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FUSION

SCIENCE • TECHNOLOGY • ECONOMICS • POLITICS

Vol. 9, No.1 January-February 1987

Features

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FUSION (ISSN 0148-0537) is published 6 times a year, every other month, by the Fusion Energy Foundation, P.O. Box 17149, Washington, D.C. 20041-0149. Tel. (703) 771-7000. Dedicated to providing accurate and comprehensive information on advanced energy technologies and policies, FUSION is committed to restoring American scientific and technological leadership. FUSION coverage of the frontiers of science focuses on the self-developing qualities of the physical universe in such areas as plasma physics—the basis for fusion power—as well as biology and microphysics, and includes ground-breaking studies of the historical development of science and technology.

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

Subscriptions by mail are $20 for 6 issues or $38 for 12 issues in the USA. Airmail subscriptions to other countries are $40 for 6 issues. Back issues are available at $5 each, postpaid.

Address all correspondence to FUSION, P.O. Box 17149, Washington, D.C. 20041-0149.

Second class postage paid at Washington, D.C. and additional mailing offices. **POSTMASTER:** Send address changes to FUSION, P.O. Box 17149, Washington, D.C. 20041-0149.

ISSN 0148-0537 USPS 437-370

On the Cover: Cover design by Virginia Baier. Symbols on the map represent Japan's nuclear plants (see page 21) and space program facilities.

Editorial

Japan: America's Partner In Defense—and Economic Revival

The Cabinet of Prime Minister Yasuhiro Nakasone announced in September 1986 that Japan will participate in President Reagan's Strategic Defense Initiative on a government-to-government basis. Estimates are that this will advance the U.S. program by at least two years, because of Japanese contributions to the area of surveillance, acquisition, and track and kill-assessment.

The Japanese are world leaders in computer technology, and they already supply chips to the United States for missile guidance systems. Clearly, the U.S. program will benefit from the availability of Japanese miniaturization technologies and their generally advanced fifth-generation computer technology. In addition, the Gekko XII laser at Osaka University is second in power only to Lawrence Livermore National Laboratory's Nova—now the world's largest laser.

Obviously, along with immediate benefits of collaborative development of frontier technologies, the strategic alliance between the two nations will be significantly strengthened. By participating in the SDI, and helping to develop an effective antimissile defense, Japan will be assured protection against a Soviet nuclear strike. This will have the immediate effect of blunting Soviet blackmail against nations in the northern Asia-Pacific Basin region.

The U.S.-Japan memorandum of understanding on "Detailed Arrangements for Transfer of Military Technologies," which has just been finalized, provides the basis for joint work on laser antimissile defense systems. The agreement was concluded on the highest government level, and large Japanese companies that have substantial R&D facilities are expected to be immediately involved. These include: Nippon Electric Company, Hitachi, Fujitsu, Mitsubishi Electric, Toshiba, Sharp, Sumitomo, and Matsushita. The companies are expected to be active in providing optical data storage systems, laser diodes, fiber optics, infrared detectors, and imagers in general, and gallium arsenide chips.

The one sticky area that may handicap the agreement is in the control of new technologies that are developed during SDI research. It is precisely in this area that U.S. companies are currently being stifled by defense contracts. The U.S. Defense Department now limits the spillover of such discoveries to the civilian area—under a number of pretexts, not all related to the issue of classification. For example, the government asserts proprietary rights over work it has paid for, which may include fairly abstract elements of the R&D work that would normally be applied to several contracts, in order to maximize productivity.

The line of argument by the U.S. government is that they have paid for the research and therefore it should not go to the benefit of civilian production. Such an irrational approach, if applied to the Apollo program, would have denied the nation all the fruits of man's trip to the Moon, including the computer industry, transistors, semiconductors, and so on. Indeed, it is precisely the ability to rapidly spill technology over into the general economy which gives the United States its biggest competitive advantage over the Soviet Union.

Harnessing the Spillover

In its potential role as a science driver for our otherwise depressed economy, the SDI can more than pay for itself. It is this bonus that interests the Japanese companies that will be involved in implementing—or not—their government's accord with the United States. As of this writing, some troubles have arisen on that score.

The Japanese have requested that these companies be allowed to follow their usual practice of applying any new technologies they develop directly to civilian production. This is a particularly sensitive issue in Japan, where there are constitutional restrictions on participation in military programs. It was precisely President Reagan's offer to share SDI technology, even with the Soviets, that made the program attractive to the Japanese.

If the Japanese can change the present self-destructive policy of the U.S. government, which is enforcing stagnation on the U.S. civilian economy by inhibiting the spillover of new technologies, then perhaps this will be the greatest boon of the new cooperative agreement. In a proper climate that encourages industrial growth, productivities will leap forward, and there will be an unprecedented economic revival. Under these conditions, the ugly concept of "Jap-bashing" will go the way of the horse and buggy.

Letters

Green Fairy Tales

To the Editor:

I was thrilled at the possibilities when I picked up a magazine that appeared to tie together the concepts of science, technology, economics, and politics. Imagine my dismay when I encountered your propaganda on the Green movement in West Germany. I could not understand why anyone would "attack" a political party whose four basic values are ecology, social responsibility, grass roots democracy, and nonviolence.

I perused your magazine a bit more and immediately realized why you acted the way you did. It is obvious that your best interests do not lie in a world the Greens hope for. Why do you fight so strongly against: ecological wisdom, grass roots democracy, personal and social responsibility, nonviolence, decentralization, community-based economics, postpatriarchal values, respect for diversity, global responsibility, and future focus?

As for the "terrorists" that were featured in the [Sept.-Oct. 1986 issue] perhaps you should check the ideologies of your "features." Such acts may lend a bit of credence to your publication and your "foundation."

Shannon Walden
Bozeman, Montana

The Editor Replies

You are right that our best interests "do not lie in a world the Greens hope for"—but neither do your best interests, nor those of the rest of the world's population.

Let's translate some of the Green fairy tales you cite into reality:

(1) "Nonviolence." It is the "nonviolent" Greens who bomb power lines every week in West Germany and attack nuclear plants with rocks, firebombs, and battering rams. The Green Party officially supports both violence and terrorism—against industry, especially nuclear industry, and its supporters.

(2) "Grass roots democracy" and "decentralization." This translates into "national socialism," otherwise known as fascism. In fact, leading Green politicians have openly praised the philosophy of Hitler. Green Party leader Rudolf Bahro told a party congress in Hamburg, Dec. 8, 1984, that "The Greens are rising to power in a way quite similar to the pattern of the Nazi Party." Another leading Green spokesman, Rainer Langhans, then announced "All of us want total war against the system. In this respect, we can still learn something from our brother Hitler."

Bahro, an East German emigre, describes the national socialism he envisions as feudal communities of a maximum of 3,000 people. "These communities will unify themselves around a 'steady state' mode of reproduction of their material foundations. They will produce their basic needs in nutrition, clothing, housing, education, and health care largely through their own work, deciding on specialized production for barter primarily to surrounding areas. . . ."

(3) "Ecology." As the Greens define it, this return to pristine nature would necessitate killing off half the world's population, mostly in the developing sector, and would send the industrial nations back to the primitive conditions of the 17th century.

(4) "Postpatriarchal values" and "respect for diversity" translate into just what the Green Party adopted as its party platform: legalization of sex with children and glorification of homosexuality as an alternative lifestyle.

(5) "Global responsibility" can perhaps best be viewed in the context of the Soviet financial and propaganda support for what the Greens are doing in the West. Why do the Soviets encourage the antinuclear movement here in the West while they are furiously advancing their own nuclear energy program? Because they know that the Green Party program is the fastest, most thorough way to destroy the economies of the West.

Western civilization was able to lift mankind out of the caves—where life consisted of back-breaking labor just to stay alive, and where most people did not live past the age of 20—to the point where man was free to develop his intellectual powers and creativity. The Greens oppose the Judeo-Chris-

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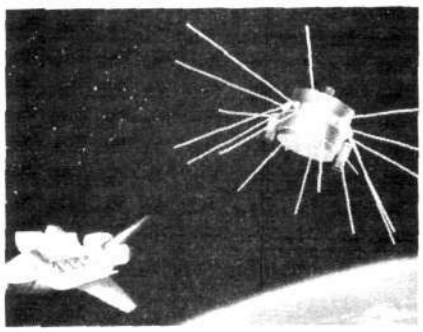
News Briefs



SDI BUDGET CUTS

SDI area	FY 1987 $ (millions) 1986/1987	Spending change
Directed energy	$803	−5%
Kinetic energy	$740	+23%

Narrowing the frontier SDI technologies with the budget axe.

FUNDING FOR SDI DIRECTED ENERGY WEAPONS CUT SHARPLY

The Strategic Defense Initiative Organization (SDIO) announced that funding for directed energy weapons next year will be half of what the agency planned, now that it has distributed the $1.6 billion cut mandated by Congress. SDIO will spend only $803 million for directed energy weapons, 5 percent lower than last year's spending. Funding for directed energy weapons is the only SDI technology area that does not increase over 1986 levels. Funding for kinetic energy weapons increases 23 percent to $740 million, while funding for systems, concepts, and battle management research increases 69 percent to $384 million.

FREE ELECTRON LASER (FEL) PROGRAM IN TROUBLE

Researchers developing free electron lasers report that a serious budgetary crisis may jeopardize the entire Strategic Defense Initiative effort. Congressional budget cuts have led to a situation where funding is now concentrated on development of a single technological approach to the FEL, based on the linear induction accelerator developed at Lawrence Livermore National Laboratory, while funding for parallel programs based on radio frequency linear accelerators have been cut back. Reportedly, funds for the White Sands rf-linac project have been cut by more than half for fiscal year 1987, from $350 million to $158 million. It is the rf-linac-based FELs, not the Livermore devices, that have demonstrated the capability to generate high power laser radiation at the short wavelengths required by the SDI mission.

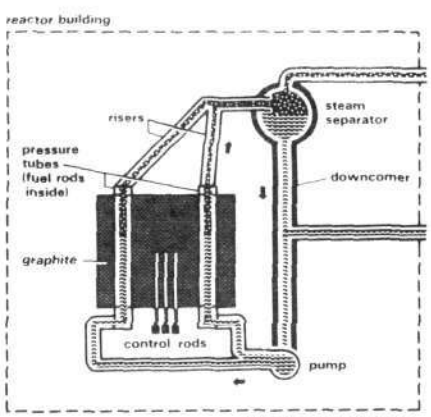
This technological narrowing comes on top of the cuts SDI director Lt.-Gen. James Abrahamson announced in November 1985, when he said that the program would accelerate only the free electron laser toward prototype development, although the initial SDI goal was to develop ultraviolet and chemical lasers as well.

'THE SOVIETS HAVE A MONOPOLY ON DEFENSE,' SAYS TELLER

"Today, the Soviets have a monopoly on defense and they intend to keep it. We have done practically nothing about civil defense," Dr. Edward Teller said in a California speech Nov. 24. Teller said that the problem with the Strategic Defense Initiative is that U.S.-deployed defensive space weapons are vulnerable. The Soviets have worked for the past 10 years perfecting laser weapons and now have a laser capable of shooting 1,000 miles without its beam spreading more than 5 feet, he said.

POLICE CONFIRM THAT SANDOZ CHEMICAL ACCIDENT WAS SABOTAGE

Swiss police confirmed Nov. 20 that the much publicized industrial accident at the Sandoz chemical plant in Basel in early November was definitely a case of sabotage. An incendiary bomb, police said, was responsible for the release of 30 tons of mercury, pesticides, and other dangerous pollutants into the waters of the Rhine River. Sabotage is suspected as the cause of another five accidents at chemical plants in West Germany during November. In the West German state of Bavaria, the government distributed 1 million leaflets Dec. 1, calling on citizens to help identify and arrest the environmentalist terrorists who are sabotaging power lines, trains, nuclear plants, and roads.



Atomic Industrial Forum

The Chernobyl reactor, a pressure-tube light water graphite-moderated reactor, had no containment building of the sort required in Western reactors.

WESTERN-STYLE CONTAINMENT COULD HAVE PREVENTED CHERNOBYL

"If the [Chernobyl plant] design had included a large containment structure, typical of Western light water reactors, our analysis shows that it could have prevented this release" of radioactivity, John Taylor, vice president of the Electric Power Research Institute, told a Washington, D.C. meeting of the American Nuclear Society and the Atomic Industrial Forum Nov. 18. The EPRI study is a preliminary evaluation of the April 1986 accident at the Chernobyl plant.

FEF'S HENKE SPEAKS AT OPENING CEREMONY OF JAPANESE SPACE CENTER

FEF's research director Uwe Henke von Parpart was among the speakers Nov. 21 at the opening of the Tokai Space Research Center in Kiyusho, Japan, the site

for Japan's new satellite and remote sensing center. The $40 million research center features an assembly of large antenna disks and sophisticated processing capability that will allow it to track satellites passing within a 3,000-mile radius of Japan. In addition to its military role, the center will compile data from Landsat satellites in order to create a global picture of the Earth's biosphere. Henke noted that this will enable scientists internationally to fully understand the widespread effects of the deforestation of the Amazon River Basin jungles and the rain forests of Sumatra and Borneo in Java. Top Japanese officials as well as scientists from NASA and Asian countries attended the ceremony.

Stuart K. Lewis

Uwe Henke: The Kra Canal and the industrial zone around it will boost the economy of the region.

FEF RESEARCH DIRECTOR TESTIFIES BEFORE THAI PARLIAMENT

Uwe Henke von Parpart testified before a special Thailand parliamentary committee in Bangkok Dec. 4 on the economic and financial feasibility of the Kra Canal project. The committee is expected to call for a full government feasibility study of the canal, and plans are under way to organize the financing for the canal. A Thai consortium is expected to own 51 percent of the canal, with 39 percent held by other investors from the Asian region and 10 percent held by investors outside of Asia.

NASA ANNOUNCES USE OF SATELLITES IN FIGHT AGAINST MALARIA

NASA researchers announced Dec. 2 that the space agency will use satellites to check on the environmental conditions that breed mosquitoes carrying malaria so that ground teams can move in quickly with pesticides and other measures to stop the mosquito breeding. The first phase of the project will aim to prove that mosquito breeding can be predicted by remote sensing. By the end of 1987, NASA researchers hope to have a remote sensing model that can be perfected in the tropics with studies of cloud covers and water vapor.

LIBYA'S QADDAFI ASSERTS SUPPORT FOR WEST GERMAN GREEN PARTY

"I support the Green Party in West Germany without any reservation. In the future we will have a common Green movement all over the world," Libyan dictator Muammar Qaddafi told the West German weekly magazine *Die Zeit* Nov. 28. "I view this movement as an expression of our ideas," he said.

MOONIE SCIENCE MEETING CALLS FOR DEPOPULATION OF AFRICA

Alexander King, founder of the Malthusian Club of Rome, opened Rev. Sun Myung Moon's Unification Church science conference in Washington, D.C., Nov. 27 with a call to control population growth in Africa. "All its religions must be changed that resist family planning or birth control in order to tackle the continent's main problem: over procreation," King said. The so-called International Conference for the Unification of the Sciences also promoted the theory of "entropy as a unifying concept," arguing that scientific progress violates natural law because it speeds up the dissipation of energy. Good science and good economics, the Moonie scientists claim, therefore seek to slow entropy by slowing growth.

LOUSEWORT LAURELS TO NATIONAL WILDLIFE FEDERATION, IDAHO

This issue's Louswort Laurels award is shared by the National Wildlife Federation and the state of Idaho for their court action Nov. 26 to block a Bonneville Power Administration plan to increase its sale of surplus hydroelectric power to California on the grounds that it would "be an adverse impact" on Idaho's salmon and steelhead trout. The Wildlife Federation said that increased transmission capacity could threaten Columbia River fishery by diminishing river flows that are needed to aid the migration of young fish to the ocean. Bonneville's environmental impact study showed that overall "increase in mean survival for anadromous fish [those that swim up rivers to spawn] would be far less (generally by a factor of 10) than survival ranges due to year-to-year changes in water conditions." In addition, Bonneville said, its new bypass systems and spill programs "may substantially improve fish survival."

Letters

Continued from page 3

tian ethic that made this progress possible, especially the Biblical injunction to "be fruitful and multiply, dominate the Earth and subdue it."

What is our responsibility to our fellow men here on Earth? It is to make this a better world for our children and our children's children. The only way to do that is by continuing the line of progress—the scientific and technological advances that make it possible for the same amount of land to support an ever-increasing human population.

Green fairy tales are not harmless utopianism. They are *evil* ideas responsible for turning a good part of our youth into mush-heads who would blithely cause the murder of more than one-half the world population—starting with the black, brown, and yellow among us—in order to please the pagan goddess "Mother Nature" and satisfy their little infantile egos.

Our advice to you, and to others lulled by Green fairy tales, is to read the great classics—Dante, Cusa, Leibniz, Shakespeare, Schiller, Alexander Hamilton, for example—and reflect on their vision for the advancement of mankind and the responsibility of the individual to carry the human race forward, not backward.

High School Gift Subscriptions

To the Editor:

Your magazine came to my attention through an American student currently studying in Zimbabwe, and it was with great interest that I read the two copies made available to me.

I would like to enquire whether there would be any possibility of our school obtaining a subscription to your magazine. We are a large government high school of 750 students of all races. Our A-level numbers close to 150 students, of whom about half are science students. In addition to the A-level science classes we have a Science Club and a Physics Club. I feel that it would be most beneficial to our students if your magazine could be made available to them through our library.

S.J. Longley
Physics Teacher
Vainona High School, Zimbabwe

The Editor Replies

Fusion Energy Foundation supporters have generously contributed several thousand gift subscriptions to *Fusion* for high schools, colleges, and libraries. We are happy to send these subscriptions, when available, to schools that request them. The gift program was set up in memory of the Challenger astronauts in January 1986, in order to promote cultural optimism, and we would like to expand the program in 1987. For the donor, the gifts are tax deductible.

Speaker Available On SDI, Defense

To the Editor:

I have had several opportunities in the last year to talk with high school groups about subjects like SDI, our space effort, the role of defense in scientific research, and the like. Two points have become increasingly evident to me. The first is that a large percentage of today's students are uninformed and misinformed about strategic defense and strategic science. The second is that they are willing and eager to learn.

Knowing that *Fusion* is distributed to many high schools, I would like to use your letters column to make an offer. I travel regularly, and I reach many parts of the country in the course of the year. As editor of *Defense Science & Electronics*, a publication that has closely followed the controversies surrounding SDI and fully supports that program's goals, I feel I am in a position to make some modest contribution to overcoming the "understanding gap" that I see.

If any of your readers would be interested in having me spend an hour with students at their high school, have them contact me. I suspect I will only be able to fit a small number of those who would be interested into my schedule, but I will do my best to visit as many schools as I can.

Jim Martin
Editor
Defense Science & Electronics
Campbell, Calif. 95008
(408) 370-3509

The Editor Replies

The Fusion Energy Foundation

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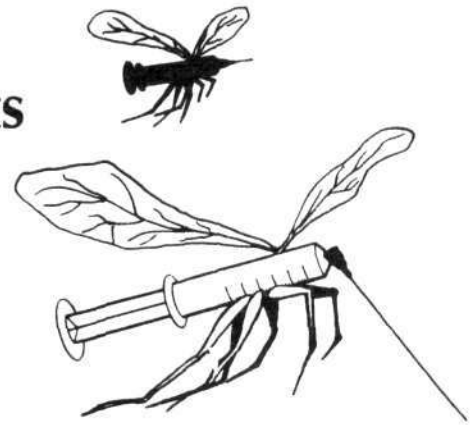
Insects and the Spread of AIDS: The Pasteur Institute Experiments



by Warren J. Hamerman

Warren Hamerman heads up the Biological Holocaust Task Force of the Executive Intelligence Review *and frequently writes and lectures on the AIDS situation.*

* * *

An extraordinary scientific paper by Professor Jean-Claude Chermann's research team at the Pasteur Institute in Paris was received by the Paris Academy of Sciences on Aug. 21, 1986. The paper was titled "Infection of Insect Cell Cultures by the HIV Virus, the Agent of AIDS, and Detection of this Virus's Presence in Insects of African Origin."

Two days later at the 14th International Congress on Cancer in Budapest, Dr. Chermann released the explosive contents of the paper, thereby instantly sending shock waves throughout the world. The paper was formally read on Aug. 30, 1986, at the Academy of Sciences and was published in their records the first week of September.[1]

The nine-scientist Pasteur Institute team—Jean-Louis Becker, Uriel Hazan, Marie-Therese Nugeyre, Francoise Rey, Bruno Spire, Francoise Barre-Sinoussi, Alain Georges, Louis Teulieres, and Jean-Claude Chermann—prepared the following abstract of their own work:

"VIROLOGY—Infection of Insect Cell Lines by HIV, Agent of AIDS, and Evidence for HIV Proviral DNA in Insects from Central Africa.

"The etiological agent of AIDS known as HIV has been shown to bind on different insect cell lines including *Drosophila*, mosquito, *Ceratitis*; and his [sic] DNA to be integrated in the cellular genome, but no expression of the viral genome was detected in those cells. None of the human lymphocytes markers is expressed at the surface of the insect cells.

"HIV proviral DNA also has been found in various insects from Central Africa (Zaire and Central African Republic), but not similar insects from the Paris area. These data suggest that insects could be a reservoir or a vector for the AIDS virus."

The 'Insect Transmission' Controversy

As readers of the Chermann paper will learn for themselves, the Pasteur Institute experiments constitute excellent and thorough scientific work, which goes to prove that good science will always tend to win out over bad science and the corrupt antiscience bureaucracy, such as that demonstrated by the Atlanta-based Centers for Disease Control (CDC) and the Geneva-based World Health Organization (WHO).

The CDC and WHO have been running a relentless campaign to suppress all scientific data and evidence which tend to show that in the poverty zones of the tropics, AIDS is carried in biting insects. Nonetheless, despite these unethical and antiscience attitudes, two U.S. doctors, Mark Whiteside and Caroline MacLeod, of the Institute for Tropical Medicine in Miami, have conducted a courageous and uncompromising campaign to expose the truth of this disease through their groundbreaking documentation of the vast number of AIDS cases outside of the so-called risk groups in Belle Glade, Fla.

As Whiteside and MacLeod show, AIDS is a tropical-based disease which spreads out of control in "high-risk areas," the collapsed poverty pockets where individuals are subject to multiple infections of insect-borne diseases in conditions of collapsed sani-

Cell strains	Origin	% of cells marked by fluorescent HIV virus	Lymphocyte markers
Drosophila melanogaster KCO	Embryo	54	Absent
Drosophila melanogaster S2	Embryo	27	Absent
Aedes aegypti	First larva stage	59	Absent
Culex pipiens	First larva stage	30	Absent
Control: T lymphocytes	Periphery blood	9.6	CD4, CD3, CD2, CD8, CD25

Source: Jean-Claude Chermann et al., "Infection of Insect Cell Cultures by the HIV Virus, the Agent of AIDS, and Detection of this Virus's Presence in Insects of African Origin."

DETECTION OF AIDS VIRUS IN INSECT CELLS

The cells described in this table were labeled with HIV-FITC. The results are expressed in percentage of fluorescent cells (after having counted at least 300 cells). The absence of T cell (lymphocyte) markers was detected on the insect cells using indirect immunofluorescence with monoclonal antibodies. T lymphocytes were used as positive controls.

tation, nonexistent insect and vermin eradication programs, poor nutrition, and overcrowded housing.

There is an irrefutable causal connection between the economic breakdown in the poverty "hellholes" of the tropics—a breakdown created by the International Monetary Fund (IMF) and World Bank that makes debt payment primary at the expense of the welfare of the population—and the outbreak and spread of deadly diseases therein.

What the Pasteur Institute Found

The Pasteur Institute experiments consisted of three phases.

(1) In the laboratory (*in vitro*) various insect cell lines, including the *Drosophila* (fruit fly) and mosquito, were infected with specially "marked" or "tagged" AIDS viruses. The viruses were "marked" with fluorescin. Six days after the infection, the genetic material of the host insect cells was inspected and found to contain significant amounts of the "marked virus" incorporated into the genetic organization of the host cell! This is the first scientific proof in the world that the AIDS virus binds onto and is incorporated into the genetic material of insect cells.

(2) The infected insect cell strains were "stressed" by various means in search for viral antigens, but none was found. This means that even though the virus bound and was incorporated into insect cells *in vitro*, the virus was "not expressed." The Pasteur scientists hypothesize that "the replication of the HIV virus is blocked by an undetermined intracellular mechanism which is specific to insect cells."

(3) The French scientists then took different types of captured insects from Zaire and the Central African Republic to see if these insects, caught randomly, already had the AIDS virus incorporated into their genome. The insects were analyzed with state-of-the-art "DNA probes." The probes make "cuts" into the genetic map of the captured insects and the map can then be read by the pattern of the genetic information on either side of each "cut." In the case of the tsetse flies, black beetles, and lion ants from Zaire, and the ticks from cattle in the slaughterhouses of Bangui, the telltale features of the AIDS virus were definitely already incorporated into the host insects' genetic material.

Warren Hamerman

The Pasteur Institute in Paris, where the Chermann team carried out its research. The bust of the great French scientist Louis Pasteur honors a champion of biological research and public health.

These findings are the impeccable scientific work standing behind the extremely bold statements that the nine French scientists make in their "Conclusion":

"The demonstration that insect cells, which are deprived of any lymphocyte-type superficial marker, can fix the HIV virus, allows [us] to state that the CD4 molecule is not the only one which is able to absorb this virus. Furthermore, the fact that insect cells, which have integrated the HIV provirus in their genotype, express no viral activity suggests the presence of intracellular factor(s) which is (are) able to regulate the replication of the virus.

"Finally, the presence of sequences homologous to the HIV virus in the genotype of insects captured in Zaire or in the Central African Republic, an endemic zone for the virus, *reinforces the idea of the possibility of AIDS transmission through this route and of the constitution of a natural reservoir for the virus, although the epidemiological data do not confirm this thesis* [emphasis added]."

Suppression of Data

Why don't the "epidemiologic data" fit the scientific data? The reason is because the CDC and WHO have deliberately suppressed and thrown out all data that did not fit their predetermined categories of restricted "risk groups"!

The "Conclusion" of the Pasteur Institute team speaks for itself, as to what has, and what has not, been proven. Their experiment will be replicated for verification and, when that is done, the antiscience leaders running the CDC and WHO will fall by the wayside.

In fact, the Pasteur Institute team presents a detailed description of the experiments in two sections: "Equipment and Methods," and "Results and Comments."

Here are excerpts from the Pasteur Institute team's own comments of their work in the formal paper:

"*1. Presence of a receptor for the HIV virus at the surface of insect cells.* Some of the mosquito and *Drosophila* cell strains [lines] fix the fluorescent virus, as is indicated by the table. Indeed, in the presence of HIV-FITC, a high ratio of them are fluorescent, which demonstrates the absorption of the virus at the surface of cells, and therefore the existence of the HIV receptor. We have verified that insect cells do not possess at their surface the classical lymphocyte antigens. . . .

"*2. Infection of insect cell strains with the HIV virus.* The cell strain of *Kco Drosophila* can be infected with the HIV virus, as is shown. . . . No signal can be detected by probing the DNA

of noninfected reference cells. The presence of HIV provirus in the genome of the *Kco Drosophila* strain is confirmed. . . .

"3. Absence of HIV virus expression in the insect cell strains. There is no virus production: No reverse transcriptase activity could be detected in the supernatant of cultures concentrated by ultracentrifugation; attempts to unmask some virus by halogenized pyrimidin (IUDR) either alone or combined with hormones such as hydroxycortison and Ecdysteron (the hormone of insect sloughing) remained without effects.

"It has not been possible to detect viral antigens in the cells of infected *Drosophila* by using techniques of immunofluorescence and of radioimmunoprecipitation of cell extracts marked with 35 S-cystein and sera of patients having AIDS. Similarly, no viral RNA can be detected in the infected cells of *Drosophila*. All these results show that the replication of the HIV virus is blocked by an undetermined intracellular mechanism which is specific to insect cells.

"4. Presence of DNA sequences homologous to those of the HIV virus in the genome of insects captured in Africa. The above described results have led us to ask questions about the possibility of finding, in the endemic zones, insects carrying the genomic sequences homologous to those of the HIV virus and evidencing their presence. Insects of various species have been captured in the Paris region. No positive signal of hybridation with the used probes could be detected by targeting DNA from insects from the Paris region.

"Among the insects coming from Zaire (mosquitoes, ants, flies, tsetse flies, bedbugs, bees, black beetles, and lion ants), only the DNA of tsetse flies, of black beetles and of lion ants possessed sequences homologous to the HIV virus's DNA. . . . From the DNA extracted from ticks, bedbugs and mosquitoes captured in Bangui, we have obtained a hybridation signal only with the DNA of ticks captured on cattle remains in the Bangui slaughterhouses. The DNA of insects presenting a hybridation signal with the 'dots-blots' method has been digested by various restriction enzymes and analyzed by 'Southern-blots.' The hybridation profiles obtained in preliminary results not reported here are different from those previously observed from various already studied isolates of the HIV virus."

More Evidence

The release of the Chermann team's experiments came as other evidence continued to mount indicating that AIDS is linked to insects in poverty-stricken tropical areas.

- In July 1986, Drs. Mark Whiteside and Caroline MacLeod released data on "other Belle Glades" in Florida. They reported another cluster of AIDS cases in a poor black section of Delray Beach, an otherwise luxury resort 30 miles southeast of Belle Glade. They reported 18 cases of AIDS among impoverished people with no other identifiable risk in a 30-square-block section of Delray Beach. They also indicated a similar pattern in two other nearby towns—South Bay and Pahokee.
- In an interview July 28 with the Italian daily *La Stampa*, Prof. Giorgio Leigheb, a dermatologist with an expertise in entomology at the Novara Hospital (30 miles west of Milan), revealed that four people at the hospital who died recently of AIDS were neither homosexuals, drug addicts, nor hemophiliacs, but were likely infected by the many mosquitoes infesting this rice-producing area in northern Italy.
- A letter from several South African scientists was published in the July 5, 1986 issue of the British medical journal *The Lancet* documenting that they had isolated the AIDS virus (HIV) from common bedbugs in their laboratory one hour after they were fed AIDS-infected blood. Doctors S.F. Lyons, P.G. Jupp, and B.D. Schoub from the Department of Virology, University of Witwatersrand, Johannesburg, wrote the following:

"The survival of HIV for one hour in *C. lectularius* [the common bedbug] following the feeding on a blood-virus mixture suggests that mechanical transmission of the virus between human beings could be carried out by bedbugs."

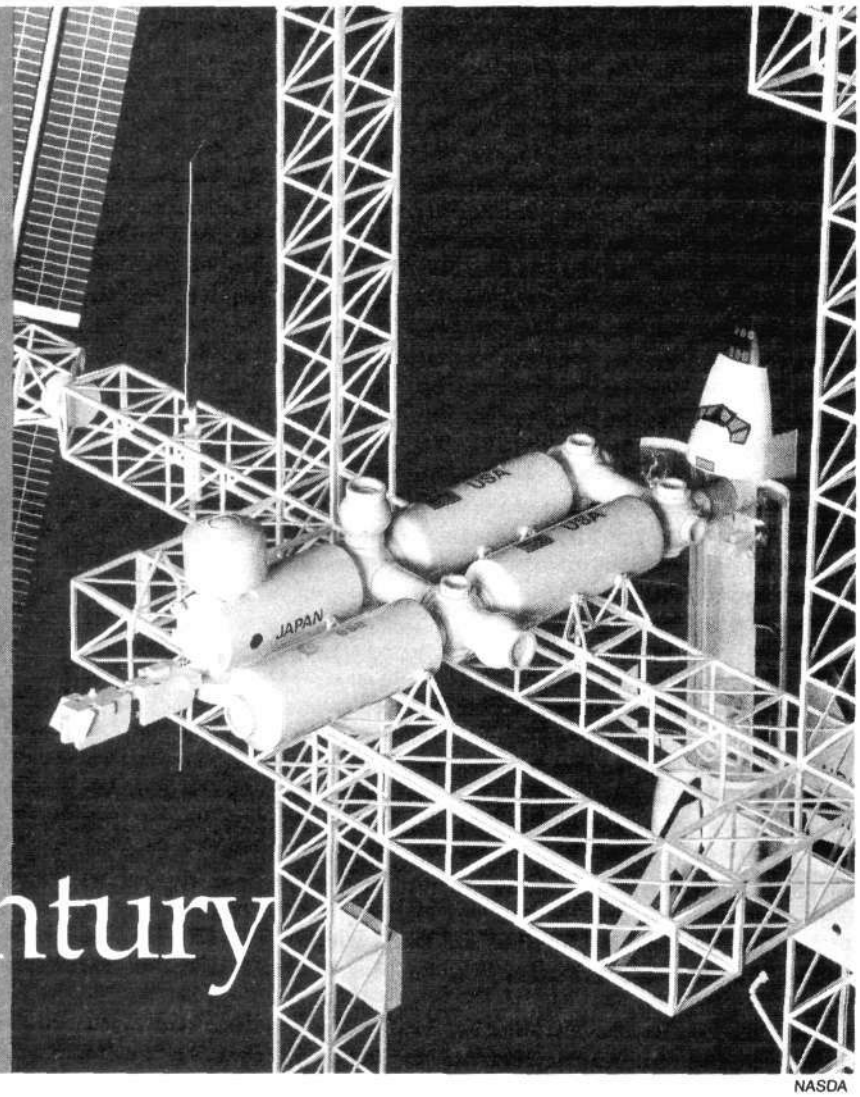
Mechanical transmission depends on an insect being infected while feeding on an infected host, and then moving to a susceptible host to complete

Continued on page 62

Japan's space program, the world's third largest, is preparing for a leap into space colonization and space industrialization in the next century.

Japan: Space Power of the 21st Century

by Marsha Freeman



NASDA

Very quietly, and somewhat out of the public eye, the Japanese have been building the third largest space program in the world. Japan is spending more money per year on space than the dozen-member European Space Agency, and is behind only the United States and Soviet Union in the commitment of resources to develop and explore space.

Because the Japanese joined the international space community more than a decade later than the two superpowers, they had to adopt a "catch-up" strategy, and they made the difficult choice of using rocket and satellite technology from the United States to save time. The Space Shuttle Challenger accident on Jan. 28, 1986, and the current two-year standdown of the Shuttle program, therefore put the space program of Japan into a state of uncertainty and reevaluation. The nations of Western Europe and Japan have depended upon the Shuttle program to provide them with a launch capability for large payloads and, more important, with access to the only manned space program in the free world. The Japanese have been developing and launching their own rocket systems for a number of years, and have larger vehicles already under development. However, if Japan is to pull out ahead and tackle the frontier, it must rely less on the American manned space and interplanetary programs.

The Japanese plan to add a laboratory module, JEM, to the U.S. space station in the 1990s. The European Space Agency (ESA) will also contribute a laboratory module. Both U.S. modules are planned for living and logistics facilities. Here is one artist's concept of the fully deployed space station. The Shuttle is docked at right.

The Japanese space program had quite modest beginnings. In 1955, the Institute of Space and Astronautical Sciences (ISAS), which was then a part of the University of Tokyo, participated in the scientific research conducted for the International Geophysical Year. Japan launched the tiny "pencil" rocket, a suborbital sounding rocket that stood 9 inches tall and weighed 6.7 ounces!

ISAS, which is responsible for Japan's space science and exploration activity, upgraded the pencil rocket and then in 1963 began development of the M (Mu) series of solid-fueled rockets for suborbital scientific experiments, which attained an altitude of 850 kilometers. In 1970, ISAS launched

the first Japanese satellite using its solid-fueled L-4S-5 rocket vehicle. It was the first satellite launched in Asia, beating the Chinese by about two months, and it made Japan the fourth nation in the world to launch a satellite. Unlike the United States and the Soviet Union, however, Japan did it with a rocket that had not first been developed as an intercontinental ballistic missile.

In 1969, Japan made the decision to accelerate the development of both larger launch systems and new satellite technologies, in order to be able to orbit space applications satellites. For this purpose, it established the National Space Development Agency of Japan (NASDA). NASDA's primary focus is to develop the practical applications of space technology in communications, weather, remote sensing, and direct broadcast.

With the establishment of NASDA and the decision to develop rocket technology, Japanese policymakers had to make a fundamental decision. The United States had already landed men on the Moon, and Japan was at least 15 years behind other industrialized nations in space. Rather than begin from scratch and build their own large rockets, the Japanese decided to license the U.S. Delta rocket technology and get a head start. Japanese satellite manufacturers bought either entire satellites or crucial components from the United States.

The first NASDA rockets were the N-1 and N-2, which are capable of placing 286 and 770 pounds of payload into geosynchronous orbit, respectively. On Feb. 23, 1977, the first Japanese satellite was put into geosynchronous orbit by a Japanese N-1, and Japan became the third nation to launch a satellite into this orbit with its own rocket. The second-generation N-II began operations in 1981, but is still 50 percent U.S. technology. The N series of rockets has two stages using liquid petroleum-based fuels, and a solid-fueled third stage. The rocket series also uses solid rocket boosters.

Reliance on the United States for the initial space technology certainly saved years of development time, but it also had it drawbacks. For example, the license agreement signed with the U.S. McDonnell Douglas Company prohibited Japan from launching anyone else's satellites with their N rockets. In addition, the Japanese suffered failures in two communications satellites in 1979 and 1980, caused by malfunctions of U.S. launcher technology that the Japanese had no control over. Japanese space officials are not even allowed to disassemble and check the systems before they fly, and have to launch without confirmation checks. There have also been specific areas where the United States has refused to transfer technology, such as in inertial guidance systems for launchers. This forced the Japanese to design their own system, which is now used on the N-II rocket.

The use of the U.S. Delta technology has also limited Japan to very brief launch seasons per year, January-February and August-September, launching only four rockets annually. This is because the large Japanese fishing lobby is concerned that falling solid rocket boosters, which are jettisoned over the ocean, will adversely affect fishing around the island. The Japanese-designed H-II rocket, however, will not have the same problem, because the rocket boosters will fall off more than 300 miles out to sea, well beyond the current 120-mile line established by the fishermen.

Reshaping Japan's Space Policy

In an interview in March 1985 in *Aerospace America*, Nobuyuki Arino, managing director of TRW Overseas in Tokyo, gave another example of the limitations of reliance on U.S. technology only. "At the time that Toshiba was developing the broadcast satellite, one of the key technologies that Japan wanted was a three-axis attitude-control system, but due to governmental constraints General Electric could not transfer the technology to manufacture a suitable one, so they delivered a black box." The Japanese could use it, but they could not look inside it.

Arino also remarked: "I think that phase one of U.S.-Japan space relations has been completed. Japan's student role in learning about advanced technology is over. . . . In the final analysis, Japan will develop its own technology. It is just a matter of time. So rather than let Japan become isolated or a bitter long-range competitor, why not build cooperation so that we do not go in opposite directions in the future."

Along similar lines were the remarks of Dr. Hiroshi Uda, the director of NASDA's Tsukuba Space Center, in the August-September 1982 issue of *Space World* magazine. Uda commented on the fear in Japan of failing and apparently "wasting time" by doing the research themselves. "We should have many experiences of successful and unsuccessful events through our space projects. Unsuccessful events can give us new ideas for next-generation successes. But our space projects receive much assistance from the United States and we have no unsuccessful events except Ayame 1 and 2. So, from the investment viewpoint our space projects are very effective. But, basically, we are losing the chance to get our own technologies and testing, and ideas for the future."

Uda did not hesitate to add that if the Japanese are to both catch up to other world space programs and develop space technologies themselves, the space budget in Japan will have to grow dramatically. Since the government funding for space is tied to the increase of the GNP in Japan, the slowed pace of recent economic growth has slowed the increases in funding for space.

Since Uda's interview in 1982, however, space policy in Japan has developed along with the technology. By the early 1980s, corporations in Japan interested in launching communications and other commercial satellites gave the Japanese government a choice—either accelerate the development of larger Japanese H-II rocket, or the companies would go to the Space Shuttle or Ariane to get their satellites into orbit.

The government responded by accelerating the development schedule for the first Japanese-engineered and -built rocket, the H-II. This $800 million-plus program, scheduled for a first launch in about 1992, will give industry a commercial-sized launch capability.

In 1982, the Science and Technology Agency of Japan, which oversees NASDA, and the Space Development Council, which directly advises the Prime Minister, began a review of the Japanese space program, and two years later

Japan's Frontier Space Science

The first launch of the Space Shuttle Columbia in April 1981 generated tremendous excitement in Japan. According to reports from Japanese scientists with whom I was speaking by phone the day the Columbia landed, nearly everything in the cities came to a standstill, as people rushed off the streets, into stores or other facilities with televisions, to watch this great achievement.

The success of the Space Shuttle opened up for Japan, Western Europe, Canada, and other U.S. allies, the first-ever access for their own experiments and scientists to go into space. On Sept. 1, 1983, aboard the Space Shuttle Challenger, an experiment was conducted to answer a question suggested by a high school student in Japan: "Can it snow in space?"

The Japanese newspaper *Asahi Shimbun* had sponsored a contest to design an experiment to be flown in a "Getaway Special" canister on the Shuttle, and this student's idea won. The experiment to answer the question was an apparatus designed by Nippon Electric to produce the first artificial snow in space. Many of the snowflakes were not six-pointed, but round, and provided important insight for scientists interested in producing crystals in microgravity.

In artificial snow experiments done on Earth, multifaceted crystals, nearly spherical in shape, are formed. But these less-than-perfect snow crystals are never more than 0.1 millimeter in diameter. In the space experiment, crystals three times that size were formed.

The experiment was first flown on the maiden flight of Challenger in April 1983, but the cold of space froze the water supplied to form the snow. On the reflight Sept. 1 that year, a heater and fan remedied the problem. In two of the four runs of the experiment, the fan blew an artificial breeze through the chamber, producing hexagonal flakes. In the other two, however, when the fan was on only intermittently or not on at all, spherical snowflakes were produced in the chamber. Apparently, in undisturbed weightlessness the path of least action for snow crystals, as with all other fluids in space, is spherical.

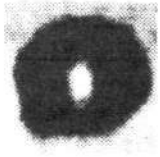
In November 1983 on the first Spacelab mission, the SEPAC particle accelerator, designed and built at ISAS in Japan, was flown aboard the Shuttle to observe the interaction of charged particles injected into the space plasma from the spacecraft, along the magnetic field line of the Earth.

Unlike the United States, where a single space agency, NASA, oversees the development of launch vehicles, applications technology, and space science, in Japan the Institute for Space and Astronautical Science (ISAS) oversees all of the space science work. Another agency, the National Space Development Agency, is responsible for the practical applications of space technology. Over its 30-year history ISAS has participated in space science research using its own small rockets, making contributions in radio astronomy, study of the aurora on Earth and plasma waves in space, solar radiation, the Earth's atmospheric structure, and other fields.

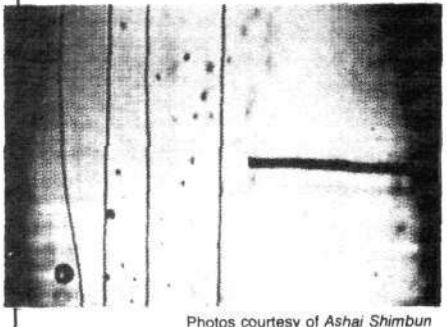
In 1985, however, the Japanese entered the field of planetary exploration for the first time, with two satellites they launched themselves, called SAKIGAKE (Pioneer), and Planet-A. The Planet-A spacecraft came within 150,000 kilometers of the coma of Halley's comet and showed a periodicity in brightness of this outer shell of the comet. Changes in the speed of the ions of the solar wind and other observations verified for scientists that indeed a comet does release heavy particles, like water molecules, from its nucleus.

ISAS has a continuing series of one scientific satellite launch per year and plans to launch ASTRO-C in 1987 to observe X-ray sources in the central core of galaxies. The MUSES satellite is planned as a lunar flyby in 1990, and Japan is also participating in a number of highly complex international space science efforts.

The decision the science institute now faces is whether it is willing to give up its policy that Japanese science missions be launched only by the small satellites ISAS builds—a policy that prohibits the possibility of doing any large-scale lunar or planetary exploration—or whether it will work with NASDA and use NASDA's larger rockets to push foward on the space frontier.



Some of the first snow crystals produced in the weightless environment of space, unlike snowflakes on Earth, were nearly spherical. Shown below is a view of the experiment at low magnification; above is a high magnification view of one snowflake. The vertical lines are rabbit hairs, used to trap the artificial snowflakes. The horizontal line is copper wire, 0.15 mm thick. The experiment was performed in a copper box that contained a heater to produce water vapor at 20 degrees Celsius, fine particles of silver iodide (which form the nuclei of snowflakes), and a blower fan. When the blower fan created an artificial breeze, hexagonal and irregularly shaped snow crystals were formed on the rabbit hairs. Two television cameras recorded the data.



Photos courtesy of *Ashai Shimbun*

the government announced its updated space policy. The "Outline of Japan's Space Development Policy" states firmly that "Japan has to develop its own technological resources so that it will be able to carry out various space development activities steadily in the future."

The policy lays out 15-year goals to "keep Japan's level of science abreast with international standards, to contribute to the intellectual progress of mankind, and to promote the development of science and its application in ways suitable to Japan." Specific goals include carrying out advancements in satellite communications; scientific satellites for astronomical observation; experiments in space in materials science and life sciences; generic satellite technologies like standardization and improved performance; launch vehicle development leading to the use of the H-II rocket; and the consolidation of space activities, including the reinforcement of national research and university work, international projects, and increased public information.

The Role of Industry

In contrast to the United States, Japanese industry plays an important role in promoting national space policy.

In 1980, the powerful Ministry for International Trade and Industry (MITI) established an advisory body for space industrial development. It estimated at that time that space will be a $4.5 billion industry for Japanese manufacturers by the mid-1990s, comparable in size to the radio and television manufacturing industries in Japan. MITI recommended that Japan's space industry "aim at the world market." In 1981, sales from space-related industry in Japan had reached $480 million, with 20 percent of that from the export of communications equipment. At the time, the head of NASDA remarked, "If we decide to save money now, our descendants may hold a grudge against us." In 1981, Japan was already spending five times as much on its space program as Great Britain.

The major corporations in Japan have formed a number of private space marketing organizations, that make the aggressive French commercial space effort pale by comparison. In February 1985, 41 companies formed the Japan Space Utilization Promotion Center, funded at 6 million yen per year and projected to be spending 60 million yen by 1988. They are now designing a space experiment data base for use by industry, and are conducting surveys of space experiments for the space station. In May 1986, the Space Technology Corporation was established by six companies and the Japan Key Technologies Center to carry out industry-funded research on materials processing in space technology. These companies will participate in experiments planned for the German D-2 and D-3 Spacelab missions on the Shuttle.

The Institute for Unmanned Space Experiment's Free Flyer was set up in April 1986 by 13 corporations to finance building an unmanned orbiting platform. The 3-ton facility will be released into space by the Shuttle, carry out experiments, and be returned by the Shuttle for ground analysis every two to three months.

As Japan's own technologies for communications and

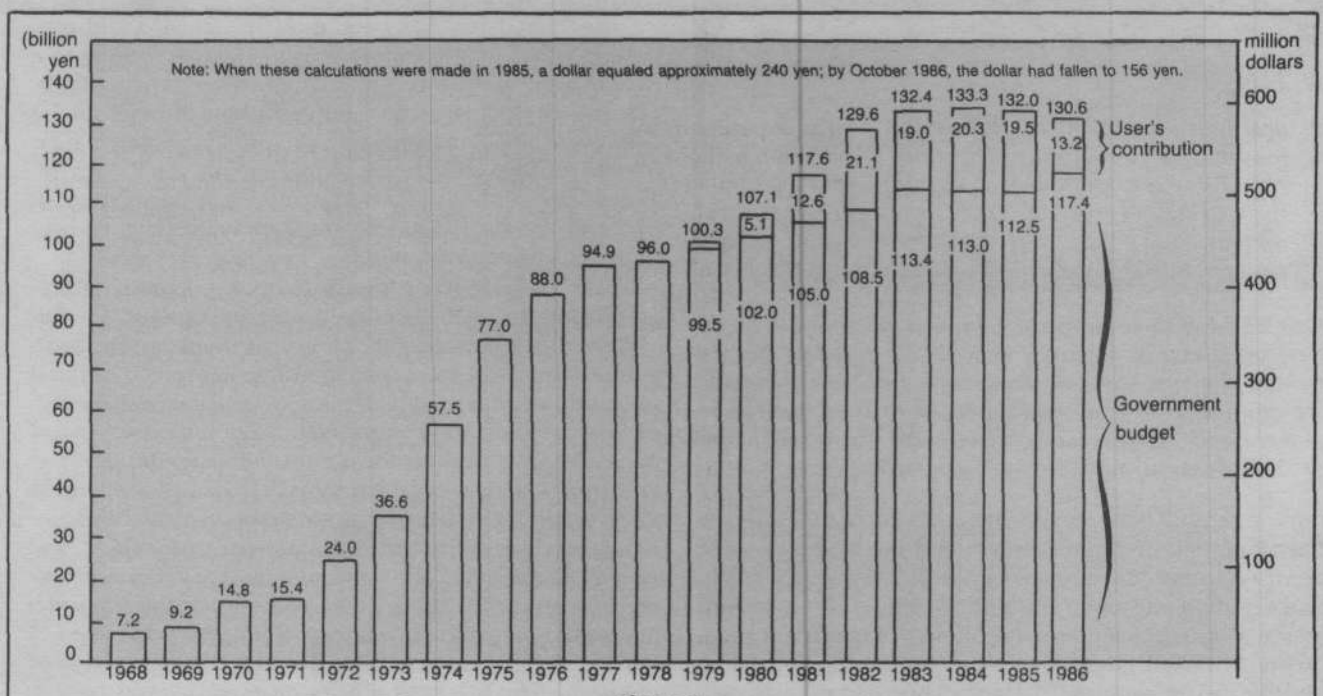


Figure 1
JAPAN'S SPACE BUDGET, 1968-1986

Government funding for space development increased steeply over the 1970s, but has recently leveled off. However, user fees from industry have increased as the government has launched more commercial satellites. By the mid-1990s, it is estimated that space will be a $4.5 billion business for Japanese manufacturers, comparable in size to the radio and television industries.

Source: NASDA

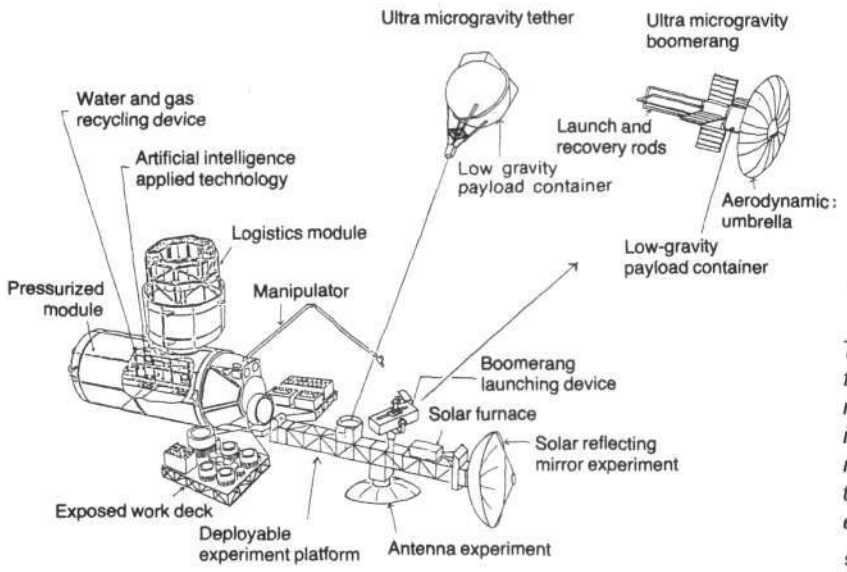


Figure 2
TECHNOLOGIES ON JAPAN'S SPACE STATION MODULE

The Japanese Experiment Module (JEM) for the U.S. space station will be a multi-billion-dollar facility. Shown here is the pressurized module for the astronauts, the exposed work deck, a logistics module to store supplies, and other technology facilities.

Source: *Science and Technology in Japan*, July-Sept. 1986, p. 31

Science and Technology in Japan

One of these three astronauts, now in training, will be the payload specialist aboard a 1990 Shuttle mission that will contain the First Materials Processing Test. The astronauts are (from left) Dr. Mamoru Mohir, professor of nuclear engineering; Dr. Chiaki Naito, a cardiovascular surgeon; and Dr. Takao Doi, an expert in hydrodynamics.

remote sensing have moved into operational use, industry has taken over the management and marketing of these services. In the future, Japan's participation in the NASA space station will open the door to the creation of new materials in space and new technologies important to industry. MITI itself is now involved in space station planning, and one can only assume that Japan's upcoming H-II rocket, and its commercial space technology, will challenge the rest of the spacefaring nations in the world marketplace.

The Importance of Space For Japan

There is a very practical reason why Japan has focused a significant effort on independently developing space capabilities. It is a nation of islands, with more than half a million people who are in such remote areas that they cannot receive conventional television transmission. In addition, Earth and ocean remote sensing from space provides the most efficient means for looking at its dispersed land and the surrounding ocean.

Since 1979, Japan has been directly receiving and processing U.S. Landsat remote sensing data, according to a NASDA agreement with NASA. The Remote Sensing Technology Center of Japan distributes the data throughout the country. In 1980, Japan hosted a United Nations seminar on remote sensing, and it holds annual training courses for the 13 members of the UN Economic and Social Committee for Asia and the Pacific, in satellite communications and remote sensing data analysis.

In 1987, NASDA plans to launch the first operational Japanese remote sensing satellite, the Marine Observation Satellite, MOS-1. Japan's first domestic Earth observation satellite will observe the ocean in visible light, near infrared radiation, and microwave. The MOS-1 will measure the color, temperature, and surface features of the ocean, ocean currents, water vapor in the atmosphere, clouds, ice floes, and the generation of "red tides." It will give scientists information that will help prevent weather-related and other natural disasters, locate fishing and ocean resources, and provide surveillance of coastal regions. It has been estimated that using the MOS-1 data will reduce the total fuel consumed by offshore Japanese fishing fleets between 10 and 20 percent, as the satellite can map the distribution of chlorophyll for fish food and improve weather watches.

In land remote sensing, the Japanese will orbit the Earth Resources Satellite, ERS-1, in about 1990. It will be their heaviest-yet satellite, weighing in at over 3,000 pounds. ERS-1 will include active sensing technology using a synthetic aperture radar, which will use microwaves bounced off the land to determine the fine relief of the surface and

provide all-weather, day-and-night coverage. ERS-1 has been jointly developed with MITI, and in 1984, Japan started preparing the establishment of the Technology Research Association of the Resource Remote Sensing System under MITI, to promote the use of the data. The group has 13 members, including the heads of oil companies, and it is directed by the president of Mitsubishi Electric Corporation.

Meteorological observation for weather forecasting is especially important from space in the Pacific, where there are few other observation points available for large stretches of ocean. So far, Japan has launched three meteorological satellites, which are used for daily forecasts and typhoon warnings. The weather data received are used throughout Asia/Pacific countries, including Australia. In 1989, a fourth satellite will be launched, to replace an older one and incorporate more sophisticated sensing technology.

The first domestic communications satellite launched in Japan was at the end of 1977. In 1983, this system was upgraded with the launch of two more satellites, for communications in an emergency and between the mainland and remote islands. As has been the case in nearly every area, the Japanese may not have launched the first communications satellite in the world, but they have deployed the latest technology as they piggybacked the United States in overall launch systems and satellite technology.

The Communications Satellite-1 (CS-1), launched in 1977, was the world's first k-band frequency system. This operates in the billions of hertz range, and though the U.S. began doing research into using this higher frequency band for communications during the Nixon administration, the research program has been canceled and restarted three times since then. CS-3, scheduled to be launched in 1988, will be the world's first to use more efficient gallium arsenide solar cells as the primary power source.

In 1982, Nippon Electric Company completed a plant in Yokahama for the mass production of satellites. The plant can produce four major satellites in the 1-ton class simultaneously, and will build the MOS-1 ocean satellite as its first one.

Direct broadcast communication technology is very important in Japan, where people in cities with tall buildings, and in remote or mountainous areas, cannot receive regular television signals. The satellite's signal is received by an individual antenna dish. In April 1978, Japan orbited the world's first direct broadcast satellite and two more went up in 1984 and earlier this year.

Putting Man Into Space

The First Materials Processing Test (FMPT), originally scheduled for this year, will be flown aboard the U.S. Shuttle in about 1990. This facility contains 34 experiments, of which 22 are in materials processing and the rest are in the life sciences. A Japanese payload specialist will be aboard this mission, and out of the 533 applicants, three are now undergoing training and one will fly on the mission.

The materials processing test will make use of acoustic levitation in a furnace, where material is processed while suspended by sound waves. In another experiment, ultrafine particles will be produced from a vaporized metal in a rare gas atmosphere, to study the way nuclear formation of heavy metals takes place. Scientists believe this process of the formation of metals is closely related to the formation of planets. In the life sciences, one experiment will examine the effect of microgravity on the differentiation of bone cells and their regulatory mechanisms in chicken eggs. These results will provide important data for scientists studying the effect of the lack of gravity on animal reproduction in space.

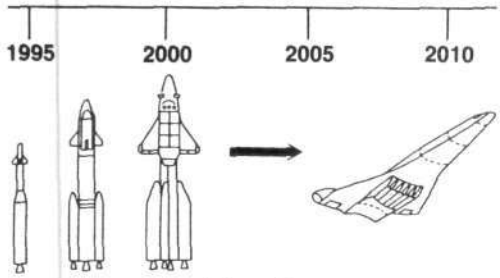


Figure 3
JAPANESE CONCEPTS OF SPACE SHUTTLE DEVELOPMENT

The timeline shows the Japanese plan to develop a small space shuttle, which would be launched on the H-II rocket. Japanese designers have already begun preliminary testing of small reusable space shuttle models. Plans also include joining with the United States to develop an aerospace plane by the year 2010.

Source: *Science and Technology in Japan*, July-Sept. 1986, p. 28

The three Japanese payload specialists, all of whom are scientists, are now in training at the Tsukuba Science Center; they will transfer to the NASA Johnson Space Center for training as their flight approaches. The Japanese plan to make full use of the Space Shuttle, as it is available, but the real thrust Japan will take into the manned space program, will be with the mid-1990s U.S. space station.

When President Reagan announced the space station initiative in 1984, he requested NASA Administrator James Beggs to offer major participation in the program to the other spacefaring nations of the free world. Though the final design of the station is still being determined, both the European Space Agency and Japan have made a commitment to provide a laboratory module for the facility. The JEM, or Japanese Experiment Module, will be built by Japanese industry, and will give enormous access for Japanese science and industry to the new environment of space.

JEM is an ambitious facility, which includes not only the pressurized module for experiments, but also an attached logistics module for extra supplies and samples and an open or exposed facility to test new materials, and perhaps be used for astronomy experiments. The module will be a multi-billion-dollar investment, and the largest international space venture yet for Japan.

According to Dr. Tatsuzo Obayashi, who heads the special committee for the space station under the Space Activities Commission, the importance of the project is that "Japan will be assuming responsibility in an important global project, it will foster new scientific skills, there will be an

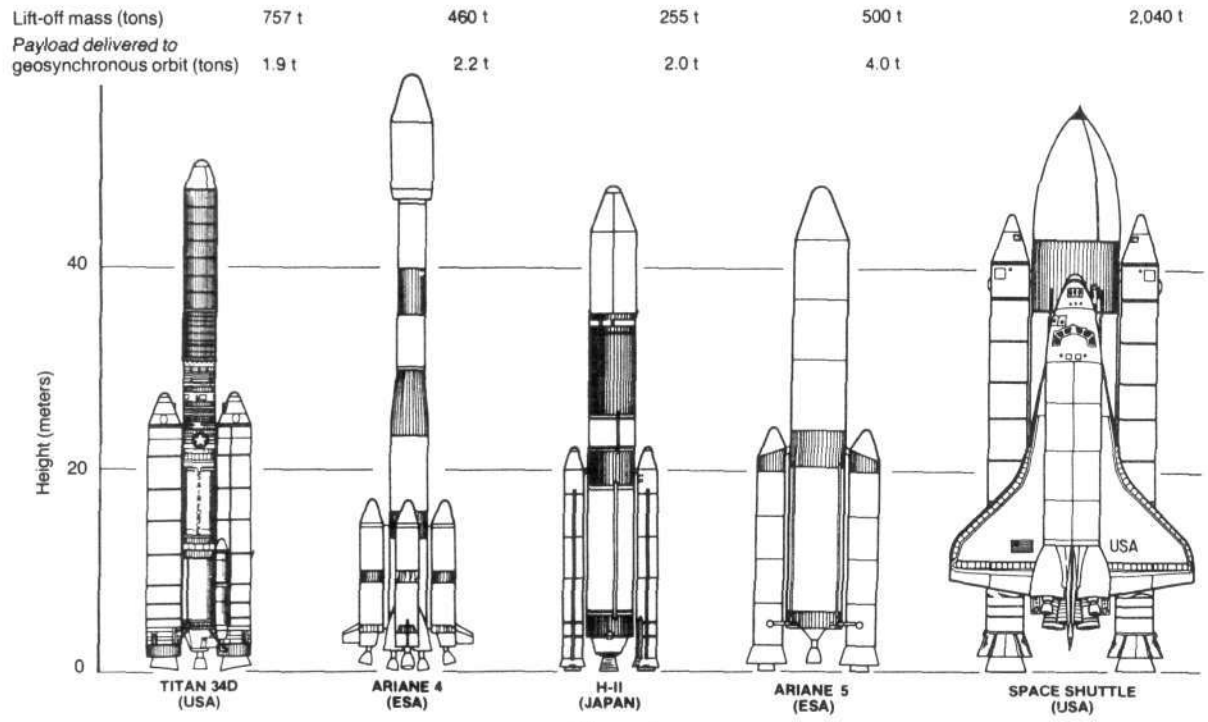


Figure 4
HOW JAPAN'S H-II ROCKET COMPARES TO OTHER ROCKETS

Japan's launch vehicle for the 1990s, the H-II, will be comparable in capacity to the Ariane 4, which is being used now by the European Space Agency. The first rocket designed and built by Japanese engineers, the H-II will use liquid hydrogen fuel and solid rocket boosters, as does the U.S. Space Shuttle.

Source: *Science and Technology in Japan*, July-Sept. 1986, p. 7.

expansion of space science experiments and probes, it will serve as a stimulus to education and economic development, and will pave the way for the establishment of space colonies in the 21st century."

In the Next Century

The Japanese fully plan to join the U.S. and Europe in manned space operation of their own in the next century. The H-II rocket, operational in the early part of the next decade, will give Japan the ability to deliver about 18,000 pounds of payload to low-Earth orbit and about 6,000 pounds to geosynchronous orbit. But it can also take about the same 6,000 pounds to the Moon, about 4,000 pounds to Venus or Mars, and 1,000 pounds to orbit Jupiter. The second stage of the H-II will have larger engines using liquid hydrogen, which will be capable of restarting once in orbit. Two large solid rocket boosters will be used to augment the first-stage liquid hydrogen engines, similar to the Space Shuttle configuration.

The Japanese are building a new launch pad at the Tanegashima Space Center and spending about 200 billion yen per year for the H-II development. In addition to being capable of taking small payloads outside of Earth orbit, the H-II could be used as a transport vehicle to the space station, similar to the capabilities of the European Ariane V, which will also be deployed in the early 1990s.

Again like the Ariane V, on top of the H-II could also sit a small reusable space shuttle or space plane. Japanese engineers have been working on space shuttle-type technology development since 1978, at the National Aerospace Laboratory. This has included research in new composite materials, hypersonic wind tunnel testing of vehicle designs, reusable rocket engines, ultrahigh-temperature-resistant materials, and optimum shape design.

According to the summer 1986 issue of the Japan's *Science and Technology in Japan* magazine, which is published by the Science and Technology Agency, the Advanced Space Shuttle Transportation System program in Japan is conducting research in aerodynamics, heat protection, navigation and guidance control, and air-breathing engine technologies.

The same issue reveals an even more interesting project. "If a nonpermanently manned 'self-reproductive' system is set up on the Moon, or on a planet," the magazine states, "the infrastructure is bound to grow, and it will become possible to take advantage of its economic potential in the near future. When this happens, large investments in the Moon are expected." The article suggests that a lunar industrialization scenario might consist of delivering a miniaturized, fully automated robotic manufacturing plant that uses the materials on the Moon. "When the automated machinery has produced sufficient materials for a man-controlled infrastructure extraterrestrially, mankind will be able to emigrate into space."

The drawback is the size of automated factories already in existence on the Earth (at least, in Japan). If the machinery

were miniaturized to one-eighth its normal size, the magazine imagines, it would make it economically feasible to transport such a system to the Moon! These systems "could also be used on Mars, the Martian moons, the asteroids, or on any other heavenly body." This project could be carried out with investments on the scale of the Apollo program, the magazine posits, and "has the potential to change everyday life. . . . This field could be a path for Japan, as one of the industrially advanced countries, to make a contribution to world development."

It is clear that Japanese leaders see their nation making a major contribution to the scientific, economic, and space frontiers of the next century. The world would be a different place if policy planners in the United States looked at the future and still-unparalleled past accomplishments of the U.S. program with the same kind of optimism.

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

'The 21st Century Will Be the Development of the Moon and Mars'

Stuart K. Lewis

To prepare for lunar base construction in the 21st century, "it is important to explore the whole surface of the Moon," Dr. Nobuki Kawashima told a U.S. conference in Washington in August.

"The 21st century will be the development of the Moon and Mars. . . . Japan has already developed almost to the same level as other countries, and I think in the 1990s our country will join in these international programs," Japanese space scientist Dr. Nobuki Kawashima told a U.S. audience in August 1986.

Kawashima, a professor of physics at the Institute of Space and Astronautical Science (ISAS) in Tokyo, was a project participant in the electron beam experiment SEPAC aboard the Space Shuttle in 1983. He has authored more than 90 scientific papers, representing two decades of research, on the behavior of plasmas in magnetic fields and related research areas.

In his presentation, Kawashima explained that although "the Apollo project was very successful . . . actually the explored spots on the Moon are very small when compared with the whole surface of the Moon—it's only a local point. For 21st century lunar base construction, it is important to explore the whole surface of the Moon so that we can find where the best place will be to construct the lunar base." ISAS is considering three possible lunar exploration mission options for the middle of the next decade, he said.

The first option is a penetrator mission, which "would make seismic observations of the Moon and determine the existence of a metal core there," Kawashima said. Because the Moon has 14 days of daylight and then 14 days of night and no atmosphere, "it is very cold at night, and very hot during the day," he explained. That makes thermal control very difficult for instruments on the surface, but "the penetrator, 1 meter below the surface, would be where the temperature does not change very much."

Second, a polar orbiter would do a "global survey of the Moon and its material composition, which would also tell us about the origin of the Moon," Kawashima said. A lander would be a third lunar mission option, but for that a significantly larger launch vehicle would be required.

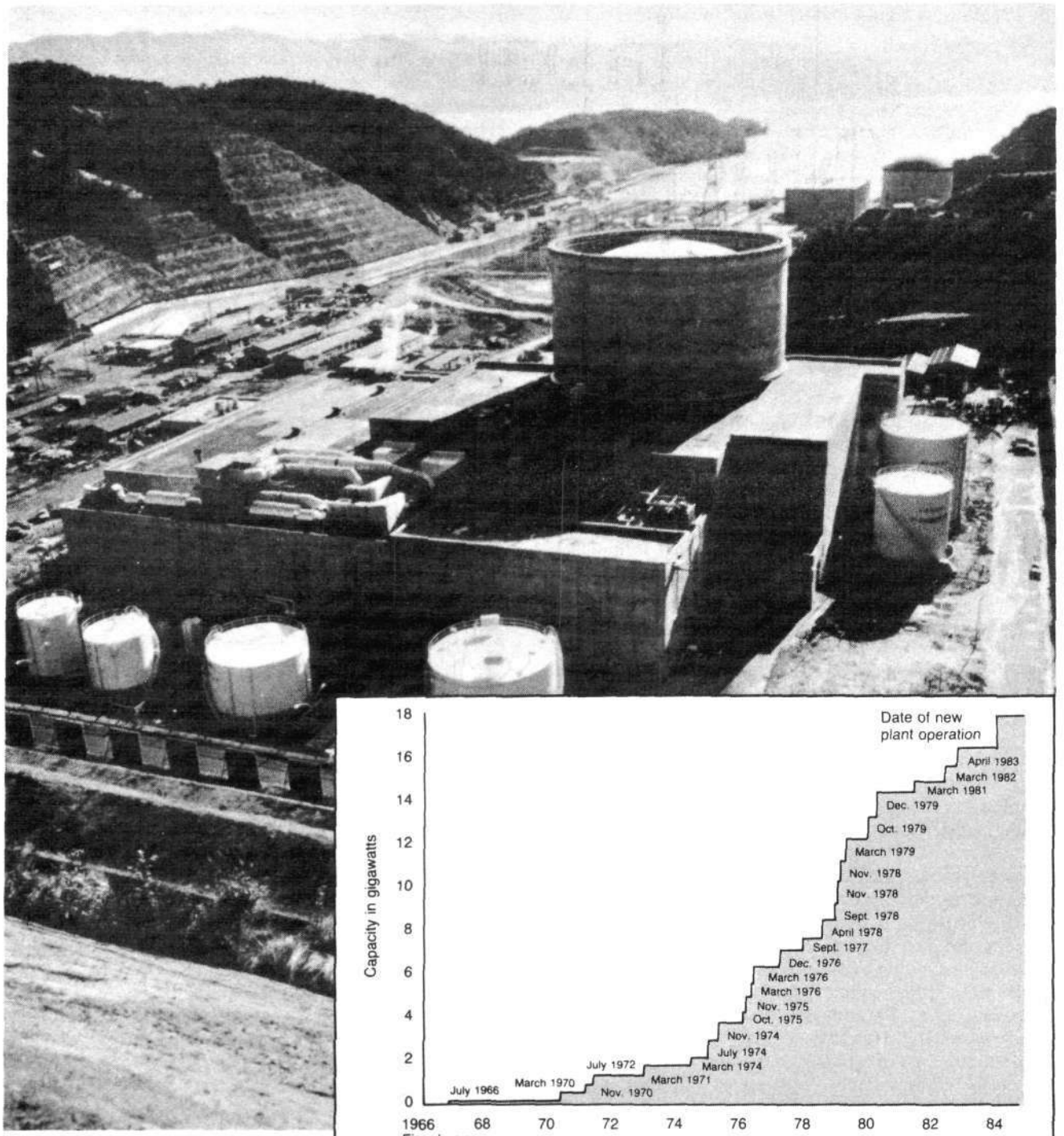
"What will be the ideal lunar mission in the mid-1990s?" Kawashima asked. In addition to the lunar polar orbiter and penetrators, a "powerful rover" would be required to "confirm the results from the lunar orbiter." All of the missions, however, he said, should be "a step to other planetary exploration." The technology would be used also for the "further planets, and other bodies in the solar system."

International Collaboration

As Kawashima explained, the first Japanese lunar mission will be conducted by ISAS in 1990. The MUSES satellite will be a lunar flyby, and will "utilize lunar gravity to kick off" and fly by the Moon. One year later, the National Space Development Agency of Japan, NASDA, which specializes in space applications and large launch vehicles, will do the first launch of a larger Japanese-designed and -built H-II rocket.

"At present," stated Kawashima quite modestly, "Japan's space development budget is only $800 million, which is very small when compared with the automobile industry and other big industries. At this moment, we cannot say that space development is an industry in Japan, but I think that in 1990, space development will become one of the industries in Japan."

However, he said, "1990s space development cannot be done by one country. The programs become bigger and bigger, so we need international collaboration." He pointed to the international effort of six spacecraft—from Japan, the Soviet Union, the European Space Agency, and the United States—which made up the Halley's Armada to observe the comet in 1986 and said that this "international collaboration was very successful."



Japan's indigenous Advanced Thermal Reactor, Fugen, uses plutonium from reprocessed spent fuel, in addition to reprocessed uranium.

Figure 1

DEVELOPMENT OF JAPAN'S NUCLEAR CAPACITY (AS OF FEBRUARY 1984)

Japan has met its ambitious nuclear schedule, putting 32 plants on-line since 1966. (Not shown are 3 more plants that went on-line in 1984 and 4 in 1985.) The capacity of each plant can be calculated by subtracting the previous year's cumulative total from the new yearly total. The first plant was a British-designed gas-cooled reactor. The others are standard light water reactors based on U.S. designs, about half being boiling water reactors and the other half pressurized water reactors.

Source: Japan Atomic Energy Commission

Japan's 'Nuclear Energy Vision'

Japan is committed to developing a full nuclear fuel cycle and making nuclear energy the main source of its power in the 21st century

by Marjorie Mazel Hecht

While most of the world's nuclear industry took to the trenches under the barrage of antinuclear propaganda and terrorism that followed the Soviet nuclear accident at Chernobyl April 26, the Japanese announced in June 1986 that nuclear energy production was expected to more than double by the year 2030, generating 58 percent of Japan's electric energy. In a report called "Nuclear Energy Vision in the 21st Century," Japan's Ministry of International Trade and Industry (MITI) reiterated Japan's commitment to make nuclear power the main source of alternative energy in the next century.

The MITI program also specifies a schedule for Japan to complete its nuclear fuel cycle, commercializing fuel reprocessing, fabrication, spent fuel management, and breeder reactors, along with an indigenously developed reactor that is a bridge between conventional light water reactors and fast breeders. Japan already has the independent capability to manufacture reactors and reactor components, and by the turn of the century, the MITI plan envisions this independence extending to the entire nuclear fuel cycle. Japan will no longer have to import uranium or turn to the United States or France for spent fuel reprocessing.

Put forward by MITI's advisory committee on energy, the ambitious nuclear program is no surprise for a country that has no indigenous fossil fuel supplies and a reliance on high-technology, energy-intensive industry. The program merely reconfirms Japan's commitment to develop the most advanced and efficient energy sources available, a commitment adopted in the 1950s. Perhaps the only element of surprise is the timing of the public announcement of a 45-year nuclear program.

The MITI plan has two tracks. The first assumes a historically very modest 2.5 percent annual rate of growth for Japan's gross national product, while the second assumes an even lower growth rate. The more optimistic plan expects to have 87 gigawatts (GW) of nuclear power capacity (3.5 times the present capacity) by the year 2010 and 137 GW (5.6 times the present capacity) by the year 2030, building a total of 122 new reactors during the next 45 years. The plan that assumes a lower growth rate expects to have 77 GW of nuclear power capacity (3.1 times the present capacity) by the year 2010 and 107 GW (4.4 times the present capacity) by the year 2030. In the latter case, 97 new nuclear reactors would be built in the next 45 years.

How does this compare with the other nuclear nations? Japan now ranks fourth among the 24 nuclear-power-generating nations (behind the United States, France, and the Soviet Union). At the end of 1985, Japan had 32 plants on line, with a total capacity of 24.52 GW, generating 26 percent of the nation's electric power. This compares to 85 units with a capacity of 68.867 GW in the United States (generating 13.5 percent of the nation's electric power), 46 units with a capacity of 22.997 GW in the Soviet Union (generating 9 percent of the nation's electric power), and 41 units with a capacity of 32.993 GW in France (generating 58.7 percent of the nation's power), according to figures for the end of 1984 from the International Atomic Energy Agency.

More significant, Japan has steadfastly pursued a goal defined in 1953 by business and government leaders as necessary for the nation's economic growth, without the slowdowns that the other nuclear nations have suffered at the hands of the environmentalists: Nuclear plants have been completed on schedule. The MITI report pointedly notes in this respect that:

> Today, the United States is not as positive as it used to be in the field of nuclear power technological development. Actually, no order for construction of nuclear power plants has been placed in the country since 1979. Under these circumstances, Japan and Western European countries are expected to play a leading role in the development of nuclear technology to promote the development and utilization of nuclear power on an international scale.

The consistent growth in Japan's development and com-

mercialization of nuclear power can be seen in Figure 1, which shows the dates Japan's nuclear plants began operating and the cumulative capacity in gigawatts. The location of these plants as well as those under construction and in the planning stage is shown in Figure 2.

The Scope of the 'Nuclear Vision'

During the next 45 years, MITI expects the total sales of the nuclear industry to be 180 trillion Japanese yen, of which 50 trillion yen would be for new construction, 60 trillion yen for operation of plants, and 70 trillion yen for the completion of the fuel cycle requirements. (For purposes of comparison, 1 trillion yen is about U.S. $6.1 billion.) In 1986, total sales of the nuclear industry are estimated at 1.6 trillion yen per year; by 2010, this is expected to be 4.2 trillion yen,

Outlook of Installed Electric Power Capacity in Japan

(in megawatts)

Power source	FY 1980/ % of total	FY 1990/ % of total	FY 1995/ % of total
Nuclear	15,510/12.0	34,000/19.0	48,000/23.0
Coal	5,260/ 4.1	14,000/ 8.0	21,000/10.0
Natural gas	19,710/15.2	40,000/23.0	43,500/21.0
Hydro	28,6 70/ 22.2	38,500/22.0	42,000/21.0
Ordinary Hydro	17, 860/ 13.8	20,500/12.0	22,500/11.0
Pumping-up Hydro	10,810/ 8.4	18,000/10.0	19,500/10.0
Geothermal	130/ 0.1	600/ 0.3	1,500/ 0.7
Oil	60,080/46.5	50,000/28.0	49,000/24.0
Total	**129,360/ 100**	**177,100/ 100**	**205,000/ 100**

Source: Japan Atomic Energy Commission

and by 2030, the figure would be 6.7 trillion yen—a fourfold growth. The significant difference in Japan's nuclear outlook and that of the United States can be seen in the fact that last year Japan spent 370 billion yen (about $2 billion) on nuclear research and development, while the United States spent $375 million (fiscal year 1986). And this year (fiscal year 1987), the administration has requested only $330 million. At its height, in fact, the U.S. nuclear R&D budget was just over $1 billion—$1.078 billion in fiscal year 1982.

MITI stresses the importance of private sector participation and new technologies:

> The technologies related to nuclear fuel cycle have so far been developed mainly under national support and guidance. But now that the time has come to put the technologies to commercial use, the expertise and resources of private sector such as electric power companies and nuclear equipment manufacturers should be aggressively introduced. Various frameworks of research and development, such as a joint research team and a research union participated in by the parties concerned, should be established to boost the private sector's ability to address prospective tasks.
>
> From the standpoint of the challenge of nuclear energy to new horizons, it is particularly important to pursue new possibilities through the amalgamation of two key fields, the so-called "high-technology field" so in vogue and comprising such aspects as microelectronics and new materials, and the field of nuclear technology. . . .

What is most remarkable in the MITI program is the renewed commitment to meet the schedule established in the 1970s and early 1980s to give Japan an independent nuclear fuel cycle in the early 21st century (see Figure 3). The MITI program outlines how this will be done by (1) improving light water reactors so that they can make use of a uranium-plutonium oxide fuel that takes advantage of all the fissionable products that can be retrieved from spent fuel; (2) introducing fast breeder reactors for practical use; and (3) building a reprocessing plant, a uranium enrichment plant, and a low-level waste storage plant. "The plan to build three nuclear fuel cycle facilities in Rokkasho-mura, Aomori Prefecture [see map], should be promoted in order that operation may proceed according to schedule," the report says.

The Japanese already have a demonstration reprocessing plant with a capacity of handling 0.7 tons of spent fuel per day, or 200 tons per year. This was built by the government fuel reprocessing company, PNC, and began trial operation in 1977, going to full operation in 1981. A second reprocessing plant is expected to come on line in the mid-1990s.

The development of fuel enrichment facilities to process new uranium for use as nuclear fuel is also envisioned in two stages. A pilot plant has been in operation since 1979, and an advanced centrifuge plant, built collaboratively by government and industry, is expected to come on line in 1990. (The United States at this time has shelved this technology, and an advanced centrifuge uranium enrichment plant is sitting unused.) The Japanese are planning to use laser isotope separation, an even more advanced and efficient technology, for the second stage of development, envisioned sometime in the 1990s. The MITI plan mentions consultation with the AVLIS (Advanced Vapor Laser Isotope Separation) project at Lawrence Livermore National Laboratory in California—a project that was chosen by the Department of Energy as the most efficient technology to pursue, but which is not being funded for accelerated development.

The MITI report discusses a demonstration facility for processing high-level waste that would come on line in the mid-1990s, with the goal of a commercial plant in operation by 2030. Currently, nuclear waste is stored at plant sites, the same way it is done in the United States.

Nuclear Fuel Independence

The question of becoming self-sufficient in nuclear fuel is a central one for the Japanese, who have very little natural

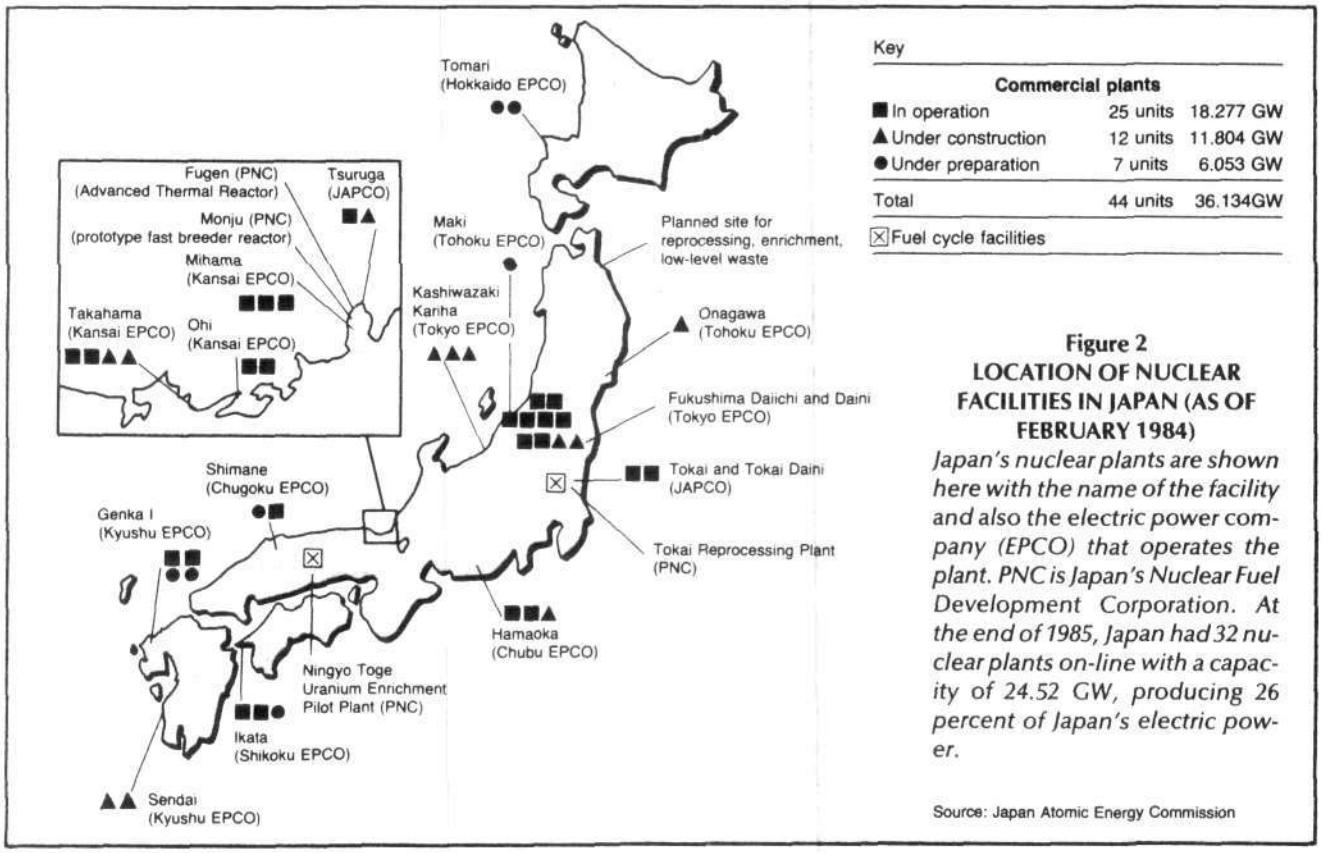


Figure 2
LOCATION OF NUCLEAR FACILITIES IN JAPAN (AS OF FEBRUARY 1984)

Japan's nuclear plants are shown here with the name of the facility and also the electric power company (EPCO) that operates the plant. PNC is Japan's Nuclear Fuel Development Corporation. At the end of 1985, Japan had 32 nuclear plants on-line with a capacity of 24.52 GW, producing 26 percent of Japan's electric power.

Source: Japan Atomic Energy Commission

uranium, a fact discovered early in their nuclear program after extensive exploration throughout Japan. An experimental 100-MWe fast breeder plant, Joyo, came on line in the mid-1970s and provided the basic necessary research. A 220-MWe fast breeder pilot plant, Monju, will come on line in 1992-1994; and a site is in construction now for a larger 800-1,000 MWe plant in western Japan that is expected to be ready by 2003, with commercialization planned for fast breeder technology after 2012.

The Advanced Thermal Reactor, or ATR, was planned as early as 1966 as the way Japan would make the most of its reprocessed spent fuel from light water reactors by using not only the uranium that is extracted but also the plutonium. The plan was to have the ATR use the accumulated plutonium from reprocessing spent fuel even before the fast breeder is commercialized. In addition to augmenting the stock of available uranium, this would lessen the burden of long-term storage of plutonium and decrease the amount of fissionable isotopes of plutonium during storage.

The government operates a prototype 165-MWe ATR plant, Fugen, which has been on line since 1979, and the Electric Power Development Co., a special corporation set up by the government, is constructing a 606-MWe commercial ATR scheduled for operation in March 1995. Fugen has operated with no problems, and is helping to establish the related technologies necessary for use of uranium-plutonium mixed oxide fuels.

The ATR is a heavy-water moderated light-water cooled reactor of the pressure tube type (Figure 4). Pressure tubes are inserted into holes in a calandria tank, each tube housing one fuel assembly. The Japanese describe many advantages to this design. For example, the control rods are immersed in the heavy water moderator, separated from the cooling system, which means that the fuel rods can be in near-atmospheric temperature and therefore have greater reliability in operation.

Internationalization

A section of the MITI report stresses "internationalization" of nuclear technology—or export policy. The emphasis here is on promoting nuclear technology by collaborating not only with Europe and the United States but with developing countries, by sending out nuclear experts and by training developing sector representatives. As the MITI report says:

> It is necessary to develop human resources capable of coping with internationalization, from the standpoint of Japanese contribution to the international society. Measures should be taken to promote a wide-scale participation of superior quality human resources of both government and private sector in international institutions. Moreover, such actions as establishing the "Nuclear Silver Volunteer Program" (dispatch of middle or advanced age nuclear experts to overseas) and other systems should be considered for improved utilization of the available manpower. Finally, more foreign students and trainees should be encouraged to come to Japan.

Such collaboration is envisioned to include the fast breeder reactor and the full nuclear fuel cycle. There was also mention of small and medium size reactors for internationalization.

The Washington, D.C. representative of Japan's electric power industry commented that Japanese companies are very eager to export nuclear reactors (Japan's nuclear manufacturers are now operating at perhaps 40 to 50 percent of their 6,000-MWe annual reactor-production capacity), but that government policy was more cautious. Personally, he said, he was "truly afraid" after Chernobyl at the attitude toward safety in the Soviet Union as well as China. For the developing nations, he said, we have to make sure that they have plenty of experience with large power plants and that they are ready with emergency planning.

Americans cannot help but be impressed by the Japanese vision in planning for a nuclear future since the 1950s and, more important, the commitment to carry through on their plans. Despite the impressive scope of the Japanese 45-year plan, however, the program has not escaped unscathed by the worldwide economic decline. The MITI report, for example, made no mention of the High Temperature Gas Cooled Reactor (HTGR), which the Japanese had helped develop in collaboration with GA Technologies in San Diego. The advanced design of the HTGR and the high-temperature process heat it made available, were seen as essential for development of the nuclear steelmaking industry of the future. Now, however, because of the slowdown in Japan's steel and iron industry, the HTGR is on hold. Ten years ago, when the market was more optimistic, an HTGR was scheduled to be on line in about 1990 (see Figure 3).

"By the efforts made so far, technological development in Japan's nuclear industry has already surpassed the stage of catching up with European countries and the United States, and now we are in a new stage which requires the realization of its own creative technological development leading the world. . . ."

Energy demand in Japan's industrial sector has declined since the 1973 Oil Crisis, even though the Gross National Product maintained a 3 to 6 percent growth rate during the same period. In the manufacturing industry, for instance, energy consumption per real gross domestic production began to decline in 1975, and by 1981 was one-half of the level of 1973. In a January 1984 study, Japan's Institute of Energy Economics documented three basic reasons for this decline: (1) energy conservation, including high-technology equipment investment, such as the introduction of continuous casting in steel making; (2) a shift to less energy-intensive industries, for example, to assembly industries from heavy industries; and (3) "achievement of high added value in manufactured goods," for example, making seamless pipes instead of steel plates.

Another way to look at this decline is the per capita production of electricity. In 1970, it was 3.48 billion kilowatt/hours; in 1975, 4.25; in 1980, 4.94. In 1984, it had declined to 4.84 billion kilowatt/hours.

Japan's Fight for Nuclear Power

It is no accident that the chairman of the MITI subcommittee for nuclear power, which prepared the 45-year plan for MITI, is a businessman—Mr. Isamu Yamashita, the chairman of Mitsui Shipping and Building Company and the vice chairman of Keidanren, Japan's business federation. Japan's business community has been in the leadership of nuclear energy from the beginning. In January 1954, it was the president of the Keidanren who helped launch Japan's nuclear program, after a visit to the U.S. Atomic Energy Commission's research facility in California, where he became convinced that Japan had to have an Atoms for Peace program. Within a year, Japan's parliament had established its own Atomic Energy Commission and had approved the first appropriations request for building an experimental nuclear reactor.

With the memory of Hiroshima and Nagasaki still vivid, the Atomic Energy Commission set up a joint government-business group called the Council for the Peaceful Uses of Atomic Energy and began to campaign for "Atoms for Peace." The first chairman of the AEC was Mr. Matsutaro Shoriki, the publisher of *Yomiuri*, one of Japan's largest newspapers. In Shoriki's inaugural statement for the council, which had close to 100 business, scientific, and political leaders on it, he said:

> It has now become clear that nuclear energy, which was once used against us as a terrible weapon of destruction, can be used as a mighty power to banish wars from the earth and liberate humanity from poverty and disease . . . to eliminate the causes of cold wars and achieve constructive peace. . . .
>
> The time has come for the whole nation to forge ahead without any hesitation whatever.

The council sponsored a vigorous educational campaign in 1955, including a six-week exhibit in a Tokyo park visited by 400,000 people. According to the polls at the time, 92 percent of those who saw the exhibit became convinced of the nation's need to go nuclear. This practice of public education has continued through the present, where education still commands a significant portion of the nuclear energy budget. It has been this vigorous education drive that has held back the antinuclear political opposition in Japan, coming mainly from the Japan Socialist Party, preventing it from squashing the nuclear industry the way it has in the United States.

In March 1956, Japan and the United States signed a technology agreement for Japan's industrial development, which covered patent licensing. Just seven years later, in 1963, Japan became the world's fifth nation to generate electricity using nuclear power, in an experimental reactor operated by the new Science and Technology Agency. Commercial production began three years later, in 1966, in a Magnox gas-cooled reactor design, purchased from the British, that

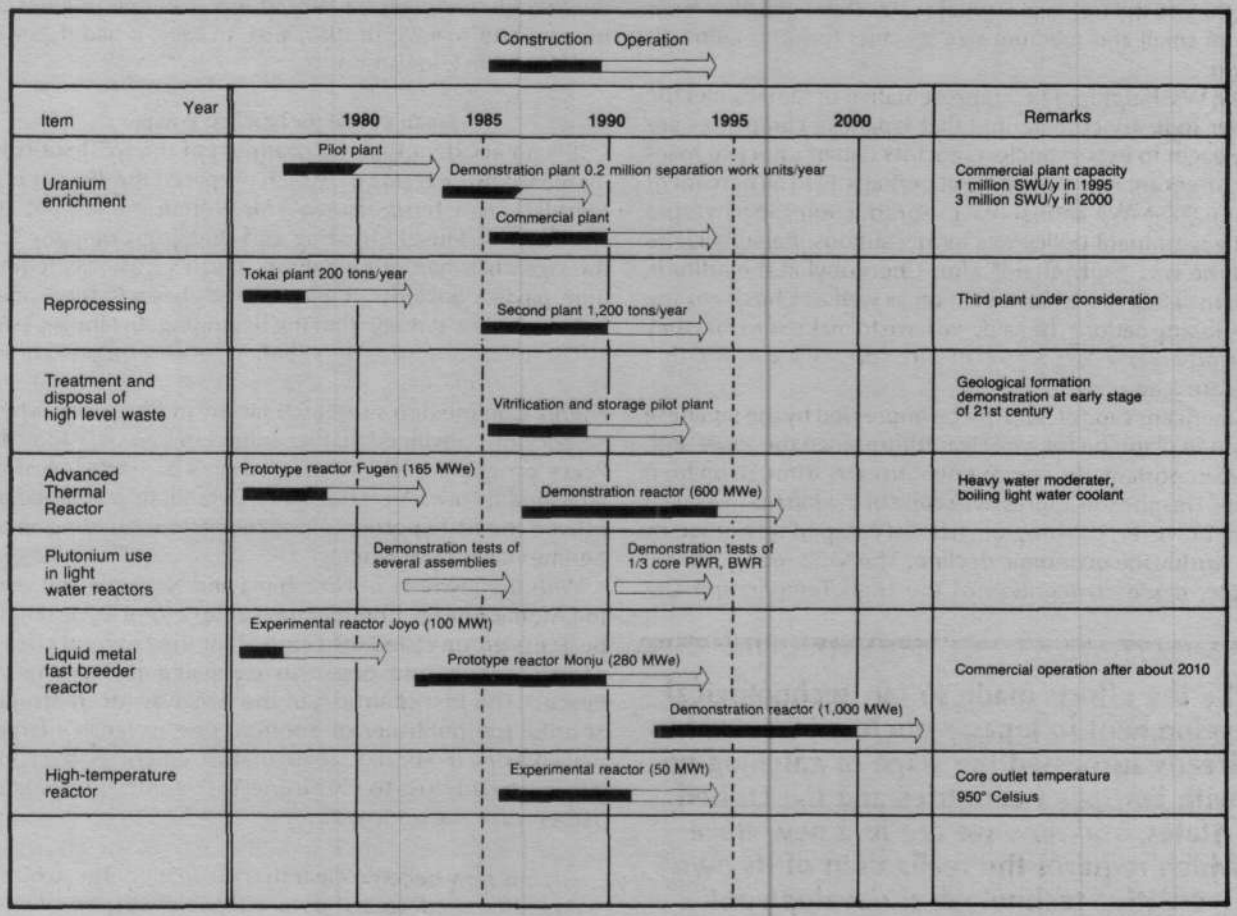


Figure 3
SCHEDULE OF JAPAN'S NUCLEAR R&D PROJECTS
MITI's 45-year nuclear development program reaffirms the necessity for Japan to meet these schedules.
Source: Japan Atomic Energy Commission

uses natural uranium as fuel. According to one report ("Future U.S.-Japanese Nuclear Energy Relations: Report of the Working Group," by the National Institute of Research Advancement, Tokyo, and the Rockefeller Foundation, New York, Oct. 1979), the United States was miffed at the Japanese decision to buy a British reactor, but subsequently made more competitive offers to the Japanese: The U.S. government then offered long-term enriched uranium supply contracts on "attractive terms" and the private sector offered more competitive bids. As a result, Japan then decided to make the U.S. light water design its basic reactor, and it ordered reactors for its ambitious program, about equally divided between boiling water and pressurized water light water reactors. By 1968, the United States had committed delivery to Japan of enough enriched uranium to fuel 11 GWe of nuclear power.

Japan's policy, according to the above-mentioned report, was "to buy one unit of each successive model of the two major U.S. reactor manufacturers," an arrangement described as "important and mutually rewarding." Over the years, Japan gained the ability to manufacture complete reactor systems and to independently improve the design performance of the light water reactor. The Japanese also contributed to joint research projects. For example, Japan put $3 million per year for three years into joint breeder research and $1 million a year for three years into the U.S. Loss of Fluid Test (LOFT) facility in Idaho.

When this bilateral cooperation began in the late 1950s, the United States was treating Japan as a "developing sector" nation; within a short period, it was obvious that Japan was an industrial leader. For Japan, especially under the "nonproliferation" activities of President Carter, it became clear that nuclear independence was essential if its nuclear program was to proceed unimpeded by the vagaries of antinuclear politics in the United States. Today, of course, while the United States has its ambitious Atoms for Peace program only as a fond memory, the Japanese are in a position to supply America with nuclear plants, should the policy here change to one of reindustrializing the nation and industrializing the rest of the world.

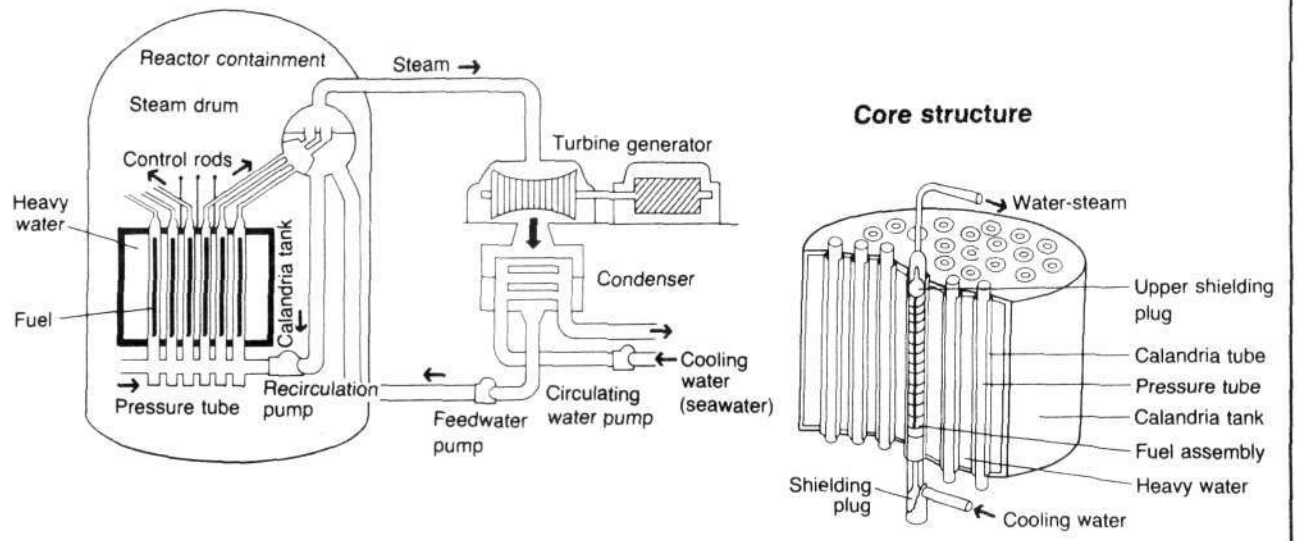


Figure 4
SCHEMATIC OF JAPAN'S ADVANCED THERMAL REACTOR

Japan's unique Advanced Thermal Reactor (ATR) is designed to make use of a mixed plutonium-uranium oxide fuel. The inclusion of plutonium, a product of reprocessed spent fuel, is aimed at enhancing Japan's nuclear fuel independence by reducing reliance on uranium. The ATR uses heavy water as a moderator and light water (boiling) as a coolant.

Source: Courtesy of Electric Power Development Co., Ltd.

Japan built up its indigenous nuclear industry using dirigist methods similar to those that built this country under the administration of President Lincoln—special low-interest loans to private industry and government-sponsored research to set up the proper infrastructure. Japan's nuclear industry today reflects the correctness of this approach. Schedules are met, and performance continues to improve. Reactors have a record of increasing reliability, for example, going from a 60.8 percent operation rate in 1980 to a 61.7 percent operation rate in 1981, to a 67.6 percent operation rate in 1982. In that year, Japan's 24 reactor units produced 103,000 gigawatt-hours of electric power—about the same as the output from France's 32 reactors for the same time period. By 1983, Japan's reactors had a 71.3 percent operation rate, even though by regulation there are 90 days of shutdown per year for reactor maintenance and refueling.

To further increase nuclear reliability, future reactors will be standardized and there is a plan for developing (by 1989) light water reactor robots—multijoint, multifinger robots that can perform diverse chores for reactor maintenance and repair.

Because of this reactor performance, a nuclear power plant that came on line in 1982 was able to produce power at 12.5 yen per kilowatt/hour, compared to 17 yen for oil-fired power and 14 yen for coal-fired power, a cost relationship that has continued. For this reason, although nuclear is only 16 percent of Japan's present electric-power capacity (see table), nuclear produces 26 percent of Japan's electricity: It is cheaper and more efficient and therefore is used proportionally more than the oil, coal, or gas electricity capacity for producing power.

The Future

Right now, Japan's major nuclear reactor manufacturers, Hitachi, Toshiba, and Mitsubishi Heavy Industries Ltd. are working at perhaps 40 to 50 percent of their current capacity for producing 6-GWe nuclear capacity per year, and the depression worldwide has kept the Japanese from developing further the nuclear manufacturing capacity of which they are certainly capable. Under MITI's proposed 45-year nuclear plan, Japan will be adding about 2.5 GW per year to its nuclear capacity, toward a goal in 2030 of 137 GW. Although this is undoubtedly the most ambitious nuclear growth rate in the Western world at this time, the truth is that in the year 1979, Japan added 5 gigawatts of nuclear capacity to its grid (see Figure 1) and MITI estimated at the time that Japan had the capability to add 6 to 10 gigawatts of nuclear power annually. The point is, that if we are to get the job done of industrializing the developing sector, Japan will have to go well beyond its most optimistic predictions of 6 to 10 gigawatts production capacity per year.

Marjorie Mazel Hecht is managing editor of Fusion *magazine.*

Note

For more on the history of the Japanese nuclear program, see articles in the August 1981 issue of *Fusion* magazine and the July 1984 issue of *Fusion Asia magazine.*

The Free Electron Laser

The free electron laser, now being developed by the national laboratories and private industry, is a leading candidate in the SDI's quest for a defensive weapon that can effectively intercept nuclear missiles in the boost phase.

LLNL

Electrons for the free electron laser at Lawrence Livermore are supplied with energy by dozens of energy storage units (shown here), which deliver accelerating power to the beam injector and accelerator cavities on the Advanced Test Accelerator.

Front-runner for U.S. Beam Defense

by Robert Gallagher and Charles B. Stevens

Lt.-Gen. James Abrahamson, director of the Strategic Defense Initiative Organization, announced a decision in November 1985 to accelerate the development of a free electron laser with the goal of constructing a prototype, ground-based free electron laser ballistic missile interceptor by the mid-1990s. Abrahamson explained that the decision was prompted by advances made in the development of free electron lasers over the previous year. Indeed, the free electron laser program had produced significant advances in beam output power, optics, and advances toward ultraviolet and X-ray free electron lasers. This article reviews recent work at major national laboratories in the United States and Europe in the development of the free electron laser and discusses the basic physical geometry of its operation.

The free electron laser is one of a group of laser devices under consideration by the SDI, including chemical, excimer, and X-ray lasers. The free electron laser was first demonstrated 10 years ago. Important scientific advances were

achieved prior to 1983 (see box), but the free electron laser has emerged as a viable technology only since President Reagan first announced the SDI, and is one of the program's major accomplishments.

The SDI plans to complete construction and testing of two prototype free electron lasers at White Sands, New Mexico, by the early 1990s. If this technology demonstration program, estimated to cost more than $3 billion, is successful, then ground-based free electron lasers could be deployed to provide one robust system for missile defense. One plan calls for deploying ground-based free electron lasers at six geographically dispersed locations with a half-dozen lasers at each site. Each free electron laser would have an instantaneous laser light energy output approaching that of a 1,000-megawatt electric power plant.

The potential capabilities of the free electron laser are impressive. Experts have calculated that a single such ground-based free electron laser, making use of large segmented relay mirrors in geosynchronous orbit (50,000 kilometers above the Earth) and 1,000-kilometer-high orbiting fighting mirrors, has the firepower to shoot down the world's current inventory of ICBMs within a few minutes, while they are being boosted into space.

The free electron laser could thus play a crucial role in a layered defense system composed of multiple technologies for interception of ICBMs and their warheads in the boost, postboost, midcourse, and reentry phases of their attack trajectory. Other technologies that could compose such a layered defense include X-ray lasers deployed from U.S. submarines upon warning of an attack, and ground-based

The Beginnings of the Free Electron Laser

The concept of the free electron laser was first discussed in 1950 by Professor Hans Motz of the Microwave Laboratory at Stanford University in a 1950 paper, "Applications of the Radiation From Fast Electron Beams," in the *Journal of Applied Physics*. "The entire spectrum of electromagnetic radiation starting with microwaves and extending to X-rays may be easily obtained from electrons with speeds ranging from a megavolt, say, to 1,000 megavolts," Motz said. He described the arrangement of the undulator as "a succession of electric or magnetic fields of alternating polarity, regularly spaced."

Motz showed the following:

(1) By varying the energy (the speed of the electrons), the spacing of the magnets, or the strength of the magnetic field, one could tune the radiation of the undulator to a desired wavelength.

(2) The spectral distribution of the radiation is a series of harmonics of the fundamental frequency of the radiation, and the intensity of these harmonics could be high if magnetic field strength in the undulator was large enough.

(3) The electrons emit radiation in a narrow cone, whose narrowness and brightness increase with the electron beam energy.

(4) In the undulator, the stream of electrons forms into bunches spaced by the optical wavelength. An undulator driven by a radio frequency linear accelerator upshifts microwave power oscillating at a radio frequency to accelerate the electrons to produce higher frequency coherent radiation by transforming the beam into a discontinuous train of dense bunches of electrons spaced at the desired (shorter) wavelength.

(5) Either magnetic or electric fields can be used to undulate the beam.

(6) The undulator can be indefinitely long.

(7) Motz derived his radiation-emission analysis from the relativistic Doppler effect, as is still done.

Confirming Motz's theory of free electron laser harmonics, the Laboratory for the Utilization of Electromagnetic Radiation (LURE) in Orsay, France, reported in 1985 in the *IEEE Journal of Quantum Electronics*, that with a magnet spacing of 8 centimeters, a magnetic flux of 3,000 gauss, and an electron beam of about 200 megavolts in energy, they were able to produce "an intense emission" of coherent laser radiation in the first 20 harmonics of 0.65-micron wavelength radiation from the LURE free electron laser. They thus produced the first coherent free electron laser emissions in the ultraviolet and X-ray portions of the electromagnetic spectrum. As they reported, "a measurement of the spectral brilliance has been made at Orsay around 300 angstroms [X-rays]. This source is about 300 times brighter than the classical synchrotron radiation obtained in a bending magnet of the same [storage] ring."

Although an entire spectrum of harmonics is always emitted from a free electron laser, one can maximize intensity at the fundamental, or particular harmonics, by varying magnetic field strength. In 1984, a joint program of Stanford University and TRW, Inc., became the second project (after LURE) to produce coherent visible light from an FEL at 0.5 microns by apparently producing laser oscillation on the third harmonic of 1.6 micron infrared radiation.

Motz's other ideas have also been confirmed by experiment. As early as 1952, Motz himself produced visible light from an undulator pumped by the Stanford linear accelerator electron beam, and with a low-energy, electron gun, produced millimeter wave radiation from the same device. In 1959, he and a collaborator announced the coherent amplification of microwaves in an undulator. Further advances were made by R. M. Phillips the following year.

Although work on development of a free electron laser was temporarily suspended after the discovery of lasers in 1960, a vigorous program in the free electron laser emerged in the United States in the 1970s out of the work at Stanford University led by Professors Alan Schwettman and John Madey.

particle beam weapons, or chemical and ultraviolet lasers.

A missile defense using a ground-based free electron laser would consist of the components shown in Figure 1: (1) the laser itself, together with its accelerator, power supplies, and beam director; (2) satellites for boost-phase surveillance and command, control, and communication (C^3); (3) two or more large phased-array mirrors in geosynchronous orbit 50,000 kilometers above the Earth (these are utilized to relay the laser beam around the world); and (4) fighting mirrors located in orbits 1,000 kilometers above the Earth.

The free electron laser would begin firing as soon as the launch of the offensive missiles was detected. The relayed beam would then be directed to several fighting mirrors at the speed of light. In this manner, a single laser could destroy more than scores of missiles per second anywhere in the world. The system would be even more effective against the slower intermediate and short-range missiles.

Although the SDI is primarily directed against the threat of nuclear-tipped missiles, the free electron laser has an even greater potential against slower-moving targets, such as jet aircraft and cruise missiles.

Thirty-six free electron lasers, each currently estimated to cost about $1 billion, would go a long way toward realizing President Reagan's goal of making offensive nuclear missiles "impotent and obsolete." But even more far-reaching than considerations of national defense, the free electron laser portends a revolution in science and industrial technology.

The Spinoff Applications

The free electron laser offers numerous advantages for military and industrial applications.

(1) *High power.* Because the free electron laser is driven by relativistic electron beams, one intrinsic characteristic is that it produces a high-power laser beam. Table 1 (column 9) shows that experimental free electron laser devices at several national labs have produced hundreds of megawatts in peak power.

(2) *Tunable output.* In principle, it is possible to develop a free electron laser whose wavelength (or frequency) of output radiation is as tunable as a radio tunes onto a signal; for example, the laser light output of a free electron laser could be tuned from red to orange to green to blue, by varying electron beam energy. The physical principles underlying this property are discussed below.

All interactions between light and matter depend in a complementary way on the wavelength of light and the properties of the gas, solid, or liquid with which it interacts. For example, specific chemical reactions correspond to wavelengths of electromagnetic radiation; specific wavelengths of electromagnetic radiation reduce specific chemical bonds. As a result, the widespread availability of tunable sources of coherent radiation, will revolutionize chemical processing and basic industry.

Tunable devices will find military applications in advanced laser radar, by which the composition of the atmosphere, or of the surface of a target, can be determined from the wavelengths of light they emit after being irradiated by a free electron laser over a range of wavelengths.

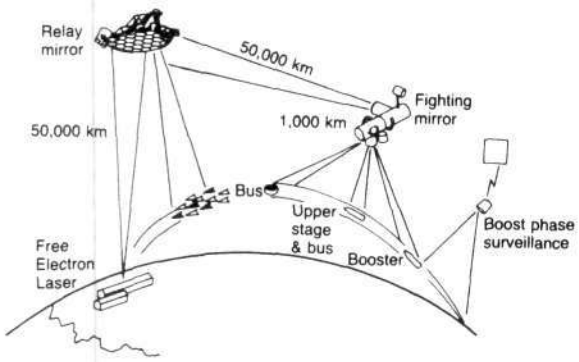


Figure 1
GROUND-BASED FREE ELECTRON LASER DEFENSE SYSTEM

A large free electron laser based on the ground generates a laser beam output sufficient to destroy tens to hundreds of targets per second. The beam is sent through the atmosphere to a large relay mirror, which is in geosynchronous orbit 50,000 kilometers above the Earth. Adaptive optics compensate for the atmospheric distortion of the laser beam. The relay mirror is composed of many smaller mirror modules that are phase-arrayed to act like one large mirror. The beam is reflected from the relay mirror to a much smaller fighting mirror that is orbiting 1,000 kilometers above the Earth. Boost phase surveillance and command, control, and communication satellites provide overall battle management.

Source: DOD

With such information on a target's surface characteristics, a free electron laser interceptor can select the optimum wavelengths with which to destroy the target. Also, once atmospheric conditions between the interceptor and the target are so determined, the interceptor can choose the specific wavelength of attack, to minimize energy-dissipating interaction with the atmosphere.

The property of tunability will permit the same free electron laser to play roles in both boost-phase ICBM interception and terminal defense against warheads. Free electron lasers tunable in the ultraviolet and X-ray portions of the spectrum may generate ultraviolet beams for relay to space-based mirrors for destruction of ICBMs in the boost phase of their trajectory (the first 5 minutes after launch), or may generate X-rays to attack and disarm nuclear warheads descending over the United States.

The first (and easiest) free electron lasers to operate, as the table shows, were not tunable nor did they generate their own signal; they only amplified a signal guided into them. The development of tunable free electron laser oscillators, devices whose inherent oscillations generate laser light, has only occurred since President Reagan's March 23, 1983 speech announcing the Strategic Defense Initiative.

Free electron lasers based on radio frequency linear accelerators have operated from 1.6 microns to 40.0 microns in wavelengths in the infrared portion of the electromagnetic spectrum. The free electron laser at the Los Alamos National Laboratory has been tuned continuously from 9 to 35 microns by varying the electron beam energy from 20 to 10 million volts. Lawrence Livermore National Laboratory has amplified millimeter radar wave radiation of 50 kilowatts to as high as 1 gigawatt in power, with the electron beam from its linear induction Experimental Test Accelerator. However, the Livermore device is not an oscillator, and thus is only as tunable as the source it amplifies.

The challenge now facing the free electron laser programs in the United States and Europe, is the development of *tunable* machines that not only can produce coherent radiation at shorter and shorter wavelengths in the infrared, visible, ultraviolet, and X-ray portions of the electromagnetic spectrum, but also can produce this radiation at sufficient power to destroy ballistic missiles in the boost phase. (Or, in the case of X-ray-producing free electron lasers, the goal would be to disarm nuclear warheads as part of a terminal defense system.)

The same free electron laser technology promises tremendous applications in basic industry, especially the chemicals industry. Free electron lasers driven by the radio frequency linear accelerators have demonstrated the capability of producing coherent radiation in pulses of a few to a few tens of picoseconds (1 picosecond is one-trillionth of a second). Radiation of such pulse lengths exhibits "self-induced transparency"; that is, its electrodynamic properties permit it to propagate *without loss* through the entirety of a chemical solution, except at those specific chemical bonds with which it resonates in wavelength and performs work.

Basic Principles of Free Electron Lasing

The free electron laser is based on the phenomenon that electrons traveling close to the speed of light emit electromagnetic radiation when they are accelerated or decelerated by the action of electric or magnetic fields. The specific wavelength of the radiation emitted is determined by the speed of the electrons and by the radius of curvature in which the electrons are forced to turn.

The concept of the free electron laser was first discussed in 1950 by Professor Hans Motz of the Microwave Laboratory at Stanford University in California. Figure 2, shows a free electron laser undulator or "wiggler," composed of magnets of alternating polarity. An electron accelerator directs a beam of electrons down the center of the undulator, which alternately turns the electrons in one direction or the other, thus undulating or oscillating their trajectory. Along a linear wiggler, magnetic field strength varies as a sinusoidal wave. The electron trajectory appears as a sinusoid in the plane of the figure, but is actually a helix. The electron can be considered as an oscillator. As the electrons turn, they emit electromagnetic radiation.

If the electrons were not traveling at a speed close to the speed of light, their undulation would result in the emission of radiation at wavelengths close to that of the spacing of the undulator magnets; that is, in the range of millimeter or centimeter radiation. However, a relativistic electron traveling near the speed of light upshifts the emitted radiation to higher and higher frequencies (shorter and shorter wavelengths) as the energy of the electron beam is in-

MILESTONES IN THE DEVELOPMENT OF THE FREE ELECTRON LASER

		FREE ELECTRON LASER CHARACTERISTICS								ACCELERATOR CHARACTERISTICS		
	(1) Date	(2) Wavelength Achieved (microns)	(3) Undulator Type	(4) Efficiency of beam energy extraction (%)	(5) Oscillator?	(6) Undulator length (meters)	(7) Pulse length (picoseconds)	(8) Laser input power	(9) Peak laser intracavity power[1]	(10) Accelerator type[2]	(11) Beam peak current (amperes)	(12) Electron kinetic energy (MeV)
Motz	1959	1,000s	Linear	NA	No							
Phillips	1960	1,000s	Linear	13	No							
Stanford	1975	10.6	Helical	0.2	No	5.2	3	0.015	NA	SL	0.07	24
SLA	1977	3.147	Helical	0.25	Yes	5.2	4	0	0.5	SL	2.6	43.5
	1984	1.57 & 0.5	Tapered-linear	1.2	Yes	5.4	4.3	0	460	SL	2.6	66
LURE (Orsay, France)	1981	0.488	Linear	NA	No	NA	NA	NA	SR	NA	240	
	1983	0.650	Optical klystron	low	Yes	1.3	500-1,000	0	NA	SR	0.05	160
Los Alamos	1983	10.6	Tapered-linear	3.7	No	1.0	5,000	MWs	900	L	NA	19-22
	1984	9-35	Linear	1.0	Yes	1.0	30	0	800	L	27-40	10-21
Lawrence Livermore	1984	8,671	Linear	5	No	3	15,000	30	80	IND	500[3]	3.5
	1986	8,671	Linear	6	No	1.3	15,000	50	180	IND	850[4]	3.5
	1986	8,671	Tapered-Linear	34	No	2.4	15,000	50	1,000	IND	850[4]	3.5

Notes
1. This measure factors out any optics technology and accelerator duty cycle limitations.
2. Accelerator types: SL = superconducting radio frequency linear accelerator; SR = storage ring; L = radio frequency linear accelerator; IND = linear induction accelerator.
3. Generated beam of 6,000 amps reduce-filtered to 500, or 8% of original current.
4. Generated beam of 4,000 amps reduce-filtered to 840, or 21% of original current.

creased. As a result, a constant-period magnet spacing of 2 centimeters and a 100-MeV electron beam, may produce visible light at a wavelength of 0.5 micron.

This upshift in frequency is produced by the movement of the source (the oscillating electron) with respect to the emitted electromagnetic waves that travel at the speed of light, regardless of the speed of the source. Any moving source of radiation will upshift or downshift the frequency of its output, depending on whether its motion, relative to the direction of the waves it emits, results in their compression or rarefaction. This is called the Doppler effect. Figure 3 shows this for two cases of water waves.

In the free electron laser, a relativistic electron emitting radiation, following close on the heels of its emitted output, upshifts the radiation frequency by a factor of the ratio of the energy to which the electron had been accelerated, to the energy of the electron at rest (0.511 MeV)—a factor of about 200 in the above example. The greater the energy of the electron, the greater the compression and frequency of radiation output.

Keeping the Free Electron Laser in Resonance

The very generation of coherent light, however, detunes the electrons and undulator, whether it be linear or helical.

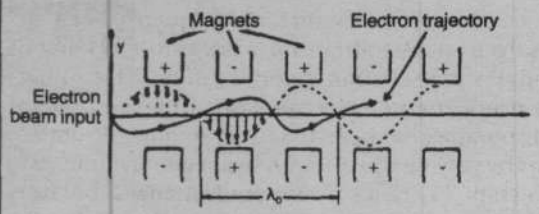


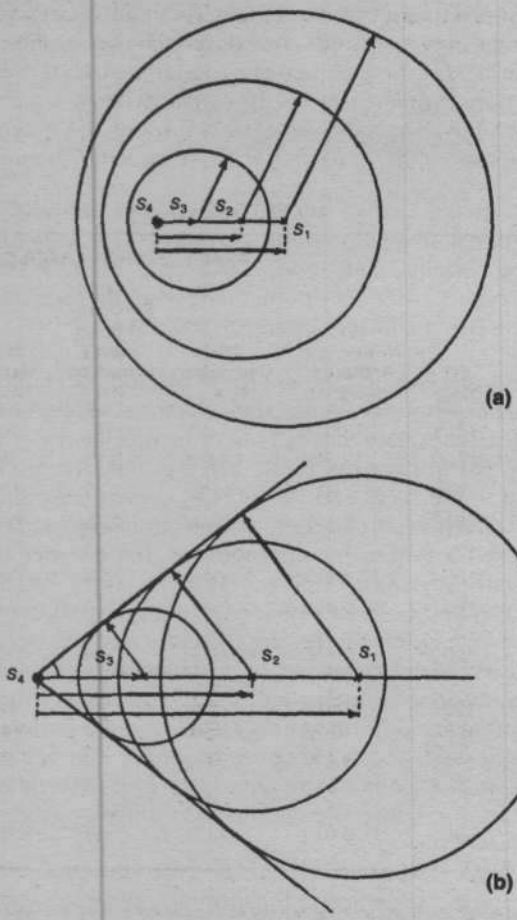
Figure 2
DIAGRAM OF A FREE ELECTRON WIGGLER DEVICE
The undulator or wiggler for a free electron laser is composed of magnets of alternating polarity in a linear arrangement. An electron beam is directed down the center of the device, which turns the electrons alternately from north to south, thus oscillating their trajectory as shown. As the electrons turn, they emit electromagnetic radiation. The dotted line shows the shape of the periodic magnetic field that oscillates the electrons; the solid line shows the electron trajectory produced in the oscillation, as currently understood.

Source: Adapted from M. Billardon, et al., "Free Electron Laser Experiment at Orsay: A Review," *IEEE Journal of Quantum Electronics*, Vol. QE-21:805 (1985).

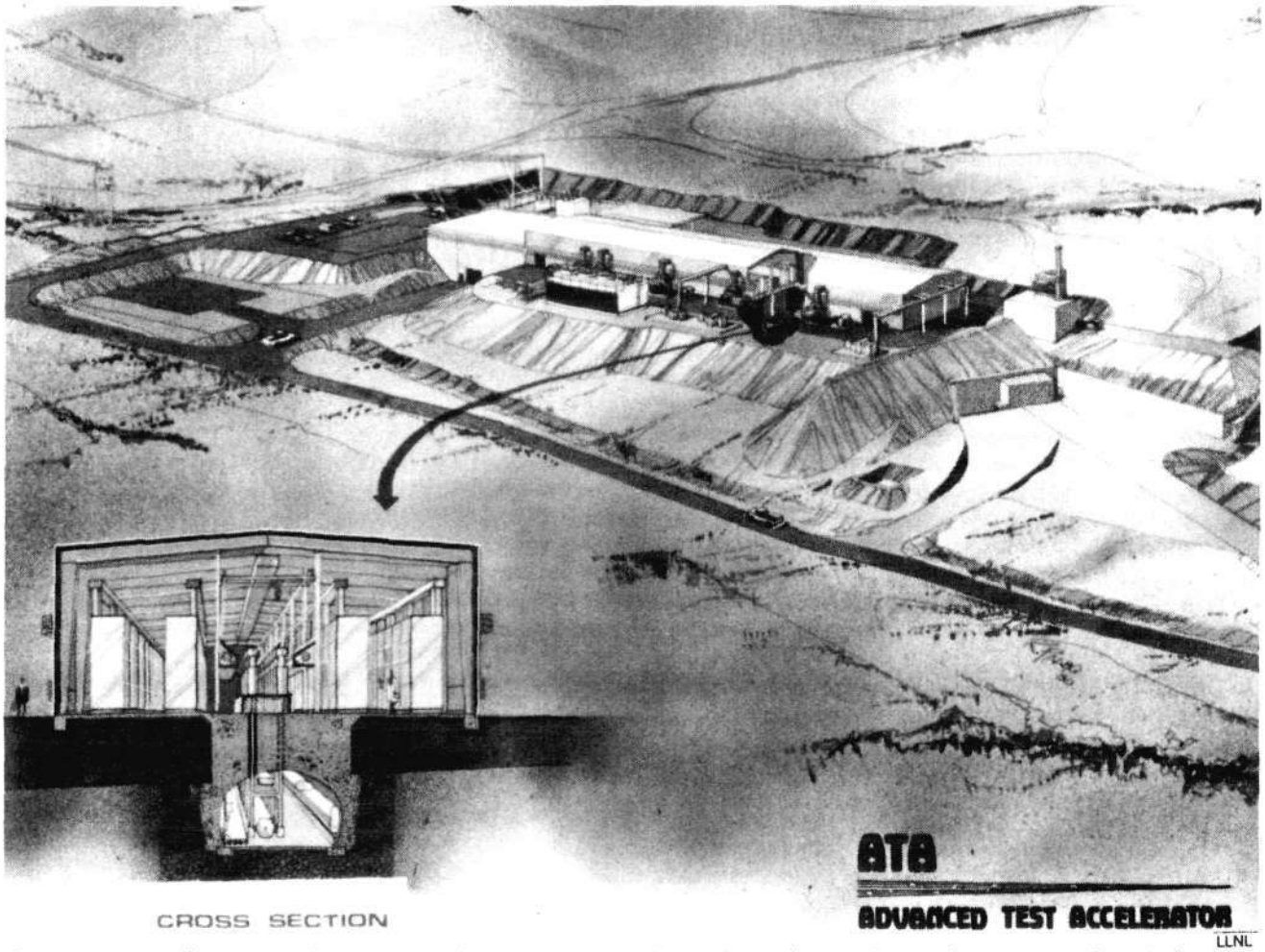
Figure 3
UPSHIFTING FREQUENCY—THE DOPPLER EFFECT
The upshift in frequency known as the Doppler effect can be produced in all types of wave phenomena—electrodynamic or hydrodynamic. In fact, the scientific foundations for understanding electromagnetic phenomena of this sort come from the hydrodynamic school of Leonardo da Vinci up through Ludwig Prandtl.

Shown in (a) is the compression and rarefaction in wavelength (or Doppler shift) of spherical water waves emanating from a source (s) that is moving more slowly than the speed of wave propagation in water. The source is shown at four positions with three concentric waves produced. The compression of waves by the forward movement of the source relative to the forward direction of wave propagation can be seen at left. Shown at right is the rarefaction of waves as they move off in the direction opposite to the movement of the source, producing a downshift in frequency (longer waves). If the source were not moving, the wave generated would have a wavelength exactly between those on the left and those on the right.

When the source moves faster than the speed of wave propagation in water, a bow wave is created, as shown in (b). The source moves out in front of the spherical waves it generates, sweeping out a cone of spherical waves. The source is in front of the waves it is generating.



Source: L. Prandtl and O. Tietjens, *Fundamentals of Hydro- and Aeromechanics*, New York: Dover, 1957.



Cross-sectional illustration of the Advanced Test Accelerator, located 18 miles southeast of Livermore. The ATA beam is born when a plasma of electrons is created and injected into a region of strong magnetic fields, accelerating the electrons to an energy of 2.5 MeV. The pulse then passes through the 190 accelerator cavities in the 256-foot-long accelerator section, which increases the beam's energy to 50 MeV.

As the electrons give up their energy to produce or amplify the laser beam, they decelerate, their electron velocity (and energy) decreases, and they fall out of resonance with the undulator. For this reason, in the first free electron lasers developed in the 1970s and early 1980s, coherent amplification and emission saturated after the electron beam passed about 1.0 to 1.5 meters into an undulator, the distance by which electrons giving up their energy to the laser field had been decelerated below resonance. If longer undulators were used in such machines, the coherence of the beam produced would be degraded by the emission of lower frequency radiation from the decelerated electrons, which were radiating at a different energy level with the undulating magnetic field, and at a longer wavelength. It appeared that there was a maximum amount of energy that could be extracted from relativistic electrons in amplifying or generating a laser pulse.

In 1960, R.M. Phillips had already foreseen this problem, and he proposed a solution in the form of varying the spacing or strength of the undulator or wiggler magnets. If the power of the magnet is gradually decreased, or "tapered" along the path that the electrons must travel down the undulator, then the amplitude of their oscillations is decreased, resulting in a shortening of the distance they must travel to get through the undulator. In this way, their average speed down the undulator may be kept constant, so that they are kept in resonance, despite their loss in instantaneous speed; thus they can give up a greater proportion of their energy to the laser pulse.

When Los Alamos operated the first free electron laser amplifier with a tapered undulator in 1981, researchers achieved an approximate 10-fold improvement in the extraction of energy from the electron beam. Two years later, a joint TRW-Stanford group headed by Alan Schwettman, operated the first free electron laser oscillator with a tapered undulator. Earlier this year, Livermore used a 45 percent taper to achieve 34 percent efficiency of energy extraction in amplifying a 50 kW microwave pulse to 1 gigawatt.

Electron Beams As Fiber Optics

Even with tapering, however, the useful length of the undulator region of free electron lasers was thought to be

ultimately limited by the tendency of the laser beam generated to diffract away from the electron beam whose action amplified it. It has been known for some time that the coherent interaction between light and electrons in a free electron laser produces a phase shift of the light, such that light is refracted toward the electron beam. A joint research team at Lawrence Livermore and Lawrence Berkeley conducted an extensive computer simulation of beam-laser interaction to study this property. Last year they announced that the electron beam in a free electron laser has properties of an optical fiber, and could itself focus the laser beam. E. T. Scharlemann and his associates at Lawrence Berkeley Laboratory described it as follows: "The electron beam in a high gain FEL physically bunches on the optical wavelength; because of the bunching, the beam has an effective index of refraction greater than 1"—that is, it focuses the laser light. There are two fiber-optic effects, they said, "refractive guiding" and "gain focusing."

> The first refers to the familiar guiding of an optical beam by a fiber with a real index of refraction. The power in the optical beam propagates exactly parallel to the fiber. The second, gain focusing, refers to self-similar propagation of an optical beam profile around a fiber with gain: power diffracts away from the fiber, but the gain in the fiber more than balances diffraction. The result is an optical profile that grows in amplitude but does not change shape (hence the description as self-similar propagation).[1]

The research team noted:

> The importance of optical guiding . . . to free electron laser performance [is that] one can contemplate FELs of exceedingly long length. In this way it appears possible to have a small electron beam radius and a very long wiggler (hence a very high gain FEL) even in the vacuum ultraviolet range.
>
> Because of the effect of optical guiding it is possible to direct and focus the free electron laser-generated optical beam. This is of interest for very intense beams, such as are contemplated for laser inertial fusion, where lenses and mirrors of conventional materials would be destroyed by the light. . . . Optical guiding applies, also, to very short wavelength light, which does not interact coherently with normal material. Application of this to the vacuum ultraviolet and to soft X-rays would appear to make possible some interesting devices. . . .

The Free Electron Laser: Two Lines of Development

The free electron laser is a relative newcomer to the field of high-energy lasers. A series of major breakthroughs was achieved in the last few years by researchers at Lawrence Livermore working on a free electron laser amplifier-type system, and by researchers at Los Alamos, Stanford University, and TRW, Inc. on free electron laser oscillator systems that generate their own laser output. The free electron laser quickly became a front-runner for ground-based laser defense systems. Other candidates included excimer-laser and chemical-laser-based systems. Although these latter systems may demonstrate antimissile defense capabilities sooner than the free electron laser—because of congressional funding cuts and the perceived greater technological potential of the free electron laser—their R&D programs have not been moved forward toward development of a prototype interceptor. As SDI Organization director Lt.-Gen. James Abrahamson has continually emphasized, Congress's single-track approach is neither the best, nor most efficient route for realizing laser-based missile defense. However, many of the system elements—the mirrors, optics, and atmospheric compensation—which are combined with the free electron laser to make a defense system, may also be compatible and effective with more conventional lasers.

Two different types of free electron lasers will be explored at White Sands. In one pioneered by Lawrence Livermore, a single, high-current pulse of electrons generated by a linear induction accelerator is passed through a wiggler system at the same time as a conventionally produced laser pulse. The amplifier extracts a significant fraction of the electron-beam energy in this single pass to amplify the input laser pulse. The Livermore type is generally referred to as the induction-linac-driven free electron laser amplifier (linac is an abbreviation for linear accelerator).

The other approach, a free electron laser driven by a radio frequency accelerator, has been more broadly pursued by researchers in industry, universities, and other national laboratories. This device is a tunable oscillator. A high-energy electron beam generated by a radio frequency accelerator, is passed through an undulator. The radio frequency accelerator uses resonant cavities powered by microwaves to accelerate electrons. At Los Alamos, the input electron beam consists of a train of very short electron pulses. When appropriate mirrors are placed at either end of the wiggler, an optical cavity is created that traps the electromagnetic output as the electron beam passes through the wiggler. The emitted light reflects back and forth between the cavity mirrors. This optically trapped radiation then acts on the transiting electron beam and results in the extraction of more energy at a greater rate. The rate at which energy is extracted from the wiggling electron beam is a direct function of the intensity of the radiation field within the cavity. In the radio frequency accelerator-driven free electron laser, the radiation field intensity is built up from the initial, relatively low electron radiation output.

The Induction Linac

The induction linac (linear accelerator) is currently among the most efficient methods of generating intense, high-current pulses of relativistic electrons. Livermore's experience with induction linacs dates back to the early 1960s' Astron program, in which induction linacs were being developed for both fusion energy research and as a possible means of destroying ICBM warheads. In this case, the electron beams would be directly shot through the atmosphere to destroy warheads as they descended on the United States.

In fact, both the current Livermore accelerator facilities—the 45-gigawatt Experimental Test Accelerator (ETA) and the 500-gigawatt Advanced Test Accelerator (ATA)—are also being utilized to determine the feasibility of intercepting

incoming warheads with their beams. Since the penetration of the atmosphere and target by an electron beam pulse is partially determined by the electron velocity, it is thought that properly "tuning" the beam velocity will result in efficient transmission through the atmosphere and deposition into the warhead's interior.

The induction linac utilizes a long series of transformers to accelerate electrons along a straight path. Transformers are among the most highly developed forms of electrical technology and offer an efficient means of accelerating large currents of electrons. There is one major technological barrier, however: The transformer action also slightly defocuses the electron beam. That is, the transformer not only accelerates the electrons in the desired path, but also slightly in the transverse direction. This defocusing is nonlinear; it grows with the energy of the beam and makes it technologically impractical to continue acceleration of the beam when its divergence grows beyond a certain level. Furthermore, achieving efficient free electron laser action depends strongly on the brightness of the electron beam—that is, having a well-focused and well-collimated electron beam.

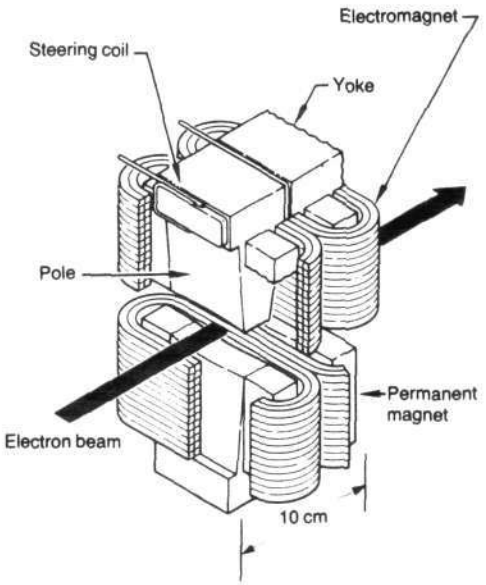
The initial method for dealing with beam defocusing, was to interpose magnetic lenses that refocused the beams. But this was only a limited remedy. A solution came in 1985 when Livermore researchers replaced their magnetic guide fields in the Advanced Test Accelerator with a low-density plasma. A low-density gas was first placed in the accelerating chamber. Then a short pulse from a small laser was used to ionize the gas and transform it into a low-density plasma. As the electron beam passes through the plasma, the plasma acts to focus the beam and remove transverse motions from the relativistic electron beam. The gas was essentially the vapor from a household cleaner, and the small laser cost less than a month's electric bill for running the magnets on the now-unneeded guide field. Plasma-electrostatic channel guiding improved the output of existing induction linacs with a concomitant reduction in operating costs.

This technological breakthrough changed everything. Prior to these developments, the ATA could not achieve its design specification of producing a 10,000-ampere, 50-MeV beam. Instead, the beam thrashed against the accelerator wall before high energies were reached. Based on this new plasma-electrostatic focusing, induction linacs can now produce even more energetic electron beams or significantly increase the power of lower energy beams.

Breaking the energy barrier. The Livermore scientists emphasized the dramatic nature of their advance in terms rarely seen in the pages of physics journals:[2] "It appears that the use of this technique to suppress BBU [beam breakup] should permit the extension of high-current induction accelerators to arbitrarily high energies."

This development is most significant for free electron lasers. Higher energy electrons mean shorter wavelengths or a much greater variety of possible configurations for generating free electron laser beams from ATA-type induction linac electron beams.

The latest breakthrough could also greatly enhance the prospects of utilizing ATA-type electron beams for direct defense against incoming nuclear warheads. As the power drive for the free electron laser, the ATA's electron beam is converted into a powerful light beam that can be shot through the atmosphere to mirrors in space orbit. An alternative, or possibly simultaneous employment would be to directly shoot an ATA-type accelerator electron beam out-



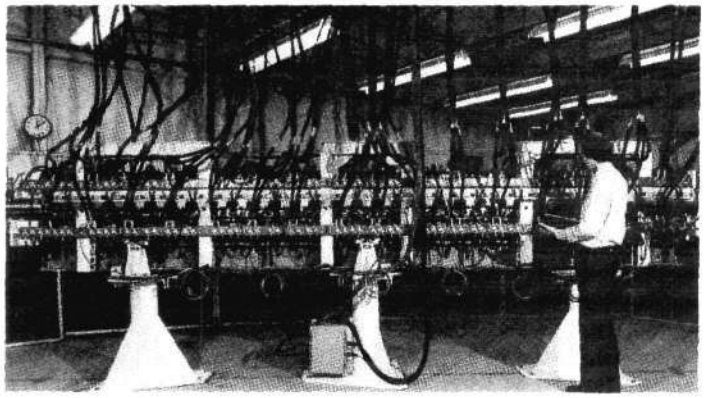


Figure 4
MODULAR COMPONENT FOR THE ATA 5-METER WIGGLER

Many of these modular components are arrayed in a series for the Lawrence Livermore National Laboratory's 5-meter wiggler. The module consists of iron-core electromagnets, which primarily produce the magnetic field, and permanent magnets, which help regulate the generation of that field. One period of the wiggler is shown.

Above is a photo of the 5-meter-long assembly of modules that converts the electron beam energy to coherent radiation.

LLNL

put at warheads descending from space. The electron beams could penetrate the atmosphere and interior of the warheads. Higher energies for the beam electrons could prove crucial in demonstrating this type of application of ATA linear induction accelerators for missile defense.

*The Paladin experiments.*The ATA with electrostatic channel guiding is being configured with an improved undulator design for experiments to test lasing at 10.6 microns—a common wavelength of carbon dioxide lasers. These experiments, code-named Paladin, are planned to resolve some of the scientific issues for amplifying near-infrared wavelengths. Utilizing the 50-million-volt, 500-gigawatt-peak-power ATA, the tests will use a 5-meter-long wiggler made with iron-core electromagnets. Higher signal gain tests will be carried out with a tapered wiggler 25 meters long, made up of elements based on the 5-meter wiggler. It is hoped that these final tests will demonstrate laser amplification at 10.6 microns with a projected extraction efficiency of about 10 percent. This is close to the 4 percent efficiency attained by Los Alamos at the same wavelength in 1983.

Other technology elements for free electron laser amplifier operation are being rapidly developed and demonstrated. For example, pulsed power systems and switches are key components for an SDI-practical free electron laser. The ATA normally operates with one electron burst per second. With new equipment, it may be capable of attaining burst rates of 2,000 shots per second. SDI free electron lasers will have to operate at high burst rates for many minutes. Therefore, long-lived and robust systems have to be developed to compress and switch electrical energy for powering free electron laser induction linacs.

The Livermore Accelerator Research Center has reported major progress in testing prototype modules, which with the new accelerator form the basic building blocks for the Livermore free electron lasers (Figure 4). The power for these modules is supplied by a nonlinear magnetic pulse compressor (MAG-I-D) shown in cross section in Figure 5. This completely passive device provides a reliable means of compressing 100-megawatt input pulses of electricity into 10,000-megawatt output impulses to power the accelerator transformers. The MAG-I-D has the inherent capability of producing these pulses at a repetition rate exceeding 5,000 times per second with an efficiency approaching 90 percent. One such device has already been operated for 100 million pulses—better than 5 hours.

The SDI's projected schedule is to construct a full-scale prototype free electron laser based on the Livermore approach by the mid-1990s. This project, the Ground-Based Laser Technology Integration Experiment, is designed to test all of the components needed for a full-scale missile defense. As shown in Figure 6, the Livermore Paladin experiments, if successful, will be followed by a further series of tests, code-named ALEX, at Livermore.

Engineering projections based on today's scientific knowledge envision that the full-scale prototype induction free electron laser, to be located at White Sands, will be about 1.1 miles long and include an 800-meter-long accelerator and a 200-meter-long wiggler. Because of its extremely high power at the point of generation, it is thought

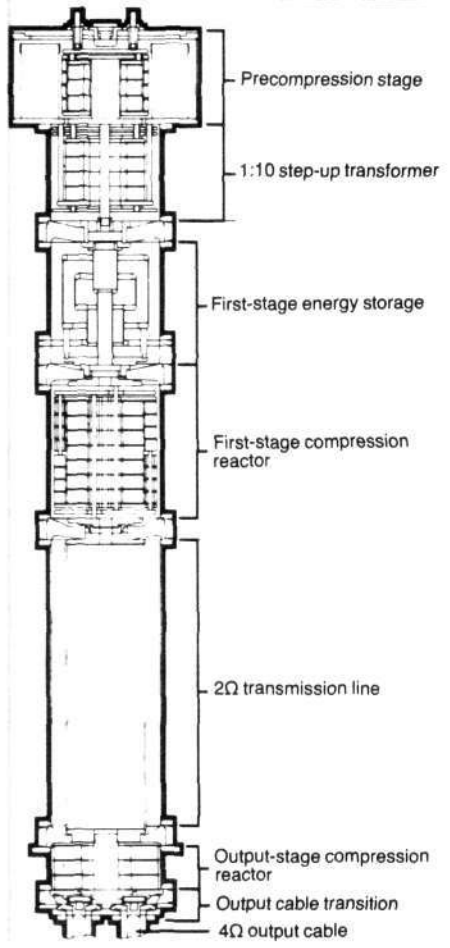
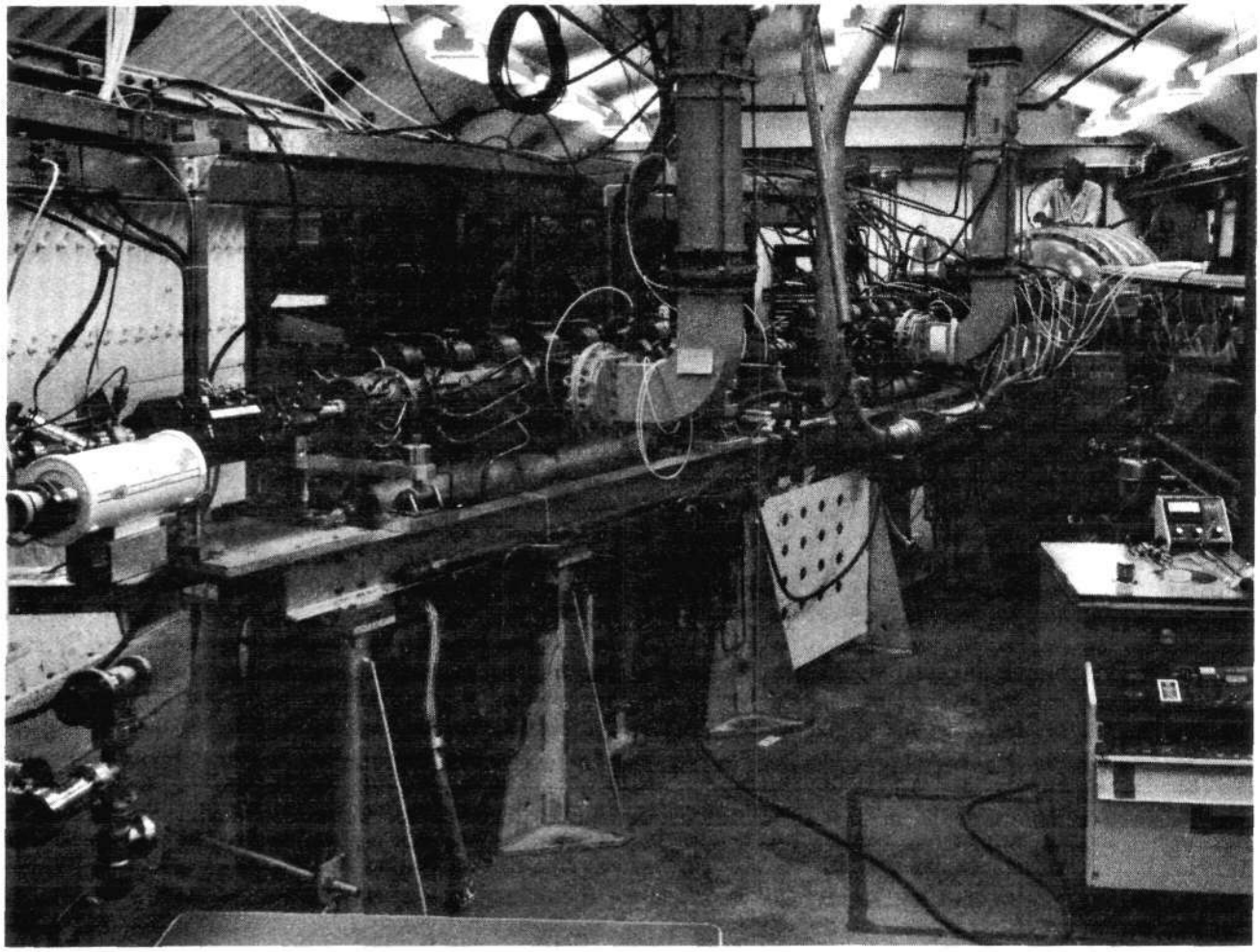


Figure 5
CROSS SECTION OF THE NONLINEAR MAGNETIC PULSE COMPRESSOR
The MAG-I-D nonlinear magnetic pulse compressor is a three-stage modulator that provides a 100-fold energy compression at an output power level of 10 gigawatts.
LLNL

that the induction free electron laser's laser-pulse outputs will have to be expanded through a 2.6-mile-long vacuum chamber. The diffraction expansion of the beam may be required to lower its power density to a point where cryogenically cooled optical mirrors can withstand the pulse. (Even so, major advances in high-power optics are an assumed part of the White Sands program.) The pulse could then be further expanded via optics, and directed to a beam director, which sends the beam on a path through the atmosphere to a mirror in space.

Radio Frequency Accelerator Drivers

In contrast with the Livermore device, the radio-frequency linear accelerator-based free electron laser is an oscillator. It is more readily operated at shorter wavelengths, tuned over a range of frequencies, and potentially far more efficient—all of which make it a tremendous candidate as a scientific and industrial tool. Los Alamos, Boeing,



Los Alamos National Laboratory

The Los Alamos free electron laser is based on a radio frequency accelerator. Because it is an oscillator, it is more easily operated at shorter wavelengths and can be tuned over a range of frequencies.

Stanford, and TRW insist that their free electron laser designs can also meet the power requirements for strategic defense.

The radio frequency free electron laser (rf linac) was first demonstrated at Stanford University in 1976. By 1982, Los Alamos scientists had successfully built and demonstrated one with a tapered wiggler, which greatly increased its efficiency. More recently, Stanford scientists report that they have succeeded in "recycling" the electron beam after it passes through the wiggler. The experiments demonstrated that 90 percent of all the energy in the relativistic electron beams exiting the wiggler could be recovered. This means that given a larger accelerator, both the relativistic electron beam and, therefore, the free electron laser output can be increased 100 times. Ninety percent electron beam energy recovery, translates into an efficiency of 95 percent or more in extracting energy from the electron beam in the accelerator/free electron laser system at Stanford. Prior to this development, Stanford and TRW had already achieved 460 megawatts peak power in 1984 in their free electron laser oscillator experiments. Later in this same year, Los Alamos researchers achieved 800 megawatts peak power in their rf linac-driven free electron laser oscillator. Los Alamos is also pursuing the technology of beam recovery.

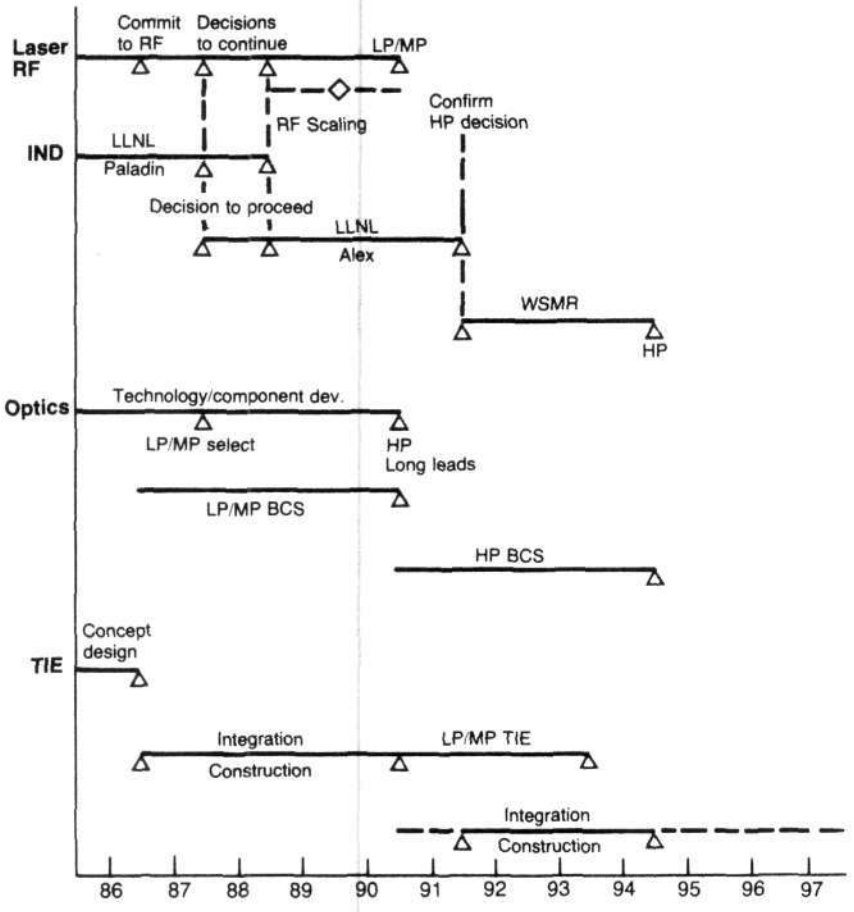
Los Alamos has developed a new, super-cold, high-current electron injector, consisting of a laser and a cold cathode. The cathode is made up of a photoelectric material, and when irradiated by the laser, it emits electrons with very low transverse oscillations. This system is projected to be capable of producing current pulses of hundreds of amperes of electrons, which will greatly enhance both the potential power and brightness of radio frequency accelerator technology.

Boeing Aerospace Corporation is constructing a free electron laser oscillator driven by an electron beam from a radio frequency linear accelerator with a current of more than 100 amperes. With this device, Boeing hopes to demonstrate the feasibility of producing high-power laser beams that meet the requirement for the SDI at a visible wavelength of 0.5 micron.

Strategic defense plans call for completing a radio frequency free electron laser facility at White Sands in the early 1990s.

Figure 6
SCHEDULE OF EXPERIMENTS AT WHITE SANDS, NEW MEXICO
The years for completion of various components of the White Sands ground-based laser technology integration experiment (TIE) and decision points for alternative paths are shown in this schedule, which was prepared by the U.S. Army. The free electron laser (FEL) oscillator driven by a radio frequency linear accelerator (RF FEL) will be built first. It will carry out low-power (LP) and medium-power (MP) experiments on laser beam propagation through the atmosphere. The Livermore induction-driven amplifier (IND) will complete tests at Livermore with the Paladin series. If successful, a high-power (HP) IND FEL will be construction at White Sands Missile Range for full-scale demonstrations beginning in 1993 or 1994. The White Sands program also includes optics, command and control, target acquisition, and tracking.

Source: U.S. Army



A Plasma Free Electron Laser

Perhaps the most interesting new development in free electron laser theory has come from Israel. Two physicists at the Soreq Nuclear Research Center in Israel, A. Loeb and S. Eliezer, proposed using the strong magnetic fields generated in laser-produced plasmas as the basis for an X-ray and ultraviolet free electron laser.[3]

One method of moving to shorter and shorter wavelengths, as discussed above, is to decrease the spacing of the wiggler magnets. Under present limitations of machining magnet pieces, this spacing must be on the order of 2 centimeters or more. In the new free electron laser under construction at Stanford under the guidance of John Madey, the shortest magnet period will be 6.4 centimeters.

Loeb and Eliezer point out that laboratory demonstrations over the past decade have shown that laser-produced plasmas are organized with intense periodic magnetic fields. They propose a free electron laser designed around this effect, which they state would have magnetic fields 3 orders of magnitude greater than conventional free electron lasers, and a wiggler magnet spacing 3 orders of magnitude shorter.

This proportionate decrease in the undulator (or wiggler) period compensates for the use of proportionately stronger magnetic fields, whose effects Motz had warned of in otherwise generating harmonics. The maintenance of this proportionality, according to his theory, confines the emitted radiation to a desired fundamental frequency. Loeb and Eliezer wrote:

> By using the above mentioned wiggler under FEL operating conditions, one is able to get amplification of coherent X-rays with presently used (in FEL-devices) electron beam energy. . . . For a typical condition of the wiggler period equaling 100 micrometers, and the magnetic field equaling 1 million gauss, we get . . . optimal gain conditions.[3]

The attractiveness of the Loeb-Eliezer design, is that it eliminates the need for precision-machining solid periodic magnet structures, a current technological limitation on the free electron laser.

Fusion Energy Foundation staff members Robert Gallagher and Charles B. Stevens write frequently on SDI-related technologies.

Notes

1. E.T. Scharlemann et al., "Optical Guiding in a Free Electron Laser," *Nuclear Instruments and Methods in Physics Research* **A239**:29 (1985).
2. T.J. Orzechowski, et al., "High Efficiency Extraction of Microwave Radiation from a Tapered Wiggler Free Electron Laser," paper prepared for submission to *Physical Review Letters*, Jun. 20, 1986, Lawrence Livermore National Laboratory preprint 94841. *Physical Review Letters* (Sept. 29, 1986).
3. A. Loeb and S. Eliezer, 1986. "Free Electron Laser & Laser Electron Accelerators based on the Megagauss Magnetic Fields in Laser-Produced Plasmas," *Physical Review Letters* **56**:2252 (May 26, 1986).

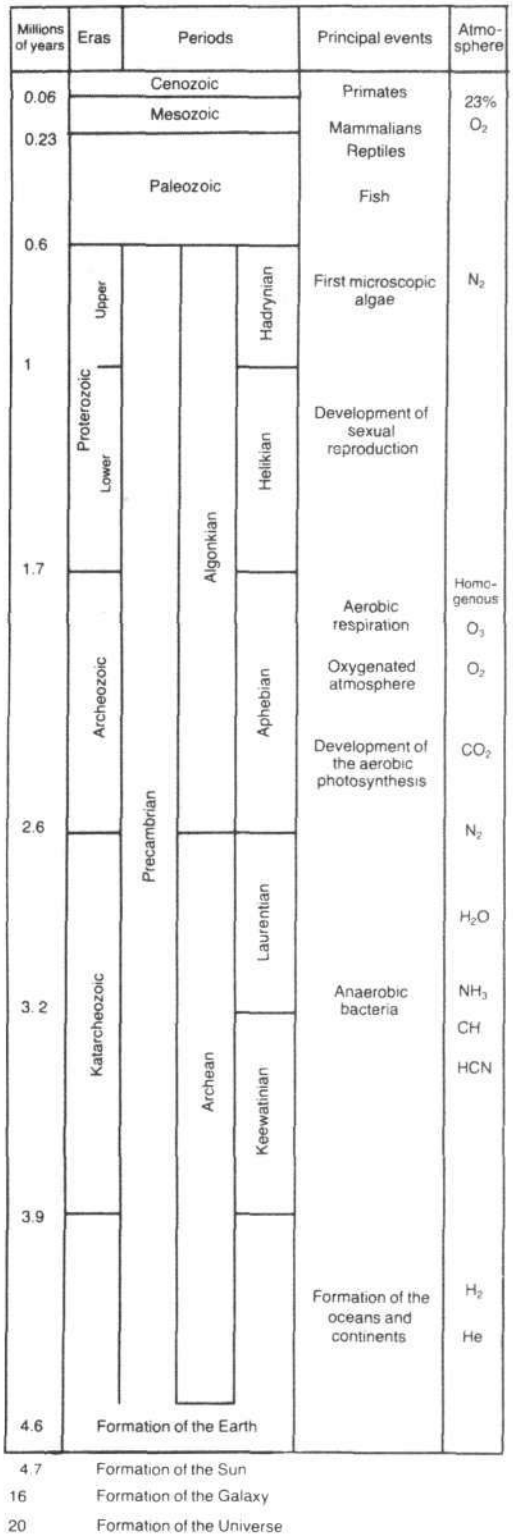


Figure 1
THE AGES OF THE EARTH
Note the lengthening time periods of the first stages of life, compared to the more recent periods.

Man Is Become

by Jean-Michel Dutuit

All men who possess a minimum knowledge of our planet's history and have sufficient imagination and courage to take in "at a glance" the last 3 billion years of biological evolution on Earth, would be struck by the coherence of this history.

What do I mean by "coherence"? First, I would like to say that the feeling one can have in contemplating biological evolution is comparable to that which one feels when viewing the accomplishment of a work of art or the completion of a scientific project of great scope: Taken individually, the smallest details of the work don't necessarily seem to make sense. Their existence seems to be regulated by chance, so that the consequence of all attempts to explain the whole work by adding the little pieces together makes the whole process look like playing poker. And yet, to view evolution as one views a work of art expresses the beauty and the power of the union of all the smallest parts, with the most economical means.

"Your observations are very subjective," a critic might reply. "Find me then several substantial parameters that would permit me to comprehend this coherence, this power."

"So be it!" we acquiesce. "Let's back away a bit, forget the subjective point of view, and attempt to comprehend that which makes the harmony of the process which we call biological evolution."

What Is Life?

Scientists agree today that living forms appeared on Earth 3 billion or more years ago. It was a matter in the beginning probably of very simple molecules that were organizing around carbon atoms with a particular geometry. One of the essential characteristics of these new forms was the establishment of a dynamic interface between them and their environment, an active interface that encouraged these simple forms to protect themselves from the attacks of the environment, and encouraged them to pump in energy from the environment so that they could better act upon it by multiplying and colonizing this environment, whose entropy they rejected. This interface became what we now call membrane; a veritable chemistry machine was then put in place. The law of these forms became to surpass themselves, transform themselves, and multiply themselves—not just to repeat physical-chemical cycles.

The establishment of this dynamic barrier, a machine to extract energy from the aquatic environment, probably ma-

Evolution Conscious

The human being, heir of evolution, must master and conquer his proper evolution.

rine, is a fundamental notion, because it is at this barrier that the important events of biological evolution unfolded.

Is There Acceleration of Evolution?

That evolution is a process that accelerates during the course of time is a common and established fact of today's paleontologists and biologists. But this established fact is only intuitive if one judges it solely on anatomical and paleozoological criteria. There is not a single measuring stick that would permit us to calculate with assurance this acceleration of evolution and its variations from these criteria. It is very much too subjective a matter, and therefore one can do what one wants. But let us attempt to be more concrete.

The existing documentation and theories in the field permit one to say that in the first approximation it took at least 2 billion years of biological evolution (out of a total of 3 billion) to arrive at the stage of the vertebrate animal (animals with an internal skeleton organized around an axial backbone and a centralized nervous system). This first vertebrate animal was initially extremely primitive, more archaic than the fish we know today. They represented, at that time, the architectural and functional plan which, by a constant process of perfection, permitted the emergence of a thinking species.

But some of the paleontologists and biologists might say, not without some good reasons, that the acceleration of the evolutionary process is not evident and that the road it took to get from the first germs of life to the primitive vertebrate plan, was by far the most difficult step. The most difficult, they say, is putting the base structures in place; the rest just represents an accommodation of details. How can we judge the importance of the phenomena presented to us in a manner more qualitative than the forms of anatomical organization?

Energy Flux As the Only Valid Criterion

It took 2 billion years to organize architecturally a being adaptable to survive in all environments, furnished with all the essential physiological parts, perfectly correlated among themselves. In its last billion years, the evolution process, departing from this basic plan, diversified in a manner so that vertebrate life was adapted to all land environments. (We will not discuss here either the invertebrates or the plants.) In one of the vertebrate groups, the mammals, the concentration and development of the central nervous system was vastly enlarged at the beginning of the Quaternary:

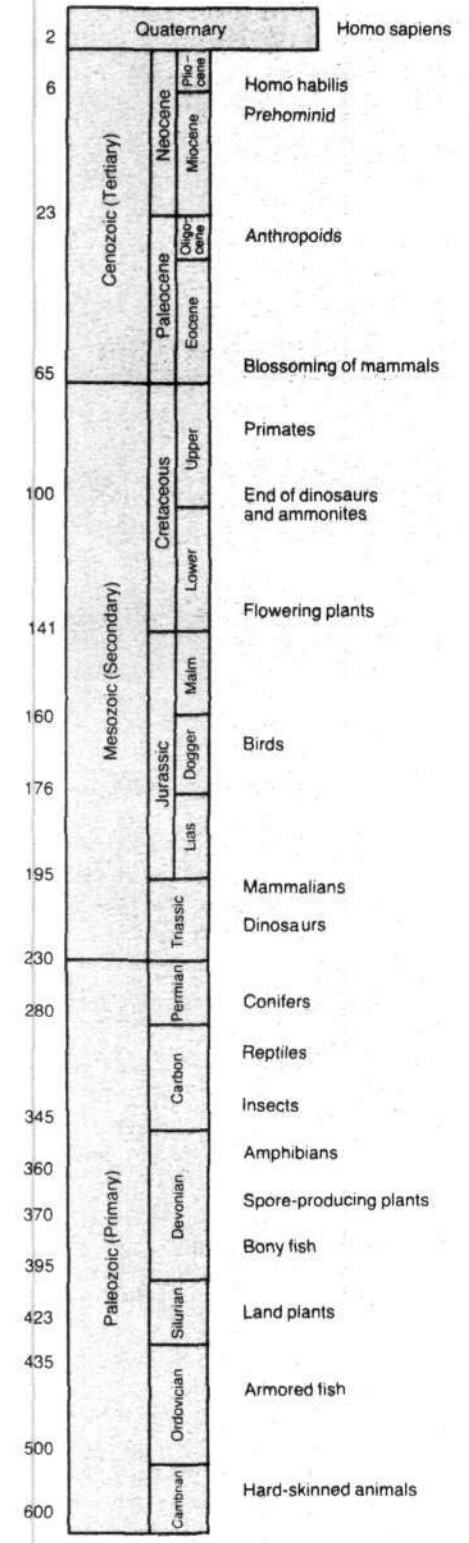


Figure 2
STRATIGRAPHIC SCALE
This stratigraphic scale shows the ages of the Earth for which we have well-documented fossil evidence.

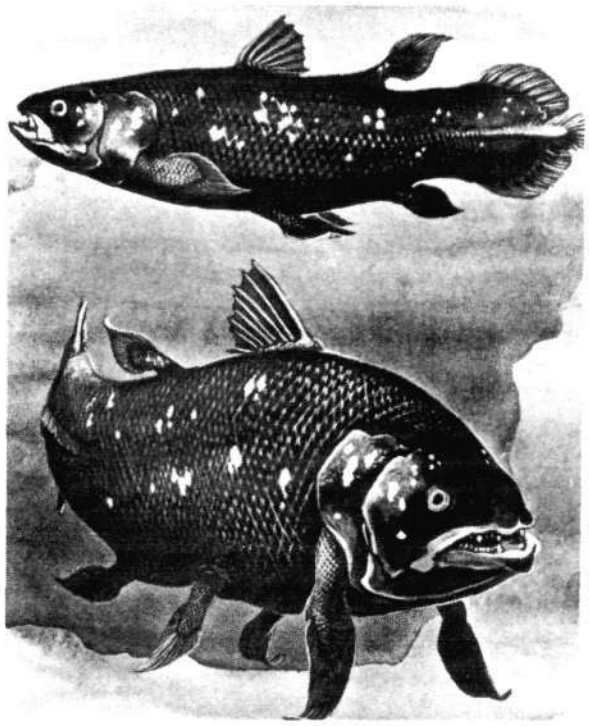


Figure 3
LATIMERIA CHALUMNAE
*Until 1938, the coelacanth of the Comores (*Latimeria chalumnae*) were thought to have disappeared at the same time as the dinosaurs, about 70 million years ago. Still living today, the coelacanth is the closest example that we have of the aquatic ancestors of the tetrapods (advanced vertebrates with four carrier appendages).*

The brain volume was multiplied by 3 in 15 million years—a very short lapse of time. It was during this considerable amelioration of the "basic plan" that the use of the tool was introduced. One can think of the recourse to a tool at a certain point (in a reflexive, creative fashion, not an instinctual one) as comparable to the appearance of the cellular membrane. Why?

(1) Because the tool represents a distance taken by man from the environment, as well as a line of protection against the possible aggressions of the same environment.

(2) It is a sign that the ability to reflect had appeared, with both mental and physical consequences.

(3) Potentially, the introduction of the tool represents the access to an unlimited quantity of energy.

Since as far as we know, it is necessary for all living beings to extract energy from the inert world if they are to survive, this indicates that the only universal gauge of the speed of evolution, and eventually of its acceleration, can be the measure of the energy flow that passes through the process.

The importance of the different anatomical-functional structures that came one after the other in the course of evolution cannot be appreciated but by the change in energy flux that passed through during the process of life before and after the appearance of a structural change. And if there really was an acceleration of the process—if it was negentropic—then we would see this energy flux developing in a nonlinear fashion. In this regard, it is a stage of the process that needs no demonstration, because of its obviousness: the brute force increase in energy. This is the history of the human line.

Thus conceived, life is a process of "increase in energy," attracting toward itself more and more universal energy, and organizing in parallel the inert world around it.

Before the appearance of the human line—that is, before that structural state marked by the appearance of a reflexive and creative thinker—what means have we to appreciate this increase of energy flux? We consider here only the direct means of seeing this, those intrinsically tied to biological groups and not to their action on nature.

There are two such means: The first is the population augmentation of the most active groups of the functional evolutionary plan. Thus, in the Jurassic period, we would search to estimate the demography of the groups of dinosaurs, while in the Permian, 250 million years ago, we make use of the mammalian reptiles and the amphibians, for example. It is a very approximate, even arbitrary, means.

The second means does not try to calculate the increasing energy globally, but examines the stages of biological organization that follow each other in the course of evolution. It demonstrates that each of these stages of organization obeys the principle of least action: The flux of free energy increases considerably after each structural modification. Consequently, the transformation of the inert environment, the external environment of the organism, accelerates. Given its homogeneity, one can deduce that the entire process functions in the same fashion. This time, these are things that can be objectively estimated.

It is important to remember that if it turns out that the flux of energy passing through the process constantly accelerates, if it is negentropic, then the profound logic of the process, which is going on on the cellular level, are facts that cannot be simply random. Fate or chance cannot be the *Deus ex machina* of life, even if we do not yet know the mechanism of organization through which modifications are each time organized in the succession of the structural stages.

What Is a Structural Stage?

Structural stage is a catchall name. There is always a certain arbitrary part in the delineation of such stages, because in certain circumstances there are intermediate groups. Let's say that each stage represents, above all, a mode of functioning of the organism that defines its biological possibilities, its mode of living, its future. It is a matter then, primarily, of a particular chain of events of different organophysiologic instruments that a stage gives to the evolution of the organism, in view of the "optimum exploitation" of the living environment. For example, there are fish, reptile, or mammal stages. These have possible subgroups, such as dinosaurian carnivorous reptiles, dinosaurian herbivorous reptiles, and the latter themselves can be organized into biped or quadriped groups.

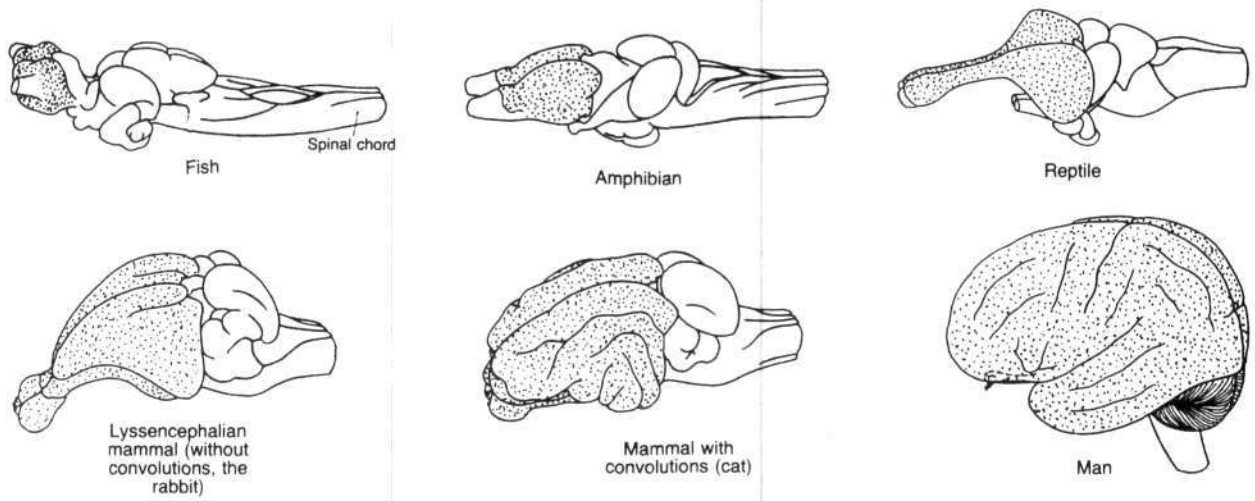


Figure 4
EVOLUTION OF THE BRAIN
During the course of evolution, there is an augmentation of the cerebral areas where information data are combined (dotted areas).

When one studies the comparative anatomy or comparative physiology of these different groups, one notices the fact of a parallel improvement of the various organic systems that came into place at the beginning of the evolution of vertebrate animals. It is what one calls the "principle of correlations" of Geoffroy Saint-Hilaire. The corollary of this parallel improvement of the various organic instruments is the amelioration of these specific performances vis-à-vis the medium where life takes place.

Now let's try to illustrate these theoretical considerations with the aid of several concrete cases.

The Conquest of the Earth

The paleontologists have osteologic evidence that permit them to situate in the second half of the Devonian, around 380 million years ago, the passage of the vertebrates onto the Earth. There are more questions than certitudes when it comes to the fashion the vertebrates used to bring about this "leaving of the water." The fossils that mark the way of this historic event are the ichthyostegalians, animals that resemble both today's coelacanth and triton. When one analyzes the conditions of this passage, one must take into account that the groups from which the ichthyostegalians issued were perfectly adapted to their living environment. They did not have any reason to leave the aquatic environment in which they lived—in which they were very accomplished, without great rivalry—to go and look for a meal in an environment more hostile. Then why did they go?

On the other hand, one can say after the recent paleontologic discoveries, that it seems that the articulation of the shoulder began to change in certain aquatic species before the actual passage to land. It is what one calls a "pre-adaptation." The third element to reflect on: There exist today some fish, that without any doubt have the anatomy of the fish group and that live almost as much on land as in water. Such is the goby or *Boleophthalmus pectiniostris* and also the periophthalm of the mangroves. The goby, of the Malaysian Archipelago, lives in the mangrove bushes that become uncovered at low tide. Gobys search the mud banks for their nourishment, give themselves over entirely to their

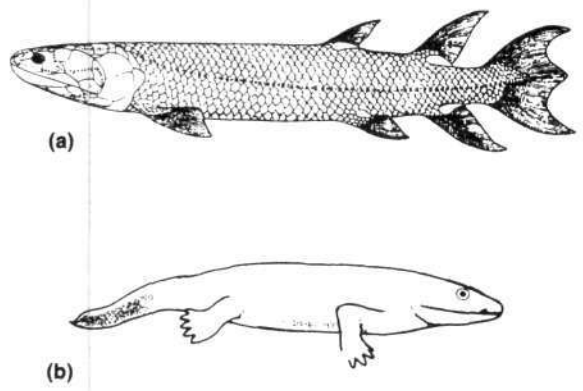


Figure 5
FROM AQUATIC TO TERRESTRIAL
The Eusthenopteron *(a), which lived during the Devonian, represents the aquatic fossil stage of evolution preceding the departure from water. Note the narrow insertion of the fins and the resemblance of the skull to that of* Ichthyostega *(b).* Ichthyostega, *an amphibian from about 350 million years ago, is considered as the first terrestrial stage of evolution. It is still very close to the* Eusthenopteron.

nuptial play, and eventually fight violently among themselves! They can bury themselves in the soil.

Certainly, one can describe the goby as an extreme case of adaptation, surprising for an animal that has only a rudimentary respiratory instrument. However, one can also draw from this a philosophical precept: that life is an exploratory process. The natural tendency of a living form is to go to the extreme limit of its possibilities and to "search to figure out" that which can happen in the structural stage to come. It is a similar conclusion that one draws from the problem of the shoulder of those fish that tends already to resemble that of an amphibian.

And what do the historical events that preceded the departure from water tell us, if not that one cannot see in this case how the neo-Darwinian mechanics would have worked, with its mutation-selection system? Here everything happened, according to the paleontologic evidence, as if the process in work, that is life, possessed an information function and an exploration function. This exploration function pushes life to explore the universe and to appropriate it. The information function informs the process on how to succeed in obedience to the principle of least action: For a given stage of the conquest of the universe, there is one structure, one way of functioning that is the most efficient, the most economical.

Saying this is not leaving the land of science for that of speculation; it is rather, in searching to consider the process in its entirety without atomizing it, to understand its essence in order to better orient our future research. How the information arrives at molecular equilibrium (that of the evolutionary program) we don't know. How the adaptation of the structure at a rate fixed in advance becomes effective, we still don't know. What we do know, however, is that fate cannot account for so many things. Life is a conquering process, using its forces economically.

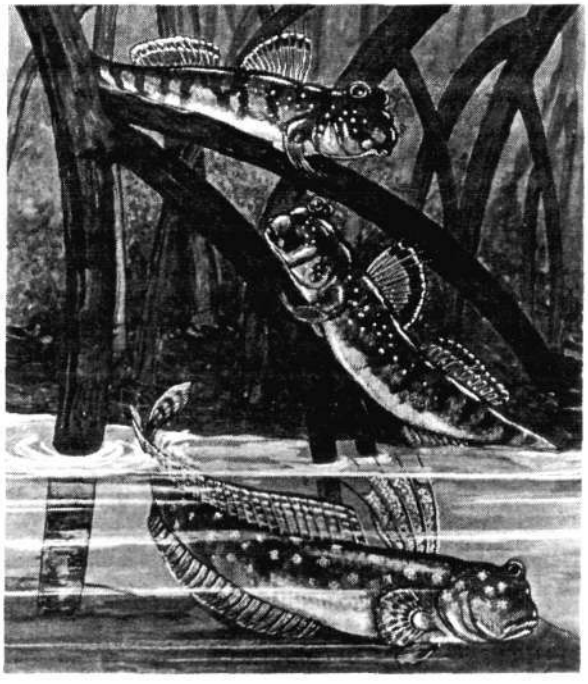


Figure 6
TRUE AMPHIBIANS

*The periophthalm of the mangroves (*Periophthalmus koelreuteri*) is depicted in the upper part of the drawing, the goby (*Boleophthalmus pectinirostris*) in the lower part. Thanks to a supplementary cutaneous oxygenation, these fish became true amphibians, even though their anatomy is that of a fish. They illustrate that rule fundamental to all structural biological stages: Explore all the physiological possibilities of the present group while "sending emissaries" to all the possible environments. When the animal group fails or turns out to be unable to move forward in conquering a new environment, evolution must go through a phase change toward a more advanced structural phase.*

A Simple Problem of Mechanics?

We would be tempted to explain away certain anatomical dispositions of the animal kingdom as a simple problem of mechanics. In effect, things are not so simple because processes that occur over a long time span rarely can be reduced to mechanics! As a concrete example, take those animals that show the types of compromise that can be established between the demands of the living environment and the processes of biological evolution.

Let us return to the ichthyostegalians, which left their trappings as fish to come live on the land. They were at the beginning of the line of amphibians, the stegocephalians, and the primitive reptile with transversal members (legs on the side), whose body is overhanging (so that the mechanical forces induced by the weight of the animal do not pass through the axis of the legs, as it does more or less in the case of mammals). One sees here in what fashion evolution proceeds: When it cannot change the structures to become the most efficient in a given environment, it adapts, insofar as possible, former structures that possibly came from the environment where it lived before.

The ichthyostegalians, with their lateral fins, led to a land animal with added parts on the body that had the same geometrical organization. With this configuration, the mechanical constraints are considerable, and furthermore, the bone is not of the same quality as that of the mammals. The lungs of the amphibians are still machines that pull oxygen from the air with little efficiency, while their hearts permit still-oxygenated blood and un-oxygenated blood to mix. All the imperfections succeeded in making of this type of animal a heavy machine—its bones are too hypertrophied to assure their resistance by the mass; it is a machine with little mobility.

As different "machines" perfected themselves successively, in order to augment their efficiency, one sees the machine refine itself: The members pass under the body and the bones of the members become the columns that can allow more rapid movements. This modification of the locomotion machine is made possible only by a concomitant modification of all the aspects of the animal economy. Because of this synergy, one can say that it is always the

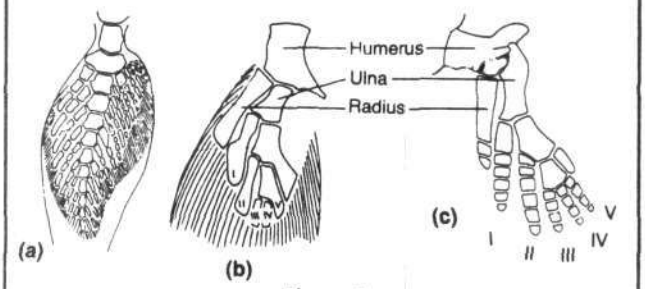


Figure 7
THREE STAGES OF EVOLUTION OF THE ANTERIOR APPENDAGE
(a) Fin of the fish type. (b) Fin of the Eusthenopteron *type. (c) Carrier appendage of the* Ichthyostega.

most economical solution that is chosen at a given stage of evolution.

The passage of the ectotherm to the endotherm represents a leap of great importance in the method of biochemical and physiological functioning. To explain: Among all of the invertebrate animals and the inferior vertebrate animals, the organism lives dependent on the exterior environment, in the sense that his activity is linked to the ambient temperature. Recall that in the domain of temperatures in which the organisms function, the life of chemical reactions doubles, roughly speaking, each time that the temperature rises 10 degrees. Think of the behavior of the present reptiles, constrained to hibernate in the winter, but active in summer. Imagine what progress the passage to an endotherm represents; that is, self-regulation by the organism at an optimum temperature equilibrium varying no more than several tenths of a degree. The endotherm is somewhat equivalent to a space suit. This working mode opened the doors to all environments by assuring an easier quest for energy and its optimum use.

A Conquest Truly Eager to Move Forward

After the ichthyostegalians, which assured the establishment of the first bridgehead on land 350 to 380 million years ago, the stegocephales took over the relay race. For a period of 60 million years, they were the only veterbrates capable of living entirely on habitable land. Then, in the Permian, 260 to 280 million years ago, the reptiles appeared, as if the amphibian groups had come to the end of the exploratory potentialities and conquered their group. Unlike the amphibians, the reptiles were no longer dependent on the aquatic environment, even during the reproductive cycle. The reptilian plan, once it appeared, still needed 100 million years yet to diversify to the limit of the reptiles; some groups evolved toward the mammals and some toward the birds. Let's analyze in more detail these important stages.

Up until the appearance of the ichthyostegalians, the stegocephalians were animals very close to the fish stage, incapable of colonizing any environment, because they were bound to live in water.

In the Carboniferous period, the land flora attained a sufficient development so that a great diversity of alimentary chains could exist—various plants, land and aquatic

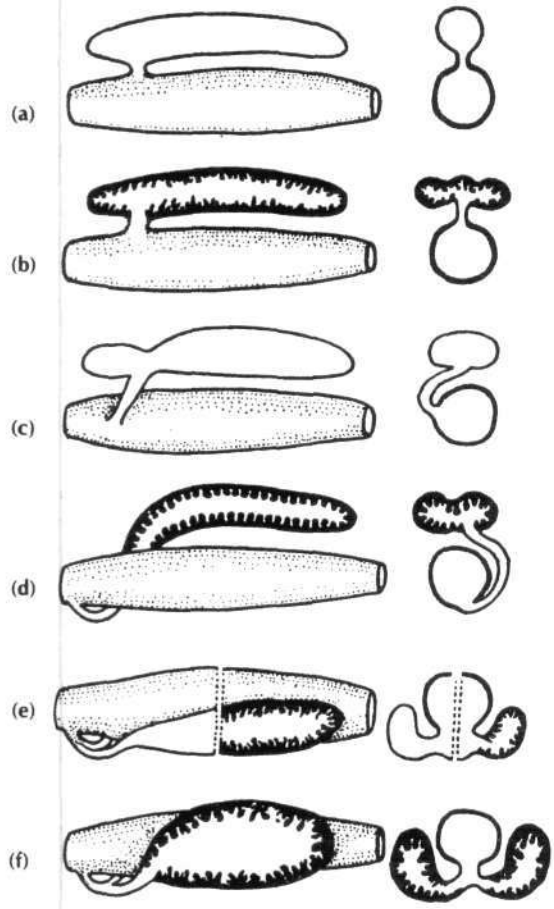


Figure 8
SOME EVOLUTIONARY STAGES OF THE RESPIRATORY APPARATUS
Embryologically, the lungs are a dependent of the intestinal tube, a fact which can be seen in the steps of evolution. (a) Membranous sac of fish (nonrespiratory). (b) Membranous sac having some respiratory function. (c) Membranous sac, attached laterally, in a bony fish. (d) Simple lung, alveolar, from the dipneusti ("lungfish"). (e)Double lungs of another dipneusti. (f) Double lungs of the upper vertebrates, with important alveolization.

invertebrates, fish and amphibians—as well as a favorable climate. In the Carboniferous, and then even more in the Permian period, the conditions came together again to make it possible for the group of newly appeared reptiles, definitively freed from the aquatic prison (except for secondary adaptation), to explode into a number of subgroups.

The amphibians were only the link between the two fundamental life environments. Building a reptile from a fish constituted too great an evolutionary gap. But building a reptile from a semiterrestrial organization was possible. From looking at this history, we should remember that ver-

tebrate life took a step on land in the Devonian period, and for 100 million years was content to develop the amphibian populations, to diversify the line out of which certain ones freed themselves little by little from the aquatic environment. At one moment of this story, there was a phase change in the process: Not only was the reptilian structure ready, but there was probably a critical-mass effect. As the whole biosphere followed a parallel evolution, the new phase literally exploded. As a result of new massive energy bases and exploring all of the environments, there was a rapid generation of all variations of the reptilian structural stage, including the mammalian variant.

In this author's opinion, the only subsequent phase change that was comparable in importance to the appearance and diversification of the reptiles, did not occur at the end of the Cretaceous period when the great reptiles disappeared, but when man appeared and with him the invention of the tool.

The idea that this brief examination puts forward is that the process of life is organized around one exigence: the accelerated populating of the surface of the Earth and the taking in charge of the planet by man.

Evolution Become Conscious

These several considerations on evolution, as disorderly as they may be, suggest these more general reflections: Man is the result, the heir, of a planetary history that has lasted 5 billion years. The several million years of existence of the human line can appear small next to these 5 billions of years. So some observers preach, "be humble and resigned before time and nature"! But by the rapidity of his evolution, by mastering all of the environments of the Earth, and by his lawful ambition to explore space, given his creative powers "in the image of God," Man has the duty to reject this false humility as, in reality, an abdication of his responsibilities.

The present role of man is to resolutely and with optimism take in hand the evolution of the biosphere, and to force the fire of the machine.

Jean-Michel Dutuit is head of a research project at the Museum of Natural History in Paris, specializing in amphibians and reptiles of the Permian and Triassic periods. This article appeared in the French-language Fusion *magazine in December 1985, and was translated by Mary Buit.*

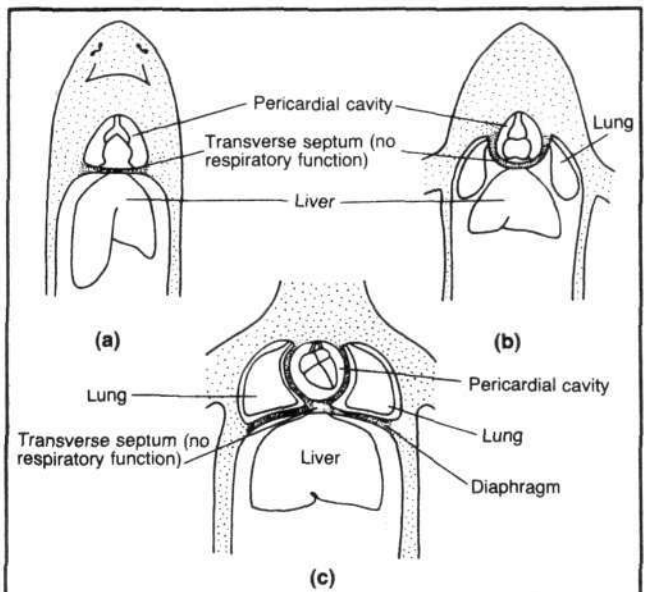


Figure 9
PROGRESSIVE WALLING OFF OF VISCERAL CAVITY BY THE MUSCULAR DIAPHRAGM
A cardiopulmonary chamber and an abdominal chamber evolved, which allowed better oxydoreduction ratios. (a) Fish. (b) Amphibians and reptiles. (c) Mammals.

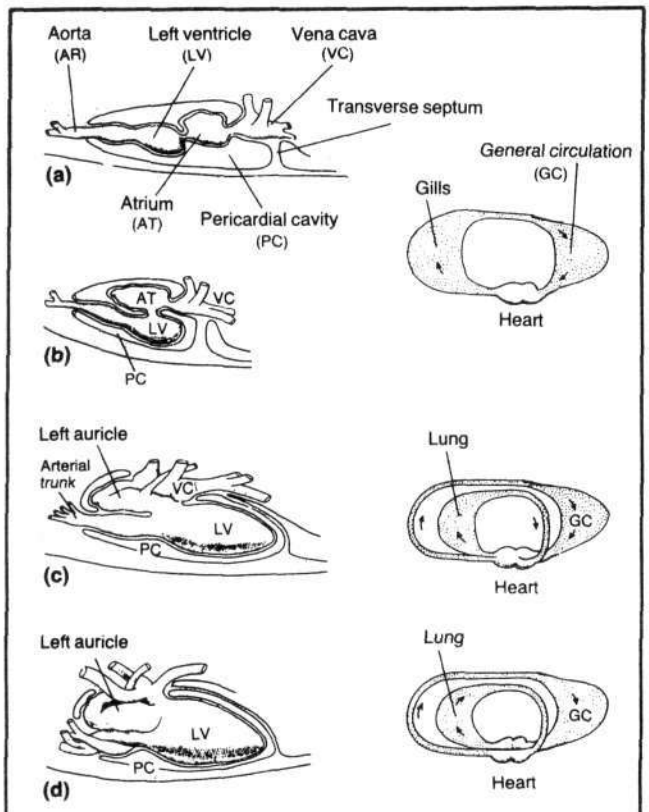
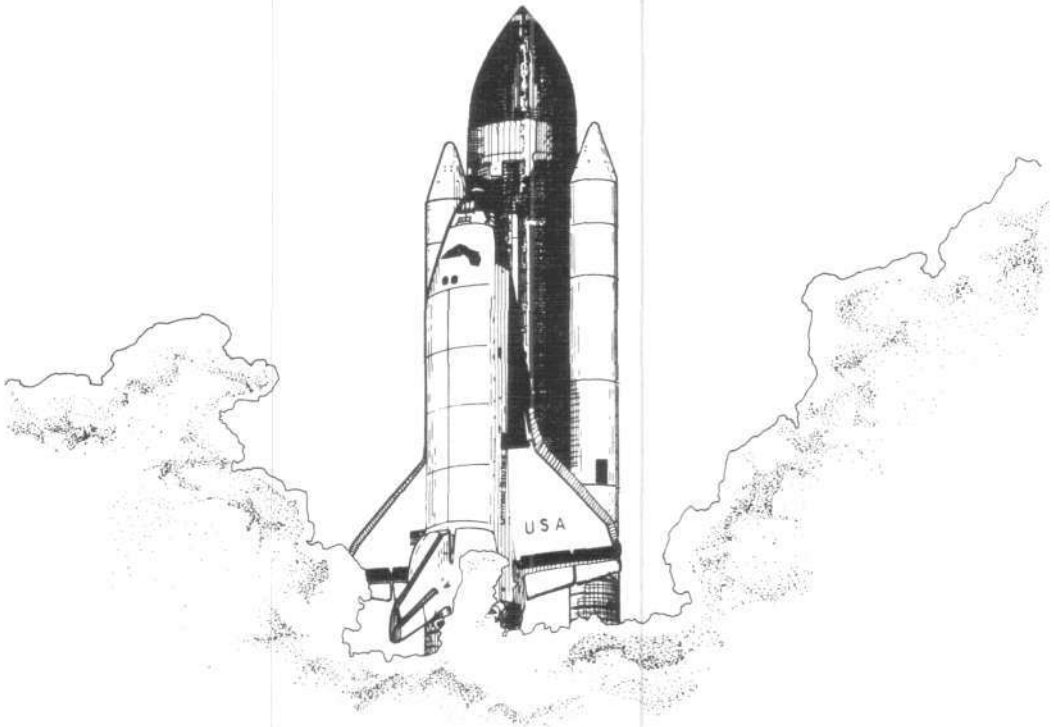


Figure 10
MODIFICATIONS TO THE CARDIOVASCULAR APPARATUS DURING THE COURSE OF EVOLUTION
Initially, in the fish stage, (a) and (b), the heart was a simple pump, in series with a cyclic circulation. During the course of evolution, the heart progressively separated its functions. The amphibian heart, with its incomplete separation of the cardiac circuits, is shown in (c). In mammals, (d), there is a half-heart with two cavities, which assures the oxygenation of the tissues by pulsing the blood provided by the lungs. The other half-heart, also with two cavities, pulses the carboxylated blood to the lungs. In mammals, the complete walling off of the heart is one of the mechanisms that permit a rigorous endothermy.

CHALLENGER



"We will never forget them nor the last time we saw them this morning, as they prepared for their journey and waved goodbye, and slipped the surly bonds of Earth to touch the face of God."

Ronald Reagan, January 28, 1986

On that day, children all over the country eagerly awaited their first lessons from space ... they never came.

All America grieved, and every heart that ever reached for the stars yearned to keep the hopes and dreams of the Challenger alive.

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The families of Dick, Mike, Judy, El, Ron, Greg, and Christa ask all Americans to share their vision of a living memorial to carry on the Challenger mission.

Challenger Center will be a national learning center through which Americans can extend their reach into space and nurture their dreams as future star voyagers.

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"Today, we promise that their dream lives on, that the future they worked so hard to build will become reality . . . Man will continue his conquest of space. To reach out for new goals and ever greater achievements—that is they way we shall commemorate our seven Challenger heroes."

Ronald Reagan, January 31, 1986

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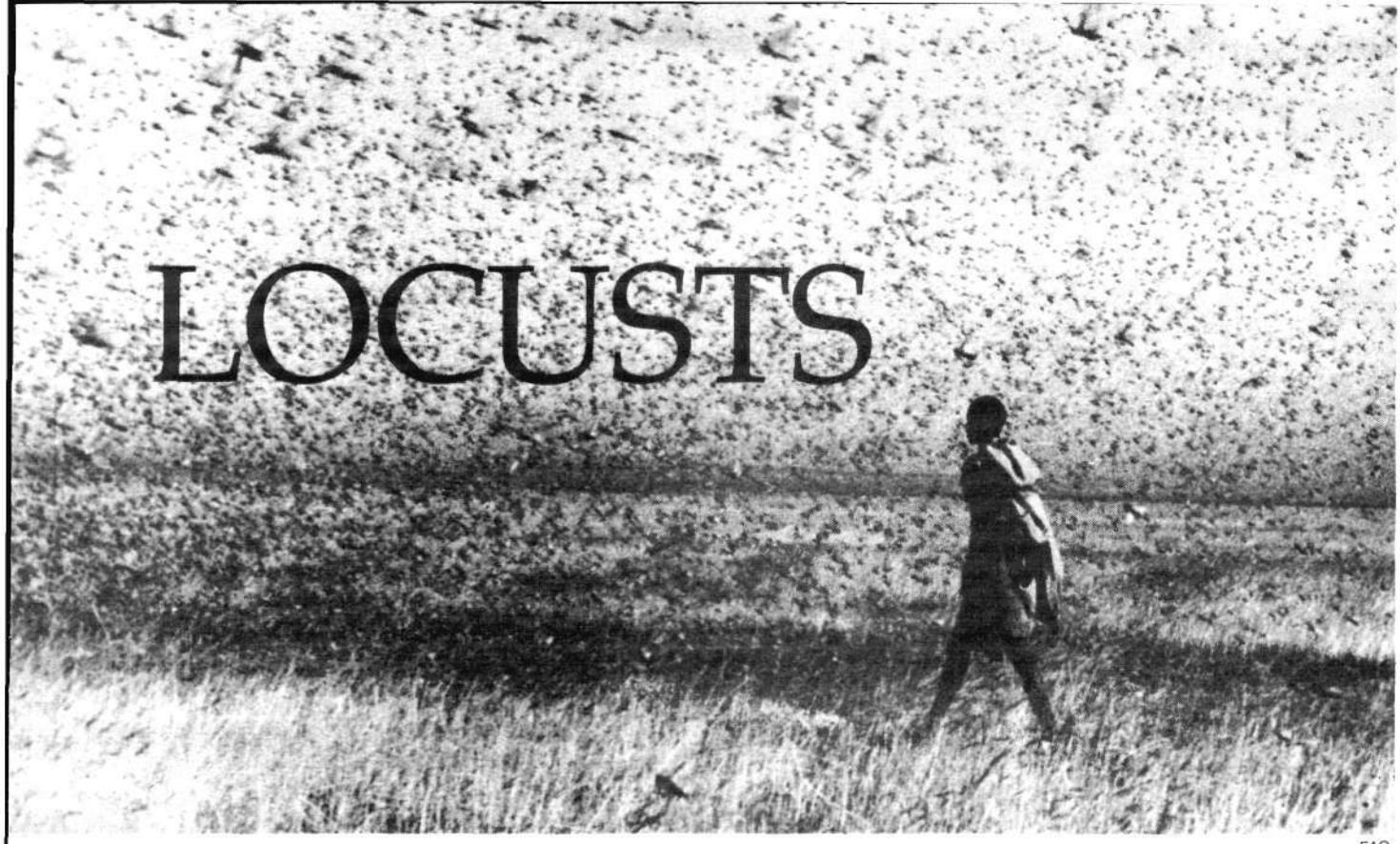


FAO

An Ancient Plague We Can Now Overcome

Although locusts have plagued man for centuries, today we can eliminate this scourge by building infrastructure projects in the developing sector and using state-of-the-art pesticide control measures.

by Marjorie Mazel Hecht

"For they covered the face of the whole earth, so that the land was darkened; and they did eat every herb of the land, and all the fruit of the trees . . . and there remained not any green thing in the trees, or in the herbs of the field, through all the land of Egypt."

—Exodus 10:15

For millennia, favorable rainfall and temperature conditions have fostered population explosions of locusts that devastate crops and wild vegetation for years, until unfavorable climatic conditions bring the plague to an end. In 1986, the same favorable conditions—plentiful rains after a period of drought—triggered plague conditions in Africa for four different locust species as well as the Senegalese grasshopper (Figure 1). The difference is that today, rather than waiting for the natural calamities of extreme cold, drought, or floods to end the plague, man can control and even eradicate the pests. The question is political, not scientific: Will the United States and its allies implement a development policy for Africa—or will the Malthusian policies of the international banking agencies and the United Nations prevail?

When temperature and climate conditions are favorable, locusts undergo a population explosion and then a phase change to a swarm state. Their physiology, behavior, and even color are different when they swarm, and the change is passed on to the next generation. They have a higher metabolic rate and a higher rate of intake of oxygen.

The technologies to prevent locust plagues from destroying crops and vegetation are not exotic; they are all state of the art:

- Satellite remote sensing can supply accurate maps of topsoil moisture, indicating areas where the pests are most likely to breed and the eggs survive and hatch. Similar satellite composites of vegetation growth can indicate where

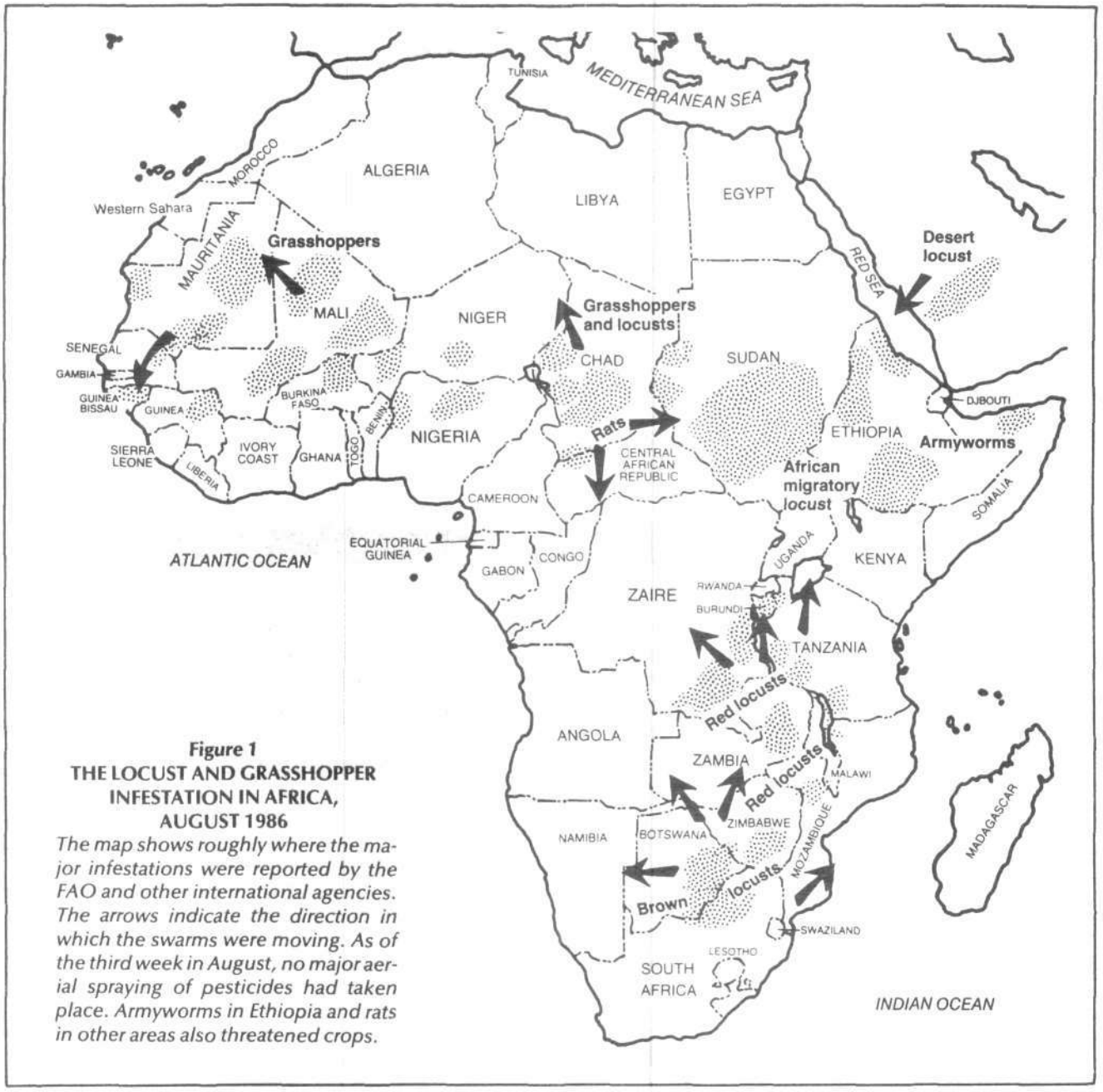


Figure 1
THE LOCUST AND GRASSHOPPER INFESTATION IN AFRICA, AUGUST 1986

The map shows roughly where the major infestations were reported by the FAO and other international agencies. The arrows indicate the direction in which the swarms were moving. As of the third week in August, no major aerial spraying of pesticides had taken place. Armyworms in Ethiopia and rats in other areas also threatened crops.

the young hoppers are likely to move in search of new plant food.

- When breeding and hatching areas are broadly mapped, these satellite data can be supplemented by color infrared photography from aircraft, which can produce a resolution of 6 inches, compared to the 200-foot resolution of satellites.
- Large plane spraying using DC-7s or C-130s that are specially outfitted for pesticide work can spray a vast area quickly—1,000 miles per sortie, flying at 200 miles per hour and cutting a swath 660 feet wide. At an altitude of 200 feet, the big planes go in 60-mile runs up and down the infested area.
- Specially tailored nonresidual pesticides, like malathion, using an ounce or so per acre, are sprayed in a fine, ultra-low-volume mist and can kill the young locusts on contact without harming man or animals. The kill rate is about 95 percent.
- Stronger pesticides can be used against adult locusts, sprayed on the ground or from aircraft.
- The history and morphology of the most destructive kinds of locusts are well known. The movements of swarms across the Sahel and West Africa, for example, follow the winds of the well-known Inter-Tropical Convergence Zone, and previous plagues have been well mapped.
- The infrastructure to monitor and prevent locust breeding is not complicated; it requires trained personnel, small planes, helicopters, ground transportation, and good radio

communications to monitor the likely infestation areas and to quickly report situations requiring action. In fact, by mid-century, there were several effective regional locust control groups functioning throughout Africa, Asia, and the Mideast. It is only recently that these regional groups were deliberately allowed to collapse as part of the overall austerity inflicted on Africa and the rest of the developing sector.

- The big infrastructure projects required to reduce the endemic breeding areas are also well known. Back in the 1970s, for example, there were proposals to control the flooding from the Niger River in Mali, thus eliminating the existing flood plains where the African migratory locust is able to breed most of the year, producing four generations. Other outbreak centers where water projects would eliminate large-scale locust breeding are the Rukwa Valley in Tanzania and the swamps surrounding Lake Mweru in Zambia where the red locust breeds. If these large-scale water projects were carried out, the migratory locust and the red locust would not have the potential of reaching the swarm stage, as they both have this year.
- Simply cultivating more land using higher technology agriculture would also contribute to the ability to control locust breeding.

Locusts: An Ancient Scourge

There are 10,000 species of grasshoppers in the world, formally known as Acridoidea, one of the five "superfamilies" of the order Orthoptera, which also includes crickets. Only about a dozen of the Acridoidea species are known as locusts. There is not much difference between locusts and grasshoppers—except that locusts all have the potential to become gregarious and swarm out of their breeding area in enormous numbers (millions), migrating where the winds take them, stripping all vegetation where they land and leaving one or two generations of eggs behind. Some grasshoppers also swarm, and some species migrate, but usually as solitary individuals.

Both grasshoppers and locusts take on economic importance because of their enormous numbers and appetites: Locusts possess a characteristically powerful chewing jaw and can eat 2 to 3 grams—two to three times their weight—each day. A 1-mile-square swarm of 150 million locusts, 5,000 feet in elevation, can go through 200 to 600 tons of vegetation daily, leaving nothing for the human or animal inhabitants except starvation. And an adult swarm can easily contain 1 billion locusts, weighing 1.5 million kilograms. In a 1958 plague in Somalia, a swarm of 40 billion locusts ate 80,000 tons a day—enough corn to feed 400,000 people for one year. For comparison, cows eat perhaps 12 kilograms per day, assuming a grazing capacity of 15 animals per square kilometer. A swarm of locusts might eat 1,000 times as much—150,000 kilograms.

Even when grasshoppers are not in a swarm stage, their destructive power is staggering. If the grasshopper density is only 8 per square yard on a 1 acre plot, over the period of one month these grasshoppers will eat 60 percent of the vegetation on that acre! With just one grasshopper per square yard, on 1 acre over a 30-day period 12 to 15 pounds of forage will be consumed.

The voracious appetite of the locust has been chronicled throughout history. Tales of the locust scourge were vividly relayed in ancient Indian and Greek legends, in the Koran, on the tombs of the Pharoahs, on the temples and palaces in Egypt, and on Greek coins dating back to the third century B.C. Tablets going back to the 9th century B.C. record news of the "noxious locust," possibly reporting on Sumerian plagues 1,000 years earlier. According to one account, it was around the 9th century B.C. that the Shang Kingdom in China appointed "antilocust officers," and by 720 A.D., the Chinese had set up a locust forecast system.[1]

In this century, man has fought at least five great wars against locusts, the last major battle being in 1967-1968, when locusts migrated from the Sudan, west across the Sahel to Morocco, and simultaneously migrated from Saudi Arabia to the Mideast, Pakistan, and India (Figure 2). This is the first time in this century, however, that four major species are striking the African continent at the same time.

A Population Explosion

A plague explodes after years of steady, gradual grasshopper population growth when there is one season of rainfall and temperature that are just right to promote the survival of most of the eggs of the previous generation. Exactly what causes locusts to change their physical appearance and behavior and join with millions of others in a swarm was not fully identified until the 1920s, although previous observers had noticed that the characteristics of certain locusts changed in years of plague.

The swarm characteristics are triggered not only by favorable climate and the availability of food; they are also passed on from one generation to the next, as well as fostered by the crowded milieu of the locust when there is a vast population increase. The only way to eradicate these pests and prevent a plague from becoming endemic is to wage a full-scale war to kill the young locusts just after they hatch and before they mature and are able to fly and to reproduce. This means that once the weather conditions are favorable and the eggs begin to hatch, there is only about a three-week period when pesticide spraying can effectively reduce the locust population to the extent that there will be no plague. Kill ratios for such aerial spraying can be close to 100 percent. In West Africa, for example, the U.S.-sponsored DC-7 planes that sprayed 2 million acres in fall 1986 had a kill ratio of 97-98 percent in most areas.

Although the reproduction cycle varies from species to species, this description of the desert locust generally applies: Female desert locusts lay 70 to 100 rice-size eggs at one time in a cluster deposited about 1 inch into the desert sand. In order to hatch, the eggs must be able to absorb their weight in water; thus it is only when the topsoil moisture reaches 30 to 60 percent that conditions are favorable for hatching. In about 40 days, the locust egg hatches into a three-legged "hopper," which can only hop or crawl slowly. It sheds its skin, turns black in the Sun, and then begins to march out in bands in search of food.

The locust molts five times, going from hopper to adult capable of flying usually within 60 days (These molts are known as instars). However, if the temperature and moisture level are good, this period from birth to maturity short-

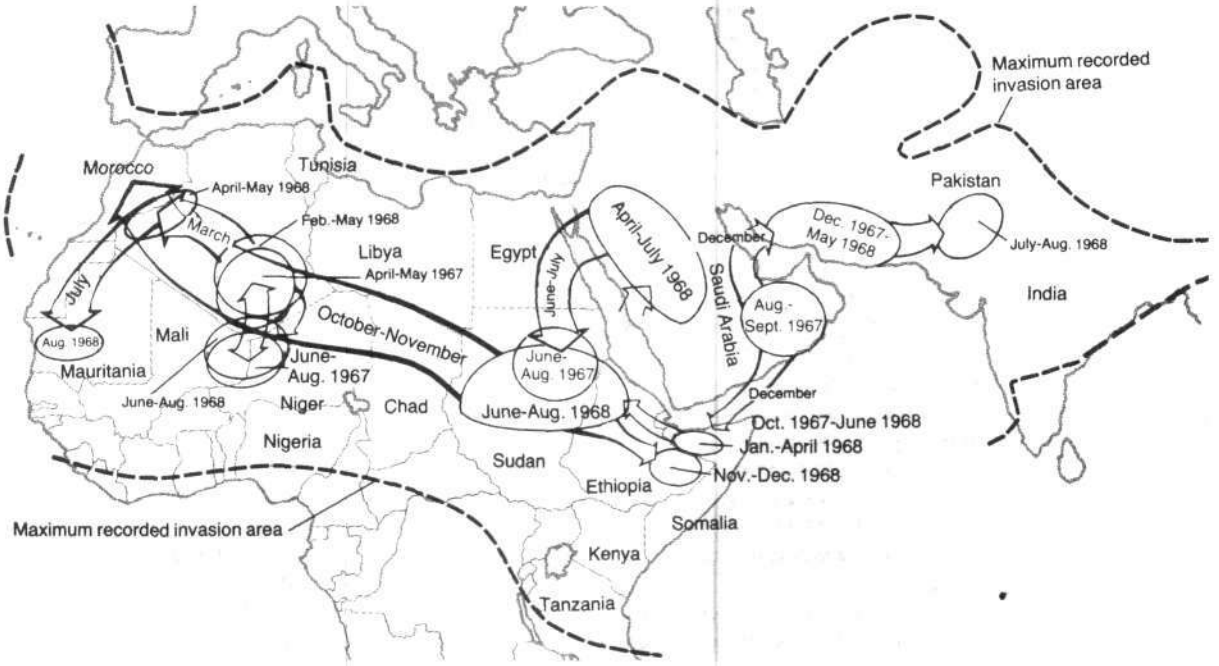


Figure 2
LOCUST BREEDING AREAS AND MIGRATIONS IN THE 1967-1968 PLAGUE
The intercontinental journey of the locust swarms in 1967-1968 followed a similar path to that taken in the 1950s plague: from the Sahel up to Morocco, back and forth from Saudi Arabia to East Africa, and from Saudi Arabia through Iran to Pakistan and India. The data are taken from a National Geographic Society compilation in 1968.

ens to 25 to 26 days—or less. When food is abundant, the locusts live about four months. In times of drought, their metabolism changes and they can survive for a year without food.

If conditions continue to be favorable, each subsequent generation of locusts will be 10 times the size of the previous one. Thus, one red locust can generate 1,020 locusts in the first generation of offspring; the second generation would number 520,200; and the third generation 265,302,000.[2] Once migrating, the swarm poses a formidable challenge even if there are adequate funds available for pesticides and airplanes to fight them to the death. Without adequate funds, it may take several years to contain the plague, if the weather conditions favor the locusts.

Until there were pesticides, once locusts were in the swarm stage, only extreme cold (the locust's body temperature must be 70° or more in order to fly), drowning in the ocean, or lack of vegetation would stop them. Now, a small amount of pesticide (usually fenitrothion or malathion) mixed with water and a little oil to keep it from evaporating, can be sprayed from the air to kill millions of locusts on contact.

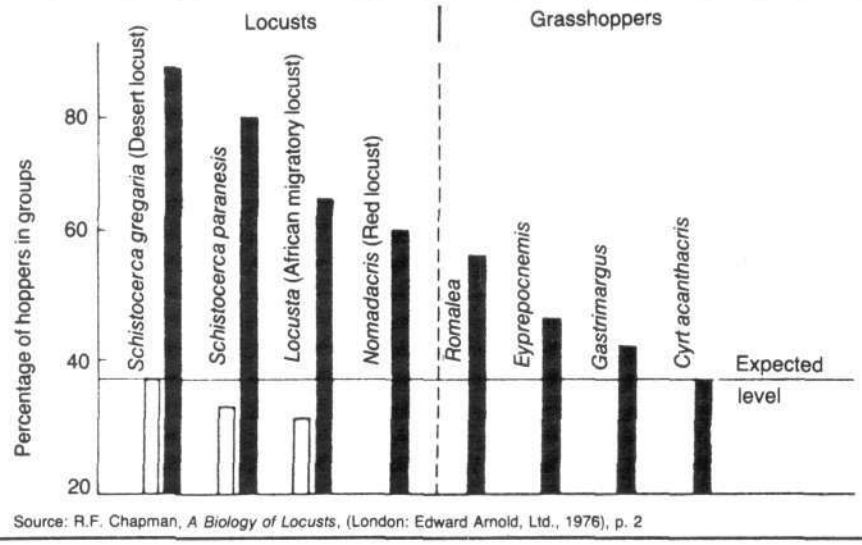
The Gregarious Locust Phase

That locust plagues are not cyclical was determined in the 1920s in experiments carried out at the Anti-Locust Research Center in London, run by Sir Boris Uvarov, whose two-volume work, *Grasshoppers and Locusts*, is still used today. Uvarov discovered that when food and water were abundant, the population explosion caused a kind of phase change in the locusts. Instead of a solitary existence, they turned into a self-propagating, gregarious swarm. Their body temperature and metabolism changed, their color changed, and they migrated, eating everything available. The gregarious locusts are so different from the solitary locusts of the same species, that for years they were identified as two separate species.

In the desert locust, the phase change to the swarm stage begins to occur when there are 5 to 15 locusts per square meter. The crowding spurs the gregariousness. In fact, researchers were able to produce gregarious behavior in solitary locusts in the laboratory simply by immersing them in a "crowded" environment. The gregarious behavior developed even when the locusts were "crowded" by continuously touching wires dangling into the cage.[2]

As shown in Figure 3, grasshoppers and locusts can be thought of as a series, from species of grasshopper that never become gregarious to species of locusts that often become gregarious. There are of course many species in between these two extremes that may occasionally swarm.

Once in the swarm stage, locusts travel up to 3,000 miles per generation. They have a double set of wings, about 5 inches across, and they fly where the winds take them, averaging between 10-25 kilometers per hour. The main source of energy for the flight is their reserve fat. In Uvarov's laboratory wind tunnel, locusts flying for 5 hours used 60 milligrams out of a total 175 milligrams of stored fat. In flight, the locust swarms are characterized by synchronized



Source: R.F. Chapman, *A Biology of Locusts*, (London: Edward Arnold, Ltd., 1976), p. 2

Figure 3
GREGARIOUS BEHAVIOR OF LOCUSTS AND GRASSHOPPERS IN LABORATORY EXPERIMENTS
In this experiment the black bars represent young insects reared in crowds, while the white bars are those reared in isolation. The horizontal line is the level of grouping expected if the insects were randomly distributed. The experiment measured the percentage in groups of two or more of 30 insects of each species and rearing type who were introduced into the same experimental apparatus for 30 minutes.

movement and parallel alignment, flying about 2 to 4 meters apart.

The enormous threat swarming locusts pose is their staying power: Female locusts in the swarm breed along the way, laying three sets of eggs, usually about 200 in all. These eggs can "overwinter," lying dormant until the next spring when they hatch as *gregarious* bands of young locusts. In the past, swarm infestations have lasted for years, even decades (Figure 4). And as the maps of past plagues show, once in progress, the winds carry the swarms from Africa to the Middle East and Indian subcontinent.

Grasshopper Control in the United States

Grasshopper plagues are not limited to tropical countries. In fact, if not for the extensive pest control programs here, grasshoppers could probably determine whether or not Americans would have food to eat, as they did in the colonial period. The United States now routinely spends about $35 million dollars a year in grasshopper control, aerially spraying about 13 million acres to make sure that grasshoppers don't ruin the grasslands on which cattle depend for grazing.

This crop and forage protection program grew out of a government response in the early years of the nation to the vast destruction grasshoppers inflicted on frontier farmers. Colonial historians report terrible locust plagues in the 1700s. "In 1749 and 1754 they were very numerous and voracious; no vegetable escaped these greedy troops; they even devoured the potato tops; and in 1743 and 1756 they covered the whole country and threatened to devour everything green."[3]

The pests regularly plagued settlers in the frontier states and in California, causing near famines, and even eating the clothes of the farmers in the fields. "One has no idea of the magnitude or destructibililty of this plague. Flying in clouds so thick as to darken the sky for an hour at a time, they leave the country over which they pass as bleak as if a fire had swept it. Millions may be killed, but like the war with China, there are 10 to take the place of every one that falls."[4]

The early settlers tried various measures to kill the locusts, but none was successful. One method popularized was for farmers to raise turkeys, which would then eat the locusts. The turkeys did eat the locusts, but during a plague they overate and became useless after about one hour! Other methods involved trapping the grasshopper in a contraption called a hopperdozer, filled with tar or water and coal oil. In 1877, Congress set up an Entomological Commission to address the problem, which later evolved into the Animal and Plant Health Inspection Service (APHIS) of the U.S. Department of Agriculture. By 1885, poison bait, bran soaked in poison, was used quite effectively, but this was expensive and labor intensive, which limited its use, and the devastation continued. In fact, in 1890, the U.S. government instituted a law that put into effect a kind of debt moratorium for settlers whose crops were destroyed by grasshoppers.

More effective remedies than using poison bait had to wait until the 1940s when DDT and other insecticides were first introduced. The crop destruction was worst during the years of the Depression. In 1931, 17,000 square miles of cropland in South Dakota and Nebraska were 75 percent destroyed. As one agricultural historian put it: "And this was but the beginning. Destruction commenced in earnest in 1934 . . . and hit an all-time peak in 1936 when damage throughout most of the affected states amounted to $106,333,000, or more than the total gross income from all farm products in Arizona, Nevada, New Mexico, Utah, and Wyoming combined."[5]

Because the pests ate everything, right down to the roots, the plague fostered water and wind erosion of the soil, thus materially contributing to the Dust Bowl of the thirties. This particular result has ominous importance for the current situation in the Sahel, where desertification is already on the march, taking over grasslands and arable land at an increasing rate.

The 1986 Plague: Will It Continue?

From the first alarms sounded in Africa, it was clear that the abundant rainfall in spring 1986, coming on top of years

of drought, had provided very favorable conditions for locusts to multiply exponentially, for the first time in about 10 years. Soon, reports from the Sahel and West and East Africa confirmed that a population explosion was about to occur among four species of locusts as well as the Senegalese grasshopper. By August, the outbreak had achieved plague status.

The response from the United Nations Food and Agriculture Organization (FAO) was slow—in keeping with their stated policy of reducing the population of Africa and restricting the diet of those left to subsistence-level cereal crops. Although individual countries had requested assistance on an emergency basis, the FAO continued to obfuscate the information. Task force teams were sent out from the FAO, from the U.S. Office of Foreign Disaster Assistance, and from other countries to verify the level and location of infestation.

Devastated by drought, famine, and civil war, and bled dry by the International Monetary Fund, the African countries themselves had few resources with which to launch a war against the locust. Also, the various regional locust organizations that had worked successfully a decade ago were for the most part nonfunctional because of funding cuts. Equipment—small planes, land rovers, communications—was either in disrepair or nonexistent.

The FAO, historically the international agency charged with responsibility for locust control, launched an emergency appeal in late April 1986. This was more than one year after the locust infestation in the Sahel had been reported as a threat. It was not until Aug. 19-20, 1986, that the donor countries met at FAO headquarters in Rome to discuss aid measures. They knew at the time that throughout the Sahel and West Africa, the window for emergency aid was only about three weeks in September. If the newly hatched hoppers were not eliminated then, there would be another, larger locust generation to contend with.

Despite the obvious large-scale infestation—millions of acres throughout the Sahel were affected—the FAO advocated a small-scale, small-plane effort targeting only the cropland to protect the crops and ignoring the vast grassland and uncultivated areas where the locusts and grasshoppers lay their eggs. (See interview with the second-in-command at the FAO's Emergency Center for Locust Operations, Rafink Skaf, p. 50.) No U.S. entomologist that this writer interviewed agreed with the FAO policy, because it was clear, given the vastness of the area to be covered, that large planes were needed to cover the territory quickly and that the breeding areas in the grasslands would have to be sprayed, if the plague was to be stopped. (See interview with U.S. entomologist George Cavin, p. 51.)

Acting against the advice of the FAO and on the basis of an on-site evaluation by a U.S. team, the U.S. Office of Foreign Disaster Assistance did mount a big-plane effort, just in the nick of time in mid-September. At the request of the government of Senegal, the U.S. and allies sponsored four DC-7 planes, supplied by the Arizona-based firm of T&G Aviation, which sprayed 2 million acres in Senegal and the nearby countries of the Gambia, Mali, and Mauritania. The spraying had a kill rate of between 95 and 98 percent—an obvious success.

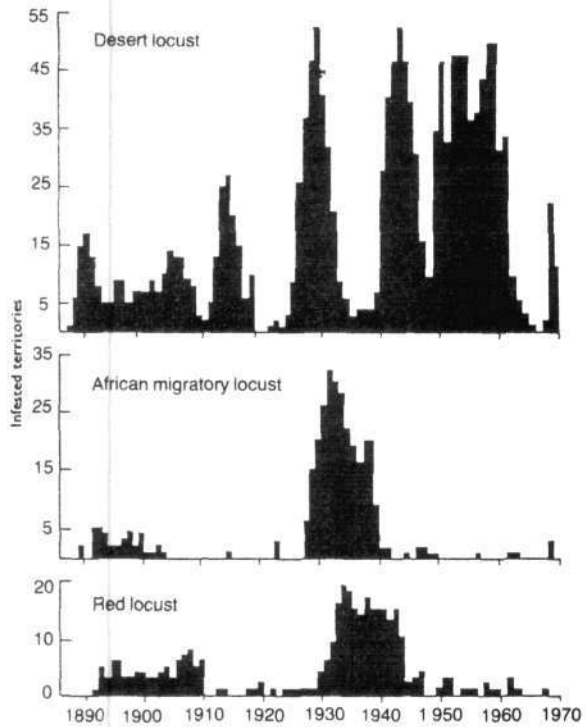


Figure 4
REPORTED AFRICAN LOCUST SWARMS OF THREE MAIN SPECIES, 1890-1970

Once the locusts are in a gregarious stage, the periods of infestation are not short. The data are from The Locust Handbook, *as cited by R.F. Chapman in* A Biology of Locusts, *(London: Edward Arnold, Ltd., 1976), p. 57.*

Other countries were not as fortunate. In addition to some crop damage, there were still nearly 2 million acres in the Sahel alone requiring treatment in mid-October, by the FAO's own conservative estimate. Nevertheless, the FAO is claiming that the $35 million emergency locust campaign was a success and that the threatened plague is now "under control" in West Africa, with 90 percent of the crops saved. In East Africa and southern Africa, where the breeding season is November-January, what happens will depend on the coming rains and how quickly and widespread the war is waged to kill the locust hoppers before they mature and multiply.

As for West Africa and the Sahel, while severe crop losses and consequent famine may have been avoided in this growing season, there is no question that the millions and millions of locust and grasshopper eggs laid in the grasslands and uncultivated areas could, if weather conditions are right next May, explode the pest population out of control in 1987.

The FAO's Malthusian 'Carrying Capacity'

The Malthusian philosophy of the FAO is amply documented in its yearly reports on the world food situation.

The FAO has determined, based on systems analysis studies carried out with the Soviet-controlled International Institute for Systems Analysis in Vienna, that Africa has already reached its population limit: At low levels of agricultural input, Africa's population in many areas exceeds its "carrying capacity," the potential capacity of the land to support people, the FAO says. (Africa's population density is actually a fraction of that of the United States, or the European nations.) FAO reports admit that with higher technology inputs, Africa's agriculture could actually support increasing population, but this is ruled out as an option, a priori. In fact, it is clear from the FAO documents, as well as those of the World Bank and the International Monetary Fund, that those agencies have already written off the continent of Africa and its 582 million people.

As early as the 1920s and certainly in the following four decades, the work of entomologist Uvarov made it clear that man was not destined to suffer famine and devastation from locusts forever. As the ecological conditions fostering the phase change to gregariousness became more known, Uvarov said, it should be possible to eradicate the pest not only by pesticide spraying, but by changing the ecology that leads to swarm formation. Today this is certainly possible, but only if the Malthusian outlook of the FAO and similar world agencies is replaced with a policy of industrializing and developing the Third World, building the kind of infrastructure—water projects, energy projects, railways, and so on—that will allow us to win the war against locusts once and for all.

Marjorie Mazel Hecht is managing editor of Fusion *magazine.*

Notes

1. R.F. Chapman, *A Biology of Locusts*, (London: Edward Arnold, Ltd., 1976).
2. Chapman p. 44.
3. Thaddeus W. Harris, *A Treatise on Some of the Insects Injurious to Vegetation*, ed. Charles Flint (Boston, 1862), p. 169, as cited by John T. Schlebecker in "Grasshoppers in American Agricultural History," *Agricultural History*, **27**:86 (1953).
4. *Pacific Rural Press*, July 22, 1878, as cited by Schlebecker, p. 87.
5. Schlebecker, p. 91.

AN INTERVIEW WITH RAFINK SKAF

The FAO's 'Small-Scale' Approach to The Locust Plague

Rafink Skaf, an entomologist, is Senior Officer at the Emergency Center for Locust Operations and has worked for the UN Food and Agriculture Organization in Rome for 21 years. These are excerpts from an interview Sept. 18, 1986 with Marjorie Mazel Hecht.

Question: Was a decision made to send the DC-7s from Senegal to Burkina Faso?

We had an informal meeting of donor countries this week to review the situation. There was an exchange of opinion and there are two different approaches: one supporting the small-scale—I mean spotty infestations—to be treated by small planes, the other for the big planes. There was an exchange of views, but the large-scale operation was not retained as far as I understand. . . .

Question: Who represented the view that there should be big planes there?

There were some entomologists in the field who submitted this idea, but then it was seen that it was better to do it differently by spraying only the concentrations, near the crops as a crop protection operation, and not a large-scale operation—in order to protect crops. . . .

Question: Do you mean that in the grasslands they are not spraying for the grasshoppers?

No, not in the grasslands, because otherwise it would be a big enterprise, far beyond the capacities of any country or of any donor at present. . . .

T&G Aviation

This DC-7, spraying malathion in Senegal, is one of four big planes that sprayed 2 million acres in West Africa. The ambassador from Senegal to the United States, His Excellency Falilou Kane, called the spraying effort a great success. "We did not accept the advice of some experts saying that we did not need these big planes," Kane said. "So we decided ourselves to do it quickly with the big planes, and I can say it was effective in our country. Perhaps it will help the others understand that big action is needed sometimes." Senegal spent $2 million for malathion to get the job done.

Question: So, because of money reasons, they chose not to spray some of the sparsely populated area?

No, it is not a matter of money. But in order to finance this it would have needed several donors' contributions, and also a consensus on the technical approach itself, and there was not unanimity on this approach.

Question: What is planned for the campaign in Botswana?

The government is providing now equipment and funds and donors too, and until now the USA has provided half of the aid fund requirement for Botswana. We filled all of the requirements according to the FAO estimates, but now the new estimates of the government are much more. But maybe they are too ambitious. They are planning to spray more than the capabilities.

Question: You know that that is the approach I would take. I don't think it is too ambitious; I think it is actually protecting next year's crop.

I tried last week to explain to you that you are too optimistic. You cannot cover all the sandy areas in Botswana, because it is impossible to cover them practically.

Question: Logistically you could do it. You have the planes and pesticide.

It is not only a matter of planes. There is no reason to spray huge areas if you are not sure where they are there. And if, suppose you do it, you can not avoid other swarms that will come from South Africa. This is why we prefer to have a pragmatic approach and to control only to protect the crops. . . .

Question: What concerns me is that the stakes are very high and if your pragmatic approach is not sufficient, a lot of people will die as a result.

Oh, no, no. We know the type of infestation of the brown locust. It is not like red locusts giving you large infestations and concentrations. It is all over scattered, and heavy in some areas, and unless you have a good reporting system on the ground, you always miss a large percentage of these infestations.

Question: What has Botswana's government asked for?

They want $8 million, just for Botswana. . . .

Question: You know that $8 million for 1 million hectares is about what the U.S. spends—in acres it's about $3 per acre.

The calculation does not work this way. Because if you want to control all that area, even with the $8 million this does not mean that you kill everything, and not achieve at the end anything because you would be invaded again from the source. My approach is to protect the crop with a few well-equipped teams that you really can train and organize. Also with an aerial control around the crops, with the heavy concentrations. And you protect the crop; that is the program. And anything else would be a waste of time and money.

Question: Are you saying that you would really leave alone areas that are infested that are not near the crop areas?

Definitely. With good targets and good concentrations in this case, it is worth it in order to protect the crops from the brown locusts. . . .

Question: But then I don't understand how your approach would work. These swarms will go wherever the crops are, so if you leave them to continue breeding in the less populated areas, they will soon be where the crops are.

Crops in Botswana are concentrated in the south. They are not all over Botswana. The distance of the swarms is not regular. They grow up according to the rains. So, a special focus, a big goal, is to protect the crops and to control the area around where they are breeding near the crops. As I said, if there aren't enough teams able to report and enough aircraft in the noncultivated areas to kill big concentrations of course it will serve a lot of breeding potentially attacking the crops. I don't reject your opinion totally, no.

Question: What you are saying is you are not going to do the *bigger effort because of money. . . . Botswana is right. They* should get the $8 million, they should do the complete job.

No, no, no. I don't think so because you know whatever they do, they will receive more [locusts] from South Africa, because there are 20 million hectares there, so that they keep receiving from there. And Botswana is a small country and they would have to do fantastic work in a short time, which is not easy.

AN INTERVIEW WITH GEORGE CAVIN

How to Fight the Locust Plague

Retired U.S. Department of Agriculture entomologist George Cavin worked for several years on locust control in Africa and the Mideast and was in Mali in 1986 as part of a U.S. AID team. These are excerpts from an interview Sept. 23 with Marjorie Mazel Hecht.

Question: The Food and Agriculture Organization has taken an approach against large-scale spraying. They are saying that there are millions of hectares infested, but they will spray only the areas near the crops in order to protect the crops, letting the grasslands go. . . . What do you think about this?

. . .If they wanted to accomplish the job satisfactorily, they must treat the insect in its larval stage before it reaches adulthood and starts to migrate. Those larval stages generally hatch out in the grassland areas. Although some do hatch out in the cropland, the general habitat for the larval stage is in the grassland area. That's where you are going to have to attack them if you are going to do a successful job of preventing crop damage. Once they return as adults and enter the crops, even though you treat them at that time, by the time mortality occurs to the insect, severe crop dam-

age is going to occur.

Question: It seems to me also that by not treating the grasslands, you would guarantee that next year you would have a bigger problem.

This is correct. You've got to treat a certain amount of the total infested area to begin to get the population to go back downhill. Generally, if you treat just the cropland, it is mainly adults that you are treating and many of those adults have already laid eggs for the next year's crop. So by merely treating in the cropland areas—what we are speaking of is migratory grasshoppers—you are not doing much toward diminishing the problem for another year.

Question: All of the U.S. entomologists whom I've talked to, who have experience in treating grasshoppers in this country, absolutely agree with what you said. I know that in Burkina Faso the FAO specifically recommended spraying only one-fifth of the area that is infested; they are ignoring the infestation in the grasslands.

I'm not aware of what the situation is in Burkina Faso right now, I know that they had a grasshopper problem early and I'm sure that those are the migratory types of grasshoppers. They moved north, and now what they are spraying is the migratory grasshoppers coming back into Burkina Faso with the retreat of the Inter-Tropical Convergence System. They are probably all adult grasshoppers, so it is likely that they have laid quite a number of eggs already. So we can expect, if conditions are favorable, that we will have grasshoppers there again next year. . . .

Question: What would you do to solve the problem, if you were not constrained by some of the obvious constraints?

I think the main step is that these [regional locust control] organizations have got to somehow be revitalized. . . . What they need is the support materials and the financing to do it. . . .

Question: In terms of the emergency situation today, what would you do?

Of course you've got a whole group of different types of grasshoppers and locust involved here. None of them can be approached by the same methods. For instance, for the African migratory locust, they've got to get back and clean up things in the central area of Mali, and in the Lake Chad basin and along the river banks leading into Lake Chad, because that's where these locust infestations develop. Since swarms have already gone out of there, they are going to start breeding in other locations. But if you want to stop it from being on an almost continuous basis, you have to get back in there and knock them down in those locations. That would certainly be the approach you would take for the African migratory locust.

The locust is pretty much the same in Tanzania and Zambia. You have got to get into the breeding areas and knock those populations down there. Eventually, the entire problem will die out if you can keep those areas under control. . . .

Question: What about the grasshopper problem?

It's practically too late now [in West Africa] unless there are aircraft right on the ground to really stop anything other than to try to protect the cropland at the present time. . . . What they need to do now is prepare for next year, and have equipment and materials and so forth on the ground in May and start treating the grasshoppers as they hatch out as the rains start in the south. They should then move north with the rains and treat them as they hatch or shortly after hatching. If they want to stop the infestation, I think that that is the primary means of doing it. . . .

Question: So for this area, we are now talking about May 1987 as the next critical point.

That's right. When all of these new generation eggs will have wintered and carry over in the egg stage until the rains come in May or early June. They will then hatch, and the hatch keeps occurring as the rains move northward with the Inter-Tropical Convergence. So you start at the south end where the rains begin and just move your control effort toward the north following the rains. . . .

Question: In the United States, in the 1930s when the normal control procedures for grasshopper control were stopped because of the Depression, the grasshoppers multiplied, eating right down to the roots of the vegetation. This destruction of the vegetation is partly what led to the creation of the Dust Bowl.

This is one of the problems that hasn't been taken into consideration sufficiently in the Sahel—the damage that these things do to the grasslands themselves. They certainly contribute to the desertification of the Sahel.

Question: Also, it cuts out your source of protein; grazing animals are still a livelihood and source of meat in much of that area.

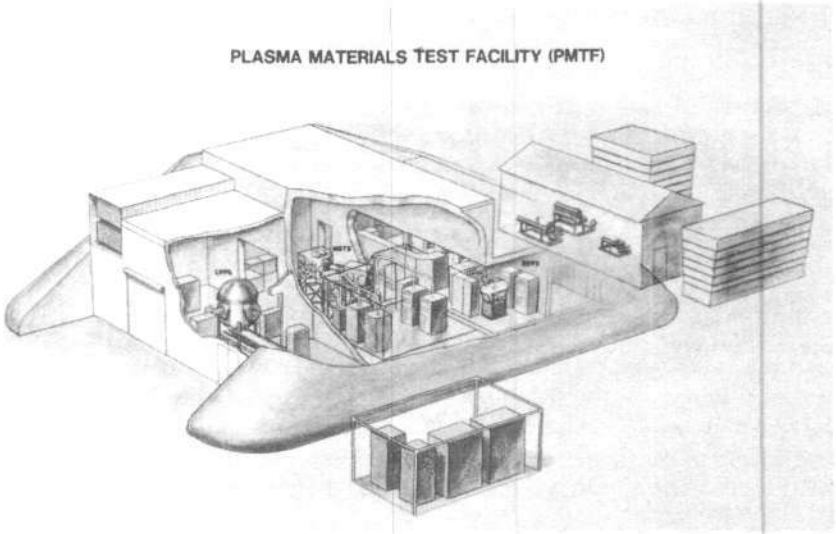
Goats and cattle are still very apparent in that area. They still have large herds.

Question: So if you get rid of your grassland, even 60 percent of the vegetation on the grasslands, you really have nothing to feed your livestock.

There's not very much left, that's right.

Question: On that basis alone, it seems to me that the FAO's prescription for the area is one that is bound to fail and cause a lot more starvation.

This whole area, the Sahel, is a very, very fragile ecological zone in the first place. Anything like that tends to disrupt it; it can have a really severe effect on it. I just think that the situation is getting to the point over there where definite action has to be taken, and it needs coordination of the governments that are assisting and so forth, because it looks like what we saw in the early 1950s, except then we really only had one problem and that was the desert locust. This time we have several locusts plus the grasshoppers, so the situation is even much more alarming. In the 1950s it took over 10 years to get the problem back under control; in fact nature did more of it than did man. . . . It is kind of a sad and discouraging thing to see. And the outlook sure doesn't look very good.



Sandia National Laboratory

Sandia's Plasma Materials Test Facility has an ion beam system that can heat materials like steel to its breaking point, as part of the testing process for materials suitable for fusion reactors. Above is an artist's illustration of the facility.

Sandia Materials Facility to Build and Test Fusion Hardware

by David Cherry

With the completion last spring of an ion beam system that simulates conditions inside a tokamak, the Plasma Materials Test Facility (PMTF) at Sandia National Laboratories in Albuquerque became fully operational.

The ion beam system can deliver 800,000 watts of heating power for several seconds at a time to a 59-cubic-foot chamber. Access to the chamber, a door 2×3 feet, is large enough to admit large test samples. The beam of hydrogen ions, 9 inches in diameter, bombards the sample, rapidly heating it. It can heat a piece of steel to the point of failure, if desired.

The kinds of equipment to be tested in the ion beam changer include limiters, magnetic divertors, actively cooled radio frequency antennas, and beam dumps. A beam dump is armor to protect the inner wall of a tokamak from the effects of neutral beam injection.

The PMTF was built in response to requests from U.S. laboratories asking Sandia to design and build components of the kind that can withstand neutron bombardment and contact with the hot plasma itself. Dr. Wilhelm Gauster, supervisor of Sandia's Fusion Technology Division, said of the PMTF, "We'll work with the physics labs to design and build the hardware to be installed in fusion machines and then go there to participate in the tests."

The PMTF can fabricate experimental heat resistant coatings with a new plasma spray machine. The machine can continuously vary the composition of a coating as it is deposited. For example, it can apply a mixture of silicon carbide and aluminum that is mostly aluminum at the base for good adherence, and pure silicon carbide ceramic at the outer surface.

The PMTF also includes an electron-beam accelerator, the original machine for the kind of testing now done

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The Young Scientist

Astronomer Diego Rodriguez and The Study of Comets

by Carlos Wesley and Carlos de Hoyos

Although even many Mexicans do not know about the work of the 17th century Mexican astronomer Diego Rodriquez, he was a major scientist of his day. Rodriquez, who lived from 1596 to 1668 and who studied the work of Kepler, laid the foundation for Mexico's leading role in astronomy today.

It was Rodriquez who prepared the way for British astronomer John Flamsteed's determination "that comets orbit the Sun and that they come back again and again"[1] Credit for that discovery is usually given to Isaac Newton's protégé, Edmund Halley, but the historical records show that Newton and Halley dishonestly appropriated Flamsteed's work. Halley's comet, in fact, more properly should be called Flamsteed's comet, or the Rodriguez-Flamsteed comet.

Until Rodriguez's work, scientists—even apparently Kepler—believed that comets traveled in a straight line. Kepler had demonstrated that Aristotle was wrong in claiming that the planets and the stars circled the Earth embedded in solid spheres of crystal. He showed that instead, the planets traveled in elliptical orbits, with the Sun as one of the foci of their ellipses. Yet Kepler thought that comets followed a straight line, not the rotational motion of the planets around the Sun.

In 1652, Rodriguez wrote a book on his observations of a comet appearing that year, *Discurso Etheorologico Del Nuevo Cometa (Ethereal Discourse on the New Comet)*. He undertook this study, he says, on the supposition that "there is a lack of knowledge about the nature of comets and how they come into being, and starting from that principle, I have sought to discover their cause."

The method he employs is the Platonic method of hypothesis. As he says, "Those things that are unknown to us and hidden from the senses, can be verified and demonstrated by locating them in the realm of possibility, insofar as they are not repugnant to reason."

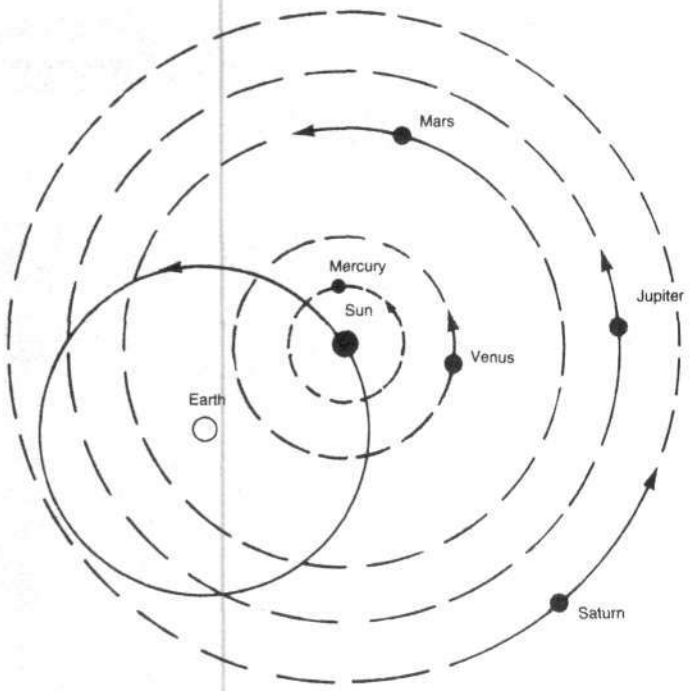

DISCVRSO
ETHEOROLOGICO
DEL NVEVO COMETA, VISTO EN aqueſte Hemiſferio Mexicano; y generalmente en todo el mundo. Éſte Año de 1652.
DECIFRADO
A la Immaculada Concepcion de MARIA Santiſsima, Madre, y Señora nueſtra.
COMPVESTO
Por el Padre Preſentado Fr. DIEGO RODRIGVEZ, del Orden de Nra Señora de la Merced, Redencion de cautivos, y Cathedratico en propriedad de Mathematicas en aqueſta Real Vniverſidad de Mexico.
DEDICADO
A la Glorioſiſsima, y Admirable Santa RITA DE CASSIA, de la Eſclarecida Religion del Gran Padre, y Patriarca San Agueſtin, Doctor de la Igleſia.
Æthereum Phœnomenon:
Ego immaculatæ originis.
El Cometa
Tabulado Xpis
Nuevo de Inmaculada
Pureza
(4) CON LICENCIA, EN MEXICO (4)
Por la Biuda de Bernardo Calderon, en la calle de San Aguſtin, donde ſe venden

Source: Elias Trabulse, *Historia de la Ciencia en Mexico*, Vol. 2, Mexico City: Conacyt/Fondo de Cultura Economica, 1984.

Diego Rodriguez argued that comets travel in orbits around the Sun. At right, the title page of Rodriguez's 1652 book on the comet appearing that year.

Rodriguez blasts the Aristotelian conception that the planets and stars were embedded in solid spheres of crystal: "Whether the heavens are solid, fluid, or made up of a very pure ether is not a question of faith, as this controversy has been rent by opinions even among the Saints and Doctors of the Church. That [faction] which affirms that there are no solid heavens, has been so validated in this century, and is so well supported by reason, that it laughs at those who hold the contrary opinion."

Rodriguez writes, "what Aristotle took away from the heavens to make them impermeable, that itself is what we will put back so that they not be. . . ." Aristotle, for example, had put comets within the atmosphere, so that they would not interfere with his view of the solidity of the celestial realm. Rodriguez is putting them back, and declaring that the heavens are not solid.



TYCHO BRAHE'S SOLAR SYSTEM

Rodriguez propounded what was then a heretical view—that the planets orbit the Sun, not the Earth. Yet he avoided the Spanish Inquisition by appearing to agree with the system of Tycho Brahe, the Danish astronomer. In Brahe's system, the five known planets—other than Earth—all orbit the Sun, while the Sun is orbiting the Earth, as shown above.

Heliocentricity

Rodriguez holds firmly to the view that the planets and the comets follow a heliocentric course—that is, that they go around the Sun, as the 16th century Polish astronomer Copernicus had maintained—and not a geocentric one. The geocentrists, like Aristotle and Ptolemy, held that all the heavenly bodies revolved around the Earth, and this was the accepted teaching of the Church in the Spanish Empire, including Mexico, at that time. To challenge that view could result in imprisonment and even death at the hands of the Inquisition.

But Rodriguez does challenge that view. The expedient he uses is what might be termed "fudging" the truth a little. The Danish astronomer Tycho Brahe (1546-1601) had hypothesized that all the planets except Earth orbited the Sun, but Brahe did not go against accepted doctrine, because he said that the Sun orbited the Earth.

One of the proofs that the heavens are not solid, says Rodriguez, "is the movements of the five planets, Saturn, Jupiter, Mars, Venus, and Mercury (as has been affirmed and proven by Tycho and many others), which move concentrically around the Sun. . . ." By mentioning Brahe, and leaving out any mention of the Earth—the only other known planet—Rodriguez was able to state his heliocentric view without incurring the wrath of the Inquisition.

The Comet Factor

Another proof that the heavens are not solid, says Rodriguez, "is the argument based on the movement of the comets, because, firstly, they move perfectly in a great orbit as the planets themselves, a feature only of the heavens and not of the region of the atmosphere, which even in rapture should not be conceded; they move at first rapidly, and later slowly and circularly, and without any eccentricity, and not with a straight-line motion, as Johannes Kepler would have it, which is not admissible in nature."

At the time Rodriguez published his book on the comets, he held the chair of astronomy and mathematics at the Royal and Pontifical University in Mexico. His successor in that post, Carlos Siguenza y Gongora, was intimately acquainted with Rodriguez's work, and actively corresponded with John Flamsteed, the English royal "astronomical observator," most assuredly making known to him Rodriguez's hypothesis that comets orbit the Sun. Since Rodriguez assumed that comets burned themselves up as they circled the Sun, it remained for Flamsteed to establish that "they come back again and again."

What about the origins of the comets? Rodriguez writes: "Regarding their generation, they begin to take the round shape of the heavenly bodies and to resemble them, according to the nobility of the substance assigned to them, although they are not permanent."

Regarding the tails of comets, Rodriguez says: "The Sun with its rays shines upon the body of the comet . . . and with its fieryness and the comet's impulse, it pushes behind it the more tenuous and superficial matter, which resisting and seeking union with its body and the

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Profile of a 17th Century Scientist

Fray Diego Rodriguez

by Carlos de Hoyos and Carlos Wesley

Fray (Friar or Brother) Diego Rodriguez was an important intellectual figure in the process of building a republic in Mexico from the Spanish colonial foundations. He worked in all areas of universal knowledge, from mathematics, astronomy, and engineering, to architecture, music, and philosophy.

Rodriquez was one of those important natural scientists, like Benjamin Franklin and Alexander von Humboldt, who serve to move the entire process of science and technology forward in their time.

Rodriguez was born in 1596 in the town of Atitalaquia. He was sent to grammar school in Mexico City, and soon joined the Mercedarian Order, which was to become one of the most important intellectual centers of the colonial period.

He allied himself with Juan de Palafox, who arrived in Mexico in 1640 as Bishop of Puebla and Visitor General of New Spain. Palafox, who became the acting viceroy, undertook open warfare against the Jesuits who controlled the Inquisition in Mexico. That fight culminated in a partial victory for the faction of Palafox and Rodriguez, with curriculum reforms in the universities of Puebla and Mexico City.

As a result of the "Palafoxian Reform," the chair of mathematics and astronomy was created in 1647 at the Royal and Pontifical University of Mexico. Fray Diego occupied the post from its founding until his death in 1668. Rodriguez updated the teaching of mathematics in Mexico by introducing the works of the modern thinkers like Kepler, Tycho Brahe, and Copernicus.

That same year, Fray Diego also was named to the Viceroy's Commission to assess the progress of the great project to solve the constant floods that threatened the city. The construction of an efficient drainage system was one of the major technological challenges of the time, and Fray Diego contributed to the work initiated by another astronomer and mathematician, Enrico Martinez, whose original name was Heinrich Martins—he was born in Germany.

Illustration by Christopher Sloan

With the exception of his treatise on comets, Rodriguez was unable to have any of his major works published during his lifetime, probably because of the Inquisition in Mexico. He attempted to have a treatise on logarithms published in Spain, but that too was blocked. According to the Mercedarian Order's chronicles, fearing that the book was going to be lost Rodriguez "decided to send it to the city of Lima, Peru, where there was a disciple of his, Francisco Ruiz Lozano." Nothing has been heard of this book since.

Fray Diego and his collaborators took charge of the cathedral-building projects in New Spain, which had been started several years before. This resulted in the magnificent buildings of the cathedrals of Puebla, Oaxaca, and Mexico City.

The Jesuit Inquisition

The Jesuit inquisitors attempted to destroy their political opponents by

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Telling Time By the Sun and Stars

by Jim Everett

Now that we have celebrated the arrival of the New Year, let's take the occasion to look a little more closely at the calendar. As often happens, a fresh look at something long familiar can open up windows to fascinating periods in human history. In the case of the calendar, we must begin over 5,000 years ago with the birth of astronomy as a science. Our story continues well into the 20th century and, as we shall see, the story is not finished even now, for our calendar is still not perfect.

Before exploring the history of the calendar, let's start with some fundamentals. The measurement of the year as expressed in days is the purpose of calendars, but also the problem. The year, astronomically speaking, is the time the Earth takes to orbit the Sun. The day is the time the Earth takes to spin once on its axis. The job of making a calendar is simply to count the number of Earth spins (days) for every one orbit (year). This is not so easy, for two reasons.

First, how do you know when to stop counting the days; that is, what astronomical event do you use as your year marker? Societies throughout history have used many different techniques, each having its advantages. One of the most famous year markers is Stonehenge, England, built at the same time as the Pyramids, almost 5,000 years ago. Stonehenge was built to observe the first day of summer, the summer solstice.

The Stonehenge calendar worked by having the observer stand in the middle of the ring of stones and look in the direction of a particular stone outside the circle. On the day when the Sun rose over that particular stone, called the "heel stone," that and no other day was the summer solstice.

To make a calendar using this observatory, you would simply have to count the days from one summer solstice to the next. No evidence survives of how many days were in the year used by the builders of Stonehenge. Because this method of measuring the occurrence of the summer solstice was not terribly exact, the Stonehenge users probably first arrived at a number that was close to, but not exactly, 365 days. With continued observations over many years, there is no reason that they could not have perfected a reasonably accurate calendar.

The Stonehenge calendar was built for observing the summer solstice.

Arriving at 365 Days

We do know that the Egyptians of about this same time had a calendar of 365 days. The yearly event they first used to mark the beginning of the year was also, indirectly, astronomical.

As the summer Sun rose higher in the sky and the air began to warm, the snow packs in the mountains of Africa quickly melted, sending down a torrent of water into a number of streams and rivers that all merged into the Nile River. Every year the Nile would reach flood stage in Egypt at almost the same time.

From a very early time, Egyptian astronomers learned that this event could be predicted by scanning the

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Books

Learned Ignorance: Four New Books on Quantum Physics

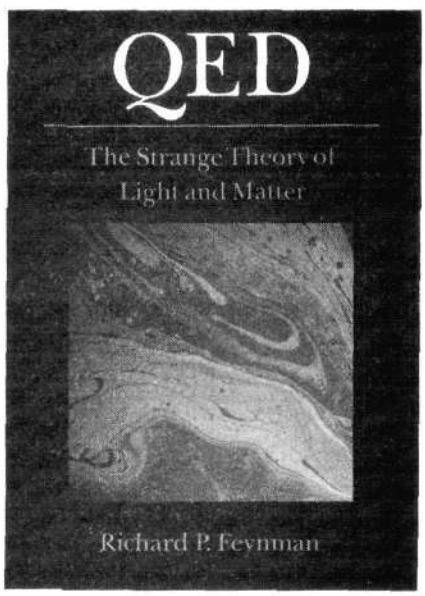
by Carol White

The Second Creation: Makers of the Revolution in 20th-Century Physics
Robert P. Crease and Charles C. Mann
New York: Macmillan Publishing Company, 1986
480 pages, $25.00

QED: The Strange Theory of Light and Matter
Richard P. Feynman
Princeton: Princeton University Press, 1985
158 pages, $18.50

Inward Bound: of Matter and Forces in the Physical World
Abraham Pais
Oxford: Clarendon Press or New York: Oxford University Press, 1986
666 pages, $24.95

Light: The Mystery of the Universe
Khalil Seyrafi, Ph.D
Los Angeles: Electrical-Optical Research Company, 1986
240 pages, $18.50



It is generally the case that popular books on the subject of quantum physics tend to adopt a supercilious air, both toward the reader, and also toward the universe at large. In short, their theme is the absurdity and irrationality of existence. The four books I am discussing here do not fall into that trap, although their authors are indeed trapped by the preconceptions of quantum theory.

It is the case that modern physics is both abstruse and intensely algebraic. Now more than ever, Nicholas of Cusa's call for the true scientist to approach his work from the standpoint of "learned ignorance" is appropriate.

In Nicholas of Cusa's day, the mid-15th century, scientific endeavor was overwhelmed with the pedantry of Aristotelian nostrums, just as today, particle physics is increasingly divorced from experiment and rule oriented.

Another way of putting it is that in both periods the search for "why?" has been abandoned. Feynman, in *QED* states the case perfectly. "The next reason that you might think you do not understand what I am telling you is," he writes, "while I am describing to you *how* nature works, you won't understand *why* Nature works that way [emphasis in original].

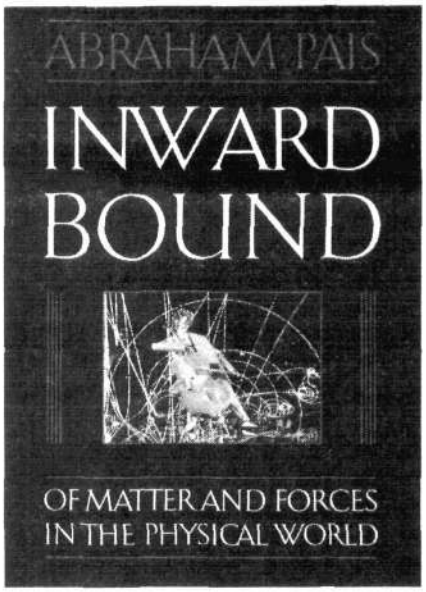
"But you see, nobody understands that. . . . The theory of quantum electrodynamics describes Nature as absurd from the point of view of common sense. And it agrees fully with experiment. So I hope you can accept Nature as She is—absurd."

Nicholas of Cusa can rightly be considered the father of modern science, and the question he solved on the most profound epistemological level was how to reconcile the apparent paradox of the one-and-the-many (in present-day terms the particle-and-the-field duality) and God's higher purpose in creating the self-perfecting universe.

It is only by recognizing that tendency for perfection, that an ordering principle for scientific theory can obtain. Am I introducing epistemology

into science from left field? The opening chapter of *The Second Creation* should dispel that idea.

The book begins by describing an ongoing experiment to determine a rate of proton decay that will substantiate a grand unification theory, which depends upon establishing that the Universe will die in 10^{31} years—a billion trillion trillion years.



The retreat from serious experiment is discussed by Pais in his book, *Inward Bound*: "The new *trend* in particle theory," he writes, "which began to emerge in the early 1950s as the result of the experiences with isospin, is perhaps best explained by comparing Lorentz invariance as abstracted from Maxwell-Lorentz theory with isospin invariance as abstracted from meson theory."

Contrasting the origins of relativity theory to the present-day theory of the atomic nucleus, he continues, "In the meson case, on the other hand, isospin survived even when the equations which had served as a means of abstraction became highly dubious.

"Isospin invariance, first introduced in phenomenological nuclear potentials, then built into Yukawa equations, became a free-floating invariance in search of a badly needed appropriate dynamics. That type of development was to recur in subsequent years: start with dynamical equations, abstract some of their general features, forget the starting point."

The palliative which Cusa recommended is more than ever needed today. The starting point for emerging from the present-day morass of quantum physics is to reject the highly intricate algebraic apparatus which has been elaborated and overelaborated; to recognize that it is necessary to reexamine what we know of the universe anew, from the standpoint of learned ignorance.

Notwithstanding, I would particularly recommend *The Second Creation*, which is profitably read with *Inward Bound*. Both books have the advantage of an extensive bibliography which references sources available to the reader. Both cite correspondence between leading scientists in great detail. Both succeed in large measure, in recreating the history of physics over the past century as a process of discovery.

The Second Creation is more oriented toward the general reader. The authors struggle, successfully, for clarity in their explanations. On the other hand *Inward Bound* is more technical and therefore more difficult. It benefits in its beginning, however, by an extensive treatment of spectroscopy and the early days of physics, which is fascinating.

Unlike the typical textbook, which oppresses the student with received wisdom, both books describe in detail the conflicts and doubts which at times almost overwhelmed physicists as they struggled to understand nuclear physics. It is noteworthy that these doubts appear to have been more profoundly felt in the first half of the century. The tendency appears to have been, alas, that physicists more and more have come to terms with the "absurdity" of their theories.

The authors of *The Second Creation* are also a lot less polite in their account than Pais is in his. One of their best reports is how the attempt was made, by the powers-that-be, to suppress evidence of what is now known as the Lamb Shift, in order not to allow accepted theory to come under attack. The role of the "science mafia" in controlling the direction of research not only by controlling grants but, in the above case, by deliberately distorting the interpretation of experimental results, is simply not treated by Pais.

Feynman's book, *QED*, is an interesting contrast. He is a great teacher. He is determined not to overwhelm the nonscientist with his or her inability to ever, ever understand what the pundits are talking about, and this makes Feynman very likable.

But—and this is a big but—although his fascinating little book may tell us a lot about how scientists go about solving certain problems, as he himself admits, the "why" is missing; not only the grand "why" of the creation, but even the "why" as it emerges in an in-depth historical account such as that by Pais or by Crease and Mann. So read it, but read it only along with an historical account of the subject.

Lastly, there is Khalil Seyrafi's *Light: the Mystery of the Universe*. This book is a thumbnail sketch of the subject of optics from the days of the Greeks to the present. Its superficiality necessarily follows.

Although I think this is an unhappy format, it can be useful to the reader who wants an easy reference at hand. However, I would particularly caution against taking Seyrafi's discussion of the Platonic tradition seriously.

Sandia Materials Facility

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more effectively in the ion beam test system.

Textor's Limiter

A sample of the work under way at PMTF is its leadership in the construction of the first limiter relevant to a working reactor, that for the Textor tokamak at Jülich, West Germany. A limiter is a belt of steel running the full circumference of the tokamak the long way, along the inside of the outer wall. Although the hottest, central portion of the plasma must not touch the walls of the machine, the outer portion of the plasma column can be limited and shaped by such a steel belt, constructed with a special heat-insulating coating.

Sandia is the coordinator of an international program to build the Textor limiter, called ALT II (Advanced Limiter Test II). The hardware designed at Sandia is now being constructed in Japan, West Germany, and at Sandia, for installation and operation in early 1987. It is a belt or blade 6-10 inches wide. The prototype blade now being made is of stainless steel with a graphite coating.

In addition to its function as a physical barrier, it includes pumping equipment outside the chamber, which is capable of controlling the density of the plasma edge and removing impurities from it. The plasma particles are collected beneath the limiter blade and channeled out through pump ducts.

ALT II will be capable of exhausting 5-10 percent of the plasma particles and of removing heat flux from the limiter face at the rate of 200 watts per square centimeter.

The ALT II group at Sandia expects the program "to provide definitive answers to many crucial materials and engineering problems for other fusion devices," according to Jorman Koski, the program director.

Sandia recently began design of a pump limiter for the Tore-Supra, a large tokamak with superconducting coils under construction near Marseilles, France. Tore-Supra is scheduled for completion in 1988. Sandia is also testing materials and components for the TFTR at Princeton and the Joint European Torus at Culham, England.

Astronomer Rodriguez

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larger portion of the matter which clings to it and pulls on it, without detaching itself forms the tail, until the persistence of the Sun's rays little by little diminishes it and consumes it, the matter being replaced constantly from the body of the comet. The Sun progressively dissolves it, alters it, and consumes it until through its tail, the whole comet vanishes."

As to the curvature of the tail, Rodriguez, following British scientist William Gilbert, says that it is due to "certain virtues in heaven, which are so strong and efficacious (more so if they are near the comet and of its same substance, and which were the main instruments that brought about its generation) which pull on the comet, as the magnet-stone does with steel."

Rodriguez's scientific work was not limited to comets. He did work on optics; he designed and built his own astronomical instruments. He wrote a treatise on the construction of accurate clocks—essential for astronomical work—basing himself on the tables elaborated by Brahe and Kepler, and using primarily geometrical methods for construction. He also established the longitude of the Valley of Mexico.

His calculation of Mexico's longitude was criticized in the 19th century by Alexander Humboldt, whose knowledge about Rodriguez came from oral reports, and not from Rodriguez's writings, which were no longer in circulation. Later it turned out that Rodriguez's calculations were more accurate than Humboldt's, with a deviation of a mere .8 of a second from the true longitudinal position.

Some of Rodriguez's unpublished manuscripts are preserved in the National Library of Mexico, including his mathematical treatise, *Tractatus Proemialium Mathematices*, the first book of which is devoted in large part to the conic sections, the circle, the ellipse, the parabola, and the hyperbola.

Note

1. See "Why the Credit for 'Halley's' Comet Belongs to John Flamsteed," by Philip Valenti, *Fusion*, Sept.-Oct. 1985, p. 44).

Letters

Continued from page 6

speakers bureau is also able to supply speakers and slide shows to schools on beam defense, space colonization, nuclear and fusion power, AIDS, and world development. Contact the FEF at (703) 771-7000.

Statement of Ownership, Management, and Circulation
(Required by 39 U.S.C. 3685)

Fusion magazine, publication no. 437370, is published bimonthly, 6 times a year, at an annual subscription rate of $20. *Fusion* and the Fusion Energy Foundation, the publisher of the magazine, are located at P.O. Box 17149, Washington, D.C. 20041-0149. The Editor-in-Chief is Carol White; the Managing Editor is Marjorie Mazel Hecht. The owner, Fusion Energy Foundation, is a nonprofit organization.

Extent and nature of circulation, Oct. 1986

	Average no. copies each issue during preceding 12 months	Actual no. copies of single issue published nearest to filing date
Total copies printed	59,000	78,000
Sales through dealers, street vendors, counter sales	22,586	26,045
Mail subscriptions	35,176	51,154
Total paid circulation	57,762	77,199
Free distribution	653	789
Copies not distributed	585	12
Returns from news agents	0	0
TOTAL	59,000	78,000

Insects and Aids

Continued from page 9

its blood meal. The South African scientists drew the following conclusion:

"There is strong evidence for mechanical transmission of Hepatitis B virus by the common bedbug. . . . Similar transmission of HIV by bedbugs may be a cause of infection in African children. In Africa, 15-22 percent of AIDS cases have been in children, whereas in the U.S.A., this proportion is only 1-4 percent, suggesting that there are modes of transmission other than those recognized in the U.S.A."

• Another letter, in the March 6, 1986 *New England Journal of Medicine*, reports finding antibodies to HIV (the AIDS virus) in 8 of 24 Venezuelan mine workers with malaria who had no other risk factor for the disease. The disease vector for malaria, of course, is the mosquito, and maps of its global distribution are the classic markers of the worldwide tropical insect belt.

Note

1. *Comptes-Rendus de l'Academie des Sciences Paris* t. 303, Serie III, No. 8 (1986).

Fray Diego Rodriguez

Continued from page 56

accusing them of heresy. In 1647, and again in 1649, the Jesuits held mass trials, convicting 103 people and burning dozens at the stake.

The Inquisition accused Fray Diego and his friend, Melchor Perez de Soto, the chief architect of Mexico's cathedral, of practicing "judicial astrology,"—a charge tantamount to witchcraft and fortune-telling. This was not the first time that Rodriguez's political opponents had tried to frame him. Earlier, he had been falsely charged with mishandling the funds of a convent for which he was responsible. Ten years later this was used to prevent him from obtaining a masters degree in mathematics, even though he was holding the mathematics chair at the university. It was not until 1664, 27 years after he made the request, that Fray Diego was awarded the degree.

Because of his reputation and position, Fray Diego avoided being put on trial in 1653, but Perez de Soto had his library confiscated, and was jailed, tortured, and kept in solitary confinement for more than two years. The Inquisition failed to extract a "confession" from him, a formality the Inquisition required to sentence heretics, and Perez de Soto was finally killed in the dungeons of the Inquisition by another inmate.

In 1655, while Perez de Soto was still imprisoned, the first bell tower of the cathedral was finished, posing the complicated problem of lowering the heavy bells from the old church, and raising them on the new tower, together with a set of new bells. From his jail cell, Perez de Soto submitted a proposal, as did other architects. Fray Diego sent his own proposal and was awarded the job. He directed the construction of the necessary structure and the maneuvers that finally placed the bells in the tower on Palm Sunday of the same year.

Once the cathedral was consecrated and endowed with its monumental double organ, it became the center of a Mexican renaissance in the worship of God through music, poetry, and drama.

Telling Time by the Sun

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early morning skies for the first summertime appearance of the brightest star in the heavens, Sirius. This, too, was not always an easy observation; the dawn skies might be clouded or unusually dust-laden at the critical time. But repeated observations over many years yielded a year length of 365 days. The Egyptians used the 365-day calendar for thousands of years, until the great calendar reform associated with the name of Julius Caesar in 46 BC.

We now have discussed the first problem in constructing an accurate calendar: the observational techniques used to tell that a year has passed. The second problem has to do with correlating days with years.

We know now that the Earth spins on its axis exactly 365.2422 times for every time it orbits the Sun. This means that if you say the year is only 365 days long, you will be off by 0.2422 days. This fraction is about ¼, so every four years these fractional days add up to one whole day. If you did not find a way to insert that extra day into your calendar, and if you marked the summer solstice by looking at the calendar rather than at the sky, you would observe that event one day too early.

This was the problem with the Egyptian calendar. Because their day was too short, their calendar moved backward through the seasons. After 1,460 years ($1{,}460 \times \frac{1}{4} = 365$), it actually returned to where it started and was accurate once more.

The Wandering Calendar

This same problem of the calendar wandering through the seasons affected the Greeks and the Romans. Caesar decided to change the system and, borrowing from the Egyptian experience, he inserted an extra day into the calendar every fourth year. This so-called Julian calendar is the origin of our leap year.

But 365.25 days is not exactly the true value of 365.2422 days, so the Julian calendar gradually moved ahead of the seasons, since the average year was now a bit too long. By the time of Pope Gregory, in 1582, the calendar had gained a full 10 days. The Pope decreed that those 10 days would be taken away and that henceforth the first year of every century would not be a leap year. The exception would be centuries that were divisible by 400—such as the years 1600 or 2000 AD. In these cases the leap year would be observed. This fairly complicated rule made the average year length become 365.2425 days long.

In this century the so-called Gregorian calendar was reformed again. The new rule is that the years 4000, 8000, and so forth, would be leap years. This makes the average year now 365.24225 days long. Our modern calendar is still not perfect, but it is now accurate to within one day in 20,000 years!

We pay a price for the convenience of having an accurate calendar. We adopt a cumbersome algebra of adding and subtracting days to keep our calendar aligned with the more fundamental astronomical time. However, the effort spent perfecting this algebraic approximation spurred mankind to learn the true geometry of the spinning and orbiting bodies in the solar system.

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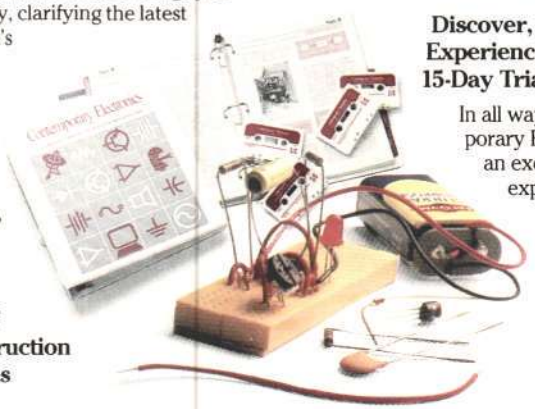

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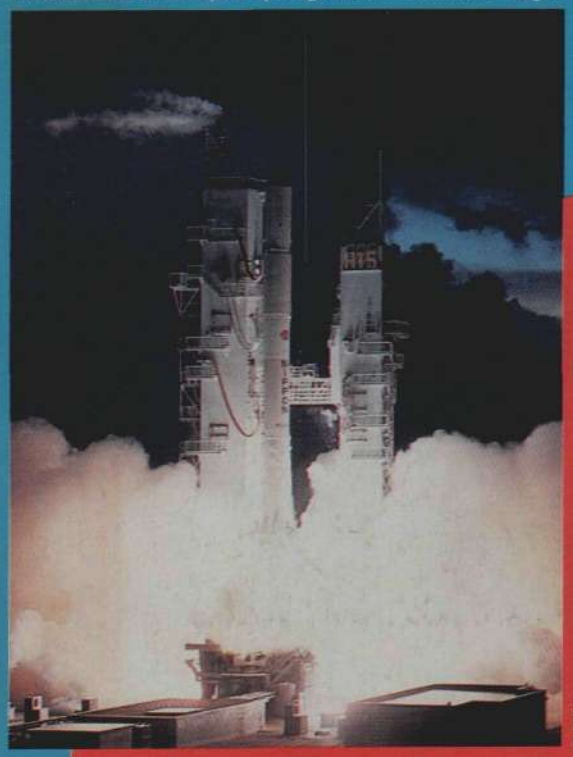
The H-1, the first Japanese-designed and engineered rocket, had its test launch in August 1986. The H-1 is the world's third rocket to use a liquid-hydrogen fuel in its second stage.



NASDA

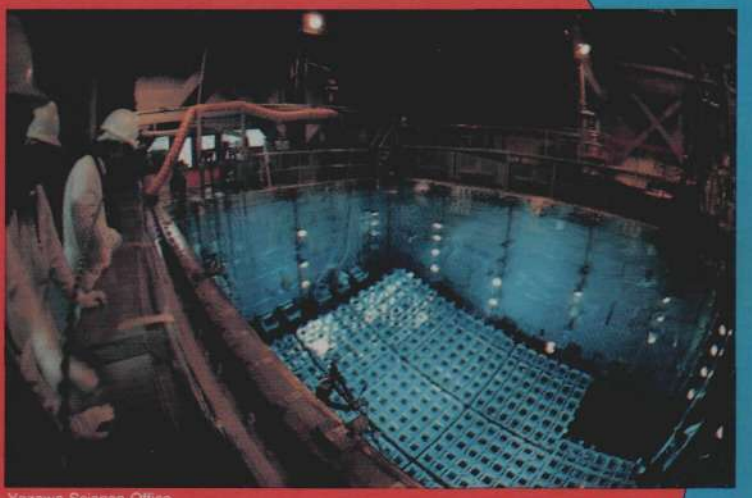
In This Issue

JAPAN'S SPACE PROGRAM: TAKING OFF FOR THE 21ST CENTURY

Japan's space program, the world's third largest, is preparing now for manned spaceflight and space industrialization based on new Japanese technologies. Very much up front in the Japanese program is that nation's commitment to "contribute to the intellectual progress of mankind." The scientific optimism and excitement of the program leave no doubt that Japan is a "superpower for progress."

JAPAN'S 'NUCLEAR ENERGY VISION'

Already in its "nuclear first, oil second" era of electricity production, Japan announced in June 1986 a 45-year perspective to make nuclear its principal energy source. As the plan states simply, nuclear energy "is superior in both energy security and economy." Called "Nuclear Energy Vision," the plan would complete Japan's nuclear fuel cycle and continue the development of nuclear technology where the United States has left off.



Yazawa Science Office

Nuclear power in Japan generated 26 percent of the nation's power supply in 1985, with a capacity factor of 76 percent. Here, the Mihama nuclear plant.

THE FREE ELECTRON LASER BY 1990?

Although it is the baby of the beam defense systems, the free electron laser is a leading candidate in the Strategic Defense Initiative to knock out ballistic missiles in their boost phase. The United States is constructing a $600 million facility at the White Sands Missile Range in New Mexico that will complete testing of two prototype free electron lasers in the 1990s. Experts have estimated that just a handful of these free electron lasers would have the firepower to shoot down the world's current inventory of ICBMs within a few minutes.

Lawrence Livermore National Laboratory

The 500-gigawatt Advanced Test Accelerator (ATA) at Lawrence Livermore National Laboratory has recently demonstrated high-power free electron laser amplifier lasing. Here a technician adjusts the electron injectors for the ATA.