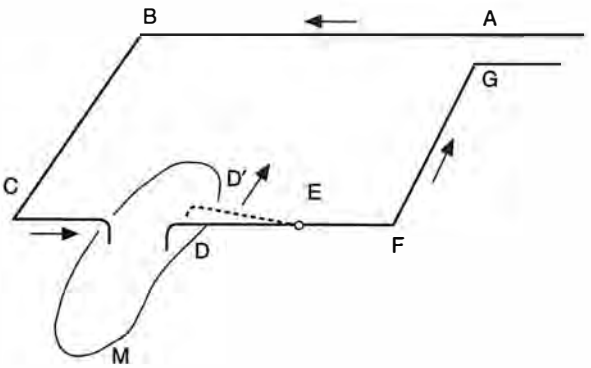


Figure 2
HERING'S EXPERIMENT

This experiment was the first example of modern research using contacts of metallic mercury. Many further efforts ensued to study longitudinal forces. In all these research efforts, heat effects were necessarily an important subject of discussion, perhaps even the most important.

The first research work of this kind involved qualitative experiments with strong mechanical effects (on account of the high current). A second direction of research consisted of

EDITOR'S NOTE

Those who know physics only from textbooks or popular-science presentations, will be surprised to hear it stated that such "simple" phenomena as a current flowing through an electrical conductor, are far from fully understood, and that there are still heavily disputed questions concerning the very laws of electromagnetism. This article addresses one of these disputed issues, whose outcome could have far-reaching consequences.

The question is the original law of the magnetic effects of electrical current, which was set forth by André-Marie Ampère on the basis of extensive experimentation. Ampère conceived of a current flowing in a metallic conductor as consisting of a large number of small "current elements," which could be represented as "infinitely small" discrete segments. Ampère assumed that, between any two arbitrary current elements, a force existed, which acted in the line joining their centers, and depended not only on the strength of the current and the distance range between the "elements," but also on their mutual spatial orientation. With his experiments as the background, Ampère stated a mathematical law for this dependency. The macroscopically ascertainable action of the force between conductors yielded the sum of the interactions of all the "elements" contained in the current. The force effect calculated according to Ampère's formula was shown to be in full accord with experience.

For several decades, Ampère's law of force served as the point of departure for the development of experimental and theoretical electrodynamics, distinguished especially by the work of Carl Gauss, Wilhelm Weber, Franz Neumann, and Bernhard Riemann. This theoretical work reached its high point in Riemann's 1858 (several years before Maxwell's) concept of "retarded potential," according to which electromagnetic impulses propagate through space, with the same velocity as light.

However, there was also widespread criticism of Ampère's law, including doubt about the highly complicated dependency of the interaction of the current elements on their respective positions. In 1845, the mathematician Hermann Grassmann put forth another law for the magnetic effect of electrical currents, which made exactly the same presuppositions as Ampère's Law for the case of interaction of two closed electrical circuits, but took a completely different mathematical form. At the end of the 19th century, thanks to the influence of Helmholtz, Maxwell's electrodynamics prevailed, and the concepts and methods of the Ampère-Gauss-Weber-Riemann school were increasingly pushed into the background. At present, what we find introduced in many textbooks as "Ampère's law of force" is not the original Ampère law at all, but Grassmann's law.

The formulations of the two laws are in no way alike. According to the original Ampère law, current elements which

quantitative experiments with weak currents, in which measurements by means of various equipment—for example, balances or dynamometers—were undertaken.

I. Observation of Strong Mechanical Effects of Longitudinal Forces Using Strong Current (100 to 100,000 A). Qualitative Experiments

(A) Break or deformation of electrical conductors

1. Experiments by Nasilowski and Graneau: Nasilowski's experiments on the blow-out of copper fuses were carried out in Warsaw in the 1950s.[5]

Nasilowski investigated the breakage of a 0.5-mm copper wire, when an electrical impulse was sent through it for 50 milliseconds. A current of 2,000 A sufficed to break the wire, and the break-point occurred close to the electrical source. The number of breaking-points increased with the strength of the current, and the points were widely spaced from one another. Moreover, the ends of the broken wire pieces were bent at right angles, while, on the other hand, there was no visible sign of melting.

Graneau carried out similar experiments with a 1.5-m-long, 1.5-mm-thick wire. Microscopic examination of the clean right-angle breaks he observed led to the conclusion that the breaks resulted from longitudinal forces, and were not the kind of effects that would come from melting or from Lorentz forces. Graneau discusses these questions on pages 112-115 of his book.[1]

2. Railgun experiments: Ampère forces are assumed to play an important role as well in strong pulsed currents, such as those used in nuclear fusion experiments or railgun accelerators, where currents up to 100,000 A are applied.

In a railgun accelerator, two parallel metallic conductors carry electrical current back and forth across an additional conductor (the armature), which spans the electrified rails and rides on top of them. This conductor is the projectile which is accelerated by means of electrodynamic forces.

Graneau investigated this kind of apparatus at the Massachusetts Institute of Technology and in England.[1,6] In his view, according to the classical Lorentz concept, the recoil or repulsion caused by the acceleration of the projectile would be absorbed by the electromagnetic field arising from the flow of current, and would exert no effect on the rails. Therefore, he thinks that the repulsion actually observed to be acting upon the rails, represents a proof of the specific Ampère longitudinal force.

(B) Movements or displacements using mercury contacts or electric arcs

In many investigations of longitudinal Ampère forces, circuits with fluid metals (mercury) are utilized, in which relative movements of conductors are possible. As in the hairpin experiment, longitudinal forces induce tension along the conductor and produce relative motion between the solid and liquid parts of the circuit. As in the hairpin experiment, in Graneau's judgment, Ampère overlooked the effect of complex magnetohydrodynamic phenomena induced in fluid metals by means of the strong electrical current.

Peter Graneau repeated Ampère's hairpin experiment, but

are lined up one behind the other—for example, immediately adjacent elements of the same circuit—repel one another. Such "longitudinal Ampère forces," however, do not exist either according to Grassmann or in electrodynamics as usually presented today. If we focus merely on the total force exerted by one closed circuit on another, the predictions of the two laws coincide. Yet "longitudinal Ampère forces," if they exist, must be somehow observable *within* a conductor.

This is the problem addressed by Professor Saumont's article. Along with an overview of earlier work, he reports on new experiments he himself has carried out in his laboratory at INSERM in Paris. These, it appears, ascertain the existence of a longitudinal force which Maxwellian electrodynamics does not predict. Of course, nothing definitive can yet be said about the cause of this effect, and its more precise conformity, or nonconformity, with Ampère's original law.

The rekindling of the battle over Ampère's longitudinal forces has, among other things, to do with the fact that during the past 10 years, in another connection—the development of new forms of electromagnetic railguns—experiments have been conducted in which extremely strong currents were produced in metallic conductors. Unexpected effects were observed, the interpretation of which, according to standard electrodynamic concepts, leads to difficulties. Of course, in view of the intensity of the processes arising at high energy densities, it remains under dispute to what extent the observed anomalies can be attributed to the existence of Ampère forces.

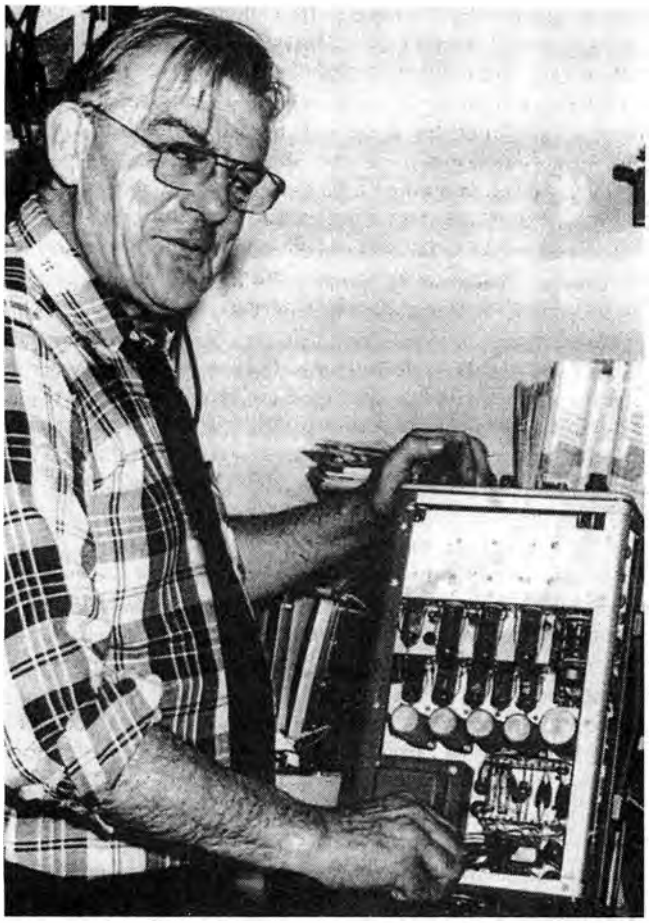
What is new about Saumont's work, is that he carried out comparatively simple, accessible experiments which, even with relatively weak currents, bring about an unexpected longitudinal force effect.

The renewed discussion of Ampère's law of force emphasizes once more, that even the seemingly most elementary things in physics conceal within them an inexhaustible wealth of interesting and important questions, if only we are prepared to look behind the facade of textbook knowledge, and never close our ears to the eternal question, "Why?"

We welcome qualified comments on Saumont's work.

To those who wish to explore more deeply the Ampère-Gauss-Weber-Riemann tendency in electrodynamics, we recommend "The Significance of the 1845 Gauss-Weber Correspondence" by Laurence Hecht (*21st Century,* Fall 1996, p. 21), the book by Peter Graneau cited in Saumont's article, the biography *Wilhelm Eduard Weber* by K.H. Wiederkehr (Grosse Naturforscher series, vol. 32, Wissenschaftliche Verlagsanstalt, Stuttgart, 1967), as well as the classic work by E. Hoppe, *Geschichte der Elektrizität,* 1884, newly reissued by Dr. Martin Sändig, Wiesbaden, 1969).

Saumont's article was translated from the German-language *Fusion* magazine (Jan.-Feb.-March 1995) by Susan P. Johnson.



Courtesy of *Le Quotidien du Medecin*

Rémi Saumont in his INSERM biophysics laboratory.

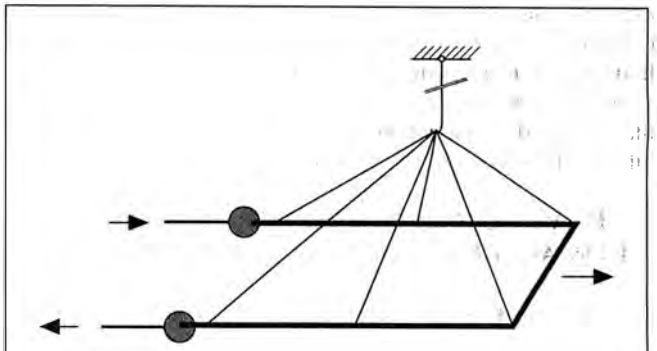


Figure 3
PAPPAS'S EXPERIMENT, FIRST VERSION

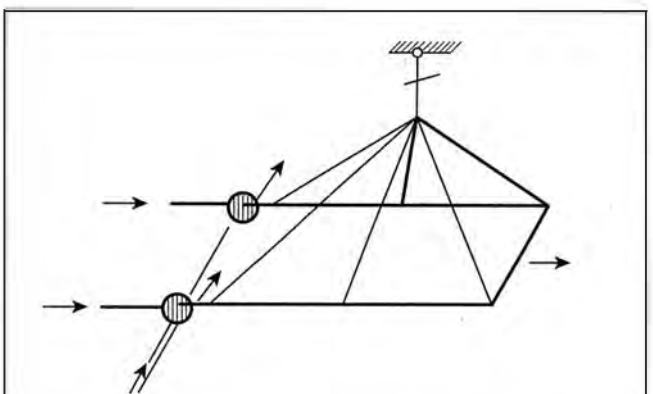


Figure 4
PAPPAS'S EXPERIMENT, SECOND VERSION

made the pin immobile.[7] When he applied a strong current to the system, he observed at both ends of the fixed hairpin a sort of "backwash," and small particles of copper which had been placed in the mercury near the ends of the hairpin were subject to repulsion.

In the same paper, Graneau reported on another interesting experiment. A piece of copper wire in the shape of a cigar was immersed in a long tank filled with mercury. It was rounded at one end, while the other end was pointed. When an electrical current was sent through the container, the wire moved forward with the rounded end in front.

The experiment showed that the force of repulsion acting on the pointed end of the "cigar" was stronger than that affecting the rounded end. Moreover, the direction of the movement was independent of the direction of the current. This was the first experiment to demonstrate that in a conducting wire, the Ampère force of repulsion increased as the diameter of the wire diminished.

A further experiment, a simpler version of Ampère's original attempt, was carried out in Athens by Pappas, who did not know about Ampère's experiment at that time.[8]

A π-shaped frame of 2-mm thick aluminum wire, 2 m long and 1.5 m wide, was hung by fine threads 2 m from the ceiling, so that it could move almost freely in the horizontal plane. The two ends of the π-shaped wire touched the surface of two basins filled with mercury.

When a car battery was attached to the two basins with two rigid wires, the π-shaped frame moved forward (as in Ampère's hairpin experiment), and the free ends of the wire jumped out of the mercury. The whole movable frame moved quickly about 2 cm (Figure 3).

In a second experiment, the two rigid hook-up wires were connected close to one another and perpendicular to the direction of the side-pieces of the π-shaped frame. In this case, the movement seemed less rapid than in the first experiment (Figure 4).

Although several parameters and experimental conditions were unknown (current density, precise duration of current throughput, amount of acceleration, thermal and other effects during the contact with the mercury, and so forth), Pappas stated in his calculations that far less energy flowed from his source of current than the Lorentz theory would require. The Lorentz force is thus excluded as the accelerating force of the pendulum.

At the Massachusetts Institute of Technology, Graneau repeated a similar experiment in improved form.[1] He replaced the aluminum-mercury contacts with 1 mm-wide electric arc junctions between the end of a hanging copper pendulum and a parallel system of copper tracks, which were powered by a 30 to 80 kilovolt condenser. In this way, the attenuating oscillator current was recorded by a cathode-ray tube connected to a serial coil. The major parameters were known, including the

extreme values of intensity (28,000 to 68,000 A), the energy delivered by the condenser, the weight, the periods of oscillation, and the displacement of the pendulum.

In this interesting experiment, there still could have been artifacts caused by melted copper, as well as heat and pressure effects produced by the electrical arc.

II. Measurement of Longitudinal Forces in Weak Currents. Quantitative Experiments

(A) Experiment by T.E. Phipps and T.E. Phipps, Jr.

In this experiment, proposed by J.P. Wesley,[9] Ampère longitudinal forces are to be ascertained by measuring pressure differential in a wedge-shaped container (a variable-transverse mercury cell) induced by a weak, low-frequency alternating current (2 Hz, low amperage). The internal potential (pressure) was found by measuring the maximum changes in a perpendicular mercury column, installed at locations of variable current density.[10,11] Two perpendicular tubes were placed at these loci of variable current density, and their state was recorded with the help of an optical amplifier, with which mercury oscillations at the micron level can be observed. On the basis of a resonance test, the authors were of the opinion that their experiment confirms Ampère's hypothesis.

(B) Measurements with a balance by Saumont

This kind of measurement was carried out in my laboratory in Paris in such a way that changes in weight in a conductor carrying an electrical current could be read off as quickly as possible on a balance. The conductor was connected to the balance through small troughs (flasks) filled with mercury. As current flowed through the system, longitudinal, repulsive forces were active at every movable contact between the mercury and the fixed metal. Depending upon the orientation of the wire ends immersed in the mercury, an apparent decrease or increase in weight was observed.

Figure 5 shows the measuring device, already described in earlier articles.[12,13] In my experiments, two beakers of mercury were placed on either side near the scale on the base of a mechanical-optical balance, Sartorius Type 2842-S-0007. The circuit consisted of 0.7-mm-thick copper wire. The 13-cm-long horizontal portion of this wire was rigidly enclosed in foam material and connected to the balance scale. Both ends of the wire were bent down 3 cm and immersed 10-mm deep into the mercury, which formed an interface with them (Figure 6).

By this means an electrical current could flow through the wire, occasioning a vertical movement, which was observed. If the balance scale moved, the buoyancy of the wire ends immersed in the mercury naturally changed, and produced a reverse force.

The sensitivity of the balance was 0.1 mg. A deviation of the balance scale by 0.1 mm corresponded to a change in weight of 10 mg. One such vertical displacement, either upward or downward, thus amounted to a reverse force of 0.5231 mg for each interface ($0.35 \times 0.35 \times 3.14 \times 0.1 \times 13.6$), or 1.0462 for both beakers.

A 12-volt storage battery delivered current to the circuit through a copper wire, with the positive pole of the battery connected to the mercury in the first beaker; the path back to the negative battery pole ran through a wire leading to the second beaker, and then through a series-connected ammeter, a variable resistance, and a switch.

The entire apparatus for supplying current was mounted about 40 cm in front of the balance, and in such a way that the elements of the circuit in the horizontal plane would go through the central part of the wire. The circuit formed a right-angled horizontal loop, with a long side of 60 cm (Figure 5).

All the experiments were conducted with the old mechanical-optical Sartorius 2842-S balance. A modern electronic balance would not have been suitable for this kind of investigation, because its scale is always connected to a magnetic core. This core extends deep into a coil, and a current flows

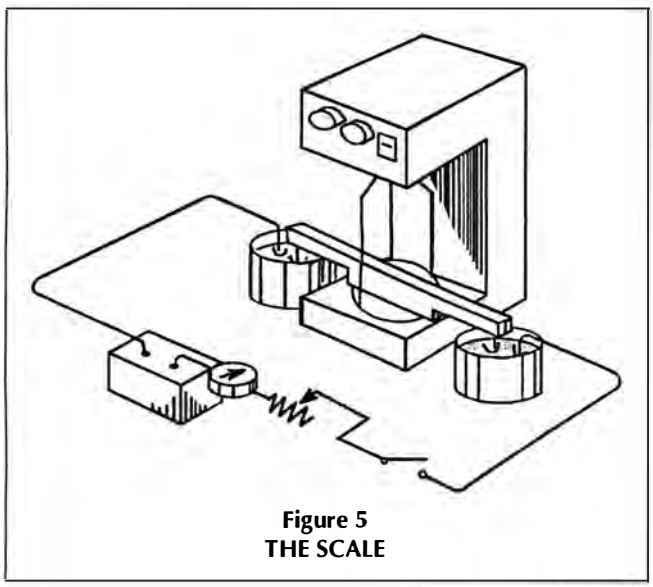


Figure 5
THE SCALE

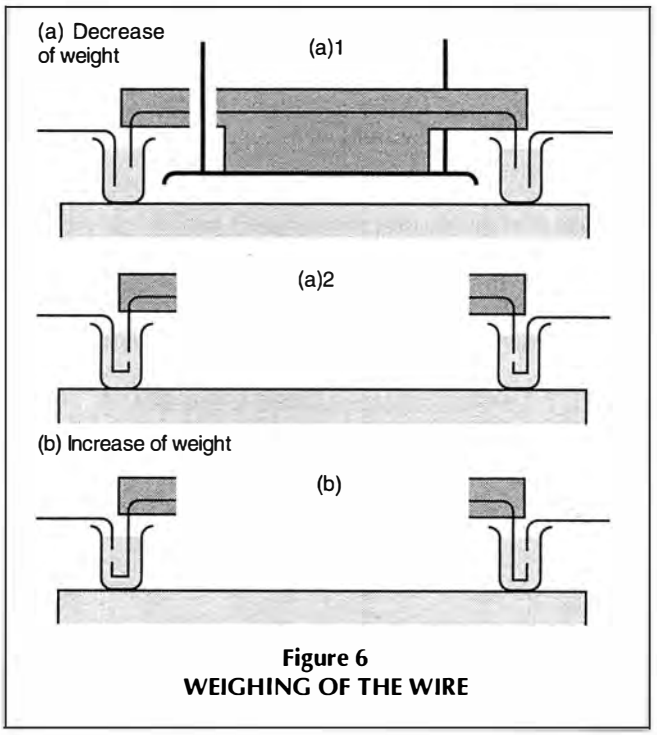


Figure 6
WEIGHING OF THE WIRE

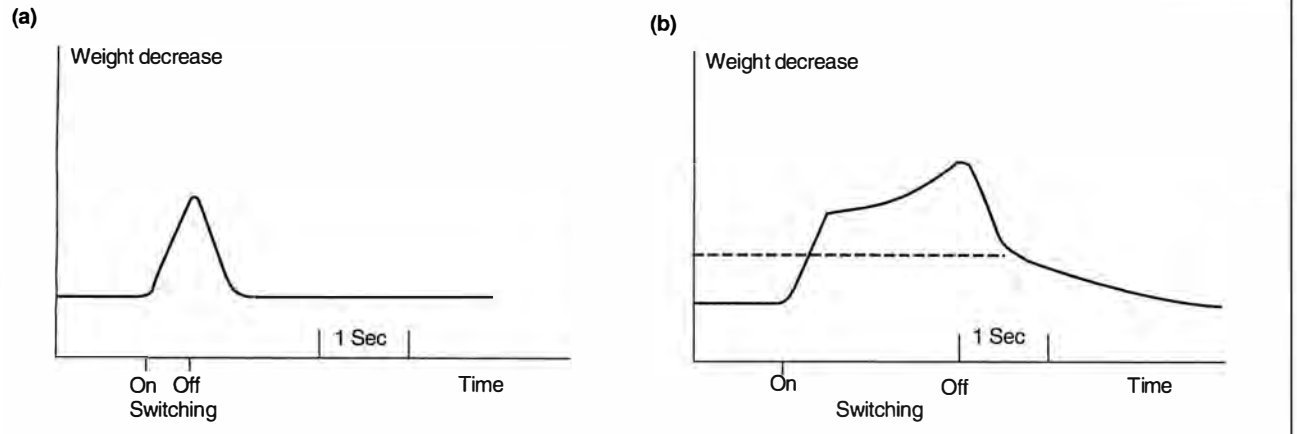


Figure 7
INTERFERING HEAT EFFECTS

A current of 12 A is passed through a copper wire 13 cm long of diameter 0.7 mm. In (a), a flow of short duration gives the correct measurement. In (b), a longer flow produces a heat effect.

through the coil, in order to achieve a balance. Thus it would be impossible to make accurate measurements if a current were also flowing through the scale. Moreover, the delayed response of an electronic balance is too long (about 2 seconds). In order to exclude heat effects, a measurement interval of 0.5 seconds should not be exceeded, if "high" intensities (10 to 16 A) are used (Figure 7).

In order to diminish the delayed reaction, I observed the moving scale of the Sartorius balance (with subdivisions of 10 mg = 1cm) by means of an exterior lens. No correction was performed to achieve the equilibrium (mg and 1/10 mg). The precision of measurement thus decreased (from 1/10 mg to 0.5 mg), but the rapidity of observation increased considerably. The reaction time corresponded to the balance's delayed reaction of 0.5 seconds.

In the first series of experiments (wire ends downward, Figure 6), when the current passed through, an apparent loss of weight in the moving parts of the system was recorded. This loss of weight increased as the square of the strength of the current (direct or alternating current). (See Table 1 and Figure 8.)

At a current of 14.6 A, the apparent weight loss was 10 mg. The deviation of the balance scale was 0.1 mm and the reverse force about 1 mg. Consequently, every measurement required a correction; in this case, an addition of 10 percent of the measured change in weight, which is 9 percent of the actual numerical value (see Table 1).

Numerous possibilities that a decrease in weight was caused by external interference had to be investigated; for example, the effect of external magnetic fields, expansion effects of the current loop, the influence of a repulsive Lenz force, electrostatic phenomena, deformation of the wire, and action on the mechanism of the balance by the field produced by the current. These possible sources of interference, discussed in my papers,[12,13] are easily eliminated.

Table 1
TWO VESSELS OF MERCURY ON THE SCALES
See Figure 6, (a)1 and (a)2.

Current in amperes	Weight decrease (mg)	Corrected value (+10%) mg
5	1	1.1
6	1.5	1.6
8	2.9	3.2
10	4.5	5
12	6.4	7
14	9	9.9
15	10.5	11.5

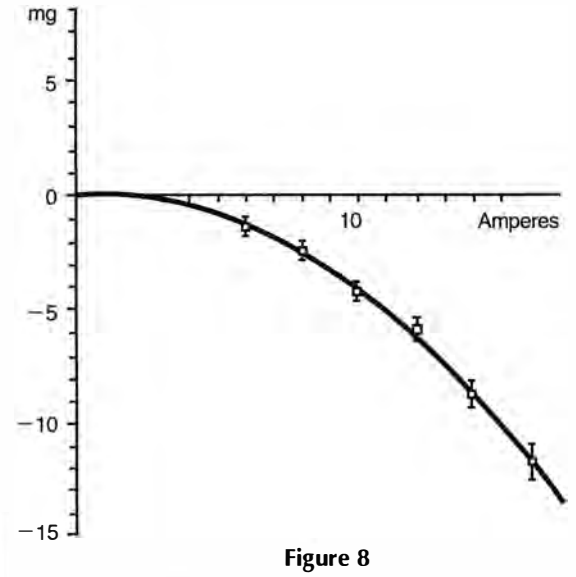


Figure 8
WEIGHT DECREASE ACCORDING TO CURRENT STRENGTH

Weight decrease of the wire according to the strength of the current, in the experimental configuration in (a)1 and (a)2 of Figure 6. No correction has been made for buoyancy.

Through the use of a coated wire, I proved that the results were not dependent on the bare part of the immersed wire. When only the cross-sectional surface of the wire was brought into play in this way, it appears that neither a change in the copper amalgam nor a change in the surface tension was responsible for these observations.

However, certain conceivable, possibly weighty causes of error must be discussed carefully; for example, stretching of the wire by heating, thermal lift effects on the gas molecules adhering to the wire's surface, or ionic conductive effects between apparatus and atmosphere, may have interfered with the observations. All these phenomena could lead to an apparent loss of weight.

In order to examine these possibilities, the end of the coated wire in the mercury container was bent upward, Figure 6(b), so that its tip (and only the cross-sectional surface was uncoated) lay beneath the current-carrying wires. In this case, a weight increase was observed, which in absolute terms, however, was slighter than the decrease (about 50 percent of the decrease).

This experiment showed that there exists a repulsive force between the solid and the liquid parts of the metallic conductor, and this force is proportional to the square of the strength of the current. Thus there was a "counterfeit" effect of decrease, which, in the first experiment, had a share in the resulting effect of repulsion; in the second series of tests, however, it was removed.

In order to verify that the apparent weight gain actually arose from forces of repulsion at the locus of contact between the mercury and copper, still another experiment was conducted. A vessel filled with mercury was placed on the balance scale, and two wires of 0.7-mm thickness were immersed in the vessel, as shown in Figure 9. When a current was sent through the mercury, a weight increase occurred, whose absolute value changed as the square of the current's strength (Table 2).

Numerous problems arose from all these experiments.

First, at a given strength of current, what was the actual value of the repulsive force on the contacts? The weight decrease, from using a horizontal wire of 2-cm length as in Figure 10, was less than the values given in Table 1 and Figure 8, which were obtained with a 13-cm-long wire. Their absolute value, however, was nearly the same as the absolute value of the weight increase in Table 2 from the experiment in Figure 9. Thus this latter result ought to be the correct one.

Yet a question remains: What was the role and significance of the repulsive force acting in the mercury?

Graneau has demonstrated that a flow is produced in mercury by means of a strong electrical current (several hundred A) applied to the copper-mercury interface.[7] Such a phenomenon should have occurred in my experiments as well, though not very significantly, given the weakness of the current and the inert character of mercury. In fact, there was no significant difference in the results of experiments (a)1 and (a)2 in Figure 6. Nor was there any significant difference in the experiment in Figure 9, when the tip of the wire lay close to the bottom of the beaker. A repulsive force acting on part of the mercury produced a downward flow, which hit the bottom of the vessel, and at the top of the connection produced a vortical flow, without any empty volume resulting.

Second, what precisely were the other forces being exerted?

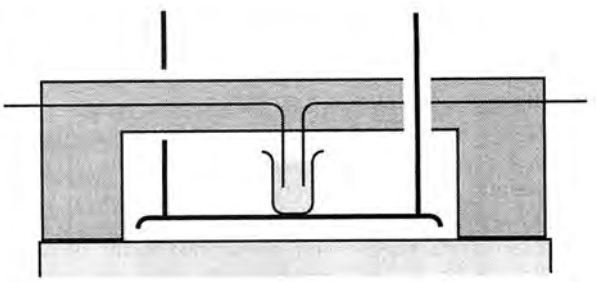


Figure 9
ONE VESSEL OF MERCURY ON THE SCALES
A weight increase is observed, as shown in Table 2.

Table 2
ONE VESSEL OF MERCURY ON THE SCALES (Figure 9)

Current in (mg)	Weight increase value (+10%) mg	Corrected amperes
8	1.3	1.4
10	2.4	2.6
12	3.3	3.7
14	5.6	6.2

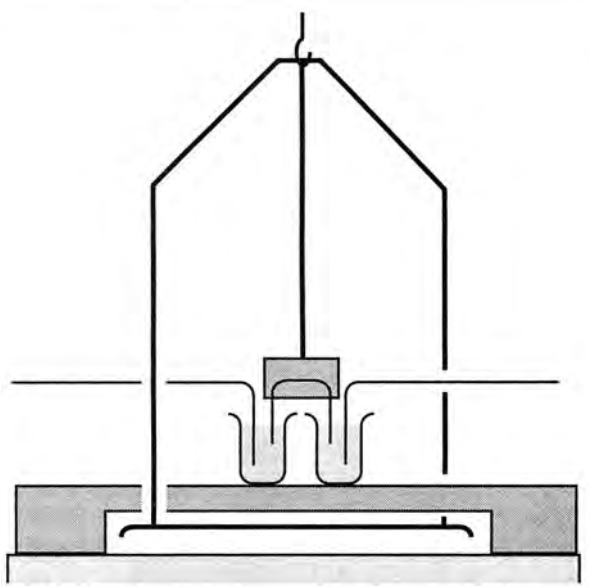


Figure 10
WEIGHT DECREASE WITH A SHORT, HORIZONTAL WIRE
The absolute values of the weight decrease nearly correspond to the absolute values of the increase in weight in Figure 9.

(1) Slow heat phenomena: Heat phenomena were easily observable during the weight-decrease experiment with the long wire, when "high" current (more than 10 A) was applied for a long time (more than 0.5 seconds). There were two different in-

dicator movements on the balance, a fast one followed by a slow one (Figure 7). The steepness of the fast movement shows the delayed reaction time of the balance and correlated with a much faster variation, the repulsive force produced by an electrical current going through the copper-mercury connection. The secondary slow movement corresponds to the secondary thermal phenomena, which require more time to emerge and develop.

The indication of repulsive force was thus easily distinguished from the false thermal indication. At the end of the short time measurement available due to the rapidity of the delayed reaction (0.5 seconds), the switching-off of the current had to effect a quick return to the previous zero line. If an exact descent did not occur within 0.5 seconds, a measurement error was considered to have taken place.

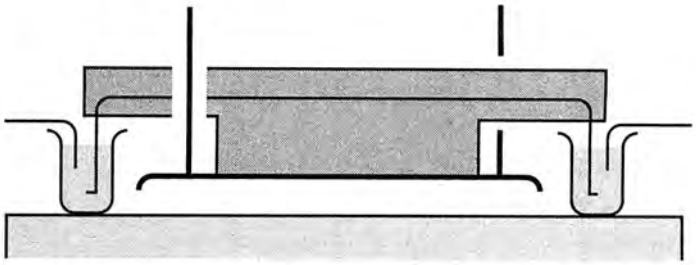


Figure 11
ENDS OF WIRES BENT OUTWARDS
The ends of the wires are bent outwards, to investigate the interfering "fast" lift forces.

(2) Fast "counterfeit" forces: In the tests with the long wire, did fast "counterfeit" phenomena exist? If so, what was the precise importance of these particular forces?

In the experiments described above with the two beakers (Figure 6), why was the absolute value of the weight increase in the case of the upwards-bent wire lower than it was in the case of the horizontal straight wire? The difference may some day be explained in terms of lift forces appearing in the segments of current at the level of the angular parts of the circuit. In this case, an effect would depend upon the form and the length of the wire above and near the surface of the mercury. Calculating such forces is extremely difficult (Graneau,[1] Wesley,[9] Cleveland,[14] Mourier[15]).

An experiment was carried out in order to directly measure the interfering "fast" lift forces, which were active, for example, in the first two beaker experiments.

For this purpose, the ends of the coated wire were bent outward in the mercury (Figure 11), so that the small horizontal segment was 5-mm long, and perpendicular to the bare metal cross-section. This method was also used by Moyssides and Pappas[16] in their experiment with the horizontal wire π-frame, in order to test the Biot-Savart-Lorentz forces.

Longitudinal forces, which were active at the ends of the wire perpendicular to the cross-section of the wire, neutralized each other, so that the weight loss ought to correspond to the "fast, counterfeit" lift force. Table 3 shows the values for this resulting force; it accounted for about a fourth of the overall weight loss in the first case. The major evidence of interest in this table is the demonstration of the existence of the longitudinal force. In fact, the difference between the corrected values in Table 1 and Table 3 gives the value of this longitudinal force for the 13-cm by 0.7-mm wire.

Table 3
INTERFERING 'FAST' LIFT FORCES

Current in (mg)	Weight decrease value (+10%) mg	Corrected amperes
8	0.5	0.55
10	1	1.1
12	1.6	1.75
14	2.1	2.3
15	2.5	2.75

Conclusion

I have made numerous attempts to examine the longitudinal force. These investigations raise some difficult experimental and theoretical problems. Theoretically speaking, two interconnected questions are addressed: Is the concept of the Ampère force compatible with the Biot-Savart-Laplace law of transverse force? What is the compatibility of the Ampère force with the paradigm of special relativity theory? More emphatically than Rambaut and Vigier[18] as well as Rambaut[19] in his earlier work, Costa de Beauregard[20] takes a stand for compatibility in both cases. I personally think that in physics, as in other matters, it is dangerous to claim more than the physical facts allow. Therefore, I hold that a rejection of the special relativity theory on the basis of the experimental verification of the Ampère force is unjustified.

Rémi Saumont is a research director emeritus at INSERM, France's main medical research institute, in Paris. The former leader of its biophysics laboratory, he is now working on physical and mathematical questions. One of his main research interests is dimensional analysis and the theory of measurement.

References

1. P. Graneau, 1985. *Ampère-Neumann Electrodynamics of Metals* (Palm Harbor, Fla.: Hadronic Press).
2. A.-M. Ampère, 1827. *Théorie mathématique des phénomenes électrodynamiques déduite de l'experience.* New edition (Paris: Gabet, 1990).
3. C. Hering, 1923. *AIEE Trans.*, Vol. 42, p. 312.
4. I.A. Robertson, 1945. *Philosophical Magazine*, Vol. 36, p. 32.
5. J. Nasilowski in *Exploding Wires*, edited by W.G. Chase and H.K. Moore (New York: Plenum Press, 1954), Vol. 3.
6. P. Graneau, 1982. *J. Appl. Phys.*, Vol. 53, p. 6648.
7. P. Graneau, 1982. *Nature*, Vol. 295, p. 312.
8. P.T. Pappas, 1983. *Nuovo Cimento B*, Vol. 78, p. 189.
9. J.P. Wesley, 1991. *Selected Topics in Advanced Fundamental Physics* (Blumberg, Germany: Benjamin Wesley).
10. T.E. Phipps and T.E. Phipps, Jr., 1990. *Phys. Lett. A.*, Vol. 146.
11. T.E. Phipps, Jr., 1990. *Physics Essays*, Vol. 3, p. 198.
12. R. Saumont, 1991. *C. R. Sci.*, Paris, Vol. 313, p. 389.
13. R. Saumont, 1992. *Phys. Lett. A*, Vol. 165, p. 307.
14. F.F. Cleveland, 1936. *Philosophical Magazine*, Vol. 21, p. 416.
15. G. Mourier, personal communication.
16. P.G. Moyssides and P.T. Pappas, 1986. *J. Appl. Phys.*, Vol. 59, p. 19.
17. P. Graneau, 1984. *IEEE Trans. Magn.*, Vol. 20, p. 444.
18. M. Rambaut and J.P. Vigier, 1990. *Phys. Lett. A*, Vol. 148, p. 229.
19. M. Rambaut, 1991. *Phys. Lett. A*, Vol. 154, p. 210.
20. O. Costa de Beauregard, 1993. *Phys. Lett. A*, Vol. 183, p. 41.

Demonstrating Gauss and Weber's Magnetometer

by Jonathan Tennenbaum

EDITOR'S NOTE

The new principles of experimental design developed by Carl Gauss and Wilhelm Weber, were the focus of a recent presentation on the history of electricity and magnetism by the author, at the year-end conference of the Schiller Institute in Germany. Weber's determination of the electromagnetic constant, c, in 1854, and the first formulation of the classical electron radius by him in 1870, were among the important results of these new principles. Tennenbaum's discussion included the material presented in "The Significance of the 1845 Gauss-Weber Correspondence," by Laurence Hecht, which appeared in the Fall 1996 issue of 21st Century.

This report describes the building and operation of a magnetometer, used by Tennenbaum in his presentation.

Christopher Lewis

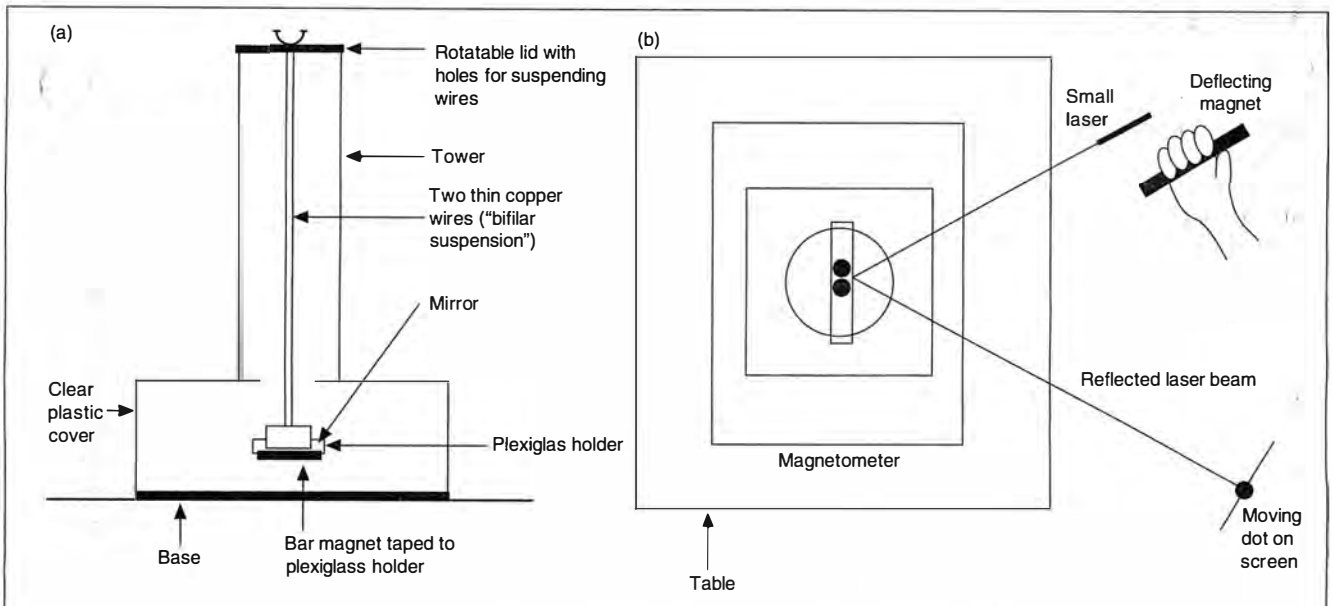
Tennenbaum demonstrates the action of the magnet. (Inset) A close-up view of the magnetometer.

The new principles of experimental design, developed by Carl Gauss and Wilhelm Weber, were crucial to the theoretical breakthroughs made by Weber beginning in 1845. To illustrate this point, we conducted a series of physical demonstrations, including a rudimentary version of Gauss's bifilar magnetometer, which makes it possible to determine angular deflection very precisely. The magnetometer, improvised in a few hours' work using commonplace materials, was sensitive enough to clearly register the motion of a small permanent magnet, held in my hand at the opposite side of the room.

The rudimentary magnetometer consists of a horizontally suspended bar magnet, about 10 cm long, taped to a plexiglass holder, which also holds a small mirror (the size of a dentist's mirror), located as closely as possible to the vertical plane containing the axis of the magnet. The assembly—with magnet, holder, and mirror—is suspended horizontally on two very thin, parallel copper wires, 0.5- to 0.8-cm apart and nearly 2 meters long.

This is the famous "bifilar suspension" introduced by Gauss. Among many advantages, it has extremely low friction; for an angular displacement of the system, the internal restoring force is derived practically from gravity alone, and is determined by the spacing of the wires and the mass of the suspended body.

To shield against air currents, the magnet assembly and suspension are completely enclosed in a wood and plastic housing. The lower part, where the suspended magnet was located, is a



SCHEMATIC OF A RUDIMENTARY BIFILAR MAGNETOMETER

Gauss's bifilar (two-wire) magnetometer was designed to precisely determine the angular deflection of a compass needle caused by a permanent magnet. This apparatus was built by Tennenbaum and Christopher Lewis.

rectangular enclosure of the type used to keep cakes and pastry, consisting of a flat base and a cover made of clear plastic. A 5-cm diameter hole was drilled in the middle of the top of the cover. The upper part consists of a tower built of wood and Plexiglas, having a square cross-section and a height of about 160 cm.

The axis of the tower is aligned with the hole in the lower enclosure, so that the twin wires suspending the magnet, run freely from the lower enclosure, along the axis of the tower, to a Plexiglas plate that forms the top of the tower. There the wires run through two small holes, drilled in the plate, and are fixed on the top side in such a way that the lengths of the wires can be slightly adjusted. It is convenient not to glue the top to the rest of the tower, but to allow it to be rotated, in order to align the system of magnet and suspending wires in any desired direction.

For the demonstration in question, the apparatus was placed on a table, and the plate holding the wires was rotated in such a way, that the axis of the magnet coincided with the magnetic meridian (the local magnetic north-south orientation). To display the angular motion of the suspended magnet, the beam of a small laser, mounted on an adjacent table, was directed onto the mirror attached to the suspended magnet, in such a way that the reflected beam was projected onto a wall or screen. If the distance from the apparatus to the screen is 10 meters or more, then very slight motions of the magnet are clearly revealed by the spot on the screen.

This use of a laser beam—which has the advantage of allowing an entire audience to follow the process—replaces Gauss and Weber's original procedure, which was to observe the reflected image on a fixed scale with the help of a telescope.

Without substantial damping, it takes a considerable time for the oscillations of the suspended magnet to quiet down. Then it will be seen, that the instrument clearly responds to the movement of a hand-held permanent magnet, held several meters or more away, especially if we rotate the axis of the magnet back and forth through 180 degrees. At even much greater distance, we can use a resonance effect to set the magnetometer into visible oscillations, namely, by rotating the hand-held magnet in proper phase with the oscillation of the magnetometer. With some practice, one can use the same effect, but out of phase, to bring the oscillating magnetometer back to rest.

We can also deflect the magnetometer with an electromagnet, consisting of a coil attached to a flashlight battery. Or, using a coil with a large number of windings, and placed in a vertical plane close to the magnetometer magnet, the electromagnetic effect of very weak currents can be seen. Here we have the bare principle of a mirror galvanometer, first successfully developed by Weber.

The final step to Weber's electrodynamometer, consists of replacing the suspended permanent magnet by a suspended coil, into which current is fed via the suspending pair of wires. (We shall report on the construction of a demonstration electrodynamometer in a future issue.)

Upsetting Arbitrary Fictions

The sensitivity of the rudimentary magnetometer made a big impression on the audience. Indeed, witnessing an actual demonstration of this sort might help to provoke a reflection on the question of whether Newton's concept of point-to-point forces, and the Maxwell-Faraday idea of "force fields" might not be arbitrary fictions. And further, to reflect on whether it would not be much better to adopt the hypothesis that the phenomena at any two points of the universe are intrinsically coupled, because everything happening in the universe is automatically happening at each and every locality, whether there is an immediate, visible effect or not.

In other words: each local event is intrinsically an action on the universe as a whole.

Viewpoint

Continued from page 9

of natural origin. Half of these pesticides tested at near-toxic levels produce cancer in rodents. Reducing human exposure to the 0.1 percent that are synthetic will not reduce cancer rates.

On the contrary, the use of synthetic pesticides increases the supply and lowers the price of fruits and vegetables, and these prevent cancer. Humans also ingest carcinogens that are produced by

cooking or roasting food. Hundreds of chemicals have been reported in roasted coffee. Professor Takashi Sugimura in Tokyo has shown that the cooking of meat produces compounds that produce cancer in rodents, and he has synthesized some of these compounds.

Sugimura recommends, among other things, that people avoid eating too much of burnt parts of food, such as burnt parts of charcoal-grilled meat and fish. "Zero exposure to rodent carcinogens cannot be achieved," he says. (The FDA made a similar statement in the *Federal Register*.)

Bruce Ames estimates that a typical American eats about 1.5 grams per day of natural pesticides, which is 10,000 times more than the average daily consumption of synthetic pesticide residues. Of the natural pesticides tested in at least one species of animal, 27 of 52 are carcinogens. For these 27, he lists 37 foods as containing a single carcinogen at concentrations greater than 10 parts per million.

Fortunately, as Ames points out, human beings are protected against low doses of toxins by many general defenses, including vitamins and antioxidants in the same foods, and we can augment these by taking supplements of vitamin E, vitamin C, and beta carotene.

Where are the Residues?

In 1988, the FDA examined 18,000 crop samples. There were no detectable pesticide residues in 60 percent and fewer than 1 percent were over tolerance. Even in that small fraction, the health risk was negligible because the tolerance level for regulation is set far higher than the tolerance level for health risk.

The lesson from these findings is that the public has been taught to worry about pesticide residues that aren't even present in foods. This brings us back to the cranberry incident of 1959, in which only 0.34 percent of the crop contained detectable (but harmless) residues of aminotriazole.

Remember the 1564 dictum of Paracelsus, on which toxicology is founded. "All things are poisonous, yet nothing is poisonous. The dose alone determines the poison." The future rests in science. We cannot go back to the good old days that never existed.

A New Approach to Cancer Treatment Using Essential Fatty Acids

by Colin Lowry

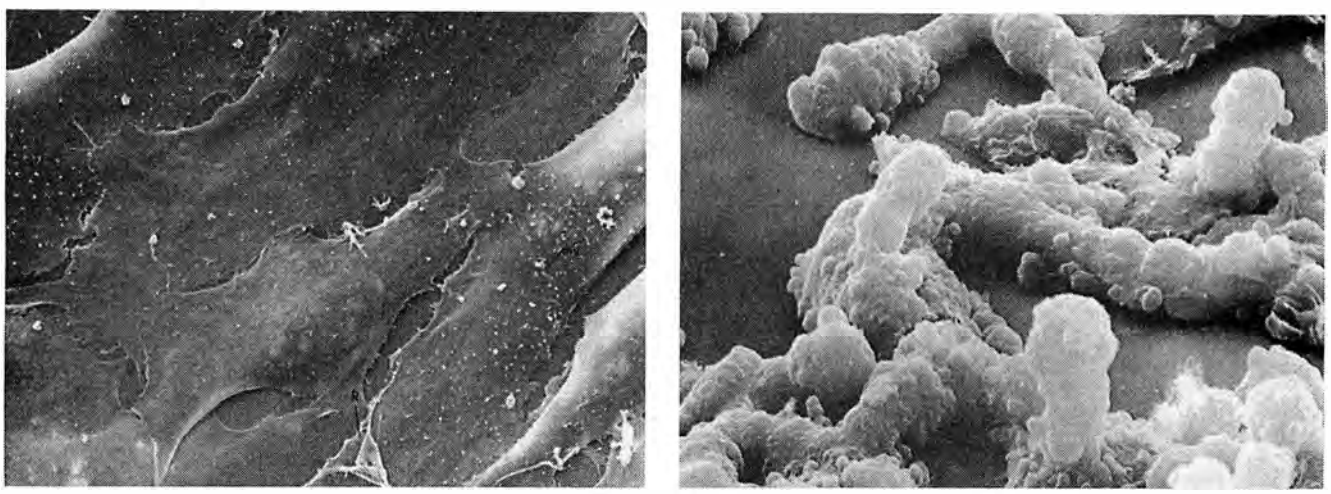


Photo by R.D. Goldman, in *Cell and Molecular Biology*, 7th edition, by E.D.P. DeRobertis and E.M.F. DeRobertis (Philadelphia: Saunders College/Holt, Rinehart, and Winston, 1980), p. 170.

Scanning electron micrographs of cultured hamster cells. Left: Normal cells spread out and grow in a monolayer. Right: The same cell type, transformed to a malignant state, grows in several layers, and its membrane structure is altered.

A little known approach for treating cancer using essential fatty acids (EFAs), is being pursued by scientists with some success and much promise. The use of EFAs has the advantage of killing the cancer cells without producing any harmful side effects.

Most of the current cancer treatments such as standard chemotherapy, radiation, and surgery all produce side effects that weaken patients and do not selectively kill cancer cells. For many cancers these approaches are not an effective treatment. The failure of the standard procedures, especially in treating brain cancers, has pushed scientists to look for new ways to kill cancer cells with greater selectivity.

Although there are only a few clinical studies using essential fatty acids, the results are promising, especially as it offers the potential to be the most successful treatment for brain cancers.

The body requires essential fatty acids (EFAs) in the diet to use in the creation of other necessary molecules through metabolic pathways. Deficiencies in essential fatty acids as a result of the disruption of the body's normal metabolic pathways are found in many diseases, such as diabetes, eczema, hypertension, hypercholesterolemia, and inflammatory diseases.

What Are Essential Fatty Acids?

Essential fatty acids are polyunsaturated, meaning that they contain two or more double bonds in the carbon chain of the molecule (see figure, p. 66).

EFAs are important components of cell membranes, influencing the various properties of the membrane by determining its fluidity. Generally, the more unsaturated fatty acids present in the membrane, the more fluid the membrane is. When the membrane is very fluid and contains large amounts of unsaturated EFAs, the affinity for binding of hormones and peptides (external ligands) is increased; with lower amounts of fatty acids, the membrane fluidity is decreased, along with the binding affinity.

EFAs are also the precursors of very active molecules that trigger or regulate many cellular processes. These are the prostaglandins and leukotrienes, which often have opposite effects regulating biological responses. For example, the prostaglandin 1 series is anti-inflammatory, stops platelet aggregation in the blood, and inhibits cholesterol synthesis. The prostaglandin 2 series is inflammatory, and enhances platelet aggregation.

Another role of EFAs is the regulation of cholesterol transport across membranes. Cholesterol can be exchanged between cell membranes or absorbed from the blood. The cholesterol esters that contain EFAs are more soluble and more easily transported across membranes than cholesterol esters that contain saturated fats. Decreases in the amount of unsaturated EFAs in the membrane and within the cell can cause problems in cholesterol transport, often

leading to high levels of cholesterol in the blood. The EFAs also influence the synthesis of cholesterol, as prostaglandin 1 inhibits synthesis, and the presence of EFAs in the membrane also reduces the need for new cholesterol production.

Two Classes of EFAs

There are two classes of polyunsaturated essential fatty acids, which are defined by the position of the first double bond in the carbon chain starting from the methyl end of the molecule. The first class is derived from linoleic acid (LA), and is called the n-6 class, referring to the position of the double bond. The second class is called the n-3 class, and is produced from alpha-linolenic acid (ALA). The two classes use the same enzymes in the metabolic pathway that convert the initial essential fatty acids LA and ALA into the derived fatty acids down the pathway. The derived fatty acids are formed through a series of desaturations, involving the addition of a double bond in the carbon chain, and elongations, which add carbons, making the chain longer (see figure).

Both the desaturase and elongase enzymes have a preference for working on the n-3 class, meaning that excess n-3 fatty acids will slow down the metabolism of the n-6 class. The first enzyme in the metabolic pathway is the delta-6-desaturase, which adds a double bond to the carbon chain, and is the rate-limiting step in the formation of the derived fatty acids. This enzyme is often disabled in diseases such as diabetes, and is deficient functionally in cancer cells.

Many of the n-6 and n-3 unsaturated fatty acids contain the same number of double bonds, but differ widely in their properties and functions. This means that the precise location of the double bonds in the molecule are important to its function. The n-6 class of fatty acids seems to be of more importance in the body, because a deficiency of the n-6 class cannot be compensated for by the n-3 class. However, an n-3 deficiency can be corrected by the addition of the n-6 class alone.

Cancer Cells and EFAs

EFAs can also be oxidized as an energy source in the cell, just like any other lipid. The difference between the oxidation of lipids in normal cells and cancer cells is important to how the EFAs can kill cancer cells.

Cancer cell membranes contain almost no polyunsaturated essential fatty acids, and instead have a very high percentage of cholesterol. This pointed to an altered fatty acid metabolism in cancer. Research scientists grouped around U.N. Das, M.E. Begin, and D.F. Horrobin, working at Efamol Research Institute, in Canada, began to test the n-6 and n-3 polyunsaturated fatty acids as anti-cancer drugs in vitro in the mid-1980s.

They first tested the ability of different EFAs to kill cancer cells grown in cell culture. They found that gamma-linolenic acid (GLA), arachidonic acid (AA), and eicosapentaenoic acid (EPA) all could kill cancer cells in a concentration dependent manner, although the potency differed between them. Linoleic (LA) and alpha-linolenic (ALA) had weaker effects, while docosahexanoic (DHA) had no effect on the cancer cells. Tests of GLA, AA, and EPA on normal cells showed that AA and EPA were toxic at higher concentrations. Experiments were done using mixed cell cultures of tumors and normal cells which were treated with a given fatty acid for 10 days. While EPA and AA could kill cancer cells, they were also killing normal cells at concentrations needed to produce a lethal reaction in the tumor cells.

However, GLA was very efficient at killing the tumor cells and did not harm the normal cells in any toxic way; the only effect on the normal cells was that their growth rates were slowed. These experiments showed that the most selective and efficient fatty acid for treating tumors was GLA.

These results bring up many questions; namely, what is the mode of action that GLA and the EFAs exert to kill cancer cells? How can GLA be cytotoxic to tumor cells while being harmless to normal cells?

The Role of Lipid Peroxidation

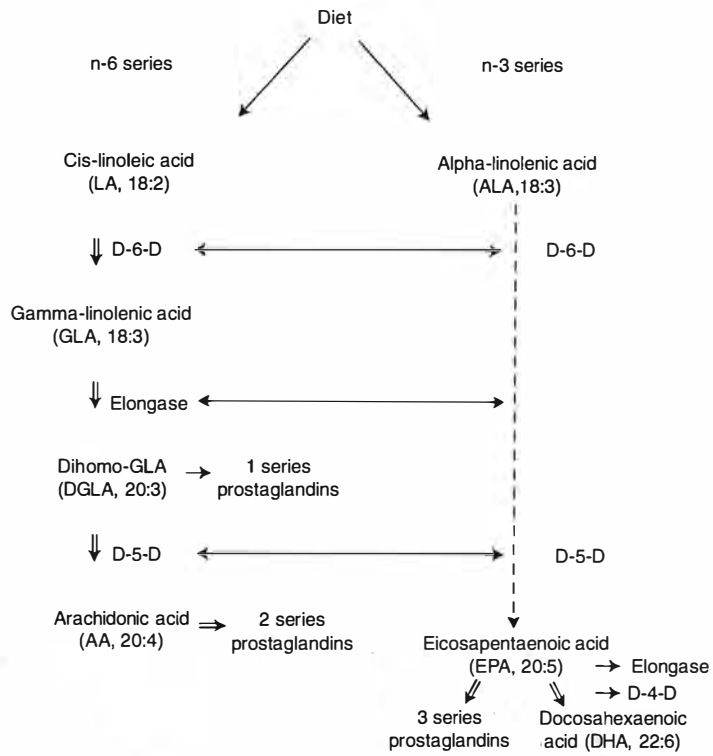
Further experiments were done with the hope of answering these important questions. Were the EFAs acting on the cancer cells through the lipid peroxidation pathway? The lipid peroxidation pathway breaks down lipids in an oxidative process into smaller molecules. Begin and Horrobin tested EFAs of both classes for their ability to induce rapid lipid peroxidation in tumor cells in vitro. They found that GLA, AA and EPA all caused lipid peroxidation, and the ability to kill the tumor cells correlated nicely with this activity. Also, LA and ALA were found to not induce very much lipid peroxidation, and DHA did not induce any, which explained why it had no toxic effect on the cells. The EFAs produced no induced lipid peroxidation in the normal cells.

Was there also a difference in the rate of uptake of the EFAs by the normal and cancer cells that could help explain the increased lipid peroxidation seen in the cancer cells? Using radioactively labeled fatty acids, they found that the cancer cells had a much slower uptake rate, about 2 to 3 times slower than the normal cells. This meant that the lipid peroxidation in the cancer cells was actually the result of internal metabolic differences.

The next step was to do experiments designed to look at certain steps and related processes involved in lipid peroxidation. Lipids can be oxidized in an enzyme-controlled pathway leading to the formation of prostaglandins, leukotrienes, and other active molecules, or in a non-enzymatic pathway which creates hydroperoxide breakdown products that are often toxic to cells. The formation of free radicals and other charged ions such as superoxide anion (O_2^-) are also known to activate lipid peroxidation, and can also do damage to DNA and proteins directly.

Experiments by Das, Begin, and Horrobin investigated the role of free radical formation as a possible mechanism by which the EFAs were killing cancer cells. They added GLA, AA, EPA, and LA to cultures of tumor cells, and then added substances known to block or enhance the formation of free radicals. When anti-oxidants such as vitamin E, or the enzyme superoxide dismutase, which scavenges superoxide anion, were added to the cultures, the cell-killing activity of the fatty acids was reduced or eliminated depending on the concentration. However, when substances known to enhance free radical formation, such as iron and copper salts, were added, the rate of tumor cell death increased. The addition of the metal salts could also lower the concentration of GLA required to kill tumor cells in culture, from the optimal dose of 20 micrograms per milliliter to only 10 mg/ml.

Clearly the formation of free radicals is important to GLA and other EFAs' ability



METABOLIC PATHWAY OF ESSENTIAL FATTY ACIDS

The numerical notation of a fatty acid gives the length and number of double bonds present in the molecule. For example, GLA is 18:3. It has 18 carbons in the molecule with 3 double bonds between carbons in the chain. Both desaturases and elongase are used in the n-6 and n-3 paths.

to kill cancer cells, but what other activities associated with lipid peroxidation are involved?

The non-enzymatic lipid peroxidation pathway produces hydroperoxide products, that can be broken down into quite toxic compounds such as aldehydes, alkenals and even singlet oxygen, which is very reactive. To find out if the hydroperoxide breakdown products were important in the death of tumor cells, the tumor cell cultures were supplemented with the enzyme glutathione peroxidase, which can remove hydroperoxide products. The cultures were then treated with GLA, but the tumor cell death was greatly reduced. This showed that the end products of the non-enzymatic lipid peroxidation pathway were definitely contributing to the death of the tumor cells.

From the above experiments and other facts about cancer cell metabolism an interesting picture develops of how GLA can be so selective in killing cancer cells. Cancer cells are deficient in the key enzyme in fatty acid metabolism, delta-6-desaturase. This means that they cannot make the derived fatty acids that occur below LA and ALA in the pathway. Cancer cells also absorb fatty acids such as GLA and AA at rates 2 to 3 times slower than normal cells. Since the EFA metabolic pathway is altered, it is very possible that the introduction of GLA and other EFAs could cause problems.

Explaining Selective Killing

Cancer cells seem to lack the mechanisms normal cells have to inhibit rapid lipid peroxidation, as normal cells do not react to EFAs by increasing lipid peroxidation. It is as if the cancer cell has to avoid using EFAs since its metabolic pathway is altered, and must use other lipids as replacements. Its membranes use very high amounts of cholesterol and oleic and stearic acid instead of EFAs. Tumor cells are deficient in the enzyme glutathione peroxidase, which makes them much more sensitive to hydroperoxide breakdown products that result from lipid peroxidation, as compared with normal cells which have adequate amounts of the enzyme.

The high level of superoxide anion and free radical production in tumors in response to GLA also points to very different metabolisms in cancer and normal cells. In the normal cell, EFAs do induce a minor amount of free radical and superoxide anion production. However, the cell has mechanisms to deal with both of these potential problems. The cancer cell, on the other hand, has a reduced capacity to eliminate free radicals, and is also deficient in superoxide dismutase enzyme, which is responsible for converting superoxides to harmless molecules. The cancer cell produces large amounts of free radicals without having the normal protective countermeasures at its disposal in response to EFAs. The EFAs cause the accumulation of free radicals, superoxides, and toxic hydroperoxide breakdown products that damage DNA, crosslink protein complexes, and cause the death of the cell.

Although the overall picture of the mechanism of how GLA and EFAs cause tumor cell death is good, there are still many unanswered questions as to the actual differences in lipid peroxidation and its relation to free radicals that are the subject of current research.

Animal Studies

The impressive results GLA gave in killing cancer cells in vitro prompted scientists to study it in animal models. The main problem in treating an animal or a person with GLA is the fact that the high concentration of the fatty acid required to kill tumors is difficult to attain by giving the drug orally, which distributes the drug throughout the whole body. However, interesting results feeding animals GLA and other EFAs at levels below those achieved in cell culture have shown other effects not demonstrable in vitro.

GLA seems to be able to influence the type of adherence protein that is expressed on the surface of the tumor cell. Tumor cell samples were assayed for the presence of a particular surface protein, cadherin, which is responsible for adhering the cell to other cell membranes. This adherence of the cell is important in growth control, as it restrains the cell

from metastasizing by releasing itself from contact with other cells and travelling through the bloodstream to a new site, where it will grow rapidly. Most tumor cells have eliminated the expression of cadherin protein on their cell surfaces so that they are not constrained in their growth. The absorption by the tumor cells in mice treated with GLA at low levels caused the re-expression of cadherin protein on the surface. This stopped the tumor from metastatic growth, and caused it to grow slowly like a benign tumor.

The research group around U.N. Das wanted to see if GLA could prevent damage to DNA, and thereby have an anti-mutagenic property. They exposed mice to chemicals or X-rays that can damage DNA, and fed one group of mice large quantities of GLA before exposure. They found that the GLA fed mice had a much lower amount of damage to their cellular DNA as compared to the control mice. While the mechanism by which GLA can act as an antimutagen is unknown, it is likely that it is enhancing the DNA damage repair mechanisms.

Treating Human Cancer

The standard treatments for glioblastoma, astrocytoma and other brain tumors have many harmful side effects and do not extend the life of the patient beyond about 1 year. The promising results GLA showed in killing tumors prompted U.N. Das and his group, working at the Nizam's Institute of Medical Sciences in Hyderabad, India, to use GLA as a treatment for human brain tumors. To assure the GLA concentration would be adequate to have a toxic effect on the tumor, they delivered the GLA directly to the tumor site using a catheter inserted into the brain. The GLA was given at 1 milligram per day, from a reservoir attached to the catheter, which was inserted under the scalp. This technique avoids the danger of infection by allowing the incision to be sealed after the initial surgery performed to physically remove as much of the tumor as possible.

The procedure continues 10 days, after which a computerized tomography (CT) scan of the brain is made and compared to a scan made before the administration of GLA. In all the patients in the study, a significant change in the tumor was seen in the scan after treatment. The overall mass shrinks, and areas of necrosis (dying cells) are seen. Also, there are no toxic effects to the patient or the surrounding brain tissue from the GLA.

Two clinical studies using first 6 patients, and then 15, have produced excellent results. The first study of 6 patients resulted in 5 patients alive and with no recurrence of the tumor after 2 years and 4 months. Only one patient died after treatment, but the tumor size and location in vital brain areas would have made it very difficult for a successful recovery.

In the next study with 15 patients, 12 were alive with no new symptoms, and no recurrence of the tumor. These results, although from small trials, have shown that GLA can treat brain tumors at success rates that no other treatment can match. The other most promising treatments, such as immune therapy and cisplatin chemotherapy, only produced about a 30 to 40 percent response rate in patients, while having significant detrimental side effects. Also, all of the other standard treatments for brain tumors all suffer from the fact that recurrence of the tumor is usually just a matter of time, with recurrence usually occurring within a year. The GLA treatment of brain tumors has surpassed all the standard treatments in its ability to kill a tumor, and eliminate recurrence.

Dr. Das's group has also used the GLA contained in evening primrose oil to treat Hodgkin's lymphoma. Using as high a dose as could be tolerated by the digestive system of the patients, the GLA produced remission of the disease in about 65 percent of the patients. Most of the patients in the trial were diagnosed as stage IV, which is an advanced stage of the disease, making the results quite remarkable.

GLA in the U.S.

In the United States, there has not yet been any use of pure GLA in the treatment of cancer clinically and the procedure developed by the Das group in India has not yet been approved here. However, there are doctors who are using natural substances that contain high amounts of GLA, such as evening primrose oil and borage oil, to treat cancer. These natural sources of GLA have long been approved by the Food and Drug Administration for treating various conditions, and this makes them available for treating cancer as well. At present, these GLA-rich sources are administered orally, which has the drawback that it is very difficult to obtain a large enough dose to produce the concentrations of GLA at the tumor site that will kill it.

Alain Thibault, M.D., working at the medical center of the University of Virgina in Charlottesville, has been studying the effect of GLA and fatty acids on cancer cells in vitro, and is now using natural sources of GLA to treat patients with brain tumors. The treatments help stabilize tumors, and restrict their growth, but with only oral administration available, attaining concentrations needed to kill tumors is very unlikely. It is hoped that Thibault's work, and that of others, will cause GLA to be approved by the Food and Drug Administration in the United States for use in procedures like that pioneered by the Das group to treat human brain tumors. This method could easily be applied to treating tumors of other tissues, by inserting catheters directly into the blood vessels feeding tumors, and delivering the GLA to the site at concentrations toxic to the tumor.

References

M.E. Begin, G. Ells, and D.F. Horrobin, 1988. "Polyunsaturated Fatty Acid-Induced Cytotoxicity Against Tumor Cells and Its Relationship to Lipid Peroxidation," *J. Nat. Cancer Inst.*, Vol. 80, No. 3, pp. 188-194.

U.N. Das et al., 1987. "Uptake and Distribution of Cis-Unsaturated Fatty Acids and Their Effect on Free Radical Generation in Normal and Tumor Cells in Vitro," *Free Radical Biol. and Med.*, Vol. 3, pp. 9-14.

U.N. Das, M.E. Begin, G. Ells, Y.S. Huang, and D.F. Horrobin, 1989. "Polyunsaturated Fatty Acids Augment Free Radical Generation in Tumor Cells in Vitro," *Biochem. Biophys. Research Comm.*, Vol. 145, No. 1, pp. 15-24.

U.N. Das, D.F. Horrobin, M.E. Begin, et al., 1988. "Clinical Significance of Essential Fatty Acids," *Nutrition*, Vol. 4, No. 5, pp. 337-341.

U.N. Das, M.R.C. Naidu, and A. Kishan, 1992. "Intratumoral Gamma-Linolenic Acid Therapy of Human Gliomas," *Prostaglandins, Leukotrienes and Essential Fatty Acids*, Vol. 45, pp. 181-184.

U.N. Das, V.S.S.V. Prasad, and D. Raia Reddy, 1995. "Local Application of Gamma-linolenic Acid in the Treatment of Human Gliomas," *Cancer Letters*, Vol. 94, pp. 147-155.

U.N. Das, M.S. Rao, et al., 1985. "Benzopyrene and Gamma-Radiation-Induced Genetic Damage in Mice Can Be Prevented by Gamma-Linolenic Acid But Not by Arachidonic Acid," *Nutrition Res.*, Vol. 5, pp. 101-105.

F.D. Gunstone, 1992. "Gamma Linolenic Acid, Occurrence and Physical and Chemical Properties," *Prog. Lipid Res.*, Vol. 31, No.2 pp. 145-161.

D.F. Horrobin, 1992. "Nutritional and Medical Importance of Gamma-Linolenic Acid," *Prog. Lipid Res.* Vol. 31. No. 2, pp. 163-194.

1996 Index

21st CENTURY SCIENCE & TECHNOLOGY

Volume 9

Author Index

Subject Index

Astronomy and Astrophysics

Biography and Obituary

Development Policy

Earth Sciences

Environmentalism

Epistemology

Geometry and Mathematics

History of Science and Technology

Medicine

Nuclear Energy

Physics

Religion

Science Policy

Space Science, Technology, and Exploration

Books Reviewed

Threatening Our Fertility, Intelligence, and Survival?—A Scientific Detective Story (Dr. J. Gordon Edwards) Fall, 52.

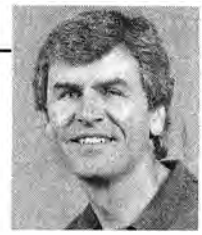
Flamsteed, John. *The Correspondence of John Flamsteed, The First Astronomer Royal,* Vol. 1, 1666-1682. Edited by Eric G. Forbes, Lesley Murdin, and Frances Willmoth. (Susan Welsh) Winter, 71.

Herschel, Sir William. *Sir William Herschel: Music by the Father of Modern Astronomy: First recording of orchestral chamber works by the celebrated 18th-century composer/astronomer.* The Mozart Orchestra, Davis Jerome, conductor. (David Shavin) Fall, 55.

Public Media Education. *Atoms for Peace.* Videotape. (Marjorie Mazel Hecht) Fall, 55.

SPACE

INTERVIEW WITH STEVEN D. HOWE



We Need Nuclear Propulsion to Get to Mars

Dr. Steven D. Howe is Program Development Coordinator in the Applied Theoretical and Computational Physics Division of the Los Alamos National Laboratory in New Mexico. During his 15 years at Los Alamos, Howe has worked on nuclear propulsion, the National Aerospace Plane, space radiation modelling, antimatter physics, and Mars mission requirements.

These are excerpts from an interview conducted by Marsha Freeman on Jan. 23.

Question: One of the current proposals for manned missions to Mars is the "Mars Direct" plan of Robert Zubrin. He makes the assertion that the radiation environment in space is no problem for the "Mars Direct" 900-day mission. But the Task Group on the Biological Effects of Space Radiation of the Space Studies Board, released a report last December, in which they say that more than a decade of research is needed to answer even the narrowest set of key questions about the effects of radiation in space, and that research "must be completed prior to undertaking the detailed design of a vehicle carrying a crew into space for periods of extended exposure."

I would make one caveat to that study. What they are saying is that the effects on the body of very highly ionized nuclei, like an iron nucleus, at very energetic speeds, is unknown. The uncertainties they are talking about are the very heavy-element composition in galactic cosmic rays. The proton constituent, which is 95 percent of galactic rays, but only about half of the dose a human might get, is well known and understood. If you can shield your ship to remove the heavy nuclei, then the uncertainty they are worried about should not exist.

In order to put that kind of shielding on a ship, however, the ship would be so heavy, a chemical propulsion system can't even begin to handle it as far as a Mars mission. But a nuclear system can easily handle that [additional] mass.

Question: So a nuclear propulsion system has the advantage of allowing an increase in the amount of payload you can carry, which allows you to increase the amount of shielding that you have?

Exactly.

"We can't do this on the cheap, or these guys aren't going to be coming home."

Question: Zubrin says that nuclear propulsion would only be advantageous if it could get people to Mars more quickly, but that this could not be done with the kind of nuclear thermal systems that have already been tested, such as the 1960s NASA program, or technologies that have been considered recently. But you are saying that even with nearer-term [solid core] nuclear propulsion, you have greater payload capability.

I can take a shielded habitat, *and* I can go faster. I get both effects, both components.

Question: Another assertion that Zubrin makes is that while nuclear thermal systems would nearly double the amount of payload you could take, it does not reduce the flight time.

I don't know where he gets that. Our studies, which we began back in 1985

Continued on page 79

Making Sure We Never Get to Mars

by Marsha Freeman

The Case for Mars: The Plan to Settle the Red Planet and Why We Must
Robert Zubrin with Richard Wagner
New York: The Free Press, 1996
Cloth, 328 pages, $25.00

"Mars Direct," the proposal that aerospace engineer Robert Zubrin has circulated in the space community since 1990, was suddenly thrust into the limelight at the end of last year, after scientists announced they had evidence of early life on Mars.

As presented in great detail in this book version of Zubrin's proposal, the idea is to bypass the Space Shuttle, the space station, lunar development, and new propulsion technology, and go directly from the surface of the Earth to the surface of Mars using chemical rockets—the same way we went to the Moon during the 1960s Apollo program.

Bob Zubrin says that he has proposed Mars Direct because he has lost patience waiting for the space agency to send people to Mars, and he does not believe that the United States, through its elected representatives, will ever embark on an effort that will take more than 10 years, or cost more than $20 billion. Zubrin reports in his book that, should the government not fund his now allegedly affordable Mars venture, conservative revolutionary Newt Gingrich has assured him that the private sector can do it.

Mars Without Direction

Since the beginning of the space age, Mars has been a long-range goal for human exploration, because it is most like the Earth. But Mars, which is 35 million miles from Earth at closest approach, is not the first target of opportunity for space colonization. The Moon, which is only a quarter of a million miles and three days away from Earth, will lay the basis for more difficult ventures. Zubrin, however, has bypassed lunar development, and many other necessary steps for exploring and settling Mars, for the sake of expediency, and political opportunism.

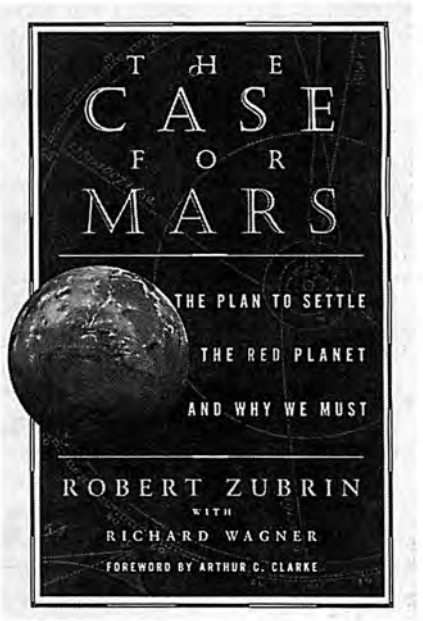
To cut costs down to $20 billion, and to save time so that the first manned flight can be done in a decade, Zubrin has eliminated the use of advanced propulsion, such as nuclear energy, and of a space station to allow for the assembly, fueling, and check-out of large spacecraft. Each Mars Direct flight, therefore, relies on the use of only one large chemical rocket.

Given the limited capabilities of such a Saturn V-class rocket, this means that a Zubrin mission to Mars will take about six months to get there, six months to get back, and require a stay on the Mars surface of 550 days. Mars Direct proposes to do this using technology to keep the astronauts alive and well that has not been tested in the environment of space even 1 day of the 910-day total mission.

In the Zubrin plan, getting the crew and supplies directly to Mars on a chemical rocket, leaves no room to take along the return fuel: The crew leaves the Earth without the fuel to come back. Before they embark on their journey, an automated robotic factory is to have landed on Mars and produced the return fuel from the Martian atmosphere (out of thin air, one might say).

For safety's sake, the crew does not leave for Mars unless a light on the robotic fuel factory indicates that it is full. So, the crew has to trust its return-flight fuel to a little green light, which may be lit when they leave Earth but somehow get hit by a problem (or a meteorite) while they are on their 180-day trip there. And if the light is off, the crew has to wait another 26 months, while another robotic factory is sent to Mars make the return fuel.

As Dr. Steven Howe, from Los Alamos National Laboratory, has pointed out, this could delay the manned mission indefinitely if a basic design flaw exists, because there is no crew you can send to Mars to fix the automated chemical fuel plant. All you can do is try sending another one, every two years.



'Comic Book Physics'

The technical capabilities Zubrin relies upon, he claims, can be easily, quickly, and cheaply developed for Mars Direct. Dr. Howe has described Zubrin's approach, however, as "comic book physics," where drawing it makes it so.

For example, Zubrin admits in his book—although he does not discuss it in his popular articles or public presentations—that only a nuclear fission reactor can provide the energy required to produce the chemical fuel for the astronauts' return trip.

So on the first Mars Direct launch, only 10 years after the program is initiated, he plans to have a 100-kilowatt electric nuclear power plant on Mars, plugged in to the chemical factory, to produce the return fuel for the first crew. However, in reality, the United States has *no* space nuclear power program, thanks to the cooperative effort of the anti-nuclear environmentalists and Newt

Gingrich's conservative revolutionaries, working together in the "Green Scissors" initiative, to kill government funding for advanced nuclear programs.

Yet, with a wave of his hand, Zubrin purports to resurrect the 1960s space nuclear technology, for a nickel on the dollar of what it cost 30 years ago. He does not explain how this currently nonexistent technology would reappear, how the original design would be scaled up an order of magnitude in power level, how it would be tested, both on Earth, and under Martian conditions, in facilities that don't exist, and in only a few years.

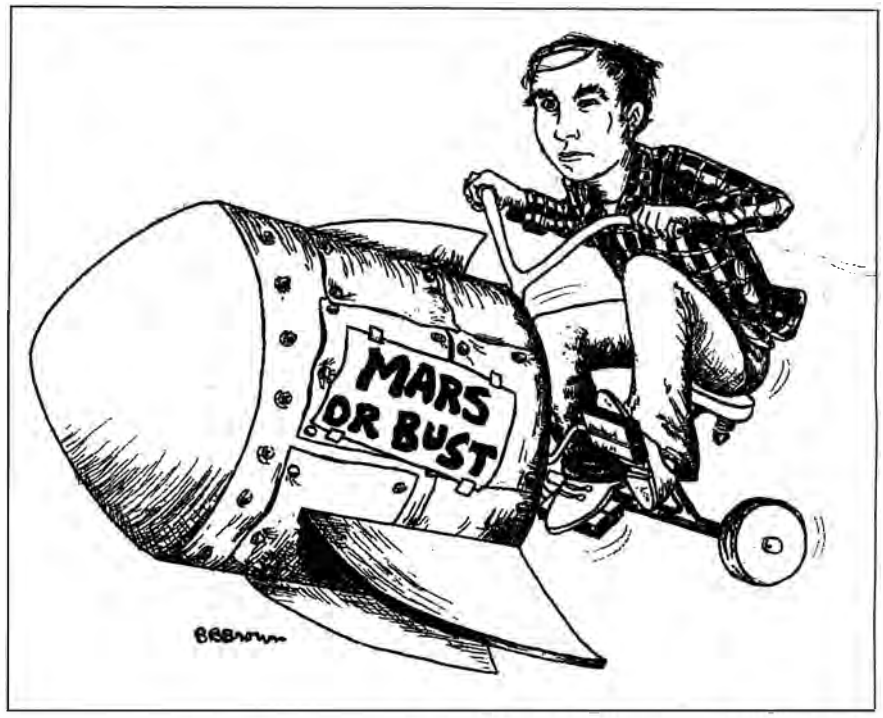
'Dragons and Sirens'

Zubrin also uses handwaving in a "make it go away" fashion, to rid the reader of any concerns about the imaginary "dragons and sirens" he says have stood in the way of sending people to Mars.

What are some of these allegedly imaginary bogeymen? They include adaptation to zero or variable gravity, and psychological stress from long-term confinement in close quarters, but one of the most important is space radiation. Zubrin claims that research conducted in the 1950s on patients receiving radiation treatment in Britain showed only a small increase in cancer incidence years after treatment. Extrapolating from that medical data, Zubrin claims that the increased risk of cancer on his Mars Direct plan is 1 percent.

However, astronauts involved in space activities will face radiation from the Sun and galactic cosmic rays—such as energetic protons and heavy ions—which people do not typically encounter on Earth. And following Zubrin's slow-boat chemical propulsion scheme, they will be exposed to the extraterrestrial radiation sources for two and a half years.

Very different conclusions were put forward by a group of scientists, convened by the National Research Council under the National Academy of Sciences, which released a report at the end of 1996. The Task Group on the Biological Effects of Space Radiation states in its report, "Radiation Hazards to Crew of Interplanetary Missions," that the level of uncertainty regarding the biological effect of both the transient radiation from solar events and that from continuous high-energy galactic cosmic rays, makes it impossible to know how to design



spacecraft to adequately shield astronauts from deleterious effects. The study points out that possible damage includes central nervous system changes, cataract formation, heritable effects, and early effects on body organs and function, in addition to cancer.

But, they suggest, since there is no base of knowledge on what the risks are, there is no way to know how much of what kind of shielding is needed. The Task Group reports that it is not possible to estimate even the cancer risk from exposure to certain kinds of radiation, such as high-energy, high atomic-number (heavy) particles, because "no human data are available." They propose a 10-year, ground-based research program to simulate space radiation, exposing animals and tissue-equivalent materials to high-energy particle accelerator radiation.

Even using first-generation nuclear propulsion systems, increased shielding from radiation is possible, because nuclear systems could double the amount of payload. Alternatively, the increased nuclear capability could be used to reduce the transit time, which would also reduce the risk to the crew. But because Zubrin decided that he cannot wait for nuclear propulsion systems to be developed and tested, he dismisses radiation as a serious problem with the wave of his hand, in order to make his flawed scheme palatable.

Zubrin's Big Lie About the Moon

By proposing that mankind not return to the Moon first, but head directly for Mars, Zubrin knows he is arguing against 40 years of rational planning. Therefore, he goes out of his way to assure the reader that the wondrous things he is proposing be done on Mars, could not be done on the Moon.

Many years before the recent discovery of the possibility that there is ice at the south pole of the Moon, space visionary Krafft Ehricke—whose crucial work is ignored in Zubrin's book—spent 15 years elaborating how all the things that Zubrin claims can be done only on Mars, can indeed be done on the Moon. Zubrin is familiar with this work of Krafft Ehricke, because he was a reader and contributor to *Fusion* magazine, when Ehricke wrote his series of articles for it.

The key issue, Ehricke pointed out, is energy density. Advanced nuclear fission and, emphatically, nuclear fusion technologies, will provide new methods of materials processing, from those currently used on Earth. The chemical means of industrial processing used on Earth will be replaced with high-powered directed energy systems on the Moon, and then Mars.

There is no reason, for example, to assume that terrestrial chemical refining processes that rely on carbon and hydro-

gen, would be used on the Moon. But Zubrin makes such an assumption only so he can "prove" that refining of metals and other materials could be done on Mars, where there is carbon in the atmosphere and water ice, but not on the barren Moon.

As Ehricke explained, nuclear energy will provide plentiful electrical power for materials processing using electrolysis, replacing the chemical and thermal methods used on Earth. Ehricke developed techniques such as underground atomic ovens for gas extraction and raw materials refining, in order to make concrete his plans to build cities for tens of thousands of citizens on the Moon, starting with Selenopolis.

Over the past two decades, scientists and engineers in industry, government research laboratories, and universities have contributed additional ideas for using microwaves, plasmas, and other highly energy-dense tools, to industrially develop the Moon. The announcement at the end of 1996 from scientists studying the radar data from the Clementine spacecraft, that they believe there is a significant quantity of water ice at the south lunar pole, only makes lunar industrialization that much easier.

Science Driver vs. 'Mars Direct'

Krafft Ehricke, and economist Lyndon LaRouche (with whom Zubrin is also very familiar), have explained in detail how the challenge to science and technology of accomplishing ever more difficult goals in space, will create completely new technologies and industries, and function as a "science driver" for the entire economy.*

On page 3 of his book, Zubrin lies, through a fallacy of composition, that his Mars Direct scheme will lead to the same result as the spending of $70 billion (in today's dollar equivalent) on the Apollo lunar program, which "contributed to the high rates of economic growth of America during the 1960s." Unlike Apollo, however, Zubrin's plan does not push forward the frontiers of science and technology, but instead is explicitly based on using the *same* technology as Apollo, developed 30 years ago!

Often when the media cover Zubrin's ideas, reporters simply assert that Dr. so-and-so high up at NASA supports his Mars Direct program, without any quotes from so-and-so. Such support may be simply more hand-waving on Zubrin's part. For example, on page 68 of his book, Zubrin includes lunar scientist Dr. Michael Duke as a supporter of his ideas. Yet, in an interview with this writer on Jan. 16, 1997, Dr. Duke stated that in his view, mankind should *not* go to Mars first, but back to the Moon. One wonders how many "supporters" Zubrin lists for his proposal would be surprised to find themsevles in that category.

Exploring and settling space should be the most uplifting and exciting endeavor of mankind for the 21st century. But Bob Zubrin admits that under his flawed scheme, it will be a dangerous journey for the few. In addition to the fact that adding more people costs too much money, he says, limiting the crew to only four people is preferable because "we are, one way or another sending a group of humans into harm's way. Thus, from a moral point of view, the fewer people we have on board the initial missions, the better."

This is no way to open the space frontier.

Notes

* See Lyndon H. LaRouche, Jr., "Why We Must Colonize Mars," *21st Century*, Winter 1996-1997, p. 16.

The Hidden Face of Greenpeace

by Emmanuel Grenier

La face cachée de Greenpeace
Olivier Vermont
Paris: Albin Michel, 1997
Paperback, 360 pages, 130 francs ($26)

This extraordinary book, *The Hidden Face of Greenpeace,* is the story of an infiltration. Olivier Vermont, the pseudonym of a French journalist, spent 10 months inside Greenpeace-France. He presented himself as an unemployed photographer, willing to serve the green movement as a volunteer. He rapidly became trusted as an assistant to the officer responsible for commando actions and for volunteers. In effect, he served as an unpaid secretary, which gave him access to a good deal of confidential information. On many points, his story, and the documents he presents, entirely vindicate the studies published by *21st Century* on Greenpeace.[1]

An Intelligence Service

In letters discovered by Vermont, a nuclear power plant operator says he has created a "secret group" with three other operators and two electricians. He was not joking. During a strike of Electricité de France, the French utility operating the nuclear plants, he locked himself and his friends inside the control room and plastered the walls with pages from *Charlie-Hebdo,* a leftist-anarchist paper, declaring: "We support you as long as you're on strike. The moment you return to operating this sh—t plant, we'll return to fighting the nuclear apparatus and its servants. With you in action!"

Another engineer from France-Telecom, France's telephone company, offered to advise Greenpeace on how to reduce its telephone bill, and said he could access the confidential files containing unlisted numbers, if it would help Greenpeace.

These two examples confirm that Greenpeace has an extensive information network, with people in strategic positions ready to give out confidential information for the service of the green cause. But there is much more—and much worse.

Greenpeace-France is a very small part of the entire Greenpeace apparatus. It is not financially self-supporting and needs donations from Greenpeace International to maintain its operations. Yet it maintains very extensive files, with precise information on politicians and journalists. The collaboration with insiders goes up to the ministerial level.

For example, on the record card for Brice Lalonde, environment minister in the Rocard government from 1988 to 1991, is the quotation from Lalonde in which he speaks of his relationship with David McTaggart, former Greenpeace guru: "When I was environment minister, we were elaborating our tricks together. It was fun. David was representing Greenpeace and I, the French state."

The information assembled in these records is of course used for lobbying purposes, but, in the words of Vermont, "they are so detailed that they look very much like the records of an espionage service."

Greenpeace also carries out brainwashing operations. Members go to politicians, presenting themselves as scientists, and of course omitting to mention that they are part of Greenpeace. They can thus give more credibility to the false information they disseminate. There are also many funny stories in the book about the infiltration of the media by Greenpeace. Two methods are used: the ideological conversion of journalists and the infiltration of sympathizers into media organizations. Vermont cites examples from *Le Monde, Liberation, Les Temps,* and Radio France, but he does not name names.

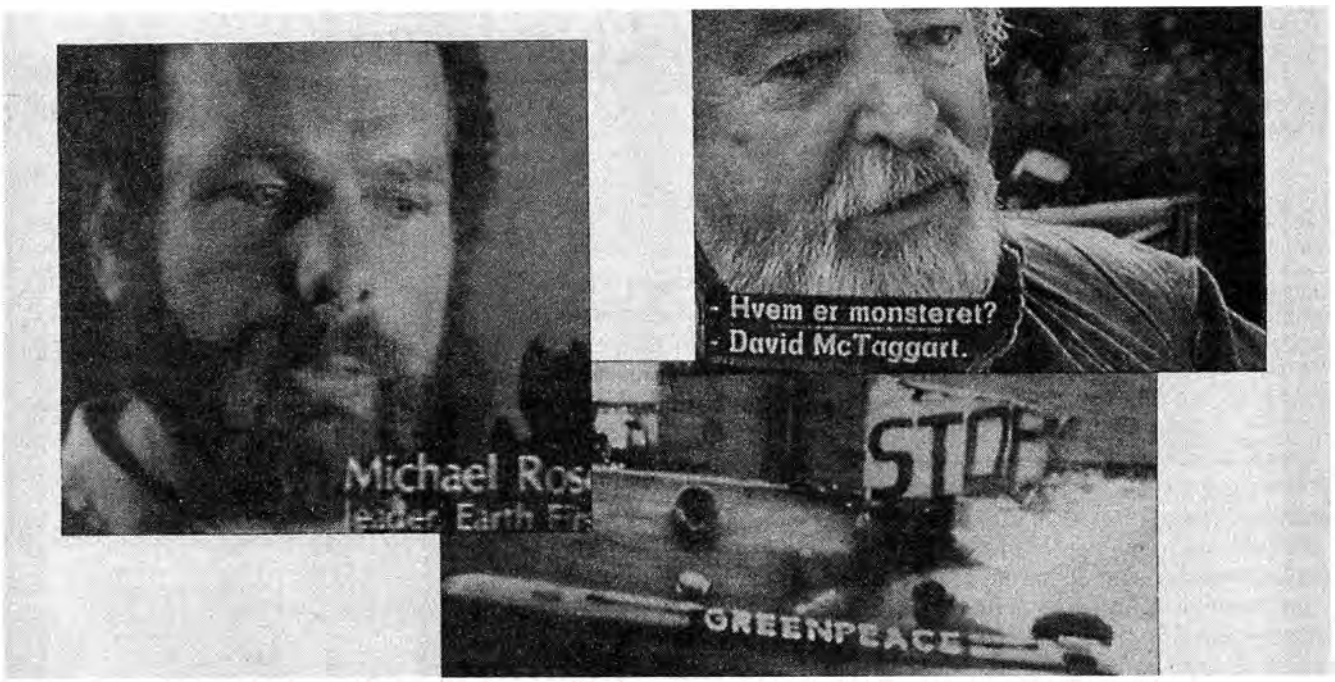
At one point, Vermont discovered, in a hidden file of his chief, an extremely precise map of the Elysée palace, complete with the location of strategic points like the President's office and the honor lodge where foreign guests are accommodated. A three-dimensional map of the President's office shows in great detail the exact location of the President's chair. Appended handwritten notes explain how to access the office most rapidly: "take the small stairway on the left," and so on. The course is carefully timed: one minute and a half is deemed necessary to get from the outside steps to the President's office.

Another document lists the security procedures in the Elysée, giving the locations of the guards and the exact hours of the changing of the guard and of inspection tours. In other words, here are the fundamentals needed to run an assassination operation.

This kind of high-level documentation gives substance to the overt threat to the life of President Jacques Chirac made in a television ad, shown during the campaign against France's most recent nuclear tests in the Pacific, which featured Chirac with crosshairs centered on him. This signal from the oligarchy that runs the green movement was sponsored by Greenpeace/Worldwide Fund for Nature under the direction of Chris Rose. Rose, a veteran of both organizations, is on the board of the media company, Media Natura. The ad was called "The Day of the Jacques," an obvious reference to the film about a planned assassination of Charles de Gaulle, called "The Day of the Jackal."

Ties to Terrorist Movements

There are many ties between Greenpeace and the terrorist movements of different denominations: regionalist, extreme-leftist, and ecologist. This is not news, but the book demonstrates the ties anew.



21st Century *has reported on Greenpeace's role as the direct-action arm of the European nobility, its open links to the terrorist groups Earth First!, and its financial irregularities—all of which are corroborated in* The Hidden Face of Greenpeace. *Here, a composite of scenes from the Danish exposé of Greenpeace, "The Man in the Rainbow": Greenpeace founder Bennett Metcalfe (top right) calls David McTaggart, the former head of Greenpeace International, a "Frankenstein monster"; a typical Greenpeace "action"; and (top left) Earth First! leader Mike Roselle brags of his working relationship with Greenpeace.*

Take, for example, the Union Démocratique Bretonne (UDB), originally a front for the terrorist FLB (Front for the Liberation of Britanny, dissolved by decision of the prime minister in 1974). In April 1992, UDB members were arrested for having safe-housed high-level members of the ETA, the Basque separatist-terrorist organization. One of the ETA members enjoying this protection was Sabino Euba Genarruzabeita, the ETA treasurer, arrested in the Paris airport as he was departing for Mexico. Among the 200 Bretons arrested were a number of green and pacifist militants with ties to Greenpeace.

Even more interesting is Vermont's detailed account of his participation—*as a member of Greenpeace*—in the commando operations at Gorleben, Germany, aimed at stopping the transport of nuclear wastes from COGEMA (the world's largest uranium recycler, situated at Cape La Hague, France) to the Gorleben waste site. Vermont presents himself as a French member of Greenpeace, "ready for some tricks." He gains the confidence of the leader of the "autonomists" in Gorleben, by referring to a commando action he participated in at Cape La Hague, with a man called Pierrick, known to the leader, Wolfgang (war-name Helmut), who tells Vermont:

"Officially, we are organizing strictly nonviolent antinuclear demonstrations. We are supposed to be struck [by police truncheons] before the TV cameras, and not the other way around. No direct provocation with the cops or the army, even though it's very exciting. But our position is flexible. We say to the media that between the risk represented by the nuclear wastes in Gorleben and the risk represented by a sabotage action to stop the transport, everyone is free to choose. You, the French autonomist, you're free. Is that clear?"

Of course, it was very clear. The very next night, Vermont participates in the sabotage of an electricity tower near Gorleben. After this action, he is nominated for eco-warrior training. A German militant, Klaus, invites Vermont to the Greenpeace training center, situated on the harbor in Hamburg. Klaus describes a very militarist training, "worse than the paratroopers":

"You're locked in a room with no heat, awakened before dawn, cold shower, hot coffee, and hours of grounding in the use of military equipment. Then you have the workshops. For example, you must form a human chain and resist the blows (with feet or truncheons) from other militants. At the end, you're covered with blood. Another exercise consists in climbing a crane and abseiling [descending with a double rope] alone. It's very risky. More than one stops there. Another example: you have to build a raft, cross a river, and bring something back.... They forbid you to sleep during the night. You become a ready-for-everything zombie, and if you pass all tests, you become eligible for commando actions."

Klaus then says that this course of training is held every month, with a group of 50 volunteers, under the direction of Harald Zindler, who has trained more than 1,000 eco-warriors.

This dialogue with Klaus may be somewhat fictionalized, because some parts are identical to precise information already published. The book's description of characters in Greenpeace-France, however, is borne out by my own experience.

Finances

Vermont had access to the secret accounts of Greenpeace-France and of Greenpeace International. For Green-

Continued on page 77

Attacking the Myth of Low-level Radiation Hazard

by Dr. Theodore Rockwell

Has Radiation Protection Become a Health Hazard?
Gunnar Walinder
Swedish Nuclear Training & Safety Center, P.O. Box 1039, S-611, 29 Nyköping, Sweden, 1995
Paperback, 126 pages, $44.00

Gunnar Walinder, the noted Swedish radiobiologist, has asked exactly the right question in the title of this book. Many scientists might doubt the scientific validity of the premise underlying current radiation protection standards and practices. That is, they would suspect that levels of radiation below the natural background are not actually harmful. But when told, "We're just trying to be conservative where public health is concerned," they might nod and think "That's reasonable."

The main thrust of Walinder's book is to show that the current premise that the hazard of radiation is linearly proportional to dose, all the way down to zero dose, is neither biologically valid nor conservative, but, in fact, leads to harmful actions and consequences. He demonstrates this both in terms of known biological data and theory, and in terms of the practical impact of regulations based on that premise.

Walinder is well qualified to present and evaluate data in this field, and he does so with directness and clarity. To satisfy the most rigorous radiobiologist and yet not lose the intelligent nonspecialist, he makes his major points in ordinary type, and then follows each such argument with more technical material in italics. He warns the readers as to what he is up to, and assures them that they may skip the italicized portions without losing the message. I found this format very effective; he really does manage to have it both ways.

Walinder notes: "The number of severe mental and psychosomatic diseases observed in people living in the Ukraine and Byelorussia has already surpassed the estimate for the late effects of radiation exposure. . . . Moreover, the fear of radiation seems, in many cases, to occur independently of whether or not the 'victim' has lived in an area where there has been radioactive fallout."

Walinder illustrates the absurdity of the linear model, by contrasting the number of deaths that it "predicts" from the Chernobyl fallout with the number of deaths the same premise "predicts" from natural radon in the home. The numbers show that if Swedes stayed indoors about one more minute per day, the additional hypothetical deaths from natural radon in their homes would offset the hypothetical deaths from Chernobyl.

Risk: A Misused Concept

Walinder also explains the misuse of the concept of risk. He supposes that someone is asked to get up from a chair, and that person asks, "Can you guarantee I won't die if I do so? Most (nonnuclear) regulators would answer: "We can guarantee that you won't. It might even be good for you. Only a person with a very weak heart would die from getting up from a chair."

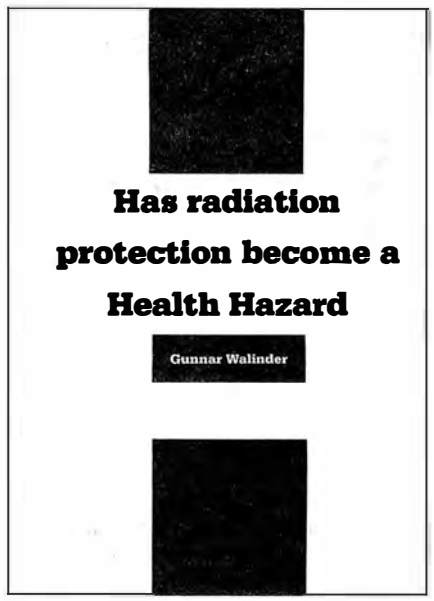
But when radiation is involved, regulators insist that they cannot guarantee that the person won't die, because he might have a very weak heart.

Walinder gives some examples of the power of "unshakable faith in the authorities," noting that this has caused problems in "interpretation of radiobiological experiments" and, above all, of epidemiological results. Researchers have not believed in their own "deviating" data, but have taken it for granted that they have made mistakes. So, a series of corrections of supposedly incorrect data have been made until the data were in better agreement with the doctrine."

Therefore, Walinder says, in evaluating data compiled by policy-makers, we must look out not only for data-bending by the policy-makers, but we must also go back and re-examine the raw data itself.

Fighting for Rational Standards

The problem is, when individual scientists question the status quo, they are easily dismissed as a deviant voice against the scientific consensus. Given this situation, an international group of scientists prominent and respected in the radiation protection field established a not-for-profit organization called Radiation, Science, and Health, Inc. (RSH, Box 843, Needham, Mass. 02194), to assemble data and critical commentary that cannot be lightly dismissed.



RSH is submitting to the National Council on Radiation Protection and Measurements a massive report on the low-level radiation problem with data and theoretical studies that have so far been completely ignored or casually denigrated in evaluating radiation protection standards. This will be a continuing process as more data and theoretical developments become available, from the molecular, cellular, and epidemiological levels.

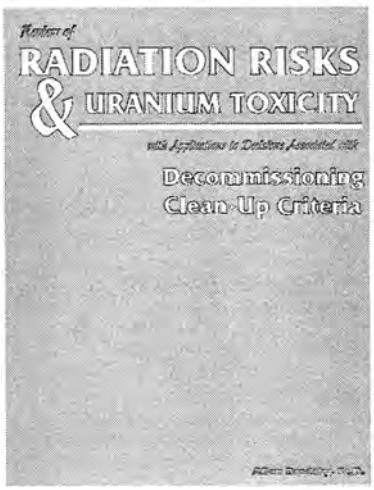
A debate on the technical merits and weakness of the current radiation policy will take place at the American Physical Society meeting in Washington, D.C. on April 21.

Theodore Rockwell, a nuclear consultant, worked for many years in the naval reactor program, where he helped develop the procedures for the safe operation of nuclear-powered naval vessels and the first civilian nuclear power plant.

A Surprising View Of Nuclear Cleanup

by Dr. John Cameron

Review of Radiation Risks and Uranium Toxicity with Application to Decisions Associated with Decommissioning Clean-up Criteria
Allen Brodsky
Hebron, Conn.: RSA Publications, 1996
236 pages, $49.95



Don't let the title of this book fool you. A better title would be "Lack of Risks From Low Level Radiation." It contains a great deal of useful information on currently used risk estimates and the recommended limits of international organizations and U.S. scientific and governmental committees and agencies. It also discusses the uncertainties of risk estimates and evidence of hormetic effects of low-level radiation.

Written initially as a report for the U.S. Army, it contains more information than the average person wants. (There are 14 pages of references and an index of about 1,000 entries.) It is an excellent summary of the current status of problems related to clean-up of sites contaminated with radioactivity.

The author points out that, "Given the planned large expenditures for decommissioning (hundreds of billions), it would seem very cost-beneficial to allocate adequate funds (millions) to properly examine the possibilities of hormetic effects at low radiation exposure levels, using appropriate research designs as suggested by Luckey." The author includes 27 pages of direct quotations from the book *Radiation Hormesis* by T.D. Luckey (2nd edition, CRC Press, Boca Raton, Fla., 1991). Many readers will be familiar with Prof. Luckey's article, "The Evidence for Radiation Hormesis" (*21st Century,* Fall 1996).

The original purpose of the book was to compare two different approaches to cleaning up a contaminated site. The author's thorough discussion of uncertainties in risk estimates makes it clear that it is scientifically impossible to distinguish any cost/benefit for one clean-up criterion over the other.

I was impressed by the wisdom of the author's last recommendation:

". . .[L]icensees should offer communities near decommissioned facilities the choice of expending funds on public clinics having obvious benefits, as an alternative to further decontamination that would be of doubtful benefit."

Saving Money and Lives

Millions of U.S. residents in seven western states are exposed to high natural background levels compared to the rest of the country. These states have about a 15 percent lower cancer death rate than the country as a whole. It would make sense not to clean up any site to a level lower than the natural levels found in Wyoming or Colorado. This would save billions of dollars of clean-up costs and perhaps reduce cancer at the same time!

John Cameron is Professor Emeritus, Department of Medical Physics, University of Wisconsin-Madison and Visiting Professor, Department of Radiation Oncology, University of Florida, Gainesville.

Greenpeace

Continued from page 75

peace-France, 60 percent of income goes to salaries. Between 1994 and 1995, when Greenpeace-France had a deficit of $400,000, the leaders nevertheless decided to increase their pay. The salaries paid to the administrators increased from $300,000 to $500,000 between 1994 and 1995!

According to the figures copied by Vermont, only 6 percent of income goes to field operations, while 11 percent is spent on lawyers' expenses, to attack critics in the press, and to defend Greenpeace members accused of illegal operations. This is basically the same picture that was revealed in Canada and in Norway, through the exposé films of Magnus Gudmunsson.[2]

More interesting is that Greenpeace pays huge amounts of money to its former leaders, with the condition that they never speak to the press after their departure! Vermont stole a dossier from Greenpeace International offices in Amsterdam, concerning these "confidentiality clauses." Paul Gilding, an Australian subject, former director of Greenpeace-Sydney and former executive director of Greenpeace International before Thilo Bode, received $160,000 for this purpose when he left. Doug Faulkner, fundraising leader for 13 years, got $200,000 when he was sacked and signed the "confidentiality clause." Since 1993, Greenpeace has paid out $640,000 for four confidentiality clauses. A strange procedure for an organization which always asks for "transparency" and "right to know."

I hope that this book will be translated into English, so that English-speakers can have the benefit of seeing Greenpeace's hidden face.

Emmanuel Grenier, based in Paris, is the editor of the French-language Fusion *magazine.*

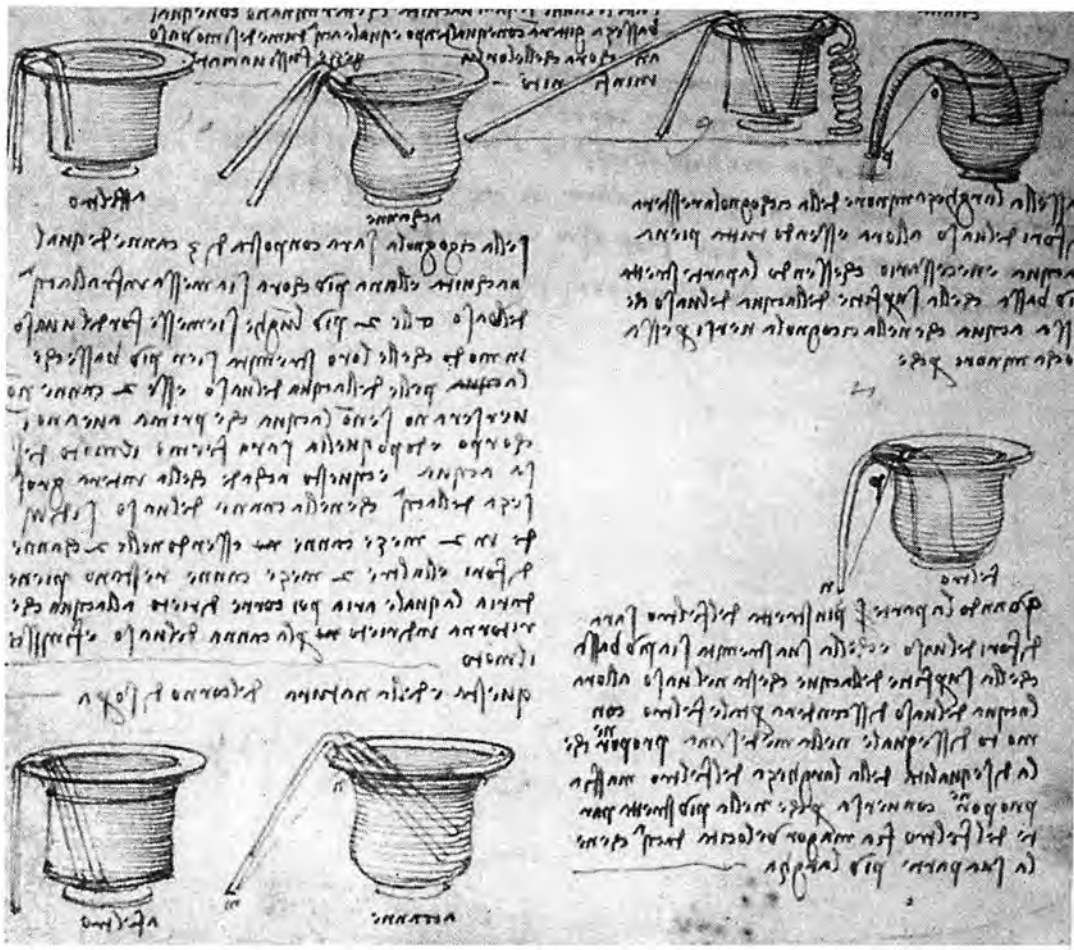
Notes

1. Ellen Chance, " 'Mind Bombs': Putting Greenpeace in Perspective," *21st Century*, Summer 1990, p. 45.
   Poul Rasmussen, "Greenpeace's Financial Misconduct Exposed in New Danish Documentary," *21st Century*, Winter 1993-1994, p. 56.
   Carol White, "The Really Shocking Royal Secret: British Crown Rules the Greens," *21st Century*, Winter 1994-1995, p. 9.
   Geoffrey Steinherz and Marjorie Mazel Hecht, "Court Affirms Greenpeace Ties to Earth First! Terrorists," *21st Century*, Fall 1995, p. 68.
2. See, for example, Poul Rasmussen, "Greenpeace's Financial Misconduct Exposed in New Danish Documentary," *21st Century*, Winter 1993-1994, p. 56.

Leonardo's Reason: Method Against Madness

by Elijah C. Boyd

Leonardo da Vinci: Codex Leicester, A Masterpiece of Science
Claire Farago
New York: American Museum of Natural History, 1996
Paperback, 180 pages, $29.95 + $6 shipping



Leonardo's notes and drawings of siphons, from the Codex Leicester.

Leonardo da Vinci's work eternally retains the power to inspire the mind to create for the future. Evidence of this creative power was manifest in the recent exhibit of his hydrodynamic works, works concerning water and its movement, centered on the Codex Leicester, at the American Museum of Natural History in New York City. The exhibit ended on New Year's Day, but the catalogue, identified above, continues to be available.

The exhibit's power lay in the arrangements for the public's engagement and participation in the exhibits, as opposed to merely observing them. Upon entering the first of the display halls, one's attention was arrested by a wall divided into a pleasant array of glass cases containing a selection of experimental investigations of water falling. Leonardo's arrangements illustrate how water can penetrate water, how water can combine with water, how water can bounce off water, how the power of falling water can be mitigated to diminish damage, and how water can produce a vortex.

The middle hall displayed pages of the Codex Leicester in humidified cases, intermittently illuminated to prevent damage from photo-dissociation. Reproductions were available for purchase to encourage serious study.

A separate reading room displayed CD-ROM copies of the manuscript for close inspection on the premises. Next to it was a continuously running film on the life and discoveries of Leonardo.

Hands-on Experiments

The proper centerpiece of the exhibit, however, was the hands-on experiments in the room at the end, fashioned from Leonardo's workbooks, illustrating the same and similar modifications of the paths of water flows, which invariably evoked ideas for the further investigation of this most ordinary substance.

The exhibit calls to mind Percy Bysshe Shelley's reference, in his *Defence of Poetry,* to "the power of communicating and receiving intense and impassioned conceptions respecting man and nature." Indeed, had Leonardo produced *only* the Codex Leicester, the world might have anointed him "The Poet of Water."

Leonardo studied the surface of the Moon and concluded that it was covered with water: "And here the Moon, being a spherical and opaque body, remains of uniform brightness in its parts which are apt to receive uniform light. And this, for what is said above, could not be, if water were not there; the water being spherical, it cannot receive the solar ray and reflect it to our eyes except through the ray incidence, which is smaller in relation to the volume of the lunar body; so that, of necessity, it must be admitted that the sea waves, each for itself, take a solar ray, and the shadow interposed between the crests of the waves blends with the luminous species and does not produce such brightness as it would do were its water without waves" (Sheet 5A, folio 5r).

The quotation is found in the catalog of the exhibit (p. 70).

The observation of the Moon, in the eye of the Artist-Scientist, refused to allow that the brightness variation of the Moon's surface could be attributed to a smooth, shiny, perfect sphere. It must be broken up, as waves break up water. Even though the rocky and cratered surface of the Moon is not water, it acts like water in reflecting sunlight.

Leonardo also studied the formation of vortices in the air: "It often happens that, when one wind meets another at an obtuse angle, these two winds circle around together and twine themselves into the shape of a huge column, and becoming thus condensed, the air acquires weight. I once saw such winds, raging around together, produce a hollow in the sand of the seashore as deep as the height of a man, removing from it stones of a considerable size, and carrying sand and seaweed through the air for the space of a mile and dropping them in the water" (p. 84).

Did Leonardo perhaps think of his thought processes in the same way? Did it occur to him that the process of thoughts intersecting thoughts "at an obtuse angle," created the "weight" of a thought-process? Perhaps that is what lies behind his cogent explanation of the anatomy of his leaps:

"I will not consider the demonstrations here, because I will reserve them for the ordered work; my concern now is to find cases and inventions, gathering them as they occur to me; then I shall have them in order, placing those of the same kind together; therefore you will not wonder nor will you laugh at me, reader, if here I make such great jumps from one subject to the other."

Given the power of this exhibit, how could *New York Times* reporter Stephen Manes, writing in the Science Times section Dec. 3, 1996, refer to it without even mentioning its location in New York?

Catalogue, CD Available

The catalogue contains reproductions of the 72 pages of the codex, and on facing pages, commentary by Farago, using the translation by Carlo Pedretti when quoting from it. A compact disk version is also available ($50 plus $7 shipping, Windows or Mac), and can be ordered from the Museum Shop of the American Museum of Natural History (79th St. at Central Park West, New York, N.Y. 10024).

Space

Continued from page 70

and continued through 1991, in conjunction with three NASA centers, show that it's a trade. You can either increase the payload by a factor of two, or you can significantly reduce the trip time, not by a factor of two, but still reduce it.

Question: About how much time saved are we talking about?

If I want to go to the extreme for the solid-core nuclear rocket, with 1,000 seconds of specific impulse, we believe you could accomplish a one-year round-trip mission. That was on the extreme end of that envelope. We could do roughly a one-year round trip, compared to Zubrin's three-year-type [chemical propulsion] program. With the solid core, certainly it could do a 400 to 430 day round-trip mission. And that had about a one-month stay-time on the planet.

Question: What kind of nuclear systems would you have to develop where you could go on a non-ballistic trajectory and have the ability you would eventually want to have, to get up and come and go whenever you please?

Let me preface this with a little statement that I have equated with Zubrin's plan. You may remember Thor Heyerdahl in years past. He contended that various early peoples could make low-technology boats and cross the oceans. One of his examples, that I recall distinctly, was the Egyptians, who could make a reed boat and sail to the Americas. Essentially, Heyerdahl all but proved this. He could make a reed boat and just get there.

To me, this is what Zubrin is talking about. He is taking essentially a low technology—we have better technology than that right now, but he doesn't want to use it. He wants to take a low-technology system that will just barely get there. Whereas, in fact, we have the technology now to almost make a clipper ship to get there is a few months' time frame, in a robust, healthy environment to withstand the storms, and essentially let the crew survive. But I equate Bob's plan with this reed boat idea.

One of the major failures of the Zubrin plan, is its 500-day stay on the Mars surface, which I consider absolutely ridiculous from a crew survivability standpoint.

I think that the basic premise here is that the radiation level on the Mars surface is relatively benign. And he's just flat wrong. It turns out that as part of the Mars Observer program, we had a fellow here in the Laboratory who did galactic cosmic-ray-induced gamma-ray measurements, using Mars Observer, to look at the elemental composition of the Mars surface. . . . What comes out of his calculations is that the radiation on the surface of Mars appears to be roughly equal to that of the Moon, or slightly greater. So, if you are going to have to shield on the surface of the Moon, you are going to have to shield the habitat on Mars.

"If we want to go into space, we must accept the challenge and do it right."

Zubrin uses what I call "comic book physics." He just draws a picture and says, "I'm going to go steal a couple of existing engines and make a heavy lift launch vehicle." That's, again, fantasy. I'm surprised, to be honest with you, at the public acceptance of this . . . [but] I don't think space works that way. This is a hostile environment, and if you're willing to accept that it's going to be expensive and it's going to be hard—just as Kennedy said, we do it *because* it is hard—you must be ready to commit the resources to do that. We can't do this on the cheap, or these guys aren't going to be coming home. . . .

Just to summarize: I believe that if you are willing to undertake this challenge, and you have the science and the technology that allows you to attack the problem, you must use it. For example, even from a legalistic standpoint, if you sent this crew on a chemical-propelled system and they all died, and you had a better technology available to you, are you now liable? Are you not ethically required to give it the best shot you can? By doing it "cheap and simple," you're evading the problem.

If we want to go into space, we must accept the challenge and do it right. Unless you're willing to do that, you've got no business trying.

BOOKS RECEIVED

Conservative Environmentalism: Reassessing the Means, Redefining the Ends, by James R. Dunn and John E. Kinney. Westport, Ct.: Greenwood, 1996. Hardcover, 275 pages, $45.

Storm Over a Mountain Island: Conservation Biology and the Mt. Graham Affair, edited by Conrad A. Istock and Robert S. Hoffman. Tucson: University of Arizona Press, 1995.

Darwin's Black Box: The Biochemical Challenge to Evolution, by Michael J. Behe. New York: Free Press, 1996. Cloth, 307 pages, $25.

Monad to Man: The Concept of Progress in Evolutionary Biology, by Michael Ruse. Cambridge: Harvard University Press, 1997. Cloth, 628 pages, $49.95.

The Eleventh Plague: The Politics of Biological and Chemical Warfare, by Leonard A. Cole. New York: W.H. Freeman, 1997. Cloth, 284 pages, $22.95.

McGraw-Hill Dictionary of Bioscience, Sybil P. Parker, editor in chief. New York: McGraw-Hill, 1997. Paper, 511 pages, $17.95.

200% of Nothing: From "Percentage Pumping" to "Irrational Ratios." An Eye-opening Tour Through the Twists and Turns of Math Abuse and Innumeracy, by A.K. Dewdney. New York: John Wiley & Sons, 1993. Paper, 182 pages, $12.95.

Feynman's Lost Lecture: The Motion of Planets Around the Sun, by David L. and Judith R. Goodstein. New York: W.W. Norton, 1996. Book and CD, $35.

World and Antiworld as Physical Reality: Spherical Shell Elementary Particles, by Erich R. Bagge. Frankfurt am Main: Haag und Herchen, 1994. Paper, 280 pages.

The Physics Quick Reference Book, by E. Richard Cohen. Woodbury, N.Y.: AIP Press, 1995. Paper, 209 pages, $30.

Newton and the Culture of Newtonianism, by Betty Jo Teeter Dobbs and Margaret C. Jacob. Atlantic Highlands, N.J.: Humanities Press, 1995. Paperback, 139 pages, $12.50.

Logical Dilemmas: The Life and Work of Kurt Gödel, by John W. Dawson, Jr. Wellesley, Mass.: A.K. Peters, 1997. Cloth, 361 pages, $49.95.

Infinite Potential: The Life and Times of David Bohm, by F. David Peat. Reading, Mass.: Addison-Wesley, 1996. Cloth, 353 pages, $25.

Making Waves, by Charles H. Townes. Woodbury, N.Y.: American Institute of Physics, 1995. Cloth, 210 pages, $29.95.

Stalinist Science, by Nikolai Krementsov. Princeton: Princeton University Press, 1997. Cloth, 371 pages, $45.

Jules Verne: An Exploratory Biography, by Herbert R. Lottman. New York: St Martin's Press, 1996. Hardcover, 366 pages, $26.95.

Edwin Hubble: Mariner of the Nebulae, by Gale E. Christianson. New York: Farrar, Straus and Giroux, 1995. Hardcover, 420 pages, $27.50.

Cosmology and Controversy: The Historical Development of Two Theories of the Universe [big bang and steady state], by Helge Kragh. Princeton: Princeton U.P., 1996. Cloth, 500 pages, $35.00.

Hubble's Universe: A Portrait of Our Cosmos, by Simon Goodwin. [Album of Space Telescope images.] New York: Penguin Books, 1997. Hardcover, 127 pages, $29.95.

The Hubble Library of Electronic PictureBooks, by the Special Studies Office of the Space Telescope Science Institute. [500 images, including some from Hubble, and 25 minutes of video from space.] Distributed by the Astronomical Society of the Pacific (San Francisco), 1997. CD-ROM, $39.95.

Exploring the X-ray Universe, by Philip A. Charles and Frederick D. Seward. New York: Cambridge U.P., 1995. Cloth, 398 pages, $79.95.

Sundials: History, Theory, and Practice, by Rene R.J. Rohr. New York: Dover, 1996. Paper, 142 pages, $11.95.

Space Shuttle: The History of Developing the National Space Transportation System [through STS-75], by Dennis R. Jenkins. Osceola, Wis.: Motorbooks International, 1996. Hardcover, 344 pages.

Mining in the Sky: Untold Riches from the Asteroids, Comets, and Planets, by John S. Lewis. Reading, Mass.: Addison-Wesley, 1996. Cloth, 274 pages, $26.

China plans 10,000 major infrastructure projects in the next decade. Will the United States adopt this approach to make its way out of the new Great Depression?

THE EURASIAN LAND-BRIDGE

The "New Silk Road" —locomotive for worldwide economic development

A new special report from *Executive Intelligence Review* including studies of:

- High-technology infrastructure development corridors
- China and Europe as Eurasia's development poles
- Crucial infrastructure projects in China
- The Eurasian Land-Bridge and development around the great ocean basins
- Financing an economic miracle: Hamiltonian credit generation
- The Eurasian Land-Bridge and the economic reconstruction of the United States

290 pages
$200

Available from:
EIR News Service
Dept. T, P.O. Box 17390
Washington, D.C. 20041-0390

Paid Advertisement

In This Issue:

THE TRUTH ABOUT 'WARMING': ICE CORE DATA SHOW NO CO_2 INCREASE

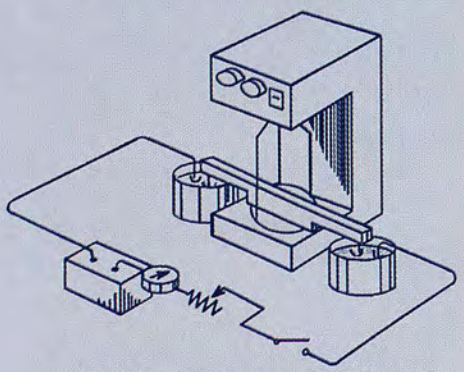
Data based on analysis of air bubbles in glacial ice samples have been used to back up the assumption that atmospheric carbon dioxide has increased since the pre-industrial era, allegedly leading to global warming. But as Dr. Zbigniew Jaworowski demonstrates, these ice core data are fudged and the actual physical processes involved in glacial ice formation are ignored to make the analysis conform to the warming thesis.

Courtesy of Switzerland Tourism

Glacial ice analysis cannot reliably determine the CO_2 concentrations of past eras because of the freezing process and contamination of ice core sampling.

BATTLE OVER THE LAWS OF ELECTRODYNAMICS

In 1825, André-Marie Ampère established the existence of a repulsive force between longitudinal elements of electrical current. Written out of the textbooks since Maxwell's time, the phenomenon stubbornly persists. French physicist Rémi Saumont reviews the experimental evidence.



Rémi Saumont's experimental apparatus to measure the Ampère longitudinal force.

THE HARMONIES OF THE ORBITS

Chaos and entropy express only the pessimism of the theorist, not the beauty of the universe, as Lothar Komp demonstrates in his discovery that the spacings of the orbits of planetary moons are determined by a barred spiral geometry. As Kepler insisted, the universe sings!

NASA

A composite of four of Jupiter's moons.