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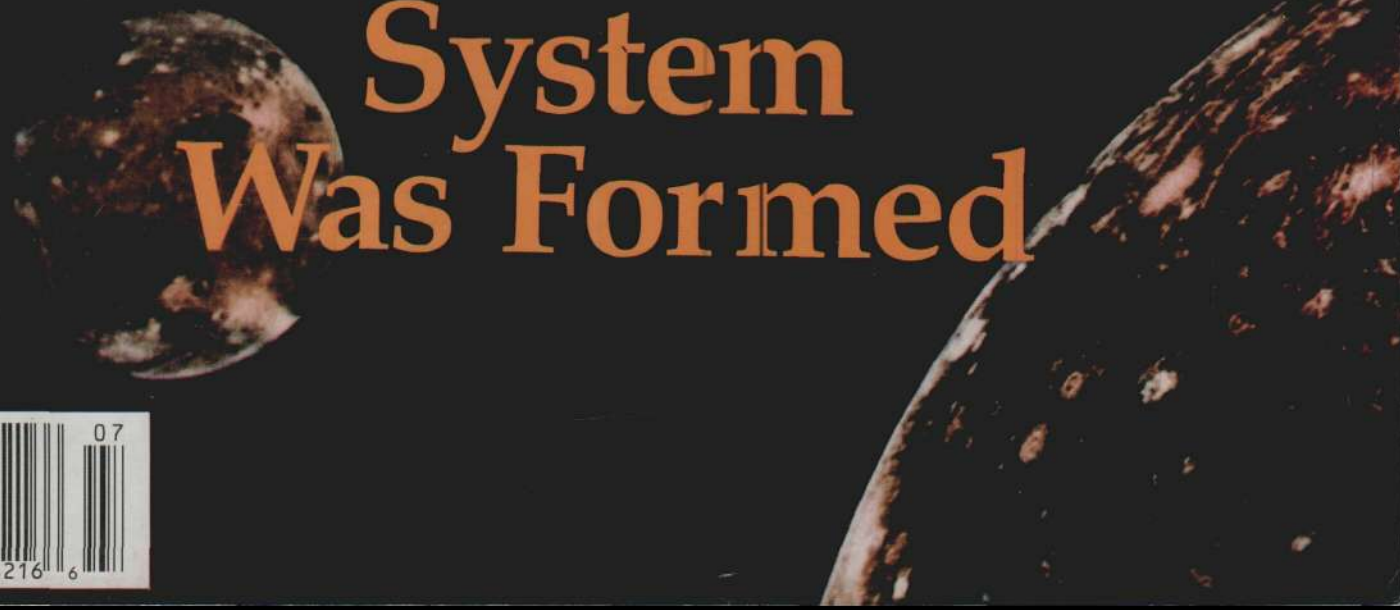

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SCIENCE & TECHNOLOGY

Vol. 1, No. 3 July-August 1988

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ISSN 0895-6820

On the cover: Composite of Voyager 2 views of Jupiter and its moons, courtesy of JPL/NASA. Cover design by Virginia Baier.

Winning the War Against Locusts

There are no scientific reasons to lose the war against locusts, only political ones.

In spring 1988, one of the worst plagues of the century threatens Africa. If the locust-favorable weather conditions continue, the swarms now in northern Africa (Tunisia and Morocco) will head south, riding the winds, to eat their way through whatever sub-Saharan vegetation they can find. Equally devastating, the female locusts will stop along the way to deposit millions of eggs in the grasslands, thus ensuring, as long as the weather remains favorable, that new generations of locusts will continue to plague the Sahel, West Africa, and Central Africa.

In a part of the continent just beginning to recover from a drought that decimated the land as well as its animals and people, locust swarms spell starvation and death. And if not stopped, the destruction will spread to other continents, as it has in all previous major outbreaks. As the head of the United Nations Food and Agriculture Organization (FAO) warned in a press release April 29, with the right weather conditions, the plague ". . .could spread to East Africa, the Near East, Pakistan, and India in the next one to one and a half years. If the swarms spread, extraordinary efforts will be needed to avert major food losses."

As we go to press, the locust swarms are already on the move. There are reports that a swarm 100 kilometers long and 30 kilometers wide was flying over northern Mali, while in Mauritania, the locusts were so thick that they forced traffic to a halt in the capital. The head of the FAO locust program warned: "We shouldn't waste any time. Otherwise the vegetation will be destroyed for years to come."

There is no question that we can win the war against locusts. If we did not know how to win such a war, the United States would not be a productive agricultural country today. Its crops and rangeland would have been devoured by insects and destroyed by natural disasters, as they were in Colonial times when locust plagues raged against the country's early settlers.

As with every other successful mobilization for a "war," victory requires an all-out effort, from surveillance of the enemy, to training the "troops," to using the weapons appropriate to get the job done. This means a crash program using today's technologies—from the latest in satellite monitoring to track the swarms, to the state-of-the-art pesticide-spraying using a combination of big DC-7 planes and smaller planes as required, to the development of the necessary infrastructure. It also means a crash effort to develop new technologies, such as the electromagnetic pulse system discussed by Warren Hamerman in this issue (page 9).

The Politics of Genocide

The war against locusts in Africa is being lost for political reasons. The FAO, the International Monetary Fund, the World Bank, and other agencies have already determined that Africa is "overpopulated," that the so-called carrying capacity of the continent has reached its limits. In other words, these agencies have already written off the continent of Africa and all its people. As a result, the emergency effort—to date with donations of $40 million—is not sufficient in funds or in scope.

If this were not the case, then the regional locust control groups in Africa would have been fully funded (instead of being bankrupted out of existence over the past decade), and thus would be monitoring the situation, so that it could not have erupted out of control. In addition, Africa would have had the kinds of development and infrastructure projects that are necessary to ensure industrialization and self-sufficiency in food. In fact, some of these development projects, proposed back in the 1950s, were specifically designed to eradicate the endemic locust-breeding areas and thus prevent plagues from getting their start.

For the United States the battle lines are clear. Will this country and its allies implement a development policy for Africa—or will Malthusian policies prevail? Will Africa be allowed to modernize, or will the wildlife enthusiasts succeed in commandeering the continent as their playground, a nature preserve devoid of people?

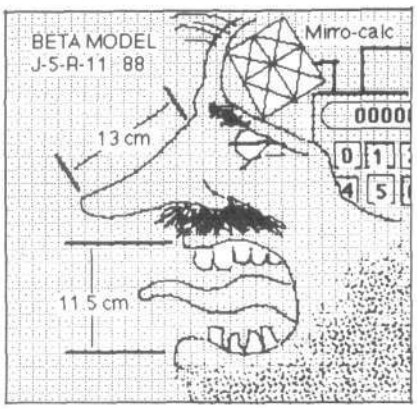
The Lightning Rod

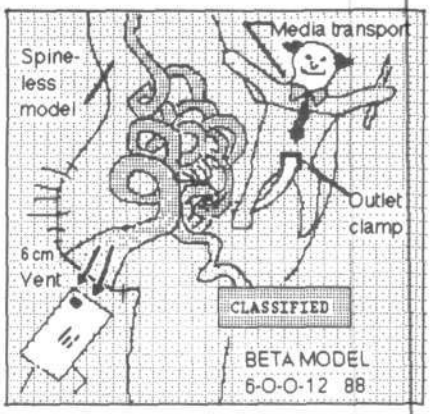
My dear Friends,

How delightful it was to learn that our distinguished Men of Science, not content merely with building a *better Mousetrap*, have taken out a patent on a *better Mouse*. Better, at least, for scientists, but not, alas, for the Mouse; for the genetic improvements that have been made upon the original Creature bred for the laboratory are devoted to the purpose of enabling it to develop Cancer more easily, presumably so that experimenters need not wait so long to discover that *force-feeding* the beast a *full box* of saccharin will make it very sick. The moment we heard of this astonishing breakthrough, we had no doubt that it could only have been accomplished by our wise men at Harvard College.

Yet, whatever may be the apparent utility of the Harvard Mouse, we have no doubt that the new art of Genetic Engineering will eventually contribute to important if not astonishing progress in combating human Illness.

In the meantime, we may be so bold as to make a suggestion of another Creature the Harvard scientists might venture to improve upon, extending the tradition of their laboratory ro-





dent. What should be the plaudits of an astonished world, when mankind should behold a perfect version of the Harvard Environmentalist?

Herewith are supplied design specifications for the project.

First, the Environmentalist should be born and live on with its eyes *tightly shut*, so as to avoid seeing the many ways in which nature might be improved upon by man.

Also, it should not be required to *Labor*, or to attempt to discover ways by which such Labor may be made less onerous, so that it remains *perfectly ignorant* of the premise of all human Knowledge.

Next, the Creature should possess a loud *bleating* cry of alarm, to be uttered whenever it feels threatened by some proposed action of actual Humanity.

The Creature ought nonetheless consider that it is the owner of an exceedingly *valuable* (and remarkably thin) Skin, which it is impelled to develop social relations for the purpose of saving.

It should therefore be endowed with the capacity to generate enormous quantities of Junk Mail, and to *go limp* automatically at the sight of a Bulldozer.

It would be exceedingly useful if the Creature were supplied with a small vial of liquid capable of turning any readily available detritus into Toxic Waste, in case none is available in its immediate vicinity. It should also be supplied with a small sac, something like a kangaroo's pouch, suitable for carrying around a Journalist to write about it.

It should possess a Brain *equal in all respects* to the functions of a solar calculator, enabling it to repeat obsessively "2 + 2 = 4" like a character in a Dostoevsky novel.

Finally, the Creature must tirelessly proclaim that *the world has too many people in it*, especially in its immediate neighborhood; that humans use up too much Earth, Air, Water, and Space; and that the proliferation of the Human Species is a threat to the Law of Entropy.

Should the men at Harvard desire a name for their new invention, we propose it be called the Rifkin. But they had better make haste if they wish to file a patent; we understand that close by, at MIT, a similar Creature is already in the beta stage of development. It is called the Forrester.

Your obt. svt.

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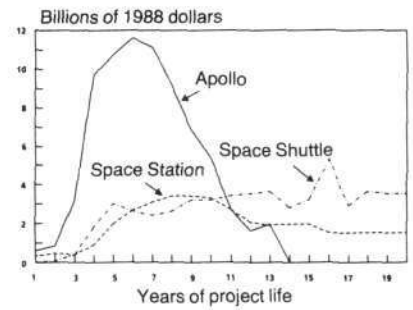

Source: Congressional Budget Office, NASA

The Apollo project spending, in constant 1988 dollars, dwarfs the estimates for spending on the Space Shuttle and the Space Station.

CONGRESSIONAL BUDGET OFFICE CALLS FOR 'NO-FUTURE' IN SPACE

In a report issued in May, "The NASA Programs in the 1990s and Beyond," the Congressional Budget Office suggests that the budget for the space agency through the next decade of constrained funding fall below that for a minimal "core" program. The so-called core program would eliminate all new initiatives, both manned missions and space science missions, leaving the space program with no future.

DEFENSE DEPARTMENT CURTAILS ELECTROMAGNETIC PULSE TESTING

The U.S. Defense Department agreed May 13 to curtail research on electromagnetic pulse (EMP) weapons at laboratories in Virginia, Maryland, Alabama, and New Mexico, in response to a suit filed by Jeremy Rifkin's Foundation on Economic Trends. The Soviets have an advanced EMP weaponry program, and the Pentagon research program was simulating EMP radiation to determine how to protect the circuitry in its planes, tanks, and ships. Rifkin alleged that the research was proceeding without an environmental impact statement and might be harmful to pacemakers or "birds and animals with delicate nerve centers."

LOS ALAMOS PROPOSES NUCLEAR SPACE PROPULSION FOR SDI

Scientists working at Los Alamos National Laboratory on the SP-100 space nuclear reactor have proposed its use to propel large satellites into geosynchronous orbit and to provide a maneuvering capability for the satellites as part of a space-based SDI missile defense system. Strategic Defense Initiative head General Abrahamson had decided last year that the test flight mission of the SP-100 would demonstrate electric propulsion.

The reactor would be coupled with an electric propulsion system to provide thrust for the transit from near-Earth to geosynchronous orbit and to provide almost continuous maneuvering to enhance survivability of the satellite. Among other advantages, the use of a nuclear reactor power source will make possible a compact design for the satellite and eliminate the need for solar panels, which produce large visible and radar signatures.

SOVIETS ANNOUNCE READINESS OF SHUTTLE-LIKE SPACECRAFT

Vladimir Shatalov, head of the Soviet training center for cosmonauts, announced on Radio Moscow April 7 that the Soviets have almost completed testing on a reusable spacecraft that will soon embark on its maiden voyage. Shatalov said that the ship was comparable to the U.S. Space Shuttle in weight, carrying capacity, and crew—29.5 tons payload and eight cosmonauts. Various high-level Soviet spokesmen have said that the test flight of the shuttle will be manned, while an equal number have insisted that it will be unmanned.

Stuart Lewis

Dr. Martin Welt: His aggressive fight to commercialize food irradiation has made him enemies.

FOOD IRRADIATION PIONEER INDICTED IN ENVIRONMENTAL CASE

Dr. Martin Welt, long the target of New Jersey's antinuclear environmentalists for his pioneering efforts to commercialize food irradiation, was indicted March 18 for alleged violation of safety regulations at the firm he founded, Radiation Technology, Inc., in Rockaway, N.J. Federal prosecutor Jacqueline Wolff said she wanted Welt jailed. Indicating the political nature of the case, Wolff was promoted to the position of "environmental crime coordinator" for the state just after she handed down the indictment.

Letters

Gift Subscriptions Appreciated

To the Editor:

We are extremely grateful to you for the gift subscription to *21st Century Science & Technology* magazine. I am sure our teachers and students will benefit greatly from this source of information.

Please say thanks also to others who are responsible for this valuable gift.

Anna Thornton
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The Editor Replies

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New Developments in Alzheimer's Treatment

To the Editor:

Since the article on Alzheimer's disease by John Grauerholz appeared in your premier issue ("New Approach Offers Hope for Alzheimer's Disease," March-April 1988, page 22), there are a couple of new developments.

First, it seems that only one in every four or five individuals diagnosed as Alzheimer's patients actually have the disease; most are just senile dementia sufferers.

Second, due to a federal government mandate, the cost of the new treatment has been cut down to $24,000 for the first year and $22,000 for the second and third years for Alzheimer's patients. For senile dementia patients, the cost is cut down even more: $8,000 for the first year, $6,000 for the second year, and $5,000 for the third year.

Also, I should note that my collaborator, with whom I developed the diagnostic test, is Neil Allen.

Chaovanee Aroonsakul, MD
P.O. Box 81552
Chicago, Ill. 60681

The Editor Replies

We will report in more detail on further developments in the treatment of Alzheimer's disease in the next issue of *21st Century*.

NEWS OF THE FUTURE

50 Years from Now

Aug. 5, 2038, SELENOPOLIS—The 4-H exhibits were the featured attraction at the annual lunar fair in the Moon's capital city today, with competitions in milk cows, steer, sheep, turkeys, and chickens.

The lunar herds, which the 4-H members help care for, are now supplying meat and poultry to all the lunar colonies. The award ceremony recalled for residents how 25 years earlier, meat was only holiday fare, because the herds were not yet mature enough to meet the demand.

100 Years from Now

Aug. 5, 2088, MARS—Twelve college students born and raised on Mars left for Earth today for a special three-year program with a group of colleges on Earth. The students, all juniors at Mars University, elected to study abroad and to participate in a lecture program across the United States. The aim of the program is to familiarize Earth-residents with the Mars colony and to recruit young colonists for Mars.

Editor's Note: *Readers are invited to contribute to this column. Please limit entries to 100 words for each item. Contributors whose entries are printed will receive a gift subscription to* 21st Century.

Correction

A table in the article "Two Days to Mars with Fusion Propulsion" (March-April 1988, page 28) mistakenly labeled exhaust velocities in miles per second. The figures given were actually in meters per second.

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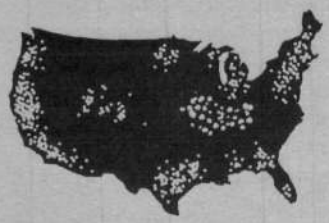

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VIEWPOINT

Food Irradiation Means Better Health

Niel E. Nielson

Most people would prefer their food to be free from disease-causing microorganisms and insect material, and would appreciate a technology that prolongs the shelf-life of fresh foods. Yet, food irradiation to ensure the wholesomeness of fresh and processed foods is under attack from a small group of antinuclear advocates who insist, most unscientifically, that they are protecting people from the alleged unknown effects low-level irradiation may have on food products.

These antinukes fail to inform their followers and the public that the established, organized scientific community worldwide encourages use of "food irradiation" done in accordance with published U.S. and international guidelines and regulations.

The focus of those who use the often misleading, all-inclusive term "food irradiation" is the processing of foods with electromagnetic energy at picometer wavelenths (trillionths of meters). It is well recognized in the scientific literature that low doses—that is, extremely small amounts of energy being absorbed—of picowave processing have the ability to disable the reproductive capabilities of essentially all insects, bacteria, parasites, and viruses. Because of this, the expanded, widespread use of this processing technique could be immediately life saving and could immediately, demonstrably, improve public health.

The basis for this assertion has been documented in studies published by the Centers for Disease Control and the U.S. Department of Agriculture, in which it is shown that thousands of lives are lost in the United States alone, annually, from such food-borne infections as salmonellosis and complications arising from such infections. In addition, there is a large amount of information on the subject that is published in highly respected scientific literature, as well as first-hand experimental and research-based knowledge of the capabilities of low doses of picowaves to kill disease-causing microbes.

Routine applications of doses of picowaves of less than 100 kilorads (this is an amount of energy equivalent to that necessary to raise the temperature of the same amount of water by less than one half a degree Fahrenheit) to foods could reduce total bacterial content in foods by more than 99 percent and could completely disable the reproduction capabilities of 100 percent of the parasites. Since the immune systems of healthy human beings can overcome smaller quantities of disease-causing organisms when ingested, this 99 percent reduction would greatly reduce the numbers of human illnesses resulting from ingesting foods containing disease-causing microorganisms.

Further, based on the findings of the Centers for Disease Control and the Agriculture Department, widespread expanded use of picowave processing of foods could save hundreds of thousands of hospitalizations annually from such food-borne infections.

The Illness Question

The salmonella problem is very real and very complex, and it highlights the importance of the routine use of picowave processing. About 40 percent of the poultry in the United States is infected with salmonella. The problem becomes obscured by the obvious fact that when you properly cook the poultry, you kill the salmonella, so you should not get it from the poultry you eat. You get it from the raw poultry contaminating things that aren't going to get cooked—salads, for example, picking it up from a cutting board, or the kitchen help's hands.

This is a two-step affair, but the result is the same: People get sick. And that says that you have to prevent the salmonella from getting into the kitchen in the first place. This is the focus of the Department of Agriculture's Food Safety Inspection Service's petition to the Food and Drug Administration to expand use of this technology to include all poultry, and at higher doses.

This is a very important issue: The antinuclear people use the argument that "unknown" illnesses are possible because 50 million people have not been tested for 50 years. The antinukes are saying that they think there is a very remote possibility of food irradiation causing a problem and therefore the technology should not be used. Yet, they completely overlook the fact that people are dying right now who could be prevented from dying if we could use the technology. That means that anyone who gives credibility to the idea that 40 years of testing in the United States and elsewhere is not enough research has lost perspective.

Doubling the Food Supply

Let's look at some of the advantages of this technology, especially for the developing sector.

There is now more food lost to insects and spoilage than would be required to overcome all the malnourishment problems worldwide, if the rest of the infrastructure for transportation, storage, and distribution were also established. If you take the whole

Niel E. Nielson, a high-technology entrepreneur, is working on the large-scale commercialization of food irradiation, particularly for nations of the Pacific Rim. His interest in food irradiation started when he was working in Lockheed's military space program in 1961-1968, where one of his assignments was to identify ways to keep the astronauts from getting ill, and it became obvious to him that radiation sterilization for food and water was the answer.

world's production, 50 percent is lost before it ever gets on its way to market. In the developing nations, 70 to 90 percent of their own production is lost, thus losing people food and income.

For example, a significant percentage of the fish and seafood harvested in the tropics contains enough bacteria that, if it isn't frozen almost immediately as it is caught and cleaned, it is not going to meet the U.S. Food and Drug Administration standards. As a result, and in some cases as a result of poor handling, the food that could be exported from those countries to the United States, is rejected in the range of 3 to 15 percent.

We could prevent a large part of the rejection of good foods—not decomposed foods—by use of routine picowave processing, which would drop down the bacteria count by 90 to 99 percent at only 100 kilorads.

This is a big number—90 percent—if you put it in perspective. In terms of sterility, it is not a big number. But you don't need sterility if you are going to eat the foods right away. All you need to do is knock the bacteria count down by 90 percent.

In the case of fish and seafood, it would be processed, frozen, and then picowaved. In the case of fruits and vegetables, it would be precooled and then picowave processed. This process would prevent insect problems that exist with a lot of these fresh fruits and currently prevent them from being brought to the United States. In many cases, the effective chemical fumigants, like EDB, are banned in the United States; in other cases, the alternative fumigant/disinfestation procedures are ineffective or damage the fruit.

UFOs and URPs

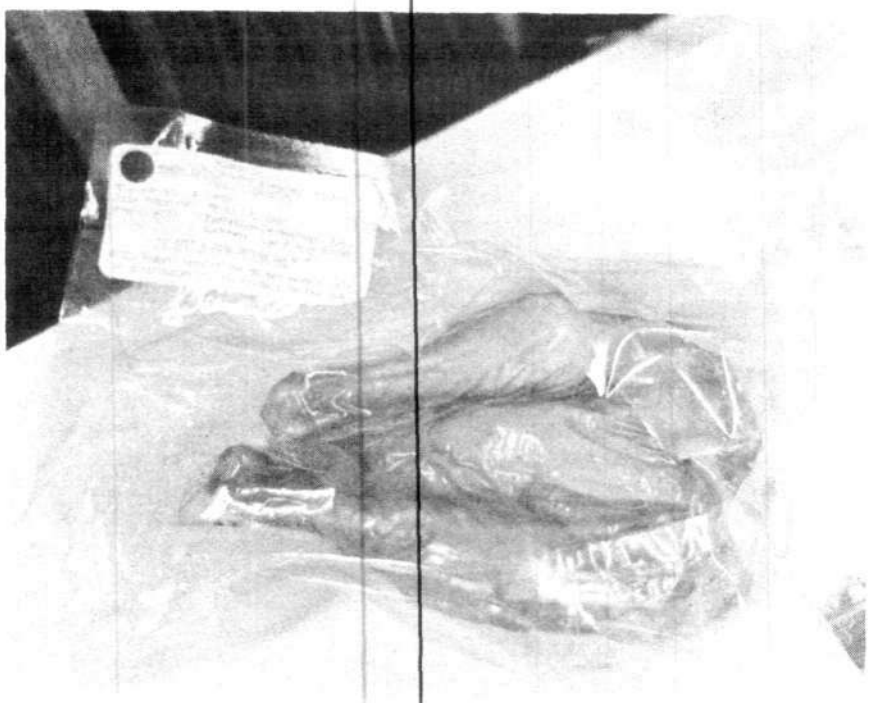
One of the scare stories of the antinukes is that there are unique radiolytic products (URPs) that appear in irradiated food. Now, there has never been a chemical identified in the processing of food by picowaves that is not already in our diets. Every food group has been thoroughly examined looking for evidence of truly unique chemical products and none has ever been found. This is a myth that the opponents of food irradiation like to scare people with, that unique radiolytic products appear in food that has been treated with low-dose radiation. These unique radiolytic products are like UFOs—frequently sighted, but not there.

To date, in the established scientific literature, there has been *no* chemical discovered to result from processing foods with electromagnetic energy at picometer wavelengths that is not already being ingested by mankind routinely in much larger quantities. All such chemicals identified to date have been found to exist in foods naturally, or as a result of several types of widely employed cooking or preserving processes, whether in commercial or domestic kitchens or food production plants.

Obviously, there are proven toxins, carcinogens, mutagens, and so on, and the Food and Drug Administration (FDA) issues standards for their content in foods, regulates the use of such chemicals and the foods that contain them, and takes enforcement actions against food processors and suppliers who do not work within the law.

Also obviously, there are chemicals such as vitamins and minerals about which we are still learning a great deal and the FDA has published (and will publish) recommendations concerning them also. But these chemicals about which we do have knowledge are a very small fraction of the total number of chemicals we ingest each day, and because there are so many different chemicals in foods that have not been thoroughly studied for their impacts upon mankind when ingested, food scientists increasingly employ such techniques as chemiclearance for evaluation of *relative* safety.

In this chemiclearance process, any resulting chemical that is identified as



Stuart Lewis

Picowave processing at only 100 kilorads can vastly reduce the problem of salmonella, which now infects 40 percent of U.S. chickens. Here, a chicken sealed in a special package and irradiated at a higher dose to ensure sterilization. This chicken can remain fresh indefinitely without refrigeration. U.S. and Soviet astronauts both ate radiation-sterilized food in space.

not having been in the foods prior to the processing is compared with all of the known toxins, carcinogens, and so on, and if not found to be among the known problems, a search is made to determine if such a chemical is already in mankind's diet.

Many highly qualified researchers focused for many years, internationally, upon chemicals that appeared to result from picowave processing and did so in every significant food category. They found all of the so-called unique chemical species that were discovered to be already existent in mankind's diet, in one way or another. As a result of all of this, those in this field of study feel very confident of the accuracy of the statement that there is *no* evidence that there will be *any* increase in risk for consumers of picowave processed foods.

Not Playing Straight

The antinukes who conveniently use the URP argument to further their purposes typically do not have anything to do with public or environmental health. This is an indictment of a lot of people, and there may be some followers to whom I should apologize for making this all-encompassing indictment. But certainly those technologists who encourage those people or who let themselves be used as references for those people, need to be indicted because they are misleading people. They are just not playing it straight.

The established scientific community, as represented by organizations ranging from the National Academy of Sciences to the American Medical Association and the Institute of Food Technologists—the people who really know food science—have all endorsed picowave processing by organization. This means that the majority of the people in these organizations—responsible, recognized scientists—realize that there is no increase in risk and that there are potentially very high benefits. The people who are objecting to the use of this technology have no such accreditation, and yet they would pretend to have a large high-technology following in the field, which in truth they don't.

What they are doing is attacking the established institutions, which the public sponsors and which have gotten us so far advanced in the last 50 to 100 years, in so many ways, including just plain quality of life. There is the underlying theme that the establishment is bad. This permeates all these anti-food-irradiation activities.

In reality, the largest number of the leaders of these antinuclear organizations are doing it for profit for themselves. They are doing it because of the popularity they get, the number of lines of press, the exposure on radio and television. So they are feeding their egos, feeding their pockets from it. However, here the stakes are so high that they can be traced to deaths and needless illnesses, needless misery that is not speculative—it is real.

There is one favorite example that the antinukes like to use—quoted completely out of context. There is an Indian feeding study carried out by the National Institute of Nutrition. This study has been thoroughly repudiated by very well respected scientists worldwide and in India. The work done by India's Nutrition Institute could not be duplicated, which is one of the cardinal requirements of accepting scientific research. Also, their peers in India would not support this study and, in fact, after an investigation of how the study was conducted, came out with a policy statement against it.

A subsequent, much larger and more comprehensive Chinese study reached totally opposite conclusions to those reached by India's National Institute of Nutrition. But when the antinukes quote this study, they do not tell anybody that it's been discredited.

Another thing the antinukes do is distort information. One of these distortions is that irradiation creates peroxides in the food. Well, that is true. Food irradiation creates peroxides. But so does the body—and without them we would not live. These people know that the public did not pay attention in high school when these sorts of topics were discussed. So they play on it.

Machine-generated Picowaves

The idea of using machine-generated picowaves instead of radioisotope-generated picowaves is gaining in popularity rather quickly around the world. This will cause people to refocus, for so many of the antinuclear factions are focused on the handling and storage of the *radioactive* cobalt-60 or cesium-137. Now we can tell them, "we've eliminated radioactive cobalt; we are using an accelerator to produce picowaves, now what are your concerns?" This throws out the most sensational part of the antinuclear argument.

The bottom line is that once we eliminate the radioisotope question, no argument brought up by the antinukes has merit. This is a bold statement from somebody with a scientific background, but it is true. The antinukes bring up arguments against food irradiation that have been authoritatively defeated, that are irrational, and in the face of overwhelming, established scientific-community rejection of their arguments, they continue to bring them up.

Commercialize Now!

What becomes unquestionably apparent to anyone who believes in the qualifications of the established scientific organizations and has read their endorsements, or has sufficient technical training to do a thorough and objective investigation of the use of this technology, are the following points:

(1) No other food processing technique, whether employing radiation or not, has been as thoroughly studied by so many scientists worldwide.

(2) There is agreement among scientists expert in the field that there is *no* absolutely safe food.

(3) All of the arguments put forth by those who would deprive mankind of use of this technology have proven to be without substance.

(4) The motivations of those who would oppose use of this technology are often for their own personal benefit and have little or nothing to do with food safety.

(5) Thirty years of delays in use of this technology—which was originally recommended for widespread use in 1958 by the food industry, the USDA, FDA, and others—have been costly in terms of the quality of life, or even the continuation of life for millions of victims of many food-borne diseases.

(6) Any further delays in widespread, expanded use of this technology are going to result in a needless continuation of thousands of deaths and hundreds of thousands of illnesses annually from food-borne illnesses in the United States alone.

How to Kill Locust Swarms Fast? 'Zap' Them with Electromagnetic Pulses

by Warren J. Hamerman

For centuries, locust plagues have periodically afflicted mankind, destroying food crops and any other green vegetation in their way. Today the ancient scourge threatens not only Africa, but also Europe and Asia. Warren Hamerman, an associate editor of 21st Century *and the director of the Biological Task Force of the* Executive Intelligence Review *magazine, reviews here a low-cost proposal for harnessing the latest beam technology to intercept these locust swarms before they devastate the food supplies of millions.*

Imagine a swarm of locusts a mile wide, tens of millions of them, coming over the horizon and devouring everything in sight. Suddenly, teams of helicopters equipped with low-cost electromagnetic radiation generators move into position. When the flying swarm is only 3 miles away—perhaps over a low-foliage desert or crossing a river—the magnetrons on the helicopters emit specially tuned microwave pulses several times per second. They sweep out and destroy a square mile of locusts in approximately 2 to 3 minutes.

"Zapping" flying locust swarms with pulsed radar is neither a dream nor science fiction; it is a scientific capability proven feasible in the research laboratory—but which the U.S. government declined to scale up and develop last year and the year before.

During summer 1986, scientists who were participating in a series of scientific seminars in the United States and Western Europe hosted by the *Executive Intelligence Review* magazine and the Fusion Energy Foundation began a project at the request of several African nations to pursue the feasibility of utilizing advanced scientific principles to knock out large swarms of locusts. By employing electromagnetic methods at the frontiers of biophysics, this international scientific team succeeded in conducting a "proof of principle" experiment in a U.S. biophysics laboratory and in working out a feasible approach for taking the method into the field.

The "proof of principle" experiment demonstrated that electromagnetic pulsed waves could generate lethal acoustical shock waves in large swarms of locusts and other biological organisms.

We had great hopes and optimism that the successful laboratory results of a low-cost, pulsed electromagnetic system would be immediately scaled up and deployed in Africa. Therefore, with the aim of saving lives in Africa, throughout fall 1986, we "cross-fired" the results to various government, scientific, and military policy circles. After further discussions, we decided to press the proposal in formal terms, since we were convinced that the advanced scientific approach would help to prevent a biological holocaust.

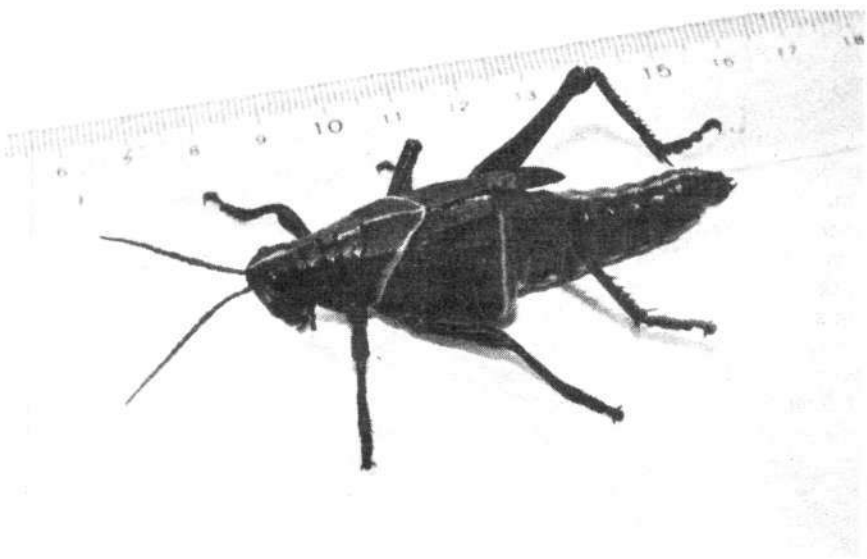
During late 1986 and the first half of 1987 we circulated a proposal through every relevant policy agency in the U.S. government, from scientific laboratories to the White House and Department of Agriculture, to the Defense Advance Research Projects Agency and Defense Science Board. The proposal also had wide circulation in private re-

United Nations

Billions of swarming locusts threaten the food supply of Tunisia, Morocco, and southern Europe in 1988. Here, Tunisians struggle against locusts in the great plague of 1952.

A locust can eat 2 to 3 grams—two to three times its weight—each day. A one-mile-square swarm of 150 million locusts, up to 5,000 feet in elevation, can go through 200 to 600 tons of vegetation daily. Once in the swarm stage, locusts can 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 about 10 miles per hour. In one 1958 locust plague in Somalia alone, a swarm of 40 billion locusts ate 80,000 tons a day—enough corn to feed 400,000 people for one year.

Here, a Lubber grasshopper used in the electromagnetic pulse experiments.



search universities, private industry, and military research areas, as well as the cabinet departments of the government. It also was later reviewed at the highest scientific levels among other nations.

After initial universal enthusiasm for the approach, encouragement and interest in the project was dashed and shut down by the U.S. government on budgetary grounds.

During the course of the project, of course, it was apparent to certain agencies concerned with national security that the new physical principles employed could have applications beyond merely neutralizing vast locust swarms, and they initially seemed as excited as we. Our focus, however, was not any military application, but immediately stopping the needless murder of hundreds of millions of Africans from the direct and indirect effects of the locust swarms.

Although there was much encouragement for our work through the early months of 1987, the highest levels of policy determination abruptly turned off their interest and "disappeared" in spring 1987. We were shocked to discover that those at the highest levels of scientific policy assessment in our nation were excited about the work and its military applications, knew that it could stop the slaughter of millions of Africans, but were unwilling to back the relatively low costs of the final phase of the work, even though Africa desperately needed the technology.

It is still not too late to revive this project, which can save millions of African lives and help to prevent the onset of an irreversible "biological holocaust."

Scope of the Project

When it first became apparent that an uncontrolled locust problem of catastrophic proportions was developing, representatives of several African nations approached us to ask if there were any advanced scientific methods that could be utilized to eliminate vast locust swarms, even were the traditional opportunities of spraying the eggs and the newly emerged hoppers missed.

Although locusts in the swarm stage can still be attacked by chemicals, the advanced technology of bioelectromagnetics is faster, cheaper, and ecologically superior. Indeed, the advanced scientific principles of electromagnetics and biophysics were demonstrated to work beautifully in generating acoustical shock waves in the organism.

The instrument used, a Japan Electric Company brain-inactivator for laboratory research, was "tuned" to the magnetic mode of the insect. The instrument was constructed for basic neurochemical research to rapidly inactivate mouse brains in very short times so that rapid turnover intermediates of brain metabolism could be studied in anatomically specific regions of the brain. Scientists using the device in basic research have caused a quantum leap in our knowledge of the way in which signals are transmitted in the brain.

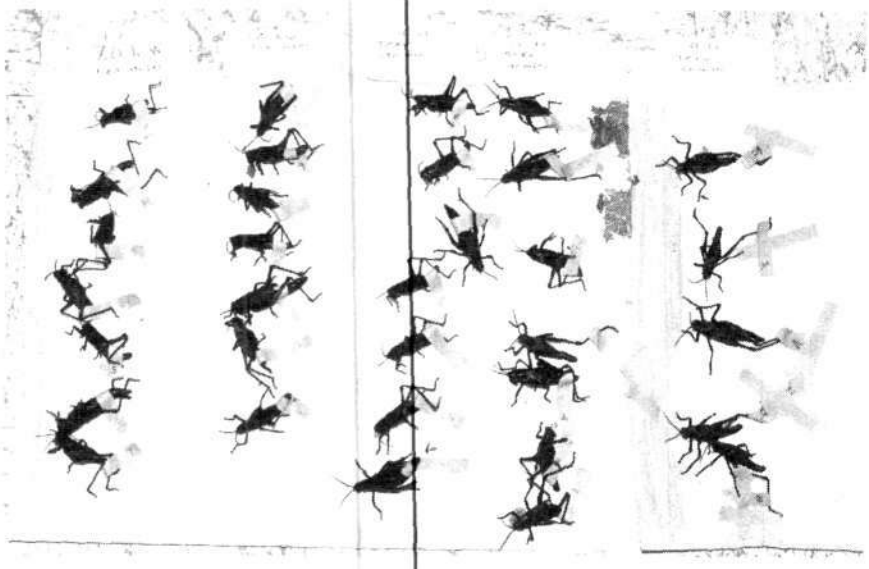
The instrument was originally developed in a research laboratory in the United States, but further commercial development proceeded in Japan because of the refusal by U.S. corporations to participate. It is now the acknowledged technique for neurochemical preparations.

The unique feature of the design of the machine is neither its maximum power nor its "tunability," but the fact that it alters the ratio between the magnetic and electrical field strength. Normally the electrical to magnetic field strength is 377 to 1. In this experimental configuration it is much closer to 1 to 1. The magnetic field intensity creates special sorts of "eddy currents" in the organism such that the energy is intensified or focused at certain points.

In a series of experiments, insects were exposed in the brain-inactivator to specially "tuned" pulses of radiation whose wavelengths were approximately the length of the insect. The experiments were conducted with lubber grasshoppers obtained from a biological supply house. These were the necessary size and had the appropriate dielectric constant to simulate their close cousins, the African locusts.

In essence, the grasshoppers became receiving antennas that the device tuned in on. Various combinations of power were tested, and the time period of the pulse varied between a short 50 milliseconds to a long 500 milliseconds (half a second). Even

Specimens from the electromagnetic pulse experiment. Various combinations of power (from left to right), 7.0 to 9.0 kilowatts, and time periods, 500 to 50 milliseconds, are indicated at the top of each column, along with the number of insects in each group. The wavelength approximating the length of the insect worked beautifully in knocking out the 33 grasshoppers used in this experiment. Even at 50 milliseconds, the grasshoppers were very woozy. The threshold for rapid kill was at 100 milliseconds.



The brain inactivator in which the grasshoppers were placed in the proof-of-principle experiment. Such devices were developed by scientists who wished to rapidly inactivate the chemical processes going on in the brains of small research animals like mice in order to study the metabolism of neurological reactions in anatomically specific areas of the brain.

at 50 milliseconds the grasshoppers were woozy and "out of it." The threshold for rapid kill was at 100 milliseconds (0.1 second). Temperature probes at the core of the dead insects revealed a temperature rise from 26 to 48 degrees Celsius.

Nonthermal Acoustic Shock Waves

It was firmly established that the effect was due to the pulsed nature of the wave and not merely "cooking" or "heating." This principle was checked in a contrasting "control" experiment. Insect "controls" were put in a research microwave oven at 60 degrees C., which is the higher end of the pulse power. The oven reached 60 degrees in 10 minutes, and it took 1 hour and 55 minutes to kill the insects this way. In the first 20 minutes the insects were hyperactive.

Thus, what was critical about the "proof of principle" experiment was the *pulsed* nature of the power delivered. As the microwave oven control demonstrated, the effect was nonthermal. The electromagnetic pulses coupled into the physiological frequencies. Temperature probes indicated that there was uneven heating in various parts of the insect.

The insect's exoskeleton, a very strong insulator (dielectric), can be polarized back and forth through wave-mixing. The surface area soaks up energy like a sponge, which facilitates the uneven absorption of energy in several focal points under the exoskeleton.

In field situations, of course, one needs a means to deliver the electromagnetic pulses other than by the brain inactivator. One could use a 100-kilowatt continuous wave capacity magnetron, pulsed at 5 to 10 per second and mounted on helicopters. At 3 miles distance, the focal area would be approximately 4 to 5 meters. The weight of the special apparatus in the helicopter would mostly be the power generator—between 1 and 2 tons. The major cost for the generator scales linearly with the kilowatt output size. At approximately $1,000 per kilowatt, a 100-kilowatt device would cost only $100,000.

Several helicopters—positioned in phased array—could sweep out 1 square mile in approximately 2 to 3 minutes from a distance of 2 to 3 miles. If the source of radiation were non-polarized, the helicopters would have to hit the swarm head-on. However, with a circularly polarized source, the insects would not have to be linearly lined up with the helicopters in a head-on firing position.

In the field situation, without control of the "waveguide" field structure inside the head-inactivator, the coupling efficiency into the insects will drop unless a very specific use of several transmitting antennae is employed to produced maximum magnetic fields inside the swarms to increase the coupling efficiency.

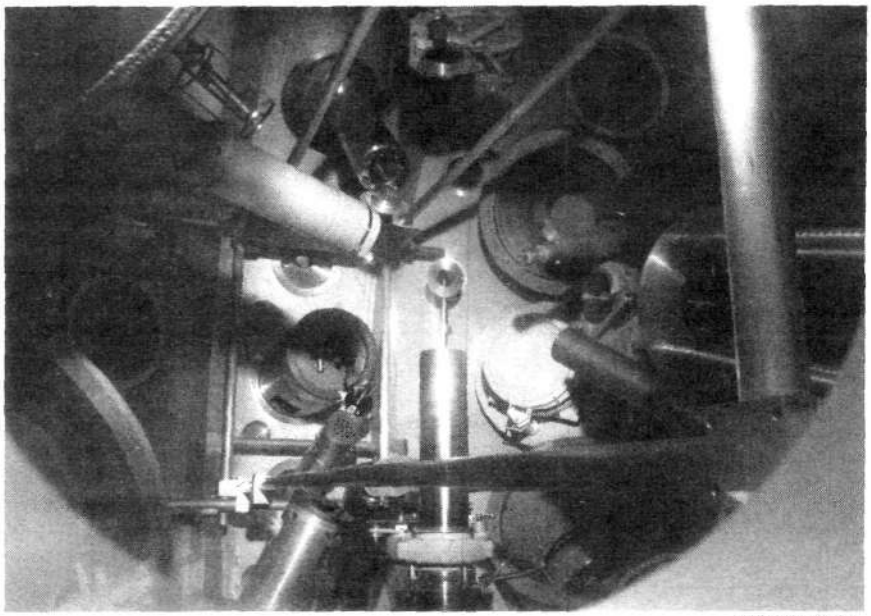
There would be little or no effect on animals or people, since there would be no penetration through the skin, which is a poor conductor at the frequency used against the locusts.

Steam Generation Inside the Locust

The senior biophysicist on the project evaluated it as follows:

"This work demonstrates that if electromagnetic energy sufficient to cause a temperature rise to around 50°C is applied to insects such as grasshoppers or locusts, irreversible damage resulting in death occurs. Energy absorbed is about 100 joules/gram in times less than a second. If this power is applied at a rate allowing cavita-

Continued on page 62



Gary Stone/LLNL

In the center of Nova's 15-foot diameter target chamber is a 1-millimeter glass capsule filled with deuterium and tritium fuel. In one billionth of a second, Nova's beams implode the fusion fuel.

Laser Fusion at Historical Turning Point

by Charles B. Stevens

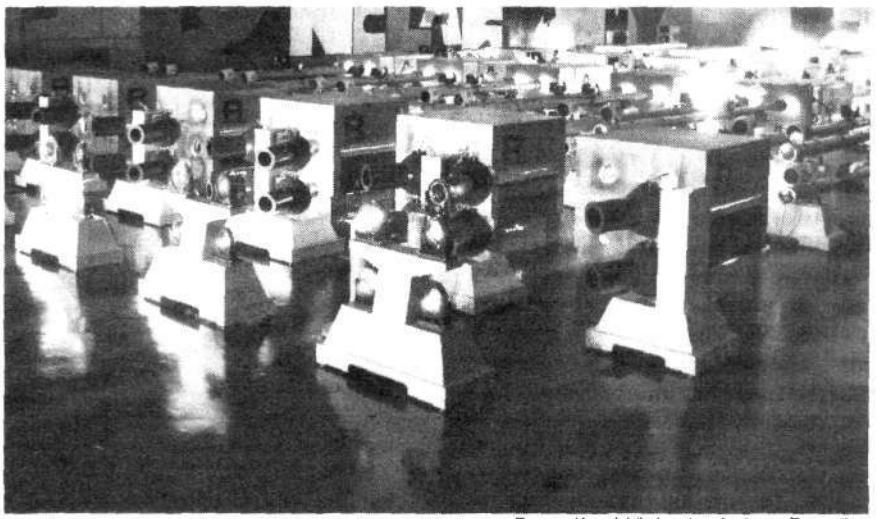
A page-one story in the *New York Times* March 21 provided for the first time the details of the spectacular success in laser fusion reported in the Fusion Report of the March-April *21st Century* (p. 10). In that issue, this author wrote, "The science for harnessing the internal combustion engine of the 21st century—the thermonuclear-powered laser fusion reactor—was demonstrated . . . by researchers at Lawrence Livermore National Laboratory."

The data disclosed in the *New York Times* confirm that the essential scientific prerequisites for harnessing laser fusion have been experimentally demonstrated. And while significant technological hurdles remain to be overcome before the full potentials of laser fusion can be realized, the only real question is not whether we can do it, but when. The U.S. effort to develop laser fusion is at the same point reached by the World War II Manhattan Project in 1942 with the successful operation of the first nuclear fission pile. That is, given sufficient resources, within less than a decade the program could demonstrate major laser fusion applications.

The *New York Times* Story

The *New York Times* article by William J. Broad reports previously top secret data from the Halite-Centurion program and the overwhelming success of the Lawrence Livermore laser fusion program:

"In top-secret experiments, federal researchers have achieved one of the nation's most costly and elusive scientific goals: to ignite a nuclear fusion reaction in tiny pellets of hydrogen, producing powerful bursts of energy. The success was achieved in unorthodox experiments some two years ago at the government's underground nuclear test site in the Nevada desert. . . . In a tantalizing, little-noticed statement last September, Sheldon Kahalas, director of the nation's microfusion effort, run by the federal Department of Energy, told a Princeton University conference that a top-secret effort code-named Centurion-Halite [sic] had achieved results that marked a 'historical turning point' for the fusion program . . . the energy needed for a laboratory laser to mimic the classified achievement would be in



Eugene Kowaluk/Laboratory for Laser Energetics

The 24 beams of the 12-trillion-watt Omega laser, which achieved record fusion fuel densities in March.

the range of 100 million joules. . . ."

In sum, " 'There's a new sense of excitement,' William J. Hogan, a microfusion official at the Lawrence Livermore National Laboratory in California, said in an interview. 'In the last two years, we've gotten almost all the data we wanted. That's remarkable. We kind of startled ourselves.' "

Routes to Laser Fusion

There are two general routes to achieving laser fusion. The first is direct drive in which lasers or high-energy particle beams are used to compress and heat a small pellet of fusion fuel. The second is indirect drive in which the same lasers or high-energy particle beams are used to generate soft X-rays in a cavity or "hohlraum" that focuses the X-rays on the small fusion fuel pellet, compressing it. The indirect drive has the same general characteristics that are used in the design of H-bombs. Most details of this approach are kept highly secret.

Since the early 1960s, there has been significant progress in the design and construction of high energy lasers. Livermore began its laser fusion R&D with a 1-joule, billion-watt laser. Today, the 10-beam Nova glass laser system generates up to 100,000 joules at a power level greater than 100 trillion watts. Nova is currently the world's most powerful high energy laser. Other lasers operating in Japan, the Soviet Union, and France generate tens of thousands of joules at power levels of tens of trillions of watts.

Because of its intrinsic characteristics and the fact that it has been studied intensively for almost four decades, the indirect-drive, hohlraum approach is currently considered the easiest approach to demonstrate laser fusion scientifically.

For power reactors, however, the indirect-drive approach would require much greater energy levels because of energy losses during the transformation of the laser energy to soft X-rays. It is hoped by many laser fusion scientists that once high-gain laser fusion has been realized through research on hohlraum targets, the knowledge gained can then be utilized to achieve high-energy gains with direct-drive targets, which require far less energy inputs and hence much smaller lasers.

This is just what the Livermore results are demonstrating. Direct-drive power reactors could operate with lasers 100 times smaller than those required for indirect drive.

Direct Drive Progress

In March, scientists working at the University of Rochester's Laboratory for Laser Energetics achieved a major milestone toward demonstrating high-gain, direct-drive laser fusion. In experiments with the Rochester Omega laser, which generates multiterawatt, multikilojoule laser pulses, fusion fuel densities in excess of 100 times the ordinary liquid hydrogen fuel density were achieved. Temperatures in the range of 5 to 10 million degrees Celsius were obtained.

Direct-drive target designers project that densities on the order of 300 to several thousand times liquid hydrogen densities, together with temperatures in the range of 50 million degrees are sufficient to ignite direct-drive targets.

Given these recent advances, an upgrade of Omega from 2,000 to 30,000 joules could provide the means to attain ignition with direct-drive targets.

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NASA

SPACE STATION FUNDING—PLANNED AND ACTUAL
(in millions of dollars)

Fiscal year	1985 NASA Plan	Administration Request	Actual
1986	230	230	195
1987	530	580	420
1988	1,050	767	425
1989	2,070	967	?
1990	2,270	?	?
1991	3,310	?	?

NASA released a five-year funding plan in 1985 for the space station. Today the space agency is already more than $1.8 billion behind where it should be in spending the money it would take to do the job, even if it is given the full $967 million requested for fiscal year 1989.

Is the Space Station Going The Way of the Shuttle?

by Marsha Freeman

Four years ago in his State of the Union Message, President Reagan instructed the National Aeronautics and Space Administration (NASA) to design and build a permanently manned space station that would be operational within a decade.

Today, that space station is two years behind schedule and less than two thirds its original size. The head of the space station office at NASA headquarters has left the space agency, and NASA administrator James Fletcher is threatening to cancel the entire program, rather than have it starve to death.

So far, NASA has spent almost $2 billion less on the space station than it had projected in 1985 would be necessary (see chart). Its original estimate that $1.8 billion would be needed in fiscal year 1989 has now been slashed to a request to Congress for a mere $967 million, and Congress will likely cut this further.

The day of reckoning for the space station is at hand. Either the commitment to give the free world a permanent manned presence in space (matching what the Soviets already have) will be renewed, or the space station will go the route of the Space Shuttle and risk being too little and too late to keep the U.S. in a position of leadership in space.

Sixteen years ago, during his first term as NASA head, James Fletcher and President Nixon announced that this nation would develop a Space Transportation System to shuttle astronauts and scientists back and forth to Earth-orbit and make access to space routine.

Within months of that announcement, the Office of the Budget, then headed by Secretary of State George Shultz, slashed the space agency budget by $.5 billion. Changes were made in the Space Shuttle design to accommodate the funding constraints, thus compromising safety and long-term economy. The program then fell two years behind schedule, a delay that caused cost overruns and the elimination of needed equipment tests.

The reasons voiced 16 years ago to delay and trim costs on the Space Shuttle are not any different from those used more recently against the space station. Critics claim that the United States does not need a manned presence in space because robots can do things more cheaply, that the station will take money away from unmanned science projects, that it will cost too much during the current budget crisis, that NASA has not clearly defined a need for the facility, that there is no reason to plan any new initiatives until the Shuttle is flying again, and so on.

When NASA began the space station program it had a very clear idea of what the multipurpose facility should do. As stated by NASA in 1986: "The Space Station will serve as a laboratory to conduct basic research, an observatory to look down at the Earth or peer out into the sky, a garage to fix and service other spacecraft, a manufacturing plant to make exotic metal alloys, super-pure pharmaceuticals, or perfect crystals, an assembly plant to build structures too large to fit in the Shuttle's cargo bay, and a storage warehouse to keep spare parts or even entire replacement satellites."

An Endangered Mission

Any questions about the role of the space station have arisen only since NASA has been told that it cannot build what it planned, and that the number

and variety of capabilities of the station will be cut back.

Now the entire space station program is in danger because of funding cuts, Congress's attempts to "micromanage" the program, the military's indecision as to what role space station capabilities should play in national security, and President Reagan's unwillingness to give up his illusions about the state of the economy and fight for the space program.

In 1984, NASA had estimated that the cost of the space station would be about $8 billion. This estimate did not include the cost of launching the elements of the station, the annual operating costs, or additional elements that might be added to the basic design. As might be expected with any research and development program, as the design became more finely defined, the cost estimate increased.

However, when the station became a bona fide program, the Office of Management and Budget (OMB) capped the program's cost at the $8 billion estimate. Therefore, in May 1985, NASA announced that a "more modest" station would be designed and built, to stay within the OMB guidelines. Then, later that year, the OMB proposed a three-year-delay in the program and a budget of only $100 million—to "save" money.

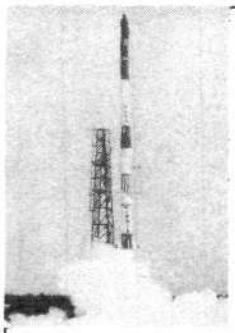
By January 1986, the administration decided that a 12- to 18-month delay would be necessary to keep the "costs" down, and the fiscal year 1988 budget request NASA had made to the White House was cut nearly in half. So much for President Reagan's promise to give the nation a space station "within a decade."

Last year, NASA had to once again revise its design for the station. At a briefing for the OMB in February 1987, NASA proposed a two-phase station deployment, in order to squeeze the program into the budgetary straitjacket. A month before, the Congressional Budget Office had recommended that the space station be canceled altogether, to "save" $8.9 billion over the next five years.

NASA had planned to up the station funding in 1989 so that the companies that won the contracts to build the station in November 1987 could finish the final design and start producing the modules and other elements. However, when the agency's projected $1.8 billion request for fiscal year 1989 came out of the White House budget process at $967 million, NASA once again had to "rescope" the entire program, to figure out when it can realistically expect to start launching the initial elements, and when people might be able to start working in space.

Without a space station, this nation and our allies around the globe will not be able to do anything new or go anywhere else in space.

This nation cannot afford another Space Shuttle-type program that is stretched out, technically compromised, and down-sized in capability. The United States and its international partners should put the space station back on track.



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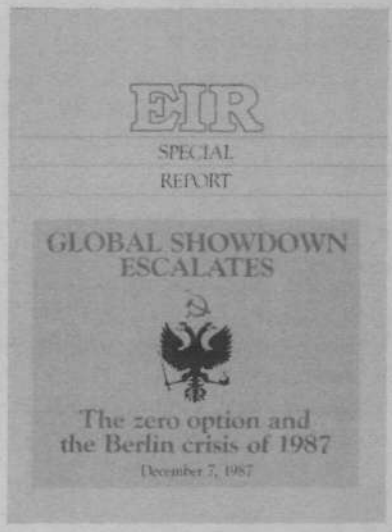

GLOBAL SHOWDOWN ESCALATES

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DEFENDING U.S. DEFENSE

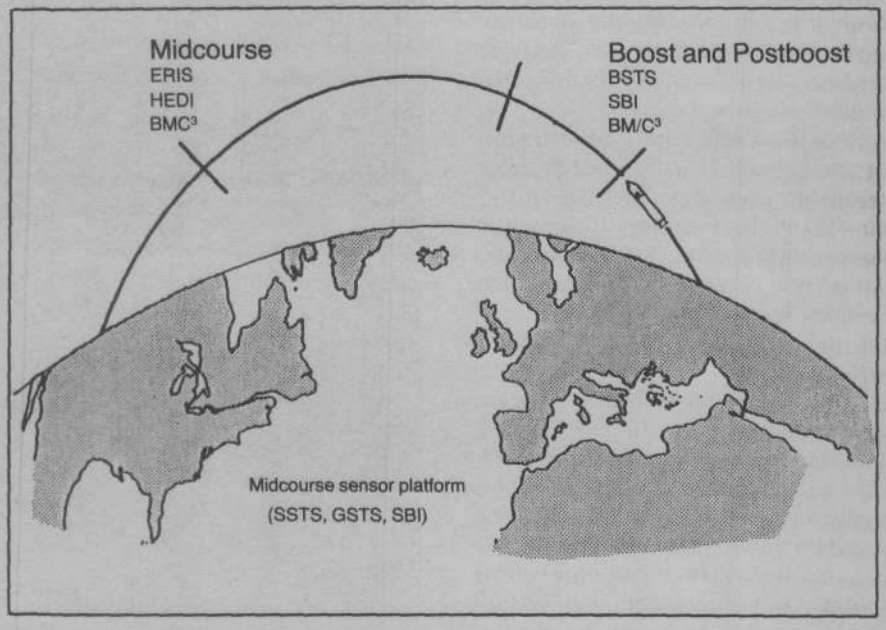
Conference Charts Progress in SDI

In the midst of mounting evidence that there will be a Soviet breakout from the 1972 Antiballistic Missile treaty in the next year, several hundred defense scientists and policymakers gathered in Washington, D.C., March 13-16 to review the status of the Strategic Defense Initiative (SDI).

The conference, cosponsored by the SDI Organization and the Institute for Foreign Policy Analysis, was timed to coincide with the fifth anniversary of President Reagan's March 23 speech establishing the SDI. However, it was intended to accomplish more than a review of the program's progress. There is now a debate going on within the Reagan administration as to whether to accept the proffer of Senator Sam Nunn, a Georgia Democrat, for a very limited point defense system using 100 exoatmospheric rentry vehicle interceptor system missiles to guard against accidental launch of a ballistic missile.

Nunn wants this Accidental Launch Protection System, or ALPS, to be deployed in the near future, while delaying the plans for a phased SDI deployment. The ALPS supporters argue that such deployment, relying upon existing technology, would "get the show on the road" at a low cost.

The Nunn proposal was roundly at-



SDI STRATEGIC DEFENSE SYSTEM PHASE 1

Shown here are the six elements of the core concept of the SDI's phase 1: boost surveillance and tracking system (BSTS), space-based interceptor (SBI), space-based surveillance and tracking system (SSTS), ground-based surveillance and tracking system (GSTS), exoatmospheric reentry vehicle interceptor subsystem (ERIS), high endoatmospheric defense interceptor (HEDI), and battle management command, control, and communications (BMC³).

tacked by a succession of conference speakers as in no way comparable to the planned missile defense system. However, since the conference, the Pentagon has been more open to ALPS as senators like Nunn have used the issue as a bargaining chip in the fight to get the Intermediate Nuclear Force treaty ratified.

At the conference, President Reagan held the door open to Nunn's idea for a bipartisan coalition on the SDI, although his keynote address reasserted a commitment to the SDI: "Congress should realize that it is no longer a question of whether there will be an SDI program or not; the only question will be whether the Soviets are the only ones who have strategic defenses while the United States remains entirely defenseless."

President Reagan pointed out that the Soviets have spent more than $200 billion on their "Red Shield" equivalent of the SDI—15 times as much as we have spent here. He further reported that the Soviets have more than 10,000 scientists and engineers working on laser weapons alone.

As Gen. Edward L. Rowney (ret.), the special adviser to the president on arms control, noted later, "We can only deploy viewgraphs," while the Soviets are deploying an actual ABM defense.

'Brilliant Pebbles' and 'Smart Rocks'

Throughout the three-day conference, many presentations covered the progress that has been made in developing the required technology for phase one of missile defense—kinetic energy weapons or KEWs.

Dr. Lowell Wood of Lawrence Livermore National Laboratory, for example, discussed how near-term developments in microcomputers and sensors, combined with the Western advantage in mass production of advanced technologies, can be harnessed to achieve miniature space-based KEWs that are so small, so cheap, and so smart, that they could be proliferated in near-Earth orbit by the hundreds of thousands as totally independent systems to provide a robust defense against ballistic missiles.

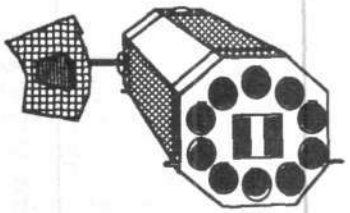
Wood reported major advances in development of microcomputers, including the S-1 project at Livermore to develop the means for automated and simultaneous design of supercomputer hardware and software. We can now develp microchip computers weighing less than 100 grams that have a computing power equal to today's largest supercomputers, like the Cray, he said.

(One version of the Cray today has a computing power equal to all the world's computers in the year 1970.)

The same technology, he said, can also be harnessed for realizing advanced microchip-based sensor systems weighing less than 100 grams. At a collision velocity of 10 kilometers per second, this mass alone has many times the wallop needed to kill missile boosters.

Wood forecast that the United States could develop a mini space-based interceptor weighing less than 5 pounds and costing less than $50,000 each. These mini interceptors, which he called "brilliant pebbles," would each use its 100-gram supercomputer to function totally independently, each making the decision of when and what to strike most efficiently as part of the overall missile defense.

The proliferation of 100,000 independent defense systems would ensure that a sufficient nmumber of them could survive any currently projected countermeasures to kill all ballistic missiles launched anywhere on Earth—at a cost of less than $30 billion.



SPACE-BASED INTERCEPTOR ELEMENT

The mini space-based interceptor is designed to destroy attacking missiles in the boost phase and reentry vehicles in the midcourse phase of their flight, using the force of its impact at extremely high speed. Boost surveillance systems would detect and track the ballistic missiles and relay this information to the battle management command, control, and communications system, which would process it and communicate target assignments to interceptors like this one. When the interceptor platform receives the command, it will launch interceptors to destroy the attacking missiles.

Justified Optimism

Many conference presentations covered the major progress in development of directed energy systems—lasers and particle beams. Even the most primitive directed energy systems, it was demonstrated, would dramatically improve the overall capabilities and robustness of an SDI missile defense system, even at the earliest stages of deployment. At the same time, it was noted, congressionally mandated budget cuts are threatening to gut this entire element of the SDI.

Compared to KEWs, directed energy weapons can be utilized in multiple roles. While KEW systems must scale linearly with the increase of the number of offensive missiles and can be overwhelmed by increasing the density in time and space of the missile launch, directed energy systems are relatively insensitive. That is, the number of space-based lasers needed to defend against an increased number of missiles would be roughly proportional to the square root of the number of new missiles deployed and insensitive to whether they are all deployed at the same location for a high-density launch.

It is obvious that the predominantly optimistic tone of the conference about the technological success of the program in easily solving what appeared to be serious problems five years ago is well justified. Despite the inherent superiority of directed energy weapons, the "brilliant pebbles" described by Wood are a capability that certainly should be deployed as rapidly as possible.

However, we are also left with ironic confirmation that the same scientific and technological capabilities that were directed to perfecting this new generation of kinetic energy weapons would have been put to better use had the directed energy program been prioritized instead.

—Charles B. Stevens and Carol White

A fusion scientist discovers that God uses the same approach to form a solar system and a stable laboratory plasma.

How the Solar System Was Formed

by Daniel R. Wells

Hale Observatories

Interest in the paths of motion of stars and planets dates back to prehistoric man. Much of the history of astronomy is the history of attempts to understand planetary motion. In the third century B.C., Aristarchos of Samos established that the planets orbit the Sun. His conclusions were pushed aside by the imposition of Ptolemy's Earth-centered system, until Copernicus reasserted the truth of the Sun-centered system in the 16th century. Real progress in describing the planetary orbits came in the 17th century with Johannes Kepler's work on Tycho Brahe's detailed data. Kepler's results stand to this day as an accurate description of the actual tracks of the planets.

Kepler's laws of planetary motion led, in turn, to Newton's law of gravitation, as well as his laws of dynamics. All of these laws are concerned with how motion occurs after a planet, or any other satellite, has been launched into orbit. After the orbit is established, there is an exact relationship between the parameters of the orbit and the initial conditions of the launch. The problem is simplified by assuming circular orbits instead of the actual elliptical orbits. If the velocity of the planet in the supposed uniform circular orbit is known, the radius of the orbit is fixed. If the radius is known, then the velocity is determined.

Newton's treatment does not determine the radius *(r)* or the velocity *(v_θ)* unless one or the other is given to begin with. In fact, neither Newton's laws nor Kepler's three laws predict what the average radius of each planetary orbit will be or what, in turn, their velocities will be. Once the average radius of each planet has been measured, the corresponding velocity *(v_θ)* can be calculated by the equations given. In the more complicated case of the actual, slightly elliptical orbits, the velocities at each point of the orbits can be calculated.

The actual relative placement of the orbits depends on the *initial conditions* existing during the formation of the Sun and planets and is not given directly by the equations of motion. This is easily shown by the following analogy: A little boy puts a stone on a string. He slings it around his head, and he can continue as long as he doesn't get tired. It will stay there; it is in a dynamic equilibrium.

Newton's laws can be used to say how much force there is on the string, how fast the boy has to turn it, and so forth. But what if you ask, "How long is his string?"

"That's ridiculous, it's as long as he cuts it."

"But I want to know *a priori* how long his string is going to be."

Of course, this *is* ridiculous so long as there is a string. But the question is a real one when you consider the orbits of the planets: The planets can be shown by the inverse square law to be in dynamic equilibrium. But, why are the radii what they are? Why is Mercury where it is? Why are Venus and Earth where they are, and so forth.

While Newton concerned himself only with the dynamics of the planetary orbits, Kepler gave a preliminary answer to the question of the radii in his first major work, *The Secret of the Universe.* There he offered a hypothesis to account for the distance of the planets from the Sun. Their placement was determined by a sequence of the Platonic solids, nesting them one inside the next, placing a sphere around each to represent an orbit. He began with a cube to determine Saturn's orbit, and then successively a tetrahedron, dodecahedron, icosahedron, and octahedron.

Further attempts to understand why the orbits have their measured dimensions were made over 200 years ago—almost immediately after the publication of Kepler's and Newton's work. These were elaborations of another hypothesis, now called the Titius-Bode relation, offered by Kepler in *The Secret of the Universe,* although he himself did not consider that it provided a sufficient cause.

J.D. Titius of Wittenberg, translating a Swiss treatise on the subject, published a numerical relation in 1766 that gives the approximate distances of the planets from the Sun. This relation, and the fact that it seems to be reasonably accurate for at least the inner planets, has never had a basis in any sound physical model. Six years after Titius published his article, the director of the Berlin Observatory, Johann Bode, popularized the relationship, and his name became associated with the concept. In the current literature, therefore, it is usually referred to as the Titius-Bode relation. The Titius-Bode law is developed from a number series that starts with 0, then 3, and then keeps doubling the last number: 6, 12, 24, and so on. Then it adds 4 to each number and divides by 10. The results (0.4, 0.7, 1.0, and so on) give the approximate radii of the planetary orbits in astronomical units (AU). One AU is defined as the radius of the Earth's orbit. (To be more exact, one AU is the semimajor axis of the Earth's elliptical orbit. The semimajor axis is half of the "long" diameter of the ellipse.)

The discovery of Uranus by the German-British astronomer William Herschel in 1781 created great interest in the Titius-Bode law because it successfully predicted the orbit of this distant planet. It also predicted a planet between Mars and Jupiter. The asteroids, mostly with orbits in that region of the solar system, were discovered 20 years later at the beginning of the 19th century. The fact that there are many asteroids with orbits that approximate the appropriate orbit, and not one planet, disturbed some critics at the time. These speculations were all about the time of the American Revolution. Later, with the discovery of Neptune and Pluto, it was discouraging to find that these planets did not fit the law.

People have tried to account for the Titius-Bode relation in many different ways, and there are entire books written on the subject. Benjamin Franklin worked on this problem and discussed it with his colleagues. Why does this strange numerology give the orbits of the planets? No convincing theory to back up the Titius-Bode series has ever appeared, despite the extensive literature on the subject (Chandrasekhar 1946; Weizsäcker 1947; Kuiper 1949; Alfvén and Arrhenius 1976; and Alfvén 1954).

Stars are continually being born in the cool, gas-dense arms of spiral galaxies like this one. How many stars come into being with planetary systems around them? This is the spiral galaxy M81 in Ursa Major, 8.5 million light years away.

The Fusion Side of the Story

To understand the creation of the solar system, one approach is to begin by studying the Sun. Since the Sun is a

giant fusion reactor, it is helpful to look at what we know about how fusion reactions work here on the Earth. As a plasma physicist, this is the approach I have taken.

There has been a concerted effort for the last 35 years to build a fusion device here on the Earth that would emulate the stars, which generate their energy with fusion. This enterprise has met with only limited success so far, but has lots of promise.

If we think about how we are going to solve this problem, then we are thinking about how to build a little star on Earth. We want to get the plasma hot enough for nuclei to fuse. *Hot* means the particles are moving fast, so there will be lots of head-on collisions that lead to fusion. The hotter the plasma, the more likely it is that a fusion process will be started. The difficulty is that just about the time the plasma is hot enough for fusion to take place and release some useful energy, the plasma begins to disappear. It gets wild when it gets hot, and it escapes from confinement.

This is the problem of containing the hot plasma. The Sun and the stars solve this problem, more or less, with gravitational forces. Every time a particle tries to escape from the Sun, the Sun tries to pull it back with a strong gravitational pull. This is a naturally occurring stable state in the Sun and in most of the stars. There are volumes written on instability; we are talking about a stability. The Sun is a stability.

Our job as plasma physicists here on Earth is to reproduce this stable state in a plasma without having the gravitational field to help us. It is here that the physicists diverge. There have been two main avenues of approach. One is to try to solve the problem in terms of a *single-particle model*, which treats the plasma as a collection of electrons and positively charged ions that make up a gas. From this point of view, the idea is to try to control the particles, and get them hot enough to fuse.

I am of the other school, which looks for naturally occurring geometries in the plasma to do the job of confinement; this means treating the plasma as a *magnetohydrodynamic* system of both ions and electrons, rather than as a mere collection of particles.

It takes some preliminary explanation to introduce the theory I am proposing. I will accompany a somewhat technical explanation with shorter, "hand-waving" arguments, so that the general reader can follow.

To achieve controlled fusion reactions here on Earth, we cannot use gravity, as everybody knows. Gas in the laboratory does not have enough mass to amount to anything as far as gravitational forces are concerned, so we are limited to electrical forces or some kind of inertial or magnetic effect. All of these things have been worked on for many years. For the purposes of this article we will use a magnetic field to try to hold the gas together.

The simplest way to describe the stars—or a plasma in a fusion device on Earth—is in terms of a magnetohydrodynamic (MHD) model, described in Equation 1 (see box, page 22, for numbered equations). For that to apply, velocities and viscosities must remain within certain ranges so that turbulence does not dominate. Suffice it to say that most laboratory plasmas that are made to try to solve the fusion problem meet this criterion for the MHD model, and so we can forget about the single-particle model.

What is the meaning of *magnetohydrodynamics?* In addition to magnetic forces, there are hydrodynamic forces active in the gas. These are the forces that make an airplane fly, and they can be simply described in terms of what is called the Magnus force.* (Terms with asterisks may be found in the glossary.) It occurs as the interaction of the vorticity*—the churning of the air—with the velocity of the wind blowing past the airplane. If you are sitting in an airplane, you can think of yourself as standing still and the wind blowing past you, so you are generating a lot of churning motion—a lot of vorticity—with your wings, and that vorticity interacts with the air blowing by to hold you up.

Glossary

Bessel functions. Solutions to Bessel's equation, a linear, second-order differential equation used in problems involving circular or cylindrical symmetry:

$$z^2d^2y/dz^2 + zdy/dz + (z^2 - v^2)y = 0$$

F.W. Bessel, a German astronomer, lived 1784-1846.

Collinear. Fields that are either oriented in the same direction, or in directly opposing directions, are collinear.

Eigenvalues. Values of a function satisfying a certain condition. For example, in Figure 3, the values of (kr) for which $J_1(kr) = 0$ are set by the eigenvalues, k, of the force-free equation, $\nabla \times \mathbf{B} = k\mathbf{B}$.

Force free. The absence of any Lorentz force. In an incompressible plasma, the Magnus force is also zero. In a compressible plasma (all real plasmas) the Magnus force is not necessarily zero and provides the containment for confinement of the hot, dense plasma necessary for fusion (Wells 1987).

Lorentz force. The force on a moving charge or electrical current resulting from its interaction with a magnetic field.

Magnus force. The force on a body resulting from the interaction of a vortex filament and a mass flow velocity. The hydromagnetic equivalent of the Lorentz force.

Minimum free energy state. Also referred to as a relaxed state. Energy available to create instabilities is reduced to a minimum. The maximum available energy is bound in one of the fields contributing to stability.

Theta pinch. The self-constriction of a plasma filament resulting from the attraction of parallel currents.

Vorticity. The spin of a baseball generates vorticity in the air. A plasma ring's vorticity is the rotation of the filament that forms the ring by virtue of being closed on itself. The ring is thus rotating into—and out of—its center.

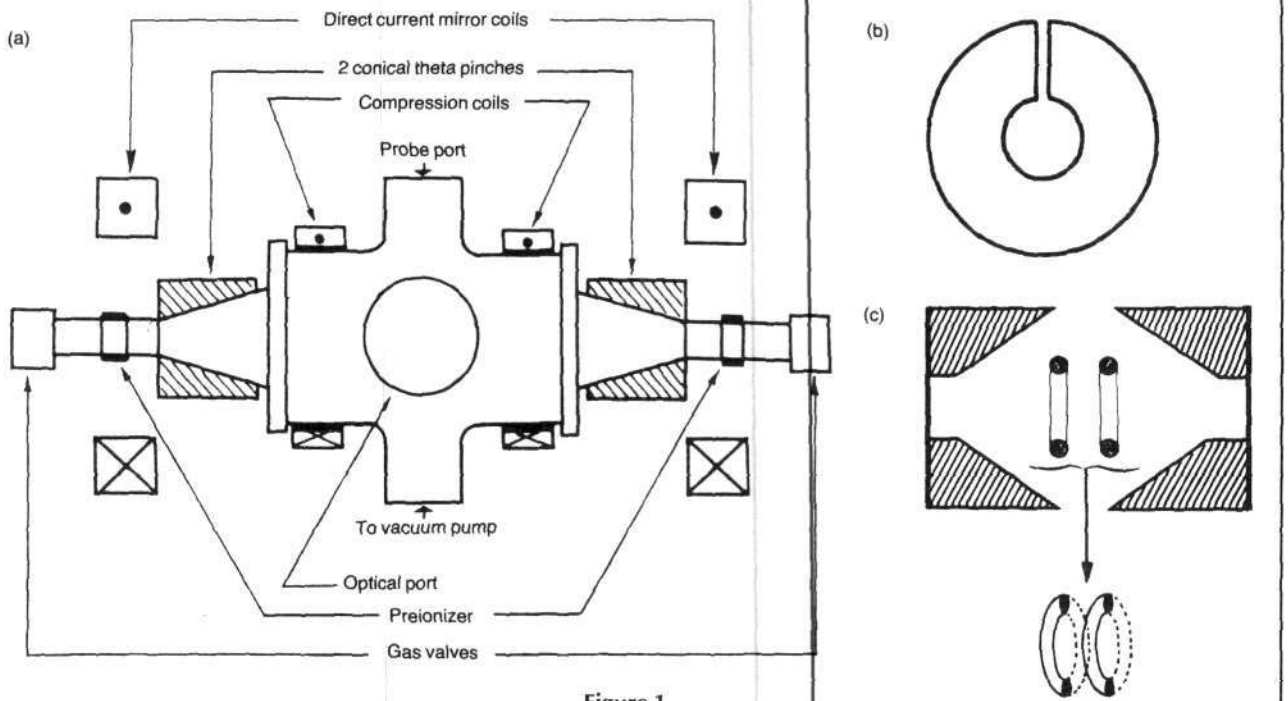


Figure 1
SCHEMATIC OF THE TRISOPS FUSION DEVICE

The Trisops device (a), designed by the author, uses the theta-pinch principle to create stable plasma rings. Two rings—one from each end—are fired at each other to create the high temperature and high density necessary to initiate the fusion of nuclei. Trisops has attained 70,000° K with a plasma density of 10^{16} particles per cubic centimeter for a duration of 100 microseconds. Hydrogen gas is puffed in through the gas valves as a capacitor bank (not shown) discharges through the two cone-shaped apertures (cross-hatching). The cones are cut into blocks of metal and function as single-turn "coils" that induce an electrical current in the ionized ring of gas.*

The "business end" of a conical theta pinch (b) shows the slot that makes it a single-turn "coil." In (c) two plasma rings are fired at each other.

These same forces are acting on the plasma fluid, and this is the crux of my theoretical discovery of 30 years ago, that the fluid or lifting forces can be utilized as containment forces in a plasma device for achieving nuclear fusion!

It was only two years ago, however, that I discovered a way of linking the creation of the solar system and the behavior of plasma vortices created in a laboratory. The story is a rather amazing one. It is a new development, and if I had heard the story then I would not have believed it. It involves the confluence of many different people and many different, apparently unrelated ideas. They all came together to produce a theory using the insights gained from working with fusion plasmas to describe the genesis of the solar system—and possibly other galactic phenomena as well.

The Magnetohydrodynamic Model

I have performed a series of experiments over the last 25 years at the Princeton Plasma Physics Laboratory in New Jersey and at the University of Miami, studying the production of naturally occurring stable plasma structures. If the plasma is described by a magnetohydrodynamic fluid model, it is possible to calculate the various fields (magnetic, current density, flow velocity, and vorticity) in a closed plasma structure corresponding to minimum free energy.* The free energy is the undirected energy available to create instabilities. The calculation involves variation of the free energy subject to certain side conditions or constraints.

This approach has always appealed to me, because I was formerly an aeronautical engineer, and I knew something about hydrodynamics or gas flow, and so I thought this was a way for me to approach this subject. I first became interested in the astronomical work of Subrahmanyan Chandrasekhar at the University of Chicago and his student Lodewijk Woltjer in connection with studies of the winding of force-reduced and force-free coils.

I was studying for my doctorate at Stevens Institute of Technology in New Jersey, and at the same time I worked at Princeton. My job at Princeton, for some years, was to assist in the design of magnetic coils for the stellarator device and other fusion machines that were part of the program to build a thermonuclear reactor. Coils are used to contain a hot plasma by creating a magnetic field that surrounds it. The problem with the coils was that they would break at just the point where the magnetic field was high enough to contain the plasma. It was like a racing car that is accelerated to 140 miles per hour, and then a piston comes flying out through the head. Just when it is leading the race at Sebring, its engine goes.

We solved the problem at Princeton by discovering that it is possible to wind a multilayer coil with the pitch of each layer of the winding arranged so that the ($\mathbf{j} \times \mathbf{B}$) Lorentz forces are zero everywhere in the winding—the forces that result from interaction with a magnetic field (Mills et al. 1961). This is the meaning of a force-free* configuration: It is free of Lorentz forces.* The coil must be placed in a magnetic field generated by an *external* winding. The external coil then takes the forces and relieves the working coil of the intense pressure gradients generated by the interaction of the currents and fields inside the windings. We designed the windings so that we could reduce those forces and still get a useful magnetic field. We could wind reduced-force coils, we could move the forces around wherever we wanted them, or we could make the coil force-free, so that there were no forces in the coil at all. That is what started me off in a direction that led from force-free coil magnets to force-free plasma vortices.

At the same time, I was working at the Stevens Institute under the direction of Dr. Winston Bostick, examining the flow of plasmas emitted by a plasma gun. The work of Safranov (Wells and Hawkins 1986) and others suggested the possibility of generating a ring of plasma with force-free properties. Plasma rings had been generated by Lindberg et al. (1961), and Wainek (1959) had suggested the possibility of generating plasmoids with a conical theta-pinch de-

Properties of Force-free Plasma Rings

In the magnetohydrodynamic model of stellar and interstellar plasmas, a plasma element (differential element of volume) with a center of mass velocity $\mathbf{v}$ obeys a momentum equation (Newton's Second Law) of the form

$$\rho(\partial\mathbf{v}/\partial t) = \nabla(p + \tfrac{1}{2}\rho v^2) + \mathbf{j} \times \mathbf{B} - \rho(\nabla \times \mathbf{v}) \times \mathbf{v} \quad (1)$$

where

p	scalar pressure,
$\mathbf{j}$	current density,
ρ	magnetofluid density,
$\nabla \times \mathbf{v}$	vorticity,
$\mathbf{B}$	magnetic induction field, and
$\mathbf{v}$	velocity of center of mass of a fluid element.

From (1), the acceleration of the fluid element $\partial\mathbf{v}/\partial t$ will be zero if all the body-force terms on the righthand side cancel or are each identically zero. Examine each term and its physical meaning. The first term will be zero if

$$p + \tfrac{1}{2}\rho v^2 = \text{constant.} \quad (2)$$

This is simply Bernoulli's equation for flow along a stream tube in the fluid. The ($\mathbf{j} \times \mathbf{B}$) term is the Lorentz force on the fluid element. The $\rho(\nabla \times \mathbf{v}) \times \mathbf{v}$ term is the Magnus force on a fluid element. This is the hydrodynamic force due to the interaction of the fluid flow and the local vorticity field.

If $p + \tfrac{1}{2}\rho v^2 =$ constant for the fluid, it will not be accelerated if the Lorentz and Magnus forces are both identically zero or if they are equal and opposite.

One must consider these two problems separately. What physical conditions correspond to Lorentz and Magnus forces both identically zero? What are the requirements for equality of these two forces?

Chandrasekhar and Woltjer invoked Hamilton's principle of least action to solve the problem of little or no mass motion in the plasma of interest. They posed the problem as follows: What configuration of plasma currents, magnetic fields, flow fields, and vorticity filaments would correspond to minimum free energy in an arbitrary closed volume of the plasma?

Using the standard formulation of the calculus of variations, they proceeded to vary the free energy subject to an appropriate set of constraints on the flow. The variation leads to a set of Euler-Lagrange equations for the fields in the form

$$\nabla \times \mathbf{B} = \Omega\mathbf{B} \quad (3)$$

$$\mathbf{v} = \pm\beta\mathbf{B}. \quad (4)$$

Equation (3) is the "force-free" equation. It makes the ($\mathbf{j} \times \mathbf{B}$) term in the momentum equation, (1), identically zero since by Maxwell's equations

$$\nabla \times \mathbf{B} = \mathbf{j}$$

if the displacement current in the plasma is neglected (usually a good assumption in the magnetohydrodynamic model).

Equation (4) is the equation of "collinearity." It means that the minimum-energy-state flow, the velocity, and magnetic induction field are everywhere parallel or antiparallel. It also means that the Magnus force will also be identically zero:

$$\nabla \times \mathbf{B} = \Omega\mathbf{B}$$
$$\nabla \times (\mathbf{v}/\beta) = \Omega(\mathbf{v}/\beta).$$

Let

$$\nabla \times \mathbf{v} = \eta^{\text{def}} = \text{vorticity vector.}$$

Then, since β and Ω can be considered constants for our purposes

vice. Ralph Wainek then built a pair of conical theta-pinch plasma guns (1959) and fired them at each other. He reported that some kind of structure was coming out of the conical pinches. Bostick asked me to investigate the nature of these structures. I built a conical coil at the Princeton Plasma Physics Laboratory and reported to Bostick, my thesis adviser, that the structures were plasma vortex rings.

While I was attempting to understand this, Dr. Robert Mills, a colleague at the laboratory in Princeton, suggested that I look at the astrophysical literature. I was an engineer at that time and had little interest in astrophysics, but I began to look at the papers of Chandrasekhar and Woltjer. There are magnetic fields in the plane of the galaxy and there are electrical currents flowing in the galaxy, but there is not much motion of plasma in the galactic plane.

Why? The explanation given was that the forces were not there: The forces that should have been generated by the magnetic fields and the currents were not there because of the alignment of the fields; in other words, the plasma was force-free, just like the coils we produced at Princeton. Nature had apparently designed the plane of the galaxy with the fields lined up in such a way that there are no forces.

I set myself the task of generating such stable forms in a plasma. The problem was to find a naturally occurring stable structure using a magnetic field to hold the plasma in place. There are several ways to do this in the laboratory. My approach was to vary the total free energy in the plasma, by using the tendency of a hot plasma to form vortices. I built a conical theta-pinch plasma gun and studied the plasma structures that were generated (Figure 1). I identified these toroidal structures as plasma vortex rings with a quasi-force-free geometry (Wells and Norwood 1969). The details of the structure were carefully studied by a student of mine, Eugene Nolting (now I was the major professor and the laboratory was at the University of Miami) (Nolting, Jindra, and Wells 1973).

The conical theta-pinch plasma gun blows what are literally plasma smoke-rings. These gas vortex rings can be likened to tornadoes, except that the base of the tornado is joined to its top, forming a ring. There are two kinds of plasma rings—corotational and contrarotational (Figure 2). A corotational ring can be made in which the magnetic and velocity-of-flow fields are parallel, causing the ring itself to move antiparallel to the background magnetic field. A contrarotational ring can also be made. Here the magnetic and flow fields are antiparallel, causing the ring itself to move parallel to the background magnetic field (Wells, Ziajka, and Tunstall 1986). Now let's move to the solar system.

$$\eta \times \mathbf{v} = 0.$$

The Euler-Lagrange equations for minimum free energy correspond to a "force-free" plasma state in which all four fields, $\mathbf{v}$, η, $\mathbf{j}$, and $\mathbf{B}$ are all parallel or antiparallel. The second Euler-Lagrange equation, (4), that is,

$$\mathbf{v} = \pm\beta\mathbf{B}$$

has other interesting implications. (Does it explain the Titius-Bode relation?)

In the general case of non-force-free fields,

$$\mathbf{j} \times \mathbf{B} = \rho(\eta \times \mathbf{v})$$

for current and vortex filaments if

$$p + \tfrac{1}{2}\rho\mathbf{v}^2 = \text{constant}.$$

The Lorentz force and Magnus force are in equilibrium. This situation is depicted in Figure 2 for two vortex filaments at right angles to the plane of the paper, one moving parallel and the other antiparallel to a magnetic guide field. The Magnus force is labeled F_h and the Lorentz force F_M. The filament traveling parallel to the guide field is called a contrarotational structure, and the filament moving antiparallel is a corotational structure. These names and motions are motivated by the $\pm$ signs in equation (4). The positive and negative signs in this equation are an indication of the essential nonlinearity of equation (1).

X and I are defined by Stokes's theorem:

$$X = \oint \mathbf{v} \cdot d\mathbf{l} = \int (\nabla \times \mathbf{v}) \cdot d\mathbf{A} =$$

vorticity in the filament;

$$I = \oint \mathbf{B} \cdot d\mathbf{l} = \int (\nabla \times \mathbf{B}) \cdot d\mathbf{A} =$$

electrical current in the filament.

From Lab to Solar System

The Titius-Bode relation is simply a series of numbers that gives the average radii of the planetary orbits of our solar system. The numbers are pretty good on a rough scale, within a couple of percentage points. They give Mercury, Venus, Mars, the asteroids, and so forth, but where does it come from?

To derive the Titius-Bode relation I apply the same method that I developed to study how to create a stable plasma in the laboratory. In both cases I use the helicity as a constraint, and I find the lowest energy state of a blob of plasma. Here we come to the heart of the matter. We have a method now, both theoretically and also in the laboratory, of generating stabilities that are going to stay around and get hot and furnish us with fusion energy. I call this the Trisops concept, using the name of the test reactor that I designed and built. We shall see whether God used a method similar to this in designing the solar system.

Until a year ago, I had never thought about applying this to the question of solar system formation. This idea came up in 1986 when I reviewed my Trisops research at a Fusion Energy Foundation seminar, and Lyndon LaRouche, one of the participants, put up his hand and asked whether I had ever tried using my concept of stabilities and variational

methods on the design of the solar system.

To begin thinking about the origin of the solar system, assume that a major disturbance in the primordial gas of the galaxy results in a cylindrical volume of plasma that is moving through the background plasma and rotating as it goes. It must further be assumed that there is a magnetic field—not necessarily a large one—present during formation of this plasmoid.

As this mass of plasma propagates through the surrounding gas, it loses energy by accelerating the surrounding plasma by convective transfer. Just as the plasma rings lose energy in the Trisops experiment, the cylinder loses energy and settles down to a minimum energy state. The geometry of this state will be a force-free collinear* cylindrical structure instead of a collinear ring structure.

The solution to the force-free equation that I use to describe the behavior of the Trisops plasmoids describes the formation of jelly-roll-like plasmoids in the hot plasma. Each layer of the cake is a vortex cylinder of plasma. That cylinder gradually shortens up because of the vorticity—it's like the coil spring on a door-slammer.

The force-free equation appears as one of a set of two Euler-Lagrange equations, partial differential equations that result from the variational calculations (Wells and Norwood 1969). These equations describe the fields and flow of the stable state.

The solutions are in the form of the zero-order and first-order Bessel functions*. These are the eigenfunctions of the force-free equation. *If you plot those out, the normalized roots of the Bessel functions agree with the Titius-Bode values within 2½ to 8 percent,* which is pretty good, considering that we are just talking about average values (Figure 3 and Table 1). The arguments of the Bessel functions (eigenfunctions) depend on the eigenvalues* of the force-free equation. The eigenvalues of the force-free equation depend on the intensity of the initial shock wave that creates the structure. This provides the celestial pinch parameter (Taylor 1986).

For Mercury, it is within 2.6 percent; for Venus, 4.2 percent. For Earth, it is 0 percent by definition, because we have normalized for that. Now here is something interesting: The next Titius-Bode number is 1.6, which is Mars, but we get an eigenvalue (root) before Mars at 1.332. There is a theory that the Moon was formed out of a planet that collided with Earth, and this would be the orbit of that planet. For values farther out, the value is pretty close for the average

A Solution of the Force-free Equation in Cylindrical Coordinates

Assume that a major disturbance in the primordial gas of the galaxy results in a cylindrical volume of plasma that is moving through the background plasma and rotating with finite angular velocity. Further assume that there is a finite but not necessarily large magnetic field present during formation of the plasmoid.

As this mass of plasma propagates through the surrounding gas, it loses energy by accelerating the surrounding plasma by convective transfer. Just as the plasma rings lose energy in the Trisops experiment, the cylinder loses energy and settles down to a minimum energy state. The geometry of this state will be a force-free collinear cylindrical structure instead of a collinear ring structure.

A solution of the force-free equation, equation (3), in cylindrical coordinates shows that the azimuthal and radial components of the flow velocity in the cylinder are proportional to a function of $J_0(kr)$ and $J_1(kr)$, the zero- and first-order Bessel functions. A restricted solution for coaxial cylindrical columns can be written in the form

$$v_r = -k^2\bar{a}\,[J_1(kr)/kr]\sin\phi$$

$$v_\phi = k^2\bar{a}\,\{[J_1(kr)/kr] - J_0(kr)\}\cos\phi$$

$$v_z = k^2\bar{a}J_1(kr)\cos\phi$$

$$v^2 = \bar{a}^2k^4\ \{(J_1/kr)^2 - (2J_0J_1/kr)\cos^2\phi + (J_0^2 + J_1^2)\cos^2\phi\}$$

where $\bar{a} = l\phi + k_2z$,

and k and l are constants defined by the boundary conditions of the plasma cylinder, and r is the radius of the cylinder in the r,ϕ,z coordinate system. We observe that for $J_1 = 0$

$$v^2 \sim J_0^2$$

$$v_\phi \sim J_0.$$

Figure 3 shows a plot of J_1 and J_0 with the function scaled to the geometry of the solar system. This maximizes the magnetic and kinetic energy at the origin. The structures described in the article contain flows described by the first eigenfunction alone. The second and higher eigenvalue solutions fall outside the boundary of the ring structures in the Trisops experiment. It would take much higher energies to drive the Trisops structures into higher eigenmodes.

In the cylindrical structure formed by the supernova explosion, the first eigenvalue corresponds to the structure of the star at the center of the hypothetical solar system, the second eigenvalue corresponds to a ring of gas just outside the star. The azimuthal velocity of the gas in the ring has a maximum at the maximum value of $J_0(kr)$ for the second eigenvalue, the azimuthal velocity of the gas in the next ring has its maximum value at the maximum of the third eigenvalue, etc. The flow in the rings is governed by equation (4).

asteroid's orbital radius, and for Jupiter it is within 3.5 percent.

The White Owl Effect

Imagine a blob of plasma—ionized gas—in the plane of the galaxy. There is as yet no solar system. Now imagine some major disturbance, some large disturbance in the plasma field, perhaps caused by a supernova, which creates the same effect that the conical theta-pinches do, electrically, in the Trisops machine. This would compress the plasma in the surrounding region and send it tumbling off.

This is how I have always described the formation of plasmoids in my machine. The plasma bumbles around in the surrounding gas, losing energy until it reaches its lowest possible free-energy state. At that point, there is a "stability." This is what I say happened in the formation of the solar system, except that instead of a sphere, a cylinder of plasma was generated—more exactly, a set of concentric cylinders—that shortened up until they became a set of concentric rings (Figure 4).

Now we must bring in another interesting concept, which I like to call the "White Owl effect." A vortex ring will, with the right initial and boundary conditions, contract azimuthally (along the circumference of the ring) to a blob at some point on the circumference.

In the 1960s, Dr. Bob Mark, an engineering colleague at Princeton, was hired by the makers of the White Owl cigar, the General Cigar Company, to design a machine that would make 10-foot smoke rings. Mark is a very bright guy and he did it. It was his White Owl machine that generated magnificent 10-foot smoke rings at the 1965 World's Fair in New York City (Figure 5). I had been interested in this since the late 1950s, so while I was at the fair I went off to watch the smoke rings. What I saw that night leads directly to an explanation of the Titius-Bode law.

I will never forget that night. It was a bitterly cold, late fall night, when the air was particularly still. The machine would make a tremendous bang, and the smoke ring would rise, illuminated by flood lights. It was very impressive. My family all went down to the lake to hear Guy Lombardo, while I stood there for 2 hours, watching these things go up.

Why was I so fascinated? Because something was happening that I never knew existed, and most people do not know to this day. Those rings would go up about 40 or 50 feet in the air, and stop. You might expect that they would stay suspended for a while and then gradually break up, but this is not the case. The rings rose up, stayed for a while, and then suddenly the smoke would travel azimuthally around the ring to produce what sounded like a clap of thunder. Suddenly, instead of a ring, there would be a ball of smoke.

Now transpose this to the case of the formation of the planets: Suppose that this cylinder, this jelly roll of plasma, is formed in the plane of the galaxy, and is foreshortened into a disk. Then the White Owl effect takes place. Now instead of having a circulating cylindrical ring, we have a cannonball-like structure of gas, traveling around the orbit that was described by the ring. It is moving with the same average azimuthal velocity that the ring had because angular momentum is conserved.

A vortex cylinder will contract axially to a disk. In both cases, the stretched vortex lines will contract to reduce the structure. The rings in the disk contract azimuthally to form the masses of the planets. Each ring forms a planet. Some rings later break up into many masses—the asteroids. One eigenvalue is skipped between the Earth and Mars. Part of the missing ring may account for the Earth's Moon.

The minimum-energy structure is force-free and collinear. The model is not self-consistent unless there is at least a small magnetic field present in the original gas nebula. This magnetic field gets compressed and intensified, and plays a vital role in the structure. Since the solution to the force-free equation—that is, the $J_0(kr)$ function—alternates

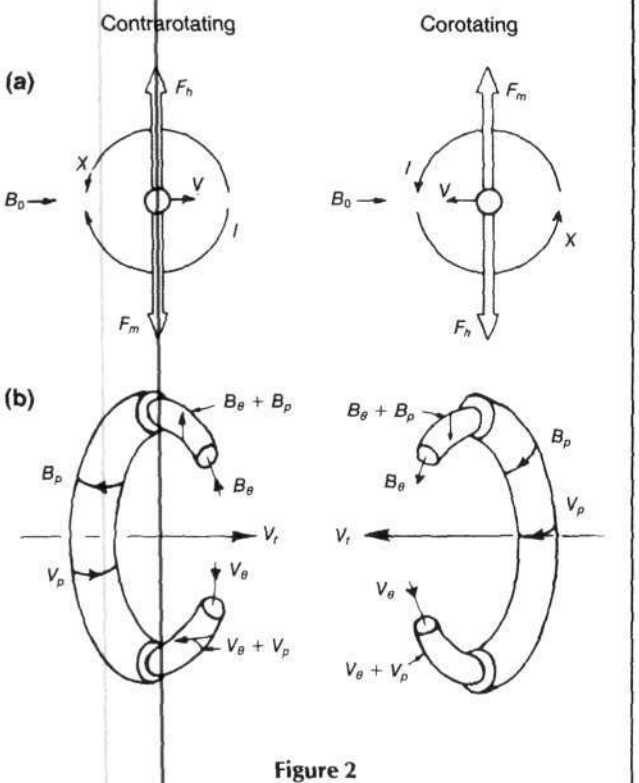


Figure 2
STABLE PLASMA RINGS

The two kinds of stable plasma vortex rings are shown in cross section (a), and in perspective (b). In (a), the filaments extend at right angles to the paper—the cross-section is the small central circle of each diagram. B_0 *denotes the stationary background magnetic field;* I, *the flow of electrical current; and* X, *the vorticity of the plasma.* V *is the translational motion of the filament—and hence the ring as a whole—given* B_0, I, *and* X. *Equilibrium is achieved because, in each case, the Lorentz force,* F_h, *and Magnus force,* F_m, *balance each other.*

In (b), the filaments are shown as closed rings. The magnetic fields (B) *and rotational velocities* (V) *of a filament are not everywhere the same, but vary continuously—indicated here by layering. The subscripts are* p, *poloidal;* θ, *toroidal;* t, *translational.*

Figure 3

AGREEMENT OF BESSEL FUNCTIONS WITH TITIUS-BODE AND MEASURED PLANETARY DISTANCES

A plot of the J_1 and J_0 Bessel functions is scaled here to the geometry of the solar system. The values shown here are also summarized in Table 1. In Wells's model, corotational vortex bands (planets) must alternate with contrarotational ones. In the first case, orbital motion (vector V) and the magnetic field (vector B) are aligned; in the latter, they are opposed. The missing planet just beyond Earth (indicated by a curved line) would have to have been contrarotational. Note that the orbital motion of all planets and also the rotational motion of the Sun is in the same direction, as it is in fact.

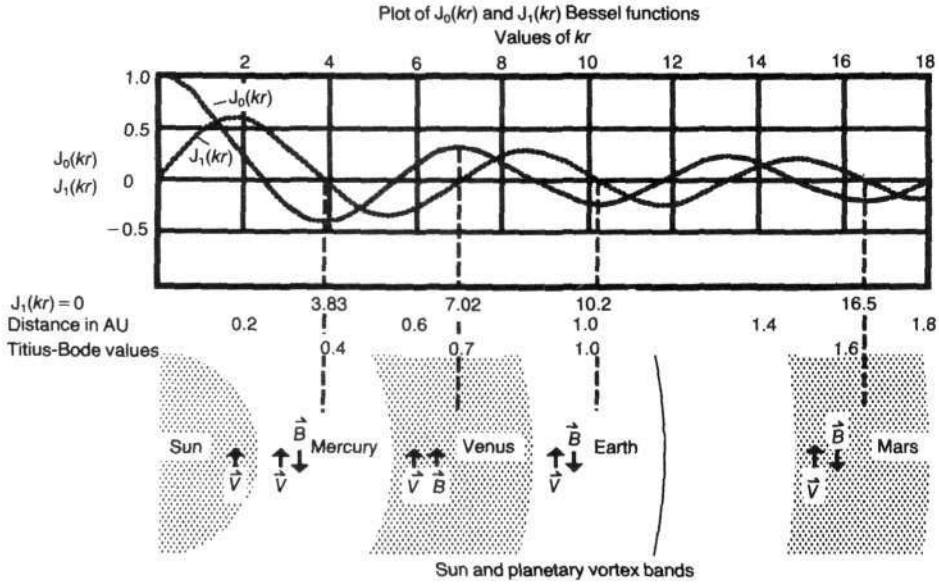


Table 1

COMPARISON OF BODE NUMBERS, THEORETICAL ORBIT RADII, AND MEASURED AVERAGE RADII

Planet	Values of *kr* for zero points of $J_1(kr)$	Bode numbers	Normalized *kr* values for zero points of $J_1(kr)$	Measured radii in AU	Percent error
Mercury	3.83	.4	.38	.39	2.6
Venus	7.01	.7	.69	.72	4.2
Earth	10.17	1.0	1.0	1.0	
Moon	13.32	—	1.3	—	—
Mars	16.47	1.6	1.62	1.52	6.6
Asteroids	19.62				
	22.76				
	25.9				
	29.04				
	32.18				
	35.33	2.8	3.08 (avg.)	3.35 (avg.)	8.1
	38.47				
	41.62				
	44.76				
	47.9				
Jupiter	51.04	5.2	5.02	5.2	3.5

The values of kr *at which the Bessel function* J_1(kr) *equals zero, provide the ratios of the planetary orbital radii within a few percent. When multiplied by a proportionality constant, therefore, they give the actual distances.* k *is a constant of the boundary conditions for the plasma cylinder;* r *is the radius of the plasma cylinder.*

between positive and negative values, the successive rings must alternate between being corotational and contrarotational. Now since the planets are all orbiting in the same direction, that means the signs of their magnetic fields must alternate. (This is illustrated in Figure 3.) The corresponding velocities are proportional to the magnetic induction according to Eq. (4). Therefore, as already discussed, the ratios of the extrema of the $J_0(kr)$ should yield the ratios of the average velocities of the planets.

The final step in checking the theory was to see how the actual ratios of planetary velocities accord with the values predicted by the force-free equation, Eq. (3). I did not really believe that they would check out. When I checked the ones I could calculate, the results were very exciting. They checked within reasonable tolerances; they came within 2.2 percent, 1.7 percent, and 8.1 percent (Table 2).

Kepler's harmonic law relating the orbital periods of the planets to their distances, is therefore also contained within the theory!

Other Solar Systems

Jupiter, in some models, is considered to be a pseudo-star that did not heat by gravitational contraction to high enough temperatures to start a thermonuclear reaction and become a true star. Did Jupiter and its inner satellites form in the same way that the Sun and its solar system formed? Comparison of the eigenvalues of the force-free equation and the radii and velocities of the Galilean (inner) satellites of Jupiter check within 10 percent.

Do all planetary systems around stars form as plasma vortex structures? Recent observations with infrared telescopes suggest that several objects currently under observation have structures similar to the artist's conception shown in Figure 4. The outstanding example is MWC 349, an object that seems to be too luminous for its corresponding spectrum by a factor of 10.

This and other similar objects are in the plane of the galaxy in regions where many young stars seem to be forming. Most of the light comes from the surrounding disks. The rings in these structures are observed to be dimming over observation periods of months. I propose that these

Table 2
COMPARISON OF RATIOS OF MEASURED VELOCITIES OF PLANETS TO RATIOS OF EXTREMA

Planet	Measured velocity v_ϕ (km/sec)	Extremum J_0kr	Ratio of Measured Velocities v_ϕ	Ratio of Extrema	Percent $J_0(kr)$ Error
Mercury	47.9	.4027	1.37	1.34	− 2.2
Venus	35.0	.3000	1.18	1.20	+ 1.7
Earth	29.9	.2497	1.24	1.14	− 8.1
Mars	24.1	.2184			

The values of kr at which the Bessel function J_0(kr) is at a maximum or minimum, provide the ratios of the actual velocities of the planets, within a few percent. For planets beyond Mars, the necessary Bessel function values are not readily available.

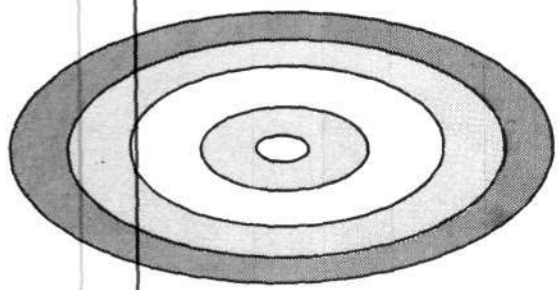


Figure 4
PLANETARY VORTEX BANDS
At this stage, the concentric vortex cylinders have collapsed into a disc of concentric bands. The matter in each band will subsequently form a ring and then a planet (see Figure 5).

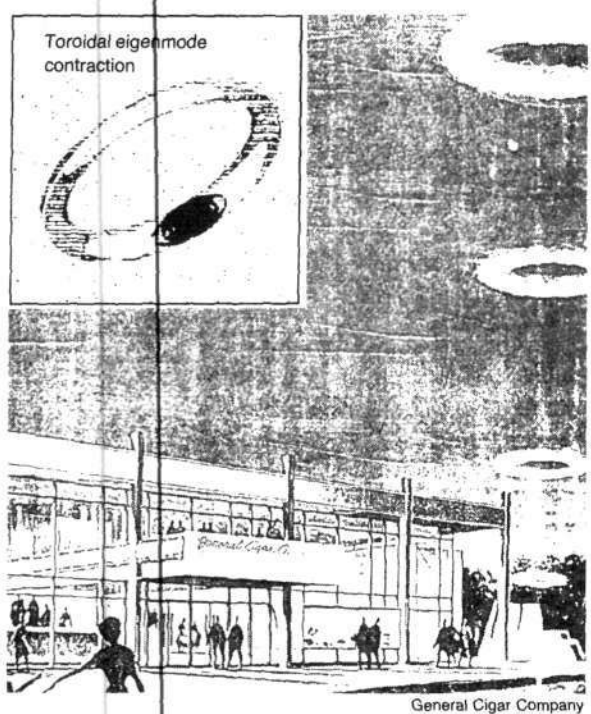


Figure 5
THE 'WHITE OWL EFFECT'
Bob Mark built the machine that blew magnificent 10-foot smoke rings from the General Cigar Company pavilion at the 1965 World's Fair. While watching it, the author discovered something: Instead of gradually breaking up, the smoke or gas in stable rings eventually "snaps"—it draws suddenly into a ball at one point along the ring (inset).

Stuart Lewis

Daniel Wells: "I am of the school that looks for naturally occurring geometries in the plasma to do the job of confinement." This approach formed the basis for his theory of the origin of the solar system.

are actually the structures described here, in the process of forming planets from the rings, by the mechanism suggested above.

We have obtained the geometry of the rings (planets) and the velocity ratios with a three-dimensional field theory that is independent of any "action at a distance" forces—that is, independent of gravitation. We have asked, what would the distances and velocities of the planets have to be if they were to achieve stable—that is, force-free—orbits, and all with orbital rotation in the same direction? To answer the question, we used the theory of plasma behavior. We used the two Euler-Lagrange equations that describe the relaxed state of a plasma ring—the force-free equation and the collinear flow equation. The solutions to these equations are two of the Bessel functions. We compared the normalized roots of the Bessel function for a fixed eigenvalue of the force-free equation $J_1(kr)$ with the Bode numbers and actual planetary distances. We compared ratios of the extrema of $J_0(kr)$ with measured velocity ratios. We discovered that the Bode numbers for the inner planets are actually eigenvalues (roots) of the force-free field equation.

To scale the semimajor axes of the planets and obtain the absolute azimuthal velocities, the initial conditions in the nebula before the start of relaxation would need to be known. If they were known, then a detailed description of both the morphology and scale of the system would be determined without invoking the gravitational inverse square law.

This was the objective of Kepler, who took the opposite approach to that of Newton and Galileo. He did not view "forces" as primary; instead, he derived his laws of planetary motion from the physical geometry of the planets and the Sun.

Daniel R. Wells, professor of physics at the University of Miami at Coral Gables, Fla., received a PhD in plasma physics at the Stevens Institute of Technology in New Jersey in 1963. Wells's theory of minimum-energy configurations for magnetic confinement of hot, thermonuclear plasmas has become the basis for fusion experiments involving spheromaks, compact tori, and reverse field pinches throughout the world.

Acknowledgements

This work was supported by the Fusion Energy Foundation, the University of Miami, and Trisops Corporation.

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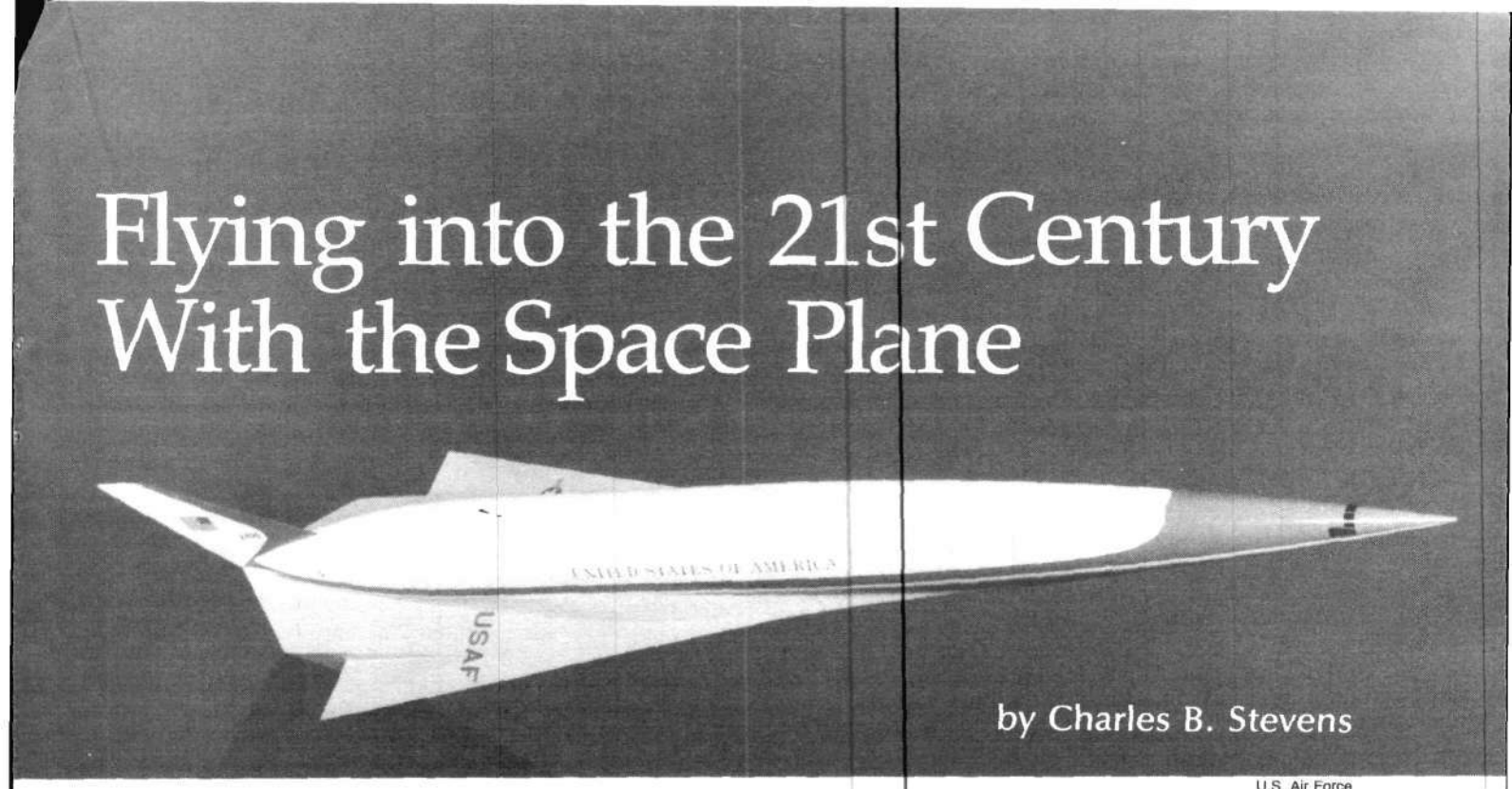
Flying into the 21st Century With the Space Plane



by Charles B. Stevens

U.S. Air Force

Just as the airplane carried man into the 20th century, advances in technology will provide us with a new vehicle to enter the 21st century and into orbit—the space plane. In fact, prototypes for the X-30 National Aerospace Plane are now scheduled for takeoff before the end of 1994. Before long, commercial versions will carry upwards of 500 passengers on two-hour flights between New York and Tokyo, and make large-scale transport to Earth orbit both economical and practical. One design, the single stage, air-breathing space plane, could reduce payload-to-orbit costs more than 100-fold below those of the existing Space Shuttle, clearing the way for large-scale colonization of Mars and beyond.

The U.S. X-30 program was announced by President Reagan in his 1986 State of the Union address. The $3.3 billion project is already the largest experimental aircraft effort in history, and private contractors have been pouring their own funds into the program four times faster than the government.

Technical progress has been so rapid that in fall 1987, the program was unexpectedly moved from phase 1, conceptual design, to phase 2, component testing and development. General Dynamics, McDonnell-Douglas, and Rockwell International were chosen to build and test prototype engines. Early in 1988, management responsibility for the joint NASA and Department of Defense program was moved from the Defense Advanced Research Projects Agency to the U.S. Air Force. Such a move had previously been scheduled to take place in phase 3 of the project, when actual construction of prototypes will begin.

This preliminary design for the X-30 National Aerospace Plane functionally integrates the airframe, wing, and engine to a degree never before seen in aircraft. Such integration is essential for the X-30 scramjet to achieve Mach-25 orbital velocities. In this model, the nose of the X-30 acts as the scramjet engine's inlet spike.

Two recent reviews of the X-30 project by the Defense Science Board and the General Accounting Office have generally endorsed the technical strategy and goals of the program. Dr. Joseph F. Shea, head of the Defense Science Board's Aerospace Plane task force, intervened to prevent major congressional cuts in X-30 funding. Shea wrote: "We strongly endorse the present program objectives. . . . We also believe that the current concept of focused technology program toward the X-30 is the most efficient and productive use of research and development funds."

The General Accounting Office stated: "The Aerospace Plane program is technologically challenging and a high-risk program; however, the potential payoffs are also high."

Jets Versus Rockets

What makes the aerospace plane so special is that it *uses* the atmosphere instead of just punching through it the way rockets do. A rocket must carry its propellant along with it, and thus 75 percent of the Space Shuttle's lift-off weight of 4.4 million pounds is propellant (and 83 percent of that is oxygen). In contrast, the fuel-efficient, air-breathing engine of the X-30 will obtain its propellant from the ambient atmosphere.

The most common type of jet engine is the turbojet found on most airliners today (various jets are compared in Figure 1). Its basic principle is that air comes in the front, is heated in a combustion chamber where fuel is burned, and is then expelled out the rear at a higher velocity to obtain a net thrust. A fanlike compressor is utilized to raise the temperature and pressure of the subsonic air flow before it passes through the combustion chamber.

Until recently, the turbojet was limited to velocities under Mach 3, because beyond that speed the temperature of the gases passing through the turbine blades would reach above 2,300 degrees F., at which point the blades would

begin to melt. However, the Air Force's Integrated High-Performance Turbine Engine Technology program has increased the turbojet envelope, and recent U.S. Air Force advances in the Aurora program have demonstrated that a turbojet can be developed to accelerate a vehicle to Mach-6 range.

A ramjet is the simplest of engines—it has no moving parts. The "ram-pressure" of the incoming air stream in a moving plane provides the intake mechanism. The air is slowed to subsonic velocities within the engine and then heated in the combustion chamber to produce the net thrust out the rear. But ramjets cannot operate until the aircraft attains at least a speed of Mach 1—the speed of sound and the speed at which shock waves are generated. Aircraft utilizing ramjets must therefore have a second set of engines—turbojets—to get them up to Mach 1.

The supersonic ramjet, better known as a scramjet, is simply an extension of the ramjet to an all-supersonic operating regime. That is, while the air is slowed down to subsonic speeds within the ramjet, the air in the scramjet maintains supersonic speeds throughout the engine. What limits the ramjet to speeds below Mach 6 is that slowing the air down to subsonic speeds within the engine causes the air temperature to rise precipitously. By keeping the airflow supersonic, the air is kept relatively cool. In more technical terms, the engine operates with isentropic flow—tending toward zero entropy change. The scramjet can achieve virtually unlimited speeds.

There are problems, however. To get enough air into the engine, almost the entire underbelly of the aircraft must be the intake for the scramjet. Also, the supersonic air in the combustion chamber spends a very short time there—a thousandth of a second or less. Thus, this requires either a very rapid chemical reaction, such as that achieved with hydrogen, or an alternative means of rapid heating, such as that provided by a nuclear reactor. The scramjet can begin to function only at speeds above Mach 4—twice the speed of the Concorde supersonic airliner.

Last but not least, the shock waves within the engine must be controlled and carefully tuned so that a minimum of waste heat is generated. The hypersonic, Mach-15-and-above scramjet will operate not only in thin air, but also on a thin margin. At high Mach speeds the exhaust velocity is only slightly above the intake velocity. A small increase in

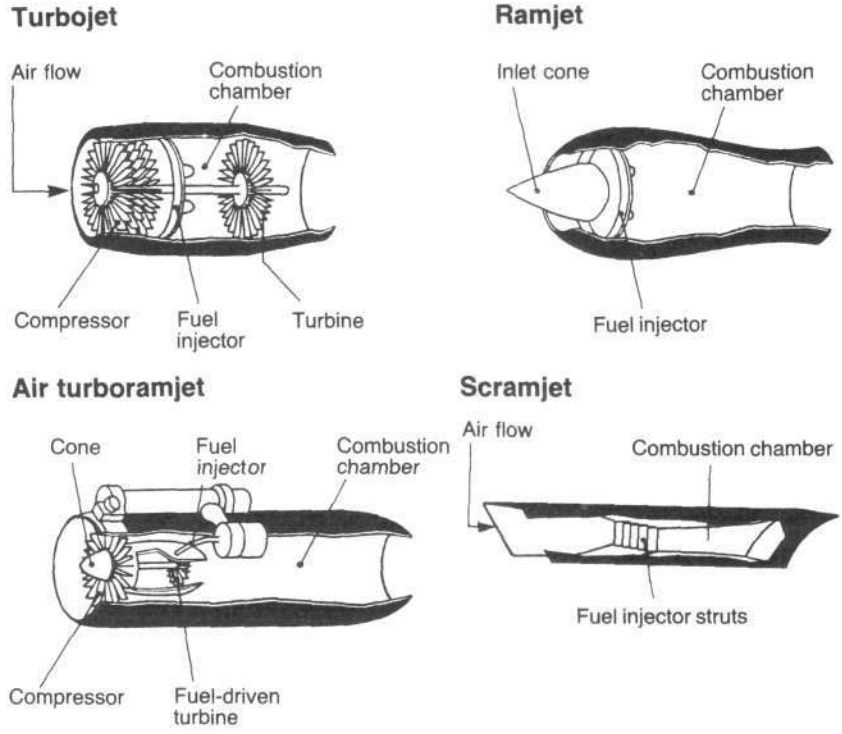


Figure 1
HOW DIFFERENT JETS WORK

Turbojets, found on most airliners, have generally operated up to about Mach 3, or three times the speed of sound. Turbojets use a fanlike compressor to raise the temperature and pressure of air before combustion. After combustion, the burning gases expand, and as they escape they power the turbine that drives the compressor.

A ramjet, the simplest of aircraft engines, operates from Mach 1 up to Mach 6. The ramjet relies on the "ram-pressure" of the incoming air stream in a moving aircraft to achieve compression. The compressed air enters the engine, slows down to subsonic speeds, mixes with the fuel, ignites, and escapes through the rear nozzle.

The air turboramjet combines the turbojet and ramjet technologies. However, with recent advances in the turbojet, this engine may not be needed for hypersonic aircraft. Its most crucial feature is that the compressor turbine is driven by the fuel in gaseous form, not by the hot inlet airstream. The hot air is diverted around the turbine to mix with the fuel coming from the turbine. Then the mixture of fuel and air burns in a ramjet-style combustion chamber.

A scramjet would begin to work only around Mach 4, and its upper limit is unknown. In the scramjet, the air maintains supersonic speeds throughout its flow through the engine. This minimizes engine heating—heat is what limits the previous three types of jet engines—since less of the supersonic air molecules' kinetic energy is converted to thermal energy. The greatest problem of the scramjet is that burning the fuel in a supersonic flow is like lighting a match in a hurricane.

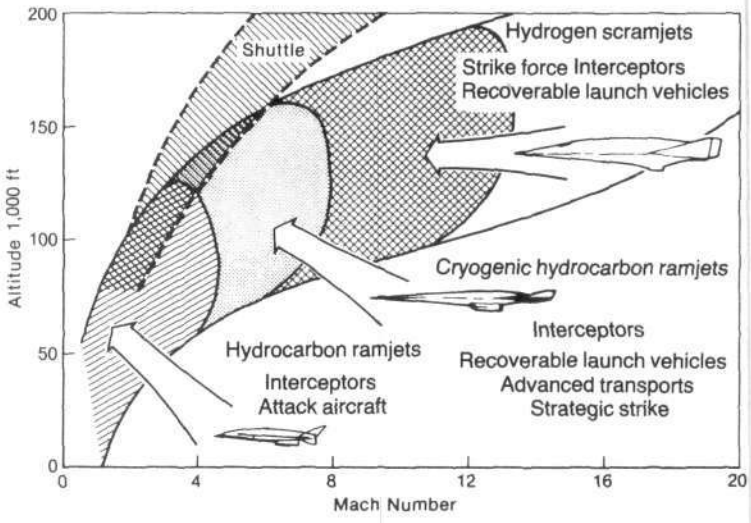


Figure 2
HYPERSONIC OPERATING REGIMES

The various operating regimes of hypersonic flight are shown here in terms of altitude (thousands of feet) and speed (multiples of the speed of sound or Mach number) for existing and future craft. Higher altitudes are required for high Mach numbers because the aerodynamic drag must be reduced to match the higher velocity. The drag decreases with decreasing air density, and the Earth's atmospheric density decreases exponentially with altitude. Existing turbojets, such as the U.S. Air Force Aurora and hydrocarbon ramjets, operate up to Mach 5. Cryogenic hydrocarbon ramjets would operate in the next region, up to Mach 8. Cryogenic hydrogen-fueled scramjet designs have been tested in wind tunnels up to Mach 14.

the inefficiency of the engine would dramatically reduce the engine thrust at high Mach numbers; for example, a 1 percent decrease in the thermal efficiency of the engine would decrease the thrust by one third at high Mach speeds.

Technical Progress

Because space plane technology has major military applications, all aspects of the X-30 project have been kept top secret. Only in recent months have reports surfaced on the stunning progress already achieved by the program:

- In February 1988, Pratt & Whitney scramjet engine component tests were carried out at Mach 14 at the Naval Surface Weapons Center. Pratt & Whitney engines use variable geometry as a compression mechanism, advanced materials, and integrated airframe-engine inlet and exhaust system designs.
- The U.S. Air Force reported: "We have made incredible progress in the area of computational fluid dynamics. . . ." This included the development of computer codes to fully solve three-dimensional equations to determine airflow paths over complex configurations at high Mach numbers, and similar codes for scramjet components.
- General Dynamics has developed a bold approach utilizing primary carbon composites for the entire aircraft, which could lead to a major breakthrough in reducing structural weight.
- McDonnell-Douglas has realized innovative new approaches to aerodynamic shaping and use of advanced control technologies, while proposing the use of materials made from a titanium-matrix embedded with silicon-carbide fibers for providing high strength-to-weight capabilities.
- Rockwell International has developed revolutionary designs that integrate the scramjet engine functions with the airframe.
- More than 100 aircraft configurations have been analyzed together with wind tunnel tests of more than 20 subscale aircraft and engine models, from subsonic to Mach 20 speeds.
- Rapid solidification production techniques have been developed for titanium-aluminide alloys.
- Leak-free welded honeycomb panels have been developed with superalloy materials.
- There has been significant progress toward demonstrating hydrogen-cooled engine components up to Mach-25 heating conditions.

From Four Engines to Two

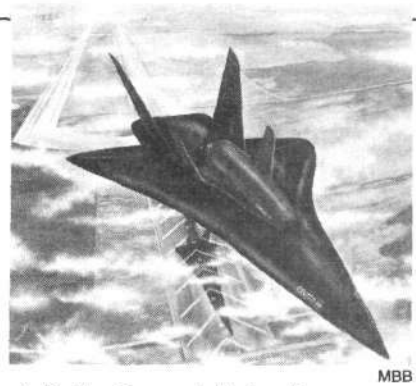
When the X-30 project was first proposed in late 1985 by presidential science adviser Dr. George Keyworth, many critics said that a space plane would never work. They pointed out that such a craft would require up to four separate sets of engines. That is, in order to take off from a conventional airport runway, the space plane would need very large and powerful, high-thrust turbojets. After takeoff, a second set of lower-power engines—the air turboramjet—would be needed to slowly accelerate the plane to above Mach 2. At this point, the air turboramjet would be transformed into an ordinary ramjet. At Mach 6, a third set of engines constituting the scramjets would take over. These engines would then slowly accelerate the craft to above Mach 16. The final boost into space would then be provided by ordinary rocket engines.

Recent advances, however, in the science and technology of scramjets and the fact that it is now possible to develop a turbojet to accelerate a vehicle to Mach-6 range, mean that a space plane can be developed that has only *two* sets of engines.

The first set of engines would consist of powerful turbojets based on the Integrated High-Performance Turbine Engine technology, providing the thrust to lift the 100-ton-plus space plane off a conventional runway. The engines would then accelerate the space plane to above Mach 6. At this point, much lower power scramjets would take over and slowly accelerate the space plane to above Mach 25—the velocity needed for reaching near-Earth orbit. In this way the space plane could deliver upwards of 100 tons of payload into space at costs potentially 100 times lower than current costs. The fact that such a system has now become

The Space Age Dream: A Fully Reusable Spacecraft

Alfredo Capuani



MBB

Left, the Capuani design for a reusable scramjet; above, the two-stage Sänger design.

Since the beginning of the space age, engineers have dreamed of designing a spacecraft that would be fully reusable to save time and money. Imagine the cost of flying today if the airline threw away the plane after every trip! As early as the 1950s, Wernher von Braun pictured a reusable spacecraft that would be launched on a rocket, go into orbit around the Earth, rendezvous with a space station, and fly back to Earth at the end of its mission.

The Air Force was researching the possibility of "flying" a hypersonic plane into space, in the X-20 or Dyna-Soar program, through the early 1960s. After the hectic development and testing phase of the Apollo program of the mid-1960s, engineers in the civilian space program began designing the next-generation vehicles that would make travel from Earth to space routine, using the more near-term rocket technology that had become operational to go to the Moon.

The earliest versions of what became the Space Shuttle separated the manned orbiter that goes into space from the vertically launched heavy-lift booster that brings it to near-orbital altitude and velocity. One design included a space plane attached to a rocket booster which, like the orbiter, had wings. It was described as a "fly-back booster." When the pair of vehicles reached near-orbital velocity, the orbiter was released from the booster. A rocket stage on the orbiter took it into space, and the booster, manned or unmanned, would fly back to a runway.

Mainly due to cutbacks in funding, the fully reusable Space Shuttle designs were not implemented.

The Sänger Space Plane

The real goal of the reusable space plane programs, however, is not to adapt to 30-year-old rocket technology, but to develop entirely new propulsion systems to go into space.

In the 1930s, German aeronautical scientist Eugen Sänger designed the first horizontally launched spacecraft, that could take off from an airport-type runway. The Sänger project, led since the 1960s by German aerospace giant Messerschmitt-Bolkow-Blöhm (MBB), has been an effort to investigate novel ways of propelling a plane from the Earth's surface into supersonic and hypersonic regimes, all the way to the Mach 25 needed to go into orbit.

Sänger's key concept was to use the oxygen in the atmosphere to burn the hydrogen fuel, rather than carrying along liquid oxygen, which has been done since the German V-2 of the 1940s. The MBB Sänger project envisions a turboramjet first stage which, carrying the second-stage orbiter, reaches a speed of Mach 7 at an altitude of about 110,000 feet.

At this point, the rocket engine on the orbiter is ignited and the second stage separates, carrying its payload into orbit, while the first stage lands horizontally. According to MBB, one advantage of this two-stage design is that the first stage produces, as a by-product, a hypersonic (Mach 7) airliner, similar to the U.S. concept for an "Orient Express."

Revolutionary Aerodynamics

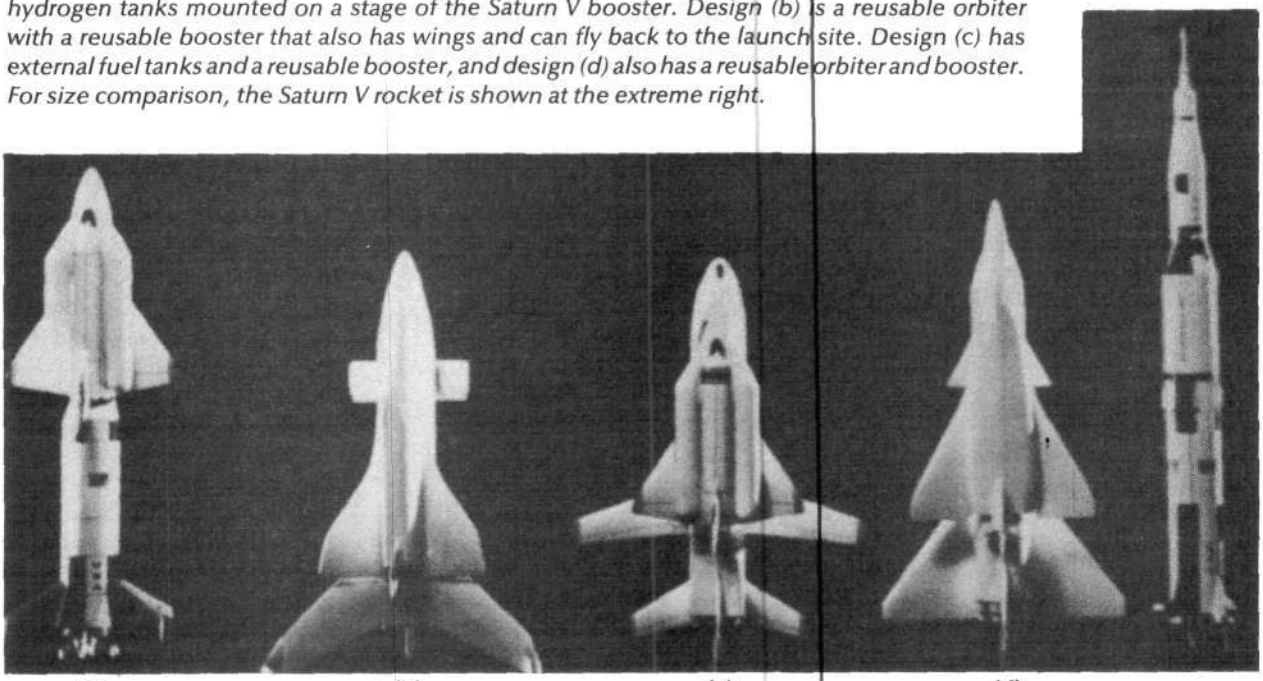
Although most of the effort internationally in the various aerospace plane projects has necessarily been in the area of challenging and risky new propulsion systems, Dr. Alfredo Capuani in Italy has been testing new aerodynamic designs to minimize the drag and maximize the efficiency of the overall space plane design. Capuani's work takes its lead from the research in supersonic aerodynamics of Adolf Busemann, who solved the problem theoretically of destabilizing shock waves that form around aircraft as they approach the speed of sound.

The unusual geometry of the Capuani space plane is derived from the formation of a "Busemann biplane" configuration, where the shock waves formed from the air flow around the wing of the plane are canceled by the use of two wings. In the Capuani design, it is the relationship between the wings on the space plane and on the carrier/first-stage vehicle that produce the Busemann biplane effect. The Capuani design also includes a high-powered lift design, which can make use of short airport runways.

—Marsha Freeman

Figure 3
THE EVOLUTION OF REUSABLE SPACECRAFT DESIGNS

During the 1950s, Wernher von Braun and others in the United States were designing reusable spacecraft, which eventually became today's Space Shuttle. In the early designs of the 1970s shown here, the entire system was to be reused. Design (a) is a reusable orbiter with external hydrogen tanks mounted on a stage of the Saturn V booster. Design (b) is a reusable orbiter with a reusable booster that also has wings and can fly back to the launch site. Design (c) has external fuel tanks and a reusable booster, and design (d) also has a reusable orbiter and booster. For size comparison, the Saturn V rocket is shown at the extreme right.



(a) (b) (c) (d)

feasible is a tribute to the major advances achieved by the U.S. aerospace-defense industry over the past decade in materials technology and shock wave science based on the work of Bernhard Riemann.

Nuclear Propulsion

The initial U.S. space plane prototypes will be chemically fueled aircraft about the size of a DC-9. Once the technology has been demonstrated, however, the follow-on space plane models will be on the same scale as the Boeing-747 jumbo aircraft and larger. At this scale, the space plane could readily support a multimegawatt nuclear reactor for nonchemical propulsion. Nuclear propulsion would transform the space plane from an aircraft capable of reaching near-Earth orbit into a true spaceship.

The technology to do this was already realized in the NERVA space nuclear propulsion program of the 1960s. Given the fit between this technology and the U.S. space plane and the potential increase in capabilities that nuclear propulsion would provide, it is very likely that this option is now being fully pursued.

With nuclear propulsion, the space plane would still use chemical fuels to achieve the high-power, high-thrust performance required for takeoff. Once the space plane had achieved hypersonic velocities, though, the primary source of propulsion power would be heat generated by a small nuclear reactor of about 5-megawatts output. Although at these relatively low power levels the space plane would take several hours to accelerate to orbital velocity, the actual fuel consumption (in terms of nuclear fission fuel burned up) to then achieve near-Earth orbit could be measured in kilograms and not tons. This means that the space plane could deliver more payload at far less cost, which is ideal for delivery of freight to orbit. If the flight mission required rapid lift to orbit, then chemical fueling could be combined with the nuclear to attain high-thrust performance.

Once the space plane arrives in orbit, the nuclear reactor propulsion unit could provide a wide variety of capabilities. For example, the system could continue to provide high-thrust impulse by utilizing nuclear-heated hydrogen as a rocket exhaust. This high-thrust mode would give the space plane the capability of rapid maneuver in space.

More generally, the nuclear reactor would be utilized to provide low-thrust nuclear electric propulsion. In this more efficient configuration, the nuclear propulsion system could operate for months. The space plane could then slowly maneuver in space, but with changes in course sufficiently fast to make it a most difficult target.

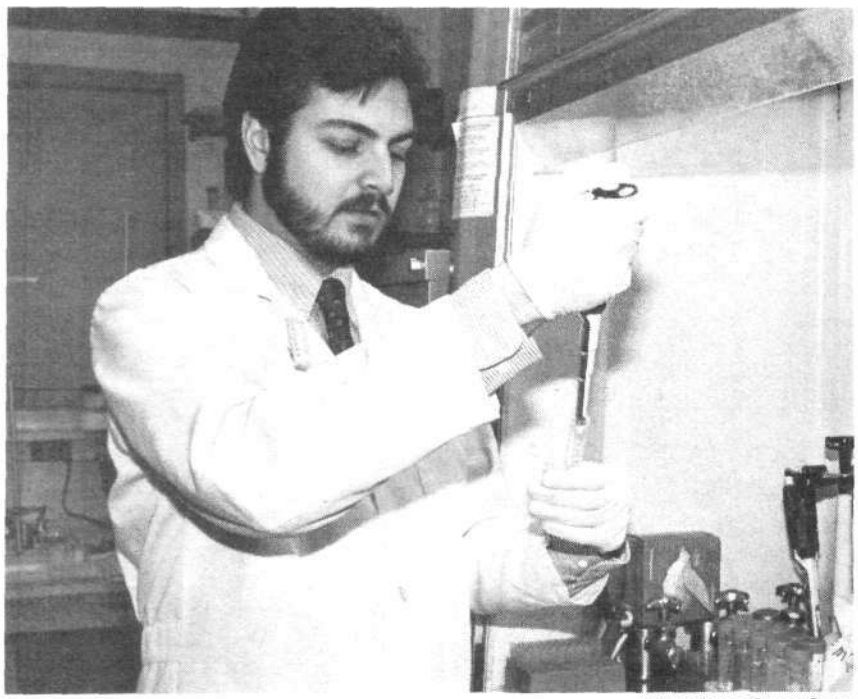
Will the X-30 take off on time? The main obstacles now are simply political.

Charles B. Stevens is an associate editor of 21st Century *magazine.*

New Technologies Hold Clue to Curing Cancer

Recent developments in optical biophysics may transform the way we diagnose and treat cancer.

by Wolfgang Lillge, M.D.



M.D. Anderson Cancer Center

Medical technologist Kevin Nellis, part of a team at the M.D. Anderson Cancer Center working on the latest diagnostic technologies.

Not so long ago, the diagnosis "cancer" more or less meant a death sentence for the patient. Even today the word "cancer" carries an undertone of despair, although in the last decade there has been significant progress in therapeutic approaches. Today, several types of cancer, which only a few decades ago had a very poor prognosis, are often cured, including acute lymphocytic leukemia in children, Hodgkin's disease, and other more rare cancers of the bone (Ewing's sarcoma) and kidney (Wilm's tumor).

Now, very recent developments may bring new, effective therapies to other types of cancer whose prognosis is still poor. These include:

- Genetic fusing of cancer cells to produce *monoclonal antibodies,* specific antibodies designed to seek out chosen targets in cancer cells. A broad field of diagnostic and therapeutic applications may open up with this capability.
- About 50 drugs have been found effective against various cancers, and more are added every year.
- New diagnostic capabilities like computerized tomography (CT scanning) and nuclear magnetic resonance (NMR) have led to a dramatic increase in the precision with which tumors can be located in the body, including the central nervous system.
- For patients undergoing surgery, radiation therapy, or hyperthermia treatment, the improved ability to locate tumors means a more effective eradication of cancer tissue and preservation of healthy surrounding tissue.
- Intraoperative radiation is now being studied, with a view to providing X-ray treatment at the time of surgery. This technique will hit the tumor more directly and eliminate residual cancer cells.

Despite all the progress, however, cancer continues to be the major U.S. killer, with an estimated 472,000 cancer deaths in 1986. Although we can cure a small percentage of cancer patients, and approved methods of cancer prevention and early detection should be applied as broadly as possible, we are far from conquering the disease.

How is it possible that all of the intense research efforts of the last 20 to 30 years, supported by hundreds of millions of dollars in funding, have not achieved a more complete understanding of what cancer is all about? We are still very much in the dark about what actually causes a normal cell to become a cancer cell, dividing and growing in an uncontrolled fashion.

It is not by accident that cancer research today is divided into a multitude of different fields, including genetics, immunology, pharmacology, epidemiology, molecular biology, enzymology, virology, radiology, and such newer fields as chalon research (investigation of specific transmitter substances) and tumor kinetics. Some critics have compared traditional cancer research with the legendary hydra, which grows seven new heads when one has been cut off! Cancer research has become so prolific, in fact, that scientists in one subfield don't know what scientists in other subfields are doing, or what relevance others' results may

have for their own work. Every month, an estimated 2,000 papers and articles on cancer are published in the world's scientific literature. If one reads them all, there would be time for little else.

Obviously, the problem with current cancer research is not funding or scientific manpower per se; the problem is the method of scientific investigation. Because cancer poses the most fundamental question of what life is all about, research into what causes a normal living cell to become a malignant cell must address the basic characteristics of the living process. Unfortunately, the pervasive approach to cancer research today employs scientific principles that may be useful in the study of dead matter, but are intrinsically incapable of discovering anything truthful about life.

Outside of the so-called scientific establishment, certain ideas and conceptions have been explored and yielded basic insights into the workings of cells and tissues and their relationship to malignant growth. Most of the results of these researchers are not "accepted" in the scientific community because, ironically, they violate those very principles that prevent the majority of scientists from uncovering more basic insights themselves.

These insights of the "outsiders" are not magic or faith-healing, but have come in a field called optical biophysics—the role of basic electromagnetic action in the control and regulation of the life process.

Cancer Research: Some History

The British surgeon Percival Pott in 1775 was probably the first researcher to pose the question of the origin of cancer. He frequently operated on tumors in his patients, and he observed that chimney-sweeps developed tumors of the scrotum at a frequency significantly above the average. The cause of these cancers, he thought, must be correlated to the soot they were exposed to from childhood. Pott's original observation was confirmed nearly 100 years later by broader investigations of "occupational cancers" in workers in German brown coal mines and paraffin factories. Scientists began to look for "carcinogenic substances," as they were later called. In 1863, the German physician Rudolf Virchow developed the thesis that cancer is caused by "chronic stimulants." However, he was unable to explain why some stimulants readily cause cancer, while others do so rarely or not at all.

By 1930, two British researchers had succeeded in isolating one of the most powerful carcinogens known, 3,4-benzopyrene, from two tons of tar. Most significant is the way this substance was isolated. The two scientists knew that tar shows a strong fluorescence in the ultraviolet part of the spectrum, at around 380 nanometers. They suspected that the substance emitting this strong spectroscopic line would have something to do with the carcinogenic properties of the tar. After careful distillation, this specific substance turned out to be 3,4-benzopyrene, and it proved to be a very strong carcinogen. This was, in a sense, the beginning of optical biophysics.

In the 1920s and 1930s, several other theories were put forward to account for the malignant transformation of cells:

(1) *The immunologic theory.* It was demonstrated that certain cancers developed in animals only when there was some impairment of the immune system. For a long time it was hoped that something equivalent to a vaccine could protect people from tumors.

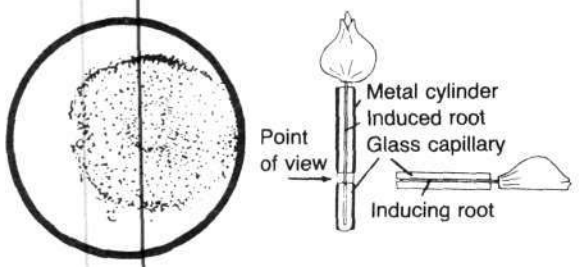
(2) *The viral theory.* A virus that could cause sarcomas in chickens was described by Rous in 1911, unaware that he was actually dealing with a virus. Only in the 1950s could it be demonstrated conclusively that certain viruses (like the polyoma virus) are capable of inducing cancer in almost all animals. Out of these observations, today's oncogene theory was developed by Howard Temin, G. Todaro, and others.

(3) *The Warburg theory.* The German physiologist Otto Warburg stated in 1923 that the ultimate cause of malignant transformation is a disruption of the cell's respiration. Normally, a cell metabolizes using oxygen, also known as aerobic glycolysis; a cancer cell, however, produces its energy to a large degree by so-called anaerobic glycolysis, without oxygen—a much less efficient process, corresponding to a lower evolutionary state of life.

(4) *The deletion theory.* This theory is based on the observation that cancer cells often have a different configuration of growth-regulating enzymes, that is, proteins to which certain carcinogens will preferentially bind. Thus, when specific enzymes are "deleted," a tumor eventually develops.

(5) *The mutation theory.* The fact that in many tumors giant cells with multiple sets of chromosomes are found, led to the idea that mutations of some kind must be the basis of cancer development.

All these theories seem to have some merit, indicating that important biochemical processes are involved in cancer development, but none of them provides a conclusive explanation of the cause of cancer. Moreover, in recent



Source: Fritz-Albert Popp, *Biology of Light*, p. 34.

Figure 1
GURWITSCH'S BASIC EXPERIMENT WITH PHOTON EMISSIONS

The Russian scientist Gurwitsch, working in the 1920s, demonstrated in this basic experiment that photon emissions from cells have an influence on life processes. When he brought the tip of an onion root near the shaft of another onion root, he observed increased cell divisions at the point of influence. At left is a microphotograph of the root cross section showing more mature cell nuclei in the half directed toward the other onion root tip.

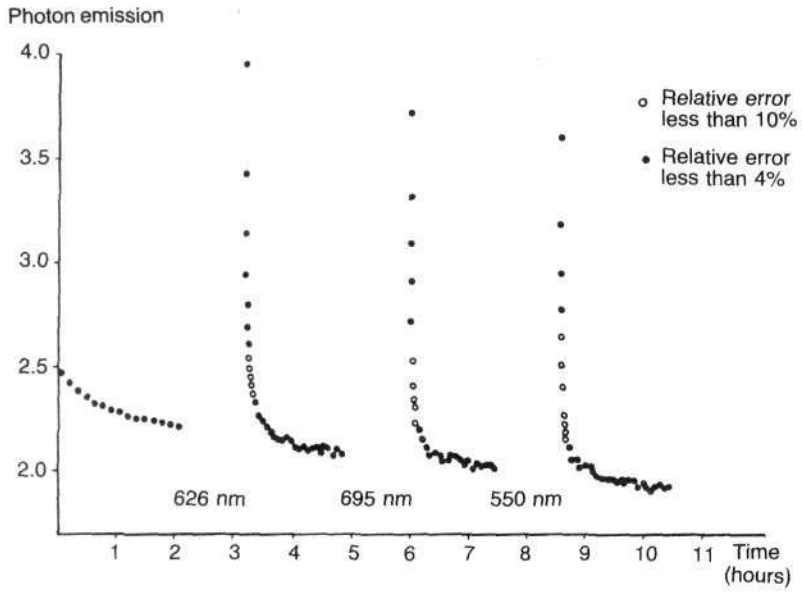


Figure 2
PHOTON EMISSION OF CUCUMBER SEEDLINGS AFTER ABSORPTION OF LIGHT

The photon emission of cucumber seedlings was measured in a dark chamber (curve at left). After two hours, the sample was irradiated with weak monochromatic light of varying frequencies. The decay curve of the stored light follows a hyperbolic decay law; that is, its half-life increases continously with time.

Source: Fritz-Albert Popp, *Biology of Light*, p. 69.

years all these theories have experienced modifications, and almost all of these modifications have only contributed to the confusion in the field. Today, there is hardly any component of the cell that has not been charged with a role in carcinogenesis. It would seem to be a harder task to find a process that is *not* correlated with cancer.

In fact, there is no such process! If we are to find the "cause" of cancer, the problem must be looked at on an entirely different level: We must seek principles of organization and control in the cell itself that determine the way in which the life process develops.

The only common element in this complex picture of tumor transformation is the role of DNA (deoxyribonucleic acid), the central "command center" of cells, containing the matrix for the production of all the key proteins involved in the cell's metabolism. Although modern genetics has progressed significantly beyond the point of the first mutation theories, current conceptions about the role of DNA in carcinogenesis are still on the same epistemological level, as the oncogene theory and similar ideas.

However, once we stop viewing DNA as a huge collection of single atoms stuck together like a twisted ladder and instead focus attention on its basic *electromagnetic pattern*, we find every indication that the DNA macromolecule in cancer undergoes some kind of destabilization of its normal harmonic property, and that this is the primary event in malignant transformation. From such observations, a more solid hypothesis has developed that a DNA molecule, destabilized in this way, tries to reinstate its electromagnetic harmony by ejecting a particle of its own substance (what can be called a *virus*) or by integrating a similar particle (what then may be considered an *oncogene*).

This hypothesis was raised at a private seminar in December 1985 on optical biophysics, sponsored by the Fusion Energy Foundation in Virginia. It is based on the idea that DNA reflects, in its very essence, the life process in general, a basic kind of harmonic that involves specific kinds of electromagnetic properties. In fact, DNA may be capable of working like a highly efficient, extremely low-energy laser, at a range of frequencies from the ultraviolet to the microwave parts of the spectrum. This laser concept, presented at the seminar by Dr. Fritz-Albert Popp of the Technology Center in Kaiserslautern, West Germany, is probably the most advanced idea about how light is the efficient means of control in the life process.

It follows that any outside interference in the coherent electromagnetic action correlating healthy functions will upset the highly ordered process in the cell, and will eventually lead to cancer.

A number of experiments have demonstrated the unique electromagnetic properties of cells, and their electromagnetic behavior when in a state of rest, when about to divide (mitosis), and when transformed into cancer cells.

Electromagnetic Behavior of Cells

The first researcher to investigate the electromagnetic behavior of cells on a rigorous basis was the Russian scientist Alexander Gurwitsch in the 1920s. He stipulated that cells emit a kind of very weak light, which, though weak, was capable of inducing cell division. He called this weak light *mitogenetic radiation*, and he demonstrated this property in a very simple experiment, in which he pointed the tip of an onion root to a point on the shaft of another onion root and observed a significant increase in mitosis at the point of the shaft in question (Figure 1). By inserting glass filters of different types between the two onion roots, he showed that the mitogenetic radiation had to be in the ultraviolet range, because the experiment worked only when he used quartz glass. Quartz is transparent for ultraviolet light, while normal window glass absorbs ultraviolet. With normal window glass, Gurwitsch did not observe an increased rate of mitosis.

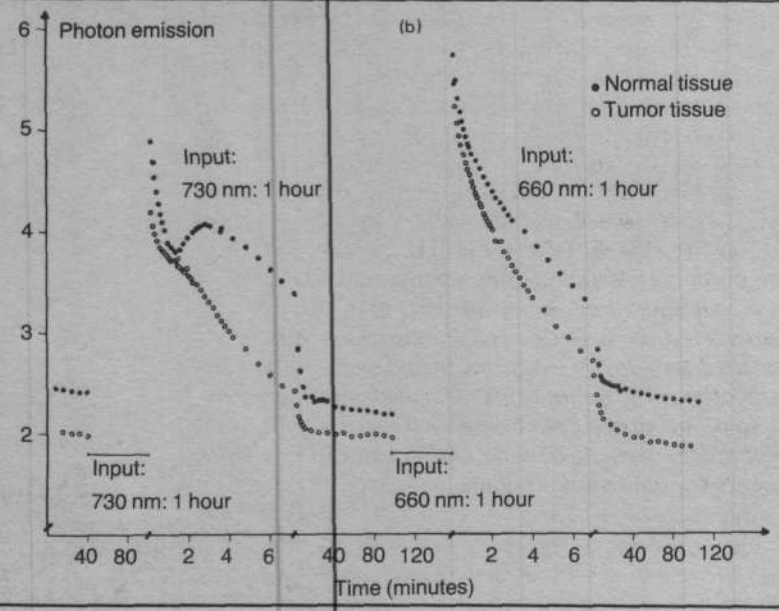


Figure 3
EMISSION OF PHOTONS FROM NORMAL CELLS AND CANCER CELLS
Popp's experiment shows that tumor tissue has a significantly higher decay rate (open dots) than normal cells (black dots). This experiment compares photon emission from normal and tumor tissue of a moss plant after excitation with monochromatic light. Tumor tissue cannot store this light as efficiently as normal cells, but emits "loose" photons at a faster rate. Furthermore, tumor cells lose the ability to increase the intensity of emission after a second input of monochromatic light.

Source: Fritz-Albert Popp, *Biology of Light*, p. 74

The actual physical existence of weak photon emissions from living cells—*biophotons*—was demonstrated only much later, in the 1950s, when a photomultiplier of sufficient sensitivity had been developed. Because the photon emissions were so extremely weak, it was also very difficult to tell where the radiation originated, if it was coherent light, and if there were other biological effects involved.

Systematic work to uncover more aspects of this bioluminescence by Fritz-Albert Popp confirmed the existence of ultraweak photon emissions from almost all living cells, especially those that were dividing at a fast rate; in several key experiments, he demonstrated the crucial role of biophotons in controlling the cell's activities.

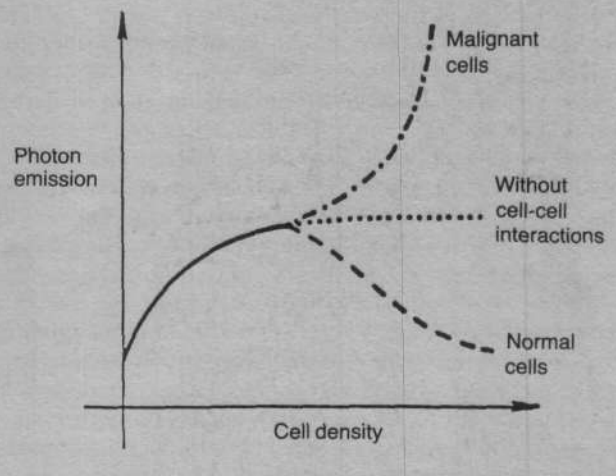


Figure 4
COMPARISON OF NORMAL AND MALIGNANT CELLS AFTER WEAK LIGHT ILLUMINATION
After illumination with weak light, normal cells give off fewer and fewer photons, while malignant cells show an increasing photon count with increasing cell density. Thus, photons seem to have a crucial role in cell communication. The horizontal line is what would be expected if there were no cell-cell interaction.

Source: Fritz-Albert Popp

Popp generated the graph in Figure 2 by means of an extremely sensitive photomultiplier that could detect a light source as weak as a firefly over a distance of 10 miles. Cucumber seedlings, which have a very high rate of mitosis, were brought into the dark chamber of the photomultiplier, where a certain count of photons was registered. Every time the sample was illuminated by a weak monochromatic light of varying wavelength in the visible spectrum, the same characteristic pattern was observed: The stored radiation decreased with a decay rate whose half-life continuously increased; in other words, it followed a hyperbolic decay law. Such a hyperbolic curve in itself indicates that the photons released by the seedlings were coherent; they have the qualities of a biolaser.

Popp used the same procedure to illustrate the difference between normal cells and cancer cells (Figure 3). Tumor tissue exhibited a significantly higher decay rate so that there was no hyperbolic curve, indicating that tumor cells have lost their ability to work as a coherent biolaser. Furthermore, tumor tissue has lost the ability to store the light of an illumination. Illumination of normal tissue leads to a resurgence of light emission.

Popp concluded from these experiments that the only molecular structure in the cell that could account for this behavior is DNA, which is able to store photons with a high efficiency. Direct evidence for this comes from another experiment Popp conducted to uncover the role of light radiation in the cell. He correlated the rate of photon emission with the rate of unwinding and rewinding of DNA superstructures as shown by a chemical dye, and he found that there is an exact correspondence. This is a crucial experiment to demonstrate that ultraweak cell radiation is dependent on the configuration of the DNA molecule.

A corresponding result has been shown for the growth

patterns of cell cultures, in normal cells or cancer cells. In a normal cell culture, there is a lower emission of photons with increasing cell density, while a malignant cell has the opposite behavior (Figure 4). If biophotons do not play any role in the cell at all, then theoretically, the count rate would be flat regardless of density. But with increasing cell density, normal tissue has an increasing tendency to aggregate, to increase coherence; therefore, fewer and fewer photons are emitted. The opposite is true for malignant cells. They refuse to build colonies, their interactions are more chaotic: thus, they emit more and more photons.

When this observation is extended to the evolution of nature as a whole, one can conclude that evolution is continuously directed toward creating higher and higher order. One could say that DNA has developed its higher structures in order to improve its ability to capture and store more and more photons, not only in the optical range but also in the microwave and radiofrequency range. With this capability, DNA would be able to control an increasing number of individual processes in the cell, thus advancing evolution.

Popp's approach to cancer would indicate that for tissue to generate a malignant tumor, it is necessary that the resonating quality of cells—their ability to store and emit light coherently—be permanently impaired to the point that new cells are not able to improve the resonating quality.

From this conception, a new and very simple idea about the role of carcinogens follows. *Carcinogens* are those substances or other means that can disturb the coherence of the DNA-generated photon field to that critical, irreparable point. What must be looked at in carcinogens is not so much their chemical reactivity as such, but their ability to absorb resonant frequencies in the cell.

The low-level coherence of tumor tissue is also associated with another property, *metastasis*. Since fewer photons are being absorbed with decreasing resonating quality, the cell adhesion in the tumor fades away, leading to separation of individual cells that will eventually grow further at different sites. A case in point is the difference in behavior between the two substances 3,4-benzopyrene and 1,2-benzopyrene. Although the former is one of the most potent carcinogens to humans and animals, the latter is an almost completely harmless substance; yet, they differ only in the arrangement of one benzene ring (Figure 5).

Popp and three coworkers investigated this issue in 1970-74. According to the dominant theory of carcinogenesis as introduced in the 1950s by the French researchers A. Pullmann and B. Pullmann (and still widely accepted today), 3,4-benzopyrene metabolizes into a highly reactive intermediate substance, a so-called epoxide, that damages the DNA and leads to genetic mutations resulting in cancer.

Popp's own calculations, however, demonstrate that there is no convincing reason that the harmless molecule 1,2-benzopyrene would not be capable of the same chemical reaction. In any case, the "chemical" explanation of carcinogenesis rests on weak foundations. A search for more clearcut differences between the two molecules was necessary. Popp found this difference clearly in the spectroscopic behavior of 3,4- and 1,2-benzopyrene: the differences in their absorption and reemission of ultraviolet light.

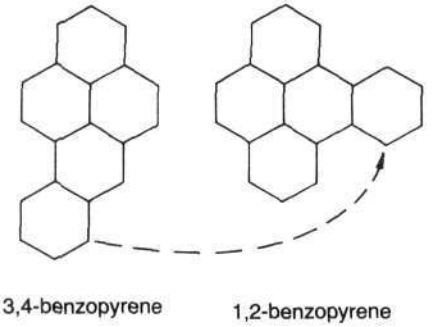


Figure 5
TWO FORMS OF BENZOPYRENE COMPARED
The placement of one benzene ring differentiates 3,4-benzopyrene, one of the strongest carcinogenic substances known, and 1,2-benzopyrene, which is considered to be harmless.

Recall that the property of 3,4-benzopyrene—its extremely strong absorption of ultraviolet light—that led to the isolation of this substance from coal tar in 1930, also proved to be the decisive factor in explaining its carcinogenic power.

As it turned out, the frequency at which 3,4-benzopyrene absorbs the strongest is the same frequency as so-called photo repair in cells. In any tissue, damage to the genetic code in the DNA is not such a rare event. However, there is experimental evidence that with ultraviolet light of low intensity, in the range of 380 nanometers, such genetic damage is effectively repaired. Assuming that light of such qualities is present in the cell itself, there is a very efficient means by which the cell is able to repair genetic errors and mutations by itself.

Now, when a molecule like 3,4-benzopyrene is placed into such a radiation field, it will disturb the repair process permanently, and with the repair disturbed, mutations are permitted to remain in the DNA. This, in turn, may be the cause for a future malignant transformation of the cell. In effect, the primary role of the carcinogen is not as a chemical compound per se, but as a chemically inactive spectral "intruder," which the cell tries to neutralize by chemical reaction.

Thus, there is a clear correlation between carcinogenic power and chemical reactivity, but cause and effect have to be interchanged. Here, chemical reactivity is not the cause for carcinogenicity, but is merely the effort of the cell to get rid of the deadly spectral qualities of the carcinogenic substance.

The Role of Raman Spectroscopy

A very sensitive method of obtaining data on living cells is a procedure called Raman spectroscopy. This has developed into a most valuable tool in the hands of biophysicists because, unlike many other techniques used, it does not kill the cell during the experiment.

The Raman effect was discovered by the Indian physicist C.V. Raman in 1928, and involves a phenomenon observed in the scattering of light as it passes through a material

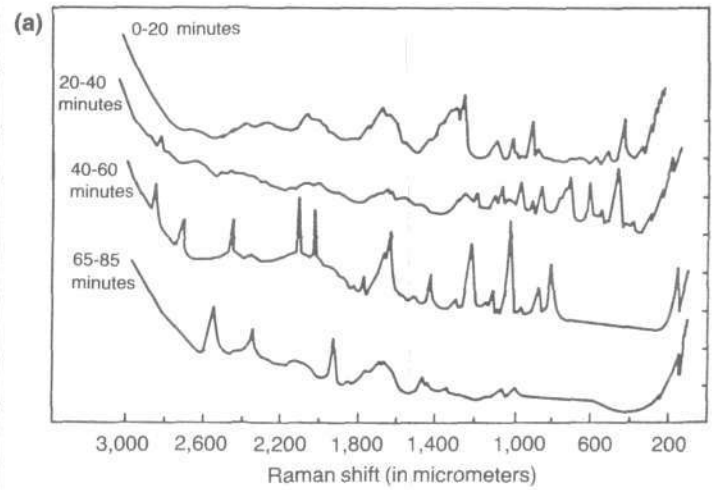
medium. In this process, the light suffers a change in frequency and a random alteration in phase. Because the intensity of Raman scattering is significantly lower than other known light scattering effects, it was utilized for scientific research only after laser sources became available in the 1960s and later.

*The Raman scattering effect can be analyzed by spectro*scopic means: Spectral lines over a range of wavelengths below the incident laser source are detected by a spectroscope, and a substance is characterized by the collection of frequencies in the spectrum of monochromatic radiation scattered by that substance. Raman spectroscopy is widely used in many areas of physics, chemistry, and molecular biology, where it has provided valuable new information regarding the structure of small and large molecules. But it has also proven to be extremely useful in studies of living processes. The current understanding of the Raman effect is that any motion of an atomic system involving a change in dipole moment leads to absorption or emission of radiation, and properties of biomolecules can be analyzed on the basis of the distribution of peaks in the spectrum.

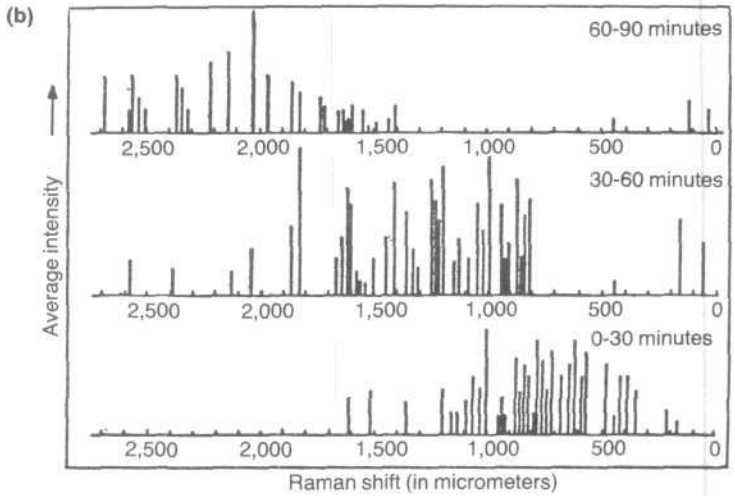
Sydney J. Webb of Canada, working with various laboratories such as the Max Planck Institute in Stuttgart, West Germany, has studied the Raman technique in detail since 1971, and some of his findings are of importance for the issue of cancer.

Before any Raman spectroscopy was carried out, it was thought that a very large number of oscillations would be present in a cell, and that these would produce a very complex spectrum of lines. However, surprisingly, no spectrum at all was found when living cells in a state of rest—in this case cultures of the bacterium *E. coli*—were investigated. It turned out that a spectrum appeared only when cells were placed in a suitable nutrient solution that would induce metabolic activity.

Furthermore, it appeared during subsequent investigations that the Raman spectrum of *E. coli* changed continuously as the cells proceeded through their life cycle. After closer studies, it was found that the changes were not random at all, but that with respect to time, sets of lines between 200 and 3,400 micrometers moved gradually to higher frequencies, while those between 5 and 200 micrometers



Source: Sydney J. Webb, in "Nonlinear Phenomena in Bioenergetics and Oncology."



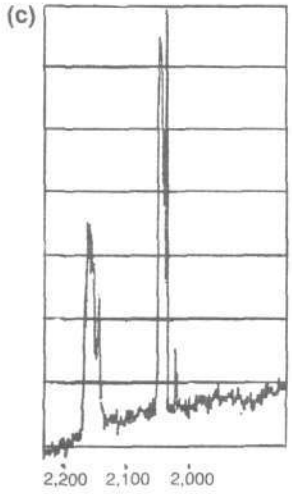


Figure 6
RAMAN SPECTRAL SHIFTS WITH *E. COLI* CELLS

Examples of Raman spectra (a) obtained with E. coli *cells that have been synchronized in their cell cycle, taken at different time intervals, from 20 minutes to 85 minutes. The shifts are not random, but sets of lines between 200 and 3,400 micrometers move gradually to higher frequencies, while those between 5 and 200 micrometers move to lower ones. Shown in (b) are the timed appearance of Raman lines seen in the spectra of synchronized populations of* E. coli *during a 90-minute cell cycle. Clearly, here the spectral lines shift to higher frequencies with time. The strong Raman lines that appear in the spectrum of* E. coli *just before cell division began are shown in (c).*

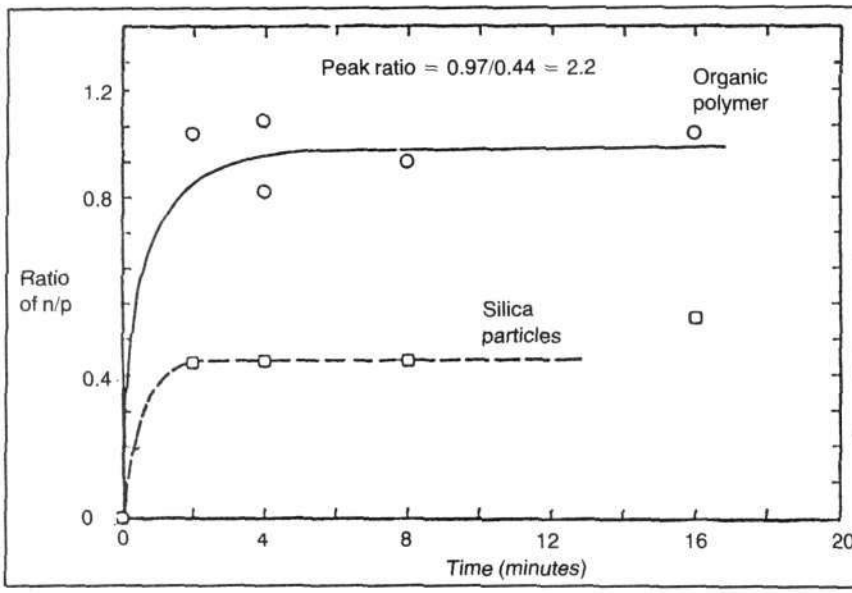


Figure 7
MICRODIELECTROPHORESIS AND ELECTRICAL OSCILLATIONS

This experiment with yeast cells and two dielectric test powders—an organic polymer of high polarizability and silica particles of low polarizability—shows that living cells prefer particles of high polarizability. The peak ratio of particles associated with the cell (n) to the concentration of particles (p) indicates that the highly polarizable particles are pulled preferentially to the cells.

Source: Herbert A. Pohl, *The Living State.*

moved to lower ones [Figure 6 (a) and (b)].

The third major finding was that just before cell division started, all the spectral lines disappeared but for one or two lines of high intensity and at high frequencies, around 2,100 micrometers [Figure 6 (c)].

Concerning the behavior of normal and cancer cells, Webb and his coworkers saw specific changes in the low-frequency part of the Raman spectrum. While normal cells (mammary tissue) always displayed a series of sharp single lines which formed two nonlinear series of "harmonics," as in similar experiments with microwaves discussed below, in spectra of all types of tumor cells studied, these lines were broader, of lower intensity, and split into two or three separate lines.

Webb admits that it is not possible to draw any comprehensive conclusions from these experimental data, and actually, more new questions have arisen than answers provided. However, some of the conclusions Webb has arrived at seem to be in line with Popp's approach to the investigation of photon emissions by cells.

The fact that resting, living cells appear to be Raman-inactive, Webb thinks may be due to the presence and activity of water molecules (*structured water*) which form a specific association with macromolecules and their complexes in the cell, such as proteins, sugars, DNA, and so on. When metabolic activity in the cell is induced, some form of condensation of closely related states takes place, which gives rise to Raman activity at a given frequency and of a high amplitude.

Since the appearance of these spectral lines could be stopped by the removal of the nutrients, Webb thinks that each line emanates from a particular oscillation induced by a metabolic process. At each of these events, the cell had to break its remarkable symmetry and momentarily become unstable at one or more sites in its structure.

Concerning the frequency shift of bacterial spectra during their lifetime, Webb discusses the idea that the known timing and occurrence of events *in vivo* may arise from an overall uniform spiral or helical motion within the cell, which brings together enzymes and their substrates at specific times and places. This spiral motion would reflect then a continuous upshift in spectral energies.

The differences in Raman spectra of normal and tumor cells Webb associates with the possibility that in normal cells, so-called degenerated states exist which become resolved as a result of the oncogenic process, and this produces the broad double-spiked peaks seen in the tumor cell spectrum. "Degenerated state" is actually a very inappropriate term in this context, because it describes the association of several macromolecules into a new complex in which two or more different oscillations "degenerate" into a new one. The opposite process would occur in a cancer cell, where highly ordered protein complexes tend to fall back into a lower state of order, resulting in a pattern of split spectral lines.

This behavior obviously correlates very well with Popp's observation that the internal organization of tumor cells becomes more and more incoherent, leading to an increased rate of photon emission.

Another group of researchers from Italy, analyzing Webb's Raman spectra, has shown that all the spectral lines above 200 micrometers emanate from two to four fundamental modes, in which all lines appear to be nonlinear "harmonics" of two to four fundamental *in vivo* oscillations. Webb concludes from this that because these lines move to higher and higher frequencies as the cell progresses through its life cycle, each successive metabolic step requires a higher energy input; thus, higher and higher energies must be directed to given areas of the cell as it ages. And after an asexual division of the cell, the daughter cell will not start its own cycle on the original oscillation of the parent generation, but with those of the next higher harmonic.

On that basis, Webb presented the hypothesis that asexual cell division may have a definite limit at some point where the energy requirements of the cell become too large, and thus there arises a need to lower the energy requirement to some basic level. This may be achieved by the sexual reproduction cycle of cells in which an exchange

of genetic material takes place.

Although there are no data yet available to back this hypothesis, it would be interesting to know more about the corresponding behavior of cancer cells. Based on Webb's results, one would expect that the uncontrolled growth of tumor cells has something to do with the way energy is utilized within the cell. Warburg's cancer theory already implied that cancer cells represent a regression to the lower evolutionary state of anaerobic glycolysis.

Microwaves and Cancer Cells

Earlier work with microwaves conducted by Webb showed results largely overlapping with his experiments involving Raman spectroscopy. Microwaves have long been known to be strongly absorbed by water. They are conveniently used in microwave ovens to heat food, and microwaves of low intensities also have interesting effects on living matter. In fact, microwaves of very low intensities and specific frequencies can be detected by living cells, which respond to such waves without any detectable increase in temperature, via some *nonthermal* mechanism.

As in the Raman spectroscopy experiments, microwaves seem to have no effect on resting cells; only when suitable nutrients are present can a change in physiological events be detected. Small differences in frequencies may cause different effects; so it is known that the frequencies that alter the rate of RNA (ribonucleic acid) synthesis *in vivo* differ from those that affect the synthesis of protein and DNA.

Also paralleling the Raman findings, it has turned out that such effective microwave frequencies form one or two definite nonlinear series, which suggests that they are all related according to the "harmonic" of some fundamental oscillatory mode or modes, and that the particular frequencies to which the cell will respond alter with its age and nutrition. In every case, however, the nonlinear relationship is unchanged.

Most interesting is the behavior of cancer cells when irradiated with microwaves: In contrast to the usual two nonlinear series of effective frequencies, tumor cells formed three and sometimes even four series. In this experiment, first a biopsy of normal human mammary tissue was investigated, showing the microwave spectrum of the undiseased mammary gland of a patient with carcinoma of the other gland. It showed a single split in one of the normal series of nonlinear harmonics, whereas the diseased tissue itself showed a double split.

On this basis, Webb has suggested the use of microwave spectroscopy to examine mammary biopsies for early presence or even predisposition to malignant transformation.

The most important question concerning Webb's microwave experiments is to determine the molecular structures of the cell that actually respond to specific microwave frequencies. There are indications that either parts of the membrane or the DNA directly are involved in such resonance stimulation. These molecular structures coherently take up the energy contained in the radiation to amplify their own activity. In the case of tumor tissue, this resonance coupling is impaired to the point that the basic harmonics of the cell are increasingly "out of tune."

Microdielectrophoresis and Cell Oscillations

By means of a very simple technique called microdielectrophoresis, Herbert A. Pohl of Oklahoma State University succeeded in demonstrating in his laboratory that living cells produce natural alternating electric fields of very low intensity. Pohl observed such fields as a unique phenomenon in a wide spectrum of cell types, ranging from primitive bacteria to human cells. In terms of relative intensity, it appears that electrical oscillations are maximal at or near mitosis.

Pohl's technique of dielectrophoresis involves the motion of tiny polarizable (dielectric) but neutral particles induced by a nonuniform electric field inside the cell. The principle is different from normal electrophoresis where particles with different charges are moved to the negative or positive pole of an electric field, a process widely used in chemistry and biology to separate substances of different electric behavior.

The motion of such neutral particles in dielectrophoresis depends on their effective dielectric constant; if it exceeds that of the surrounding medium, the particles will move toward the region of highest field intensity. In the opposite case, when particles have a lower effective dielectric constant than that of the medium, there will be repulsive motion away from the highest field intensity.

Microdielectrophoresis experiments require only the selection of an appropiate mixture of dielectric particles and a microscope. A mixture of cells and particles is put under the microscope and the fraction of particles associated with the cell n is counted. The ratio of n to the concentration of particles p expresses the degree of association of the particles with the cell (Figure 7).

Experimental evidence shows that in living cells, but not in dead cells, there is a preference for particles of high polarizability over those of low polarizability; that this is suppressible by substances that block the cell's metabolism and those that change the effective dielectric constant of the medium to exceed that of the test powders; and that this is maximal near mitosis.

On this basis, Pohl hypothesizes that such electrical oscillations in the radiofrequency range are a requirement for cellular reproduction, and that this mechanism involves the process of contact or density inhibition observed in normal cell cultures, which stop growing once the cells become confluent and cover the growth medium. Pohl thinks the increasing density of cells modifies the electric environment of an individual cell in such a way that specific oscillations preferred during mitosis are more and more damped out and suppressed.

Pohl suggests that the phenomenon of cancer growth as well as wound healing, normal body cell replacement, and embryonic growth might be accomplished by a shift of oscillating frequencies away from the region of high damping in question. This frequency shift may be under the control of a normally repressed gene responsible for the biochemistry of oscillating reactions.

Although there is a good deal of speculation involved in this conception, the observation that there are coherent electrical processes (oscillations) and lawful upshifts or downshifts of frequencies involved is valid experimental

evidence that may give us clues as to the right direction in which to proceed.

The Role of Nuclear Magnetic Resonance

Dr. James Frazer is one of the frontier researchers in optical biophysics using nuclear magnetic resonance (NMR) spectroscopy to find new ways of characterizing cancer. NMR techniques, now becoming more broadly available in clinics as a unique imaging capability, can be used to generate highly specific signals from the molecular makeup of living matter. Placed in a strong magnetic field, the sample is beamed with radiowaves or other radiation to trigger spinning signals from various atoms or molecules present in the sample.

Together with colleagues at the M.D. Anderson Cancer Institute in Houston, Frazer studied two different tumor cell lines of a mammary adenocarcinoma, one with a high metastatic potential (a malignant tumor) and one with a low metastatic potential (a benign tumor). They found that the malignant tumor, in contrast to the tumor with low metastatic potential, had a glycoprotein in its membrane that was liberated into the medium. The benign tumor cell line had a slightly different glycoprotein on its surface, but did not liberate it. In the next phase, it was observed that macrophages, immune cells that are designed to eliminate tumor cells, failed to attack the highly metastatic cancer cells, while they were effective against the benign tumor. Obviously, the macrophages were in some way disabled by the liberated glycoprotein.

By means of NMR spectroscopy, Frazer and his group succeeded in obtaining clearly different signals from each of the relatively similar tumor cell glycoproteins. But the slightly different structure was not the only factor that led to these unique signals. One of the glycoproteins was packaged near the surface of the cell and was exposed to solvent. Related studies are now under way in Houston to determine the differences between four types of leukemia by means of NMR spectroscopy in an attempt to make leukemia diagnostics simpler, more reliable, and faster.

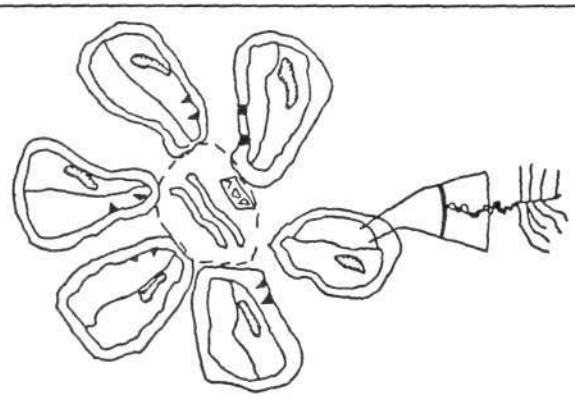


Figure 8
A NEW MODEL OF CELL STRUCTURE
In James Frazer's model of cell structure, the cell is depicted as a sectioned orange, with several components of the cell grouped around the nucleus. The surface is mobile, and while moving along the nucleus the membrane structure is determined. Penetrating surface glycoproteins represent a direct connection between outer cellular space and the nucleus.

The broader significance of these findings is that surface glycoproteins play a crucial role in determining the properties of cell membranes in respect to antigenicity and receptor qualities, and that only a very small change in a genetically linked characteristic of the cell results in the formation of an entirely different cell surface. A small change in the structure of the glycoprotein and a different arrangement in the membrane determine whether a carcinoma is highly metastatic or nonmetastatic.

Coherence in Living Matter

Taken together, the research results reviewed above represent a wealth of knowledge and insight into the living process in general, and the process of cancer development in particular, that must be expanded and brought into a common epistemological focus. In particular, Popp's concept of the impaired resonance quality of malignantly transformed cells defines the reverse: The basic concept of life is a necessary process of harmonic resonance of electromagnetic action, totally counterposed to statistically random collision theories of molecular biology.

To complement the approach of some of the research work reported here, what might we say about the role of coherence and the necessity of electromagnetic action as a primary controlling element in life?

The first crucial point is that there is a significant qualitative difference in the behavior of molecules, especially macromolecules, and other components of the cell, when *in vitro* and *in vivo,* that is, when investigated isolated in the test tube or in the real living environment. Del Giudice, S. Doglia, M. Milani, and S.J. Webb, in a paper on in vivo ordered structures as seen by laser Raman spectroscopy develop conceptions that can be considered first approximations of actual cell organization and structure. They write:

> *In vivo,* macromolecules form a specific somatic architecture in which a) all molecular entities occupy specific positions in space, relative to one another; b) function as complexes not as individuals, and c) at rates which far exceed those possible by random diffusion and collision mechanisms. In addition, each metabolic event occurs at a specific time in the lifetime of a cell and these form into ordered series leading to the synthesis of proteins, nucleic acids, and polysaccharides by the sequential placement at a specific time of a specific amino acid, nucleotide or sugar to a growing chain.

Obviously, we are dealing here with a geometry in the very small that is a self-organizing, self-focusing process, and the efficiency of a cell performing this work process is beyond imagination when you consider that several million molecules per second are synthezised in every cell.

There are still other formidable tasks for a living organism: The human body has to replace an average of 10 million cells per second to make up for dying cells. There are tissues that are dividing very fast, like the bone marrow, the

cells in the gut, and in the skin, which may reach a multiple of this rate of replacement.

Immediately, the question occurs, what are the means of control for these processes? To illustrate this with an example: Given that the human body is composed of approximately 10 trillion (10^{13}) cells, by simple calculation one can see that there must be a highly coordinated control to prevent too few or too many cells from being replaced in a given period of time. Popp has actually presented such a calculation, which assumes that any neighboring cell must be "informed" about the death of a cell in the exact time interval separating that death from the next cell death. Based on the figures of cell count and death rate given above, this would mean a time interval as short as 10^{-7} seconds. Given a distance between two cells of approximately 0.001 centimeter, the minimum velocity at which the "news" of the death of a cell must travel would be 10^{-4} centimeters per second, which corresponds to the speed of sound. But if all the cells of the body must be informed of the event, one is dealing with the speed of light!

Any conception of cell regulation based on "messenger substances" falls to pieces when only the speed of sound is required for communication. *This means that only electromagnetic action can account for the necessary coordination and information of the whole system.*

Even more complicated than the simple maintenance of the body's cell volume is coordination of the metabolic process in each single cell. No conception of the cell's interior as a molecular soup with random occurrence of chemical reactions can account for the performance of a cell.

These are only some very preliminary ideas about how the substructure of a cell is organized to allow for the incredible precision of cellular events. Biophysicists who know about the challenge to investigate these matters correctly complain that many of their colleagues in the physics and biology departments pay too little attention to processes on the subcellular, molecular level. Physicists are very used to measuring gross structures and try to transfer this to microscopic events.

A case in point is the role and structure of the cell membrane and of cellular water.

For pedagogical purposes, James Frazer has developed a model of an eukaryotic cell that deviates radically from any conventional conception (Figure 8). It looks very much like sections of an orange grouped around the nucleus. The membranes of these sections form a bilipid molecular leaflet; however, at regular intervals, there is a penetrating protein that has a hydrophobic segment going through the membrane. It branches out into a long polymeric strain of different kinds of sugars. These glycoproteins, some of which Frazer has identified as expressing specific tumor qualities, are associated with the function of a cell "receptor." This receptor, rather than undergoing a "chemical reaction" with a given hormone or other substance, is the mediator of shifts in charge densities across the membrane, thus triggering specific metabolic actions within the cell.

Furthermore, these receptors seem to be in contact with a large and intricate network of fibrils, microfilaments, and microtubules—a microtrabecular lattice that forms a three-dimensional structure inside the cell and even seems to link up with the nucleus. Thus, through this kind of cytoskeleton, reactions triggered from the outside could have effects right down into the nucleus, while in turn, processes in the nucleus might immediately effect changes in the membrane and be communicated to other cells in the same tissue. Frazer's new cell model also includes the idea that the membrane parts of the different cell sections are in constant motion, so that their own structure is determined by what is transcribed in the nucleus at the moment of their passage.

All these conceptions, which can only be touched on here, have revolutionary implications concerning our understanding of life processes. It must be stressed, however, that these are not the usual conceptions of the cell found in standard textbooks. The same is true concerning conceptions about the geometry of metabolic activity. From several investigations, it follows that enzymes, enzyme complexes, the substrate, intermediary products, and so on, are all closely associated with the trabecular lattice mentioned above. So, we actually have a molecular organization beyond our current grasp, and this total three-dimensional structure is encoded in the nucleus.

Add to this the role of cellular water: Although not all the details are known, there is strong evidence that all water present in living cells exists in the form of "structured water," that is, it exhibits properties that are distinctly different from those of the pure liquid. Cellular water of such a form will have totally different effects on cellular macromolecules than one could find in the test tube.

These are some of the key leads that current research has to follow up to achieve a comprehensive conception of what makes life life. Cancer and other diseases will then find their lawful explanations, and more specific causal cures can be developed.

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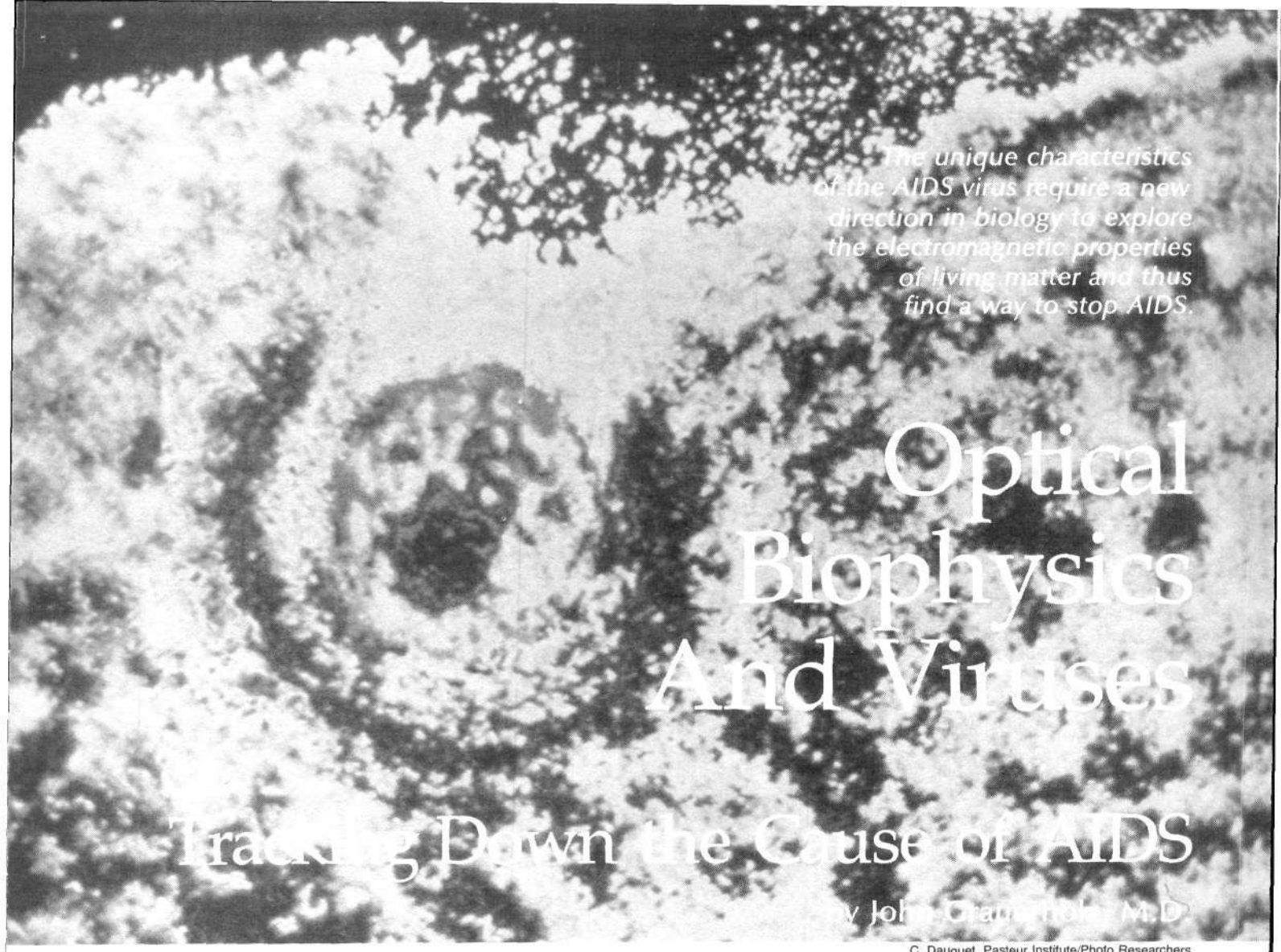


The unique characteristics of the AIDS virus require a new direction in biology to explore the electromagnetic properties of living matter and thus find a way to stop AIDS.

Optical Biophysics And Viruses

Tracking Down the Cause of AIDS

by John [illegible], M.D.

C. Dauquet, Pasteur Institute/Photo Researchers

AIDS virus penetrating a cell, magnified many thousands of times.

The discovery that AIDS was only one of the potential consequences of infection by a human retrovirus known as the Human Immunodeficiency Virus, or HIV, has created a crisis in science as well as in public health. Medical science has never before confronted a deadly epidemic caused by an agent with the characteristics of the class of retroviruses to which HIV belongs.

In fact, if one wanted to design a perfect biological agent, it would be hard to do better than the AIDS virus, according to Dr. Robert Gallo of the National Cancer Institute, a co-discoverer of the AIDS virus. There are three major problems that have made this virus such a formidable foe: It attacks the immune system itself; it replicates in protected tissues and is capable of establishing a latent infection; and it constantly changes its immune profile, so that by the time antibodies are formed new variations have arisen that are not affected by these antibodies.

Looking at these problems from the current perspective of molecular biology, there is good reason for pessimism. However, as in cancer research today, there is a handful of researchers working in the frontier area of biophysics whose work holds hope for arriving at an understanding of what *causes* life—and therefore hope of a vaccine or cure for AIDS. These new approaches range from the use of lasers to cleanse the blood of the AIDS virus, to a microwave deactivation system that does the same, to an electromagnetic "jamming" of the virus's resonant frequencies. These differing approaches, discussed below, all focus on the virus's electromagnetic properties. First, however, let's look at the scientific problem in more detail.

The Nature of Retroviruses

The retroviruses are unique. Unlike other viruses, whose genetic material consists of either DNA or RNA, the retroviruses exist in both forms (see box and Figure 1). Outside of a host cell, they exist as virus particles containing their genetic material in the form of RNA. However, when they enter a cell they are capable of converting their RNA into DNA, which can then enter the nucleus of the cell and integrate itself into the chromosomes of the cell, thus becoming a permanent part of the heredity of that cell.

In short, infection by a retrovirus results in a change in the genetic potential of the infected cell. The cell acquires a new set of genes which, if activated, will produce a change

in the form and function of the cell. If the virus is a tumor virus, or oncovirus (*onco* means cancer), the change is a malignant transformation, converting a normal, differentiated, functional cell with a finite lifespan into an abnormal, primitive, nonfunctional cell, which is capable of infinite growth as long as it can obtain nourishment. In the case of the lentiviruses like HIV, activation results in virus production and the destruction of the cell.

HIV can also destroy cells by producing an immune reaction against the body's own immune cells. It works like this: When a previously latent gene like a cancer gene appears, there is a change in the chemical composition of the external membrane of the cell. The altered surface chemicals are known as antigens. In the case of cancer cells, these antigens are called tumor-specific antigens because they result from activation of specific cancer-causing genes or oncogenes.

These new surface antigens stimulate the immune system to produce chemicals, known as antibodies, which bind to the antigens. The presence of these antigen-antibody combinations (known as immune complexes) on the surface of a cell marks that cell for destruction by other cells, which are known, appropriately enough, as "natural killer" cells.

In the case of the cell that is depleted in AIDS patients, the T-lymphocyte, activation of the HIV provirus results in production of pieces of the virus envelope on the surface of the cell. Antibodies to the virus envelope will bind to these antigens and form immune complexes on the surface of the cell, thus marking the cell for destruction by natural killer cells. In the early stages of infection, this serves as a mechanism for eliminating virus-infected cells and thus controlling the infection.

However, if an infected cell is not expressing its newly acquired virus genes, then it will escape destruction. The presence of such latently infected cells enables the infection to persist in spite of the production of antibodies that are capable of neutralizing the virus (that is, making it noninfectious) and destroying the openly infected cells. In the case of the retroviruses, the latently infected cells carry the

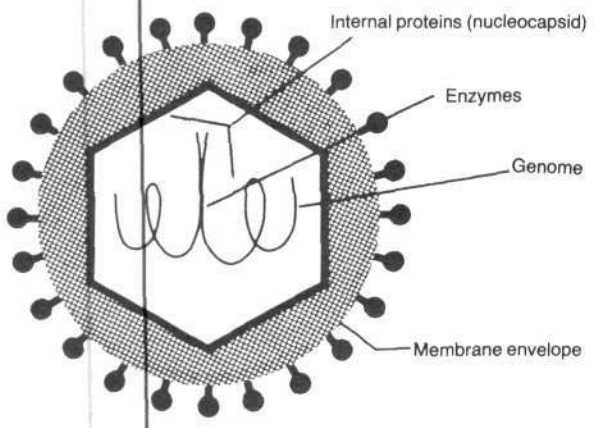


Figure 1
SCHEMATIC OF A TYPICAL RETROVIRUS
A retrovirus is formed by RNA acting on DNA, instead of the usual reverse process. The retrovirus core consists of the RNA genome of the virus, along with the enzymes for converting the viral RNA to DNA within the cell (reverse transcriptase). Surrounding this are the internal proteins which, in turn, are surrounded by an envelope derived from the membranes of the host cell.

Viruses: 'Bad News' That Grows

A virus consists of a segment of genetic material, DNA or RNA, surrounded by a protein capsule and, in cases like HIV, an envelope composed of fats, proteins, and sugars, As one immunologist put it, a virus is bad news wrapped in a protein coat—the bad news being the genetic information in the DNA or RNA of the virus. Unlike bacteria or other parasites, which contain all the metabolic machinery necessary to reproduce themselves and are capable of growth outside of cells, viruses are totally dependent on the metabolic machinery of the cells they infect—they are obliged to reproduce inside host cells and are wholly inert ouside of a host cell.

The most common forms of human illness caused by viruses result from what are called productive infections, where the virus enters the cell and takes over its metabolic machinery to reproduce itself, destroying the cell. The copies thus produced go on to infect other cells and repeat the cycle until the host is either destroyed or mounts an immune response that eliminates the virus. The destroyed cells are replaced by new cells where possible or sometimes by scar tissue. In the case of cells that cannot be replaced, like nerve cells, the patient may be left with permanent damage, as in the case of polio.

Certain viruses, like herpes, can remain in an inactive or latent form within certain cells where they are hidden from the immune system. When such latent viruses are activated, they cause a local productive infection, like a cold sore, which generally heals as the immune system eliminates the newly produced virus. However, some of the virus remains in the latent form to serve as a reservoir for future infections.

Other viruses are associated with the development of tumors, which may occur long after the initial infection. In these cases, rather than causing cell death from productive infection, the virus transforms the infected cell and immortalizes it.

virus as a genetic trait and are capable of migrating into areas that are relatively shielded from the immune system.

A more serious problem arises when these latently infected cells begin to express their virus genes. Such cells produce not only complete viruses, but also large quantities of incomplete viruses and fragments of viruses, such as the virus envelope glycoproteins. All these bits and pieces are antigens and can bind with the appropriate antibodies to form immune complexes. In addition, the virus envelope glycoprotein is responsible for binding the virus to a specific chemical molecule, known as a receptor, on the surface of a white blood cell known as a T-4 lymphocyte (or T-4). This envelope glycoprotein bound to the surface of a T-4 cell can also bind antibody and result in a cell with an immune complex on its surface. Such a cell will be destroyed by killer cells even though it is not actually infected by virus.

The depletion of these T-4 lymphocytes, which play a major role in coordinating the immune response, leads to the severe derangements of the immune system seen in full-blown AIDS. In addition, other white blood cells known as monocyte-macrophages also carry the HIV virus, although it does not appear to destroy them as it does the T-lymphocytes. These monocyte-macrophages, which are capable of traveling throughout the body, act as a storage reservoir and transportation vehicle for the HIV virus.

Other cells, including the monocyte-macrophages and some cells in the central nervous system, are capable either of being directly infected by the virus, or of binding fragments of virus envelope and thus being subject to antibody-dependent cell destruction. A more general term for this process is an autoimmune reaction, a situation in which the immune system mounts an attack against the body's own tissues. The case of AIDS is the ultimate form of autoimmune reaction because the immune system actually attacks itself!

Finding a Vaccine or Treatment

Since the discovery of sulfa and the penicillins, medical science has been able to produce thousands of drugs to treat bacterial and other parasitic infections, yet very few effective antivirus drugs have been developed. The reason is that bacteria and other higher organisms are complete living systems with their own metabolic machinery. Therefore, it is possible to find a drug that will interfere with a process unique to the parasite, while not substantially affecting the host organism. Viruses, however, lack almost all metabolic machinery and utilize the metabolic machinery of the host cell to reproduce themselves. Thus, any drug that interferes with virus reproduction tends to interfere with normal cell processes.

In the case of retroviruses the problem is compounded by the fact that infection can exist as a *dormant* genetic potential for the life of the cell. Thus even if an effective drug were found, it might have to be administered for life in order to prevent expression of the virus. Since such drugs, like the recently developed AZT, tend to be toxic to normal cells and have significant side effects, the possibility of long-term therapy is remote.

Prospects of developing a safe and effective vaccine are, if anything, even more remote. Vaccines are preparations of weakly infectious or noninfectious virus, or fragments of virus, that stimulate the production of antibodies to the viral antigens. Such antibodies then bind to virus particles and render them noninfectious. Antibodies that have this capacity to render virus particles noninfectious are called neutralizing antibodies.

AIDS patients develop such neutralizing antibodies but the problem is that these antibodies do not prevent the progression of disease. Further, even if a vaccine produced neutralizing antibodies, the hallmark of success in assaying vaccines, there is no guarantee that it would prevent infection or illness in the vaccinated person. One reason is that, in at least some cases, infection is transmitted by actively or latently infected cells, rather than by free virus particles. The virus may then spread directly from cell to cell without being exposed to the circulating antibodies. Finally, the ability of the virus to change its outer envelope, the most immediately available target for neutralizing antibodies, results in the production of virus particles that are not affected by preexisting antibodies.

These problems arise from the molecular-biological approach to describing living processes. This approach, which is based on application of the statistical chemistry of nonliving processes to living systems, cannot rigorously distinguish between living and nonliving systems. In the case of viruses it leads to the question of whether or not viruses are "alive" and to attempts to answer this question by determining the exact chemical composition of these particles.

Lasers Against AIDS

One of the promising research areas in the battle against AIDS comes directly out of the Strategic Defense Initiative (SDI): using lasers to kill AIDS.

One source of infection by HIV is transfusion of virus-contaminated blood, which is a source of both free virus and cell-associated virus. Tests for the detection of antibodies to HIV have significantly reduced, but not eliminated, the problem of HIV-contaminated blood transfusions. This is due in part to the fact that in the early stage of infection, high levels of virus may be present before antibodies are formed. Blood from such a donor is infectious even though no antibodies are detectable.

A potential answer to this problem, and the more general problem of contamination by other viruses, has been developed by Dr. Les Matthews and his colleagues at the Baylor Research Foundation in Houston, working under a contract from the SDI program. The SDI is supporting a major study of the potential medical applications of the various lasers now being developed as part of the SDI, and this gives the Baylor researchers access to lasers that are not yet available commercially.

One Baylor project is a study of the effect of laser light on viruses. The particular technique, known as photodynamic therapy, was originally developed for the treatment of cancer and is based on the fact that cancer cells will take up a certain molecule, known as hematoporphyrin derivative (HPD), whereas normal cells will not. If HPD is illuminated with coherent light of a specific wavelength, it will fluoresce

and thus identify the malignant cells. And if the illumination is continued, a chemical reaction takes place that destroys the cells.

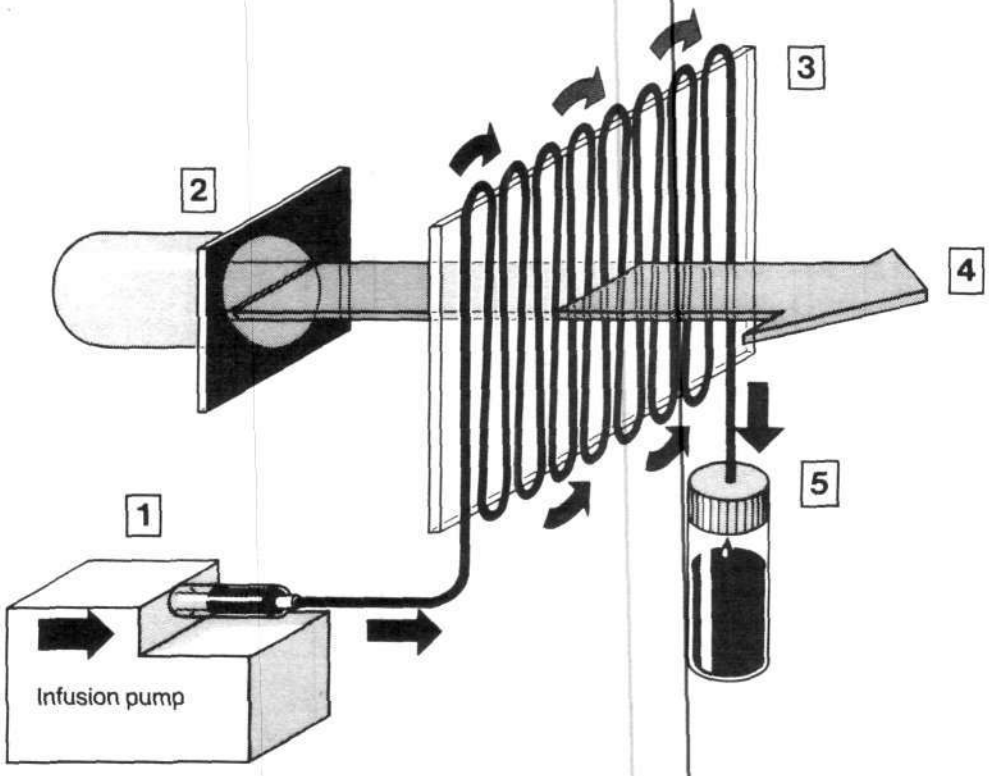
Matthews and his coworkers showed that enveloped viruses also take up HPD, and that if these viruses are then illuminated with coherent red light the viruses become noninfectious. They demonstrated this effect on cultures of a number of enveloped viruses, including herpes, measles, hepatitis, and HIV.

To test the effectiveness of this technique as a method of eliminating enveloped viruses from banked blood, the Baylor group constructed an apparatus that would allow the HPD-treated virus cultures to flow through a segment of plastic tubing that was exposed to a xenon light source (Figure 2). The tubing was folded back and forth to maximize exposure to the light source.

Having proven that this flow system was capable of rendering the cultures noninfectious, the researchers then addressed the question of whether the technique would work on whole blood. There were two areas of concern. One was that the red blood cells would interfere with the absorption of the red light from the xenon light source. The other was that in the process of inactivating the virus, the technique would also damage the blood cells.

To answer the first question, the researchers "spiked" a unit of blood with herpes virus, added the hematoporphyrin derivative, and then ran it through their apparatus. The result was that they inactivated the virus without having to increase the amount of energy of the light source, so the red blood cells did not interfere with the absorption of the light by the viruses. This experiment proved, in principle, that there was no reason to expect that the technique would not work with other viruses, like HIV.

To answer the second question, the researchers ran blood from two patients with AIDS through the apparatus, utilizing similar power levels to that used for the herpes virus. Since they did not have virus levels on the two patients, they were unable to evaluate virus killing but they were able to establish that no significant damage to the blood cells themselves had occurred. Subsequent experiments



Source: Baylor University Medical Center

Figure 2
A LIGHT IRRADIATION SYSTEM FOR INACTIVATION OF VIRUSES

Both laser light and uncollimated monochromatic xenon light were used in this experiment, with the same result. The apparatus shown is for the xenon experiment.

A syringe containing blood or the culture medium, the enveloped virus, and the dye is inserted at (1). These are hit with a xenon-arc light source with a red filter (2). The virus is then transported in front of red light in a "flow cell," transparent tubing on a glass plate (3). The light excites the dye, which alters the outer coat or envelope of the virus, thus inactivating the virus (4). The blood or culture medium containing the inactivated virus is then collected in a sterile container (5).

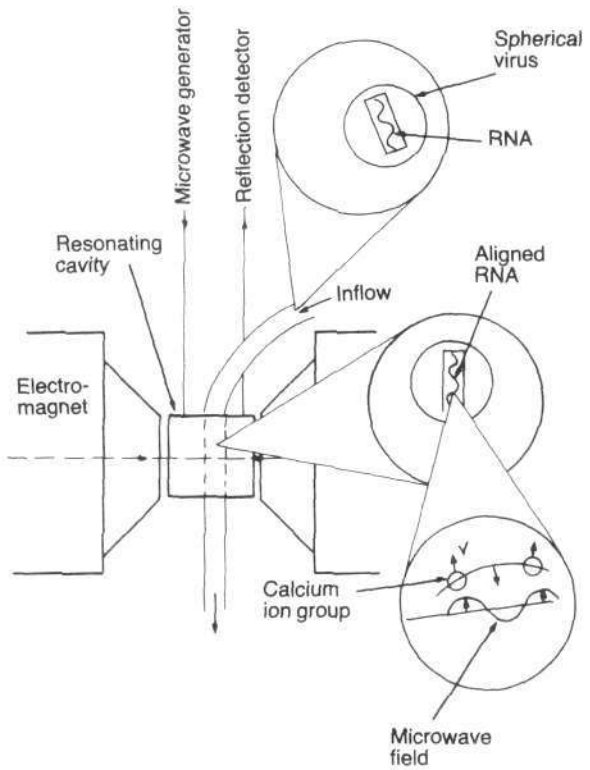


Figure 3
SCHEMATIC FOR MICROWAVE DEACTIVATION OF AIDS VIRUS IN THE BLOOD

This proposed device designed by Marvin Luther at Illinois State University would pass blood through a rapidly changing, intense solenoidal magnetic field, forcing the AIDS RNA nucleus into alignment parallel to an oncoming beam of microwave radiation. The RNA nucleus functions as an antenna for this radiation, absorbing enough energy to agitate it and displace one or more calcium ions. The damaged virus would then be returned to the AIDS patient, so that it could stimulate an immune response and begin to destroy the AIDS virus.

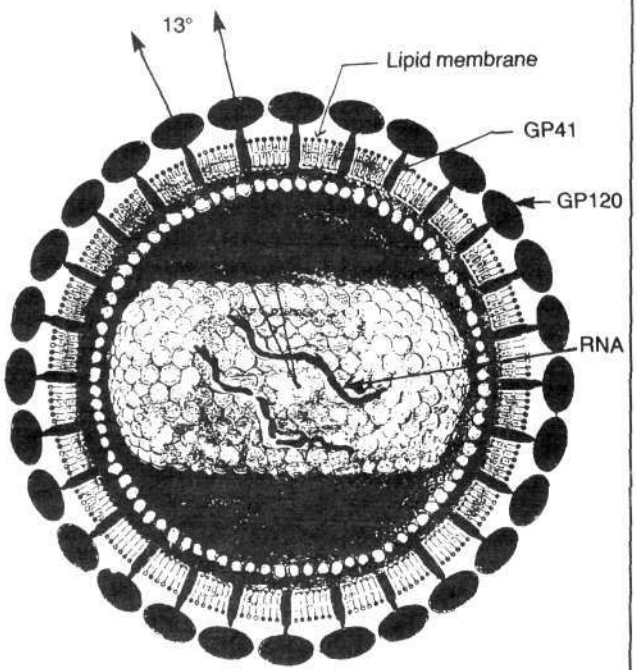


Figure 4
SCHEMATIC OF THE HIV VIRUS SEEN AS AN ANTENNA

Philip Callahan has proposed that the envelope of the HIV virus functions as an antenna array, allowing the virus to find the T-4 lymphocytes. In his design, the external envelope glycoprotein of the virus, composed of GP41 and GP120, acts as a capacitor-plate antenna, where the lipid membrane of the virus functions as the ground. There is a 13° spread between each GP41-GP120 dielectric antenna.

Callahan has calculated that the antenna would operate in the ultraviolet spectrum, based on the dielectric constant of the envelope glycoprotein and the length of the rod-like complex.

appear to confirm that, as predicted, the technique is effective in eliminating HIV from blood.

The important theoretical implication of this work is that unlike most laser applications in medicine that are based on the focusing of heat energy, this is a nonthermal effect that is highly specific and highly wavelength dependent. It is a photochemical, and not a photothermal, effect. The significance of the connection to the Strategic Defense Initiative is that one of the most promising SDI technologies is the free electron laser which is tunable over a broad spectrum of wavelengths, unlike other lasers. This will enable the rapid evaluation of hundreds of photoactive chemicals without the necessity of using hundreds of different lasers to find the optimal optical wavelength for each compound.

Another approach to attacking HIV in the bloodstream has been proposed by Dr. Marvin L. Luther of the Physics Department of Illinois State University (Figure 3).

Looking at HIV As an Antenna

Dr. Philip S. Callahan, now a senior researcher at the Bio-Communications Research Institute in Wichita, Kan., has spent a lifetime studying antenna theory and its role in insect communication. One of his findings is that the sense of smell is, in fact, an electromagnetic phenomenon rather than a chemical one. That is, an insect senses the emission of photons from a molecule rather than actually coming into physical contact with the molecule itself. Callahan believes that most communication in biological systems involves transmission and reception of coherent electromag-

netic radiation through various antennae systems at all levels, from the molecular up through the whole organism.

With this in mind, Callahan offered a hypothesis of how the external envelope of the HIV virus might function as an antenna array to enable the virus to home in on the T-4 lymphocyte. The external envelope glycoprotein of HIV consists of two molecules known as GP41 and GP120 (Figure 4). (The numbers refer to the respective molecular weights, 41,000 daltons and 120,000 daltons.)

The combined GP41-GP120 structure has the configuration of what is referred to as a capacitor-plate antenna or a "top hat" loaded dipole antenna. Instead of the usual conducting antenna made of metal, the envelope glycoprotein is a dielectric antenna. Dielectric antennae are composed of insulating substances, like plastic, wax, or sugars, and work mainly at high frequencies and at wavelengths of centimeters, millimeters, and micrometers. These are wavelengths of the scale of single cells and microorganisms.

The efficiency of dielectric antennae is a function of their ability to store electric charges, that is, to act as a capacitor. Thus a dielectric antenna is not a detector, but a collector and concentrator of high-frequency electromagnetic energy—a waveguide. Such antennae, whether naturally occurring or man-made, are almost always rod shaped, like the HIV glycoprotein or the rod shaped projections on lymphocytes. Based on calculations of the dielectric constant of the envelope glycoprotein and the length of the rod-like GP41-GP120 complex, Callahan calculated that the antenna would operate at a wavelength in the 100-angstrom or 0.01-micrometer portion of the ultraviolet spectrum.

The significance of this is indicated by an experiment conducted in 1979 by the Russian scientist V.P. Kaznocheev and his colleagues (Figure 5). Working with monkey cells, they showed that virus disease could be induced from one culture to another simply by the passage of ultraviolet light—without the transmission of the virus itself.

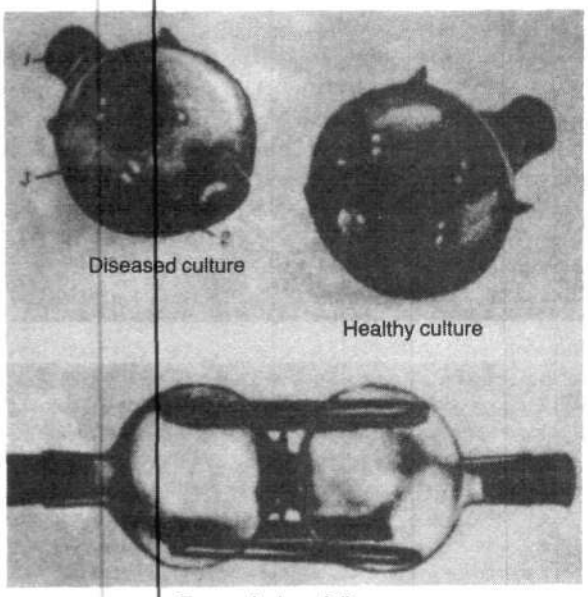
Callahan reasoned that if disease could be produced by a resonant frequency, it could also be prevented by jamming that frequency. He then conducted a series of experiments with a scaled-up model of the GP41-GP120 molecule and a radar generator and receiver. From these experiments he concluded that the molecule functions as a highly directional transmitting antenna enabling the virus to "home in" on the target lymphocyte. In addition, he determined that the entire virus can function as a waveguide antenna.

Callahan is now developing a number of proposals for a low-energy, nonionizing radiation cure for AIDS. In order to cure AIDS however, it will be necessary to not only inactivate HIV virus particles but also to deal with the problem of the DNA provirus in the cell, especially the latently infected cell in which the virus exists only as a change in the genetic potential of the cell. Is there any evidence that we can utilize our growing understanding of optical biophysics and resonant electromagnetic effects to alter genetic expression?

Radiofrequency Treatment of AIDS

Indeed, experimental results reported by West German and Soviet scientists over the past 15 years indicate that low-intensity microwaves and other radiofrequency radiation can selectively control the expression of the genetic material that regulates processes in living cells. The effects depend on the frequency of the applied radiation and are relatively independent of the power utilized. In other words, they are resonant, nonlinear, nonthermal effects. Research with millimeter-range waves indicates the possibility that they could be used to intervene directly to deactivate viral expression. Although millimeter waves do not penetrate deeply into living organisms, they could be transported to the sites of actual infection in the nervous system, or elsewhere in the whole organism as a "chirp" on lower-frequency waves. In this way, millimeter waves would be able to propagate through tissue that they usually would not be able to penetrate.

A number of experiments indicate that microwaves act "nonlinearly" to affect the expression of extrachromosomal or chromosomal DNA. For such treatment to be effective against viral infections requires frequencies of radiation that affect only the disease process, and do not disturb the



Transmission of disease symptoms through quartz window

Figure 5
ULTRAVIOLET PHOTON EMISSION: THE KASNOCHEEV EXPERIMENT

The Russian scientist V.P. Kasnocheev conducted an experiment in 1979 with monkey cell cultures that demonstrated the transmission of virus via ultraviolet photons. A healthy culture was placed in one flask and a virus-infected (but otherwise identical) culture placed in another flask (right). When the two flasks were then separated by a quartz window that allows the passage of ultraviolet light, the healthy cells soon showed the symptoms of the disease and began dying off, although there was no virus present.

Callahan reasoned that if disease could be produced by a resonant frequency, it could also be prevented by jamming that frequency.

healthy functioning of the body. The intensity of the radiation must be below levels at which it would begin to heat (and destroy) healthy living tissue; its action must be nonthermal.

This requires that the action of the radiation upon the body be *nonlinear*, which means it must be frequency-specific and independent of intensity. Prior to some of the work discussed below, it was almost universally believed in the West that nonlinear effects of radiofrequency waves were not possible. Recently, however, the prestigious Max Planck Institute in the Federal Republic of Germany declared after intensive study that nonlinear biological effects of radiofrequency waves exist, and the phenomenon is gaining wider acceptance.

Experimental results showing that externally applied microwaves can activate dormant genetic sequences in the healthy organism were reported as early as 1973 at the Scientific Session of the Division of General Physics and Astronomy of the USSR Academy of Sciences. There A.Z. Smolyanskaya and R.L. Vilenskaya discussed how irradiation of strains of human intestinal *E. coli* bacteria with specific wavelengths of microwaves, activated a portion of normally inactive extrachromosomal DNA that then induced the synthesis of a colicin, a protein that is poisonous to bacteria, within the cells. The *E. coli* died (Figure 6).

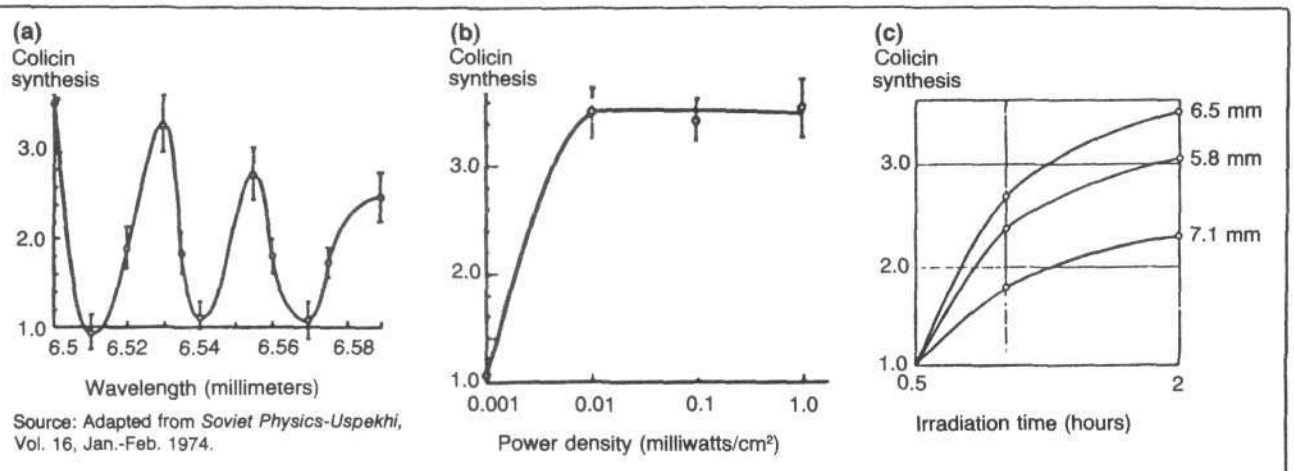
If microwaves can induce the expression of genetic material of *E. coli* bacteria, it is certainly conceivable that the appropriate frequency or mix of frequencies could prevent expression of the AIDS virus in cells infected with it. The experiments with *E. coli* show that microwaves can regulate the expression of DNA outside the chromosomes (extrachromosomal DNA). Can the function of chromosomal DNA also be affected by microwaves?

Experiments conducted in the Federal Republic of Germany by Werner Grundler and Fritz Keilmann of the Max Planck Institute for Mechanics have shown that specific frequencies of low-intensity microwaves can alter the rate of cell division in cell cultures of yeast. Since the rate of cell division and metabolism is regulated by chromosomal DNA, the genetic material in the chromosomes, underlying a change in the rate of cell division or metabolism must be a change in genetic expression of chromosomal DNA (Figure 7).

In more recent experiments, Grundler and Keilmann have attempted to isolate just where in the cell cycle the microwaves act. The latest results provide further evidence that microwaves act on cellular genetic material.

Successful demonstrations that resonant microwave effects upon expression of cellular genetic material exist within laboratory cell cultures of yeast and *E. coli* bacteria are encouraging for the prospects of the therapeutic application of radiowaves to the sort of disorders in genetic expression found in AIDS, but other important criteria must be met: First, have any nonlinear effects of radiowaves on biological processes been found in irradiation of more highly organized mammalian cells? Second, do the effects persist in vivo, that is, when the intact whole organism is exposed to low-intensity radiowaves?

These are important questions for the development of any low-intensity radiotherapy. Higher organisms are more



Source: Adapted from *Soviet Physics-Uspekhi*, Vol. 16, Jan.-Feb. 1974.

Figure 6

INDUCING BACTERIA TO POISON THEMSELVES USING LOW-POWER MICROWAVES

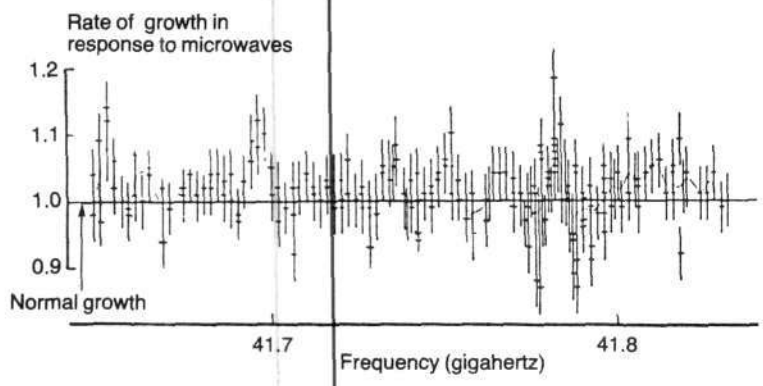
Russian scientists A.S. Smolyanskaya and R.L. Vilenskaya irradiated E. coli *bacteria with specific wavelengths of microwaves, which then activated extrachromosomal DNA to induce the synthesis of a colicin protein that killed the* E. coli. *They found that the wavelength of the microwaves used determined the rate of synthesis of the colicin. Shown in (a) is the value of the coefficient of induction of colicin synthesis as a function of wavelength.*

There was a power density threshold of 0.01 milliwatts per square centimeter to produce the synthesis (b). Once the power density exceeded this threshold, the effect did not change with further increases in power. Because the effect depends on frequency and not on power density, it is termed nonlinear.

The time necessary to irradiate the bacteria to produce the effect also depended on the wavelengths of the microwaves. Of the three cases shown in (c), microwaves 6.5 millimeters in length were most effective, next were microwaves of 5.8 millimeters, and third were microwaves of 7.1 millimeters.

Figure 7
MICROWAVE CONTROL OF GROWTH OF CELL CULTURES

A West German research team varied the rate of yeast cell culture growth by as much as 10 percent by irradiating the cells with frequencies of microwaves. Shown here is the response to the microwaves as a proportion of normal growth (1.0) over a spectrum of frequencies around 41.7 gigahertz. Each point of the curve is an average of three experimental data points. The radiation intensity required to produce this effect is only 0.1 milliwatts per square centimeter.



Source: *Physik in Unserer Zeit*, 1985

resistant to intrusion from the external environment. If low-intensity radiofrequency electromagnetic radiation does not affect their cellular processes resonantly, prospects for therapeutic treatment become dim. However, if the effect were resonant, this would confirm that the mechanism of action of microwaves upon the intracellular environment is coherent with fundamental electromagnetic interactions critical to cellular reproduction. If this radiation were not consistent with the intracellular environment, it would quite probably be screened out.

The experimental results show that low-intensity radiowaves can affect genetic expression and other processes in living organisms in a manner that is specific to the frequency of the radiation applied. They demonstrate the feasibility of a research program to develop means of using radiofrequency electromagnetic radiation to treat AIDS infection.

Much research remains to be done. We require a "Biological Strategic Defense Initiative" in biophysical research to blaze the path toward a viable form of treatment of infection with the deadly AIDS virus. Research on nonlinear radiofrequency bioeffects must proceed along a broad front, while more specialized research programs with the AIDS virus and AIDS-infected cell cultures are conducted in high-security laboratories.

In order to guide research in the area of nonlinear effects of radiowaves so that future research will result in the fastest progress toward mastering these phenomena for medical applications, it is important to formulate hypotheses about what biophysical characteristics might be making the nonlinear effects of radiowaves possible. The following questions must be addressed:

(1) How can microwaves affect the processes of cells whose dimensions are thousands of times smaller than their wavelength? As the yeast experiments show, obviously there is more to radiofrequency wave effects than the mere spatial interaction of the radiation with cellular material.

(2) How can radiation with an energy that is tremendously lower than that required to break chemical bonds, and even lower than the thermal energy attributed to molecules in living organisms, affect cellular processes? The elementary unit of electromagnetic radiation is the photon—a unit of an electromagnetic radiation equal to one full rotation of an electromagnetic wave. High-energy ultraviolet photons, with an energy of several electron volts, are required to break chemical bonds. By comparison, microwaves have an energy less than one-thousandth of an electron volt, yet they are capable of inducing frequency resonant changes in cell function.

(3) The intensity of "random," thermally induced collisions assumed to occur inside a living cell at 27 degrees Celsius is 25 time greater than the energy of the most energetic microwaves. Statistical thermodynamics holds that this thermal excitation is 0.025 electron volts in energy, and that it would smear out of existence any effects of lower energy forms of action; but the actual experiments discussed here show that this concept does not hold for living systems.

(4) The spectra of frequencies that dead biological material absorbs do not show the sharp "resonance lines" observed in the experiments with living cells or whole organisms. In the yeast experiments, if the frequency of the microwaves used was changed only a few megahertz from where the growth effect was maximal, the effect completely disappeared. The width of the frequency band over which the effect occurred was 8 megahertz. Resonances in dead tissue are tremendously broader—making selective action by microwaves practically impossible. What produces this qualitative difference in the frequency spectra between living things and dead tissue?

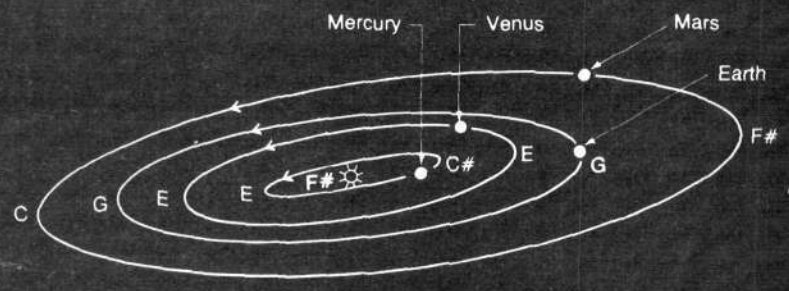
The questions noted here are at the frontiers of research in optical biophysics, the investigation of the electromagnetic properties of life. The wonderful thing about this subject is that there are many more questions than there are answers. Posing the right questions is the first step in fundamental research. For example, what, electromagnetically, distinguishes the nature of healthy biological processes from diseased ones? In answering this, we will go a long way toward finding a treatment or cure for AIDS infection.

John Grauerholz, a pathologist, is an associate editor of 21st Century.

The Universe Sings

A geometrical derivation of the musical scale that shows what music and astrophysics have in common with living forms.

by Carol White



The Four Inner Planets

Johannes Kepler's first great discovery was his answer to the question: Why did God create the Universe just so? Why did he place the planets at their given distances from the Sun? He sought a governing principle in the geometry of the golden mean, since that is the geometry of living beings. Kepler published a book explaining this theory, *The Secret of the Universe,* in 1596.

As Leonardo da Vinci and his collaborator Father Luca Pacioli had taught a hundred years before, the structure of man's body follows the same golden-mean geometry as the spiral seashell. And so Kepler sought the golden mean in man's home, the solar system. In this instance, he found the golden mean to reside in the relationship of the Platonic solids: the cube, tetrahedron, dodecahedron, icosahedron, and octahedron.

Kepler represented the orbits of the six then-known planets as spheres, and he nested the Platonic solids within these spheres successively (Figure 2). The golden mean geometry of the family of solids is determined by the pentagon on the face of the dodecahedron and the internal structure of the icosahedron. This model gave a remarkably close fit to the actual distances separating the planets.

From out of these orbits, then, the planets were created.

Kepler's Three Laws

Kepler then devoted himself to describing how the planets traveled around their orbits. He discovered that their orbits were not precisely circular, but that the planets actually traveled in elliptical paths. Nor did they travel at a uniform speed; instead, their rotational action was governed by the Sun's field in such a way that over any time span—such as an Earth day, for example—a given planet always swept out the same area. To see this, imagine that the planet is attached by an elastic string to the Sun. The area then is swept out by this string radius, and the planet travels proportionally more rapidly the closer it is to the Sun.

Only with his "third law" did Kepler relook at the distances of these elliptical orbits from the Sun. He then found a relationship between the major axes of the ellipses and the length of the planetary years: For any two planets, the ratio of the cubes of the semimajor axes is proportional to the squares of the durations of the planetary years.

Another way of looking at this is in terms of rotational action. The action accomplished upon a planet is conventionally described as the product of the area swept out per unit of time, the mass of the planet, and the given duration of time.

It is typical today that books on astronomy describe Kepler's discovery of the geometry of the planetary orbits as a lucky accident, a happy example of "curve fitting" to data provided to him by astronomer Tycho Brahe. Kepler's theoretical work is then disparaged as confused mysticism, or numerology. In contrast, Isaac Newton is presented as a great theorist.

This is a gross distortion of the true history.[1] It was Kepler, not Newton, who made the major theoretical discoveries in the field of astronomy upon which all of modern science still depends. It is only a reflection of the theoretical impoverishment of modern physics that textbooks typically accord theoretical preeminence to Newton and disparage Kepler as a kook. While Kepler would have been the last person to deny the benefit to him of having Tycho Brahe's excellent observations at his disposal, Kepler was first and foremost a brilliant theoretician.

From the distorted point of view of "Newtonian science," the action of the Sun on each of the planets is arbitrary—determined by the distance of the planet from the Sun. Kepler, however, had already understood that the planets were created in orbits at certain unique distances from the Sun, which had been determined according to a principle governed by the geometry of the golden mean—the law of the nested planetary solids. Combining this with Kepler's "three" laws, we see that he actually anticipated modern quantum physics. According to Kepler, the planets taken together formed a system with the Sun. After the Creation, the planets were maintained in orbit by the action of the Sun, which itself rotated. Since this rotational action is distributed through the solar system, it is quantized according to the golden mean principle that guided the Creator.

A little simple algebra shows that the orbital action will

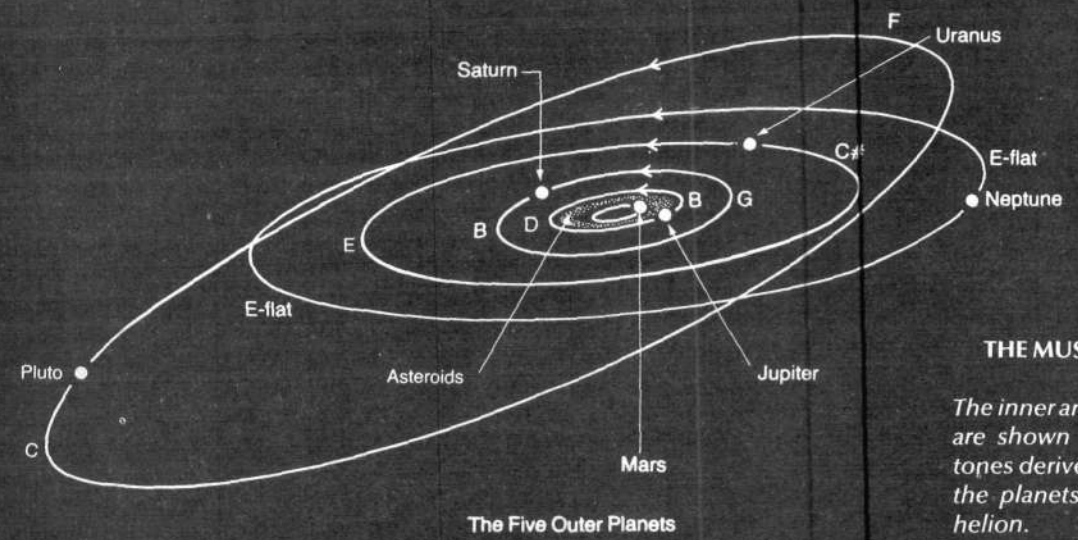


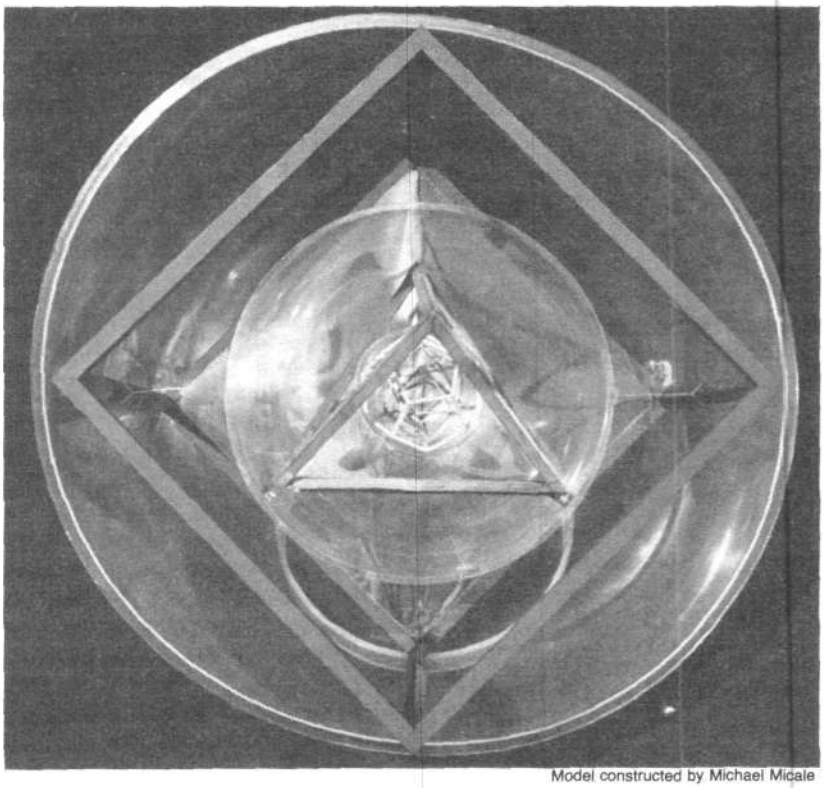
Figure 1
THE MUSICAL TONES OF THE PLANETS
The inner and outer planetary orbits are shown here with the musical tones derived from the velocities of the planets at perihelion and aphelion.

vary approximately as the square root of the average distance of the planet from the Sun. A more precise measure (though it does not take into account differences among the masses of the planets) is the distances as measured by the semilatus rectum of each planet. The semilatus rectum is the radius perpendicular to the major axis of an ellipse (Figure 3).

Thus, the Sun's action upon the planets increases in a quantized fashion. At the same time, we know that the planets have maintained approximately the same orbits over billions of years; therefore we have empirical confirmation that these are force-free, least-action orbits.

What Is Least Action?

Unlike the parody of a theory of evolution suggested by Charles Darwin, which states that the law of the universe is dominance by brute force, Kepler understood that God's universe must evolve toward a continually greater perfectibility. It embodies a creative principle within it. It is man's task to understand this law, so that he may conform himself



Model constructed by Michael Micale

Figure 2
KEPLER'S INITIAL HYPOTHESIS ON THE PLANETARY ORBITS
Kepler represented the distances from the Sun of the six then-known planets by alternating a series of spheres (the orbits) with the Platonic solids in a nested arrangement. The largest sphere is Saturn's orbit. A cube is nested within it. Inside the cube is a sphere representing Jupiter's orbit, and a tetrahedron is nested within it. The dodecahedron, icosahedron, and octahedron follow in that order. Kepler presented this model in the first edition of The Secret of the Universe, *1596.*

to the purpose of the Creator, by aiding in the Creation—most immediately by turning this Earth into a garden.

In order that the Creation can continue, God has embedded within all processes a principle of least action. Everything proceeds according to laws of geometry, in which evolution is measured by the increasing rate at which transformations can occur, offering greater potentialities for still further transformation.

This rate of transformation is measured by the ordering of singularities. In terms of our solar system, the planets emerged as new potentialities, the singularities of the process. They were created from orbits that expressed the most efficient, least-action configuration for the system as a whole—that configuration which maximized the potentiality for the emergence of the new.

Nicholas of Cusa was the first scientist of the modern era to recognize the significance of such least-action configurations, which he explained using the isoperimetric principle of circular action. For any given area, a circle will be that figure that bounds it using a minimum perimeter. In other words, circular action encompasses the maximum area with the least effort.

Cusa showed how a family of circles would start at a point—the minimum—and would grow to a maximum or infinite circle. He demonstrated that this maximum circle was identical with a straight line. To understand this, consider how the Earth appears to us as flat, although it is really an oblate spheroid in shape. The straight line that we appear to walk upon is really more or less a circle. Cusa insisted that rotational action is the primary form of the Universe, that the point and the straight line both are derived from this circular action and are other-than-circles in appearance but not reality. Thus the isoperimetric least-action principle is paradigmatic for the Universe as a whole.

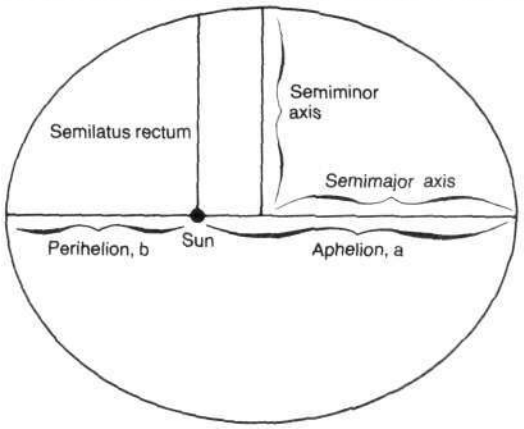


Figure 3
THE ELLIPTICAL GEOMETRY OF PLANETARY ORBITS

Kepler discovered that the planetary orbits were not circular but elliptical and that the planets did not travel at uniform speed. If the aphelion is equal in length to a, *and the perihelion to* b, *then the semimajor axis will equal the arithmetic mean,* (a + b)/2, *the semiminor axis will equal the geometric mean* $\sqrt{(ab)}$, *and the semilatus rectum will equal the harmonic mean* 2ab/(a + b).

The ratio of the velocity at aphelion to that at perihelion is the inverse ratio of these lengths, or b/a. *Velocity at the latus rectum is the arithmetic mean of the velocities at aphelion* (1/ka), *and perihelion* (1/kb), *where* k *is a proportionality factor:* ½[(1/ka) + (1/kb)]. *That, in turn, is equal to* (a + b)/2kab, *which is* k *times the inverse of the length of the semilatus rectum* 2ab/(a + b).

Kepler took Cusa's method as his own; indeed, that method has always guided great science. Before Cusa there were Plato and Archimedes; then the Christian humanists such as Saint Augustine, the great poet of science Dante, Leonardo, and Copernicus; and since Kepler, Karl Gauss, Bernhard Riemann, and Georg Cantor, following nobly in his footsteps.

Nothwithstanding, Kepler faced a problem. If Cusa were correct, why were the orbits of the planets not a family of circles, with the Sun at their center?

The Music of the Spheres

Kepler sought a higher-order least-action principle that would account for the elliptical geometry of the orbits. To do this he reverted to a hypothesis first raised in the fifth century B.C. by Plato in the *Timaeus*. Plato called God the "composer" of the universe, and likened its geometry to the governing principle of the musical scale. In poetic form, this same assertion was made by St. Augustine in his thesis on the composition of music and poetry and by Dante in the *Divine Comedy*. Kepler, however, was the first to change the concept from a bare assertion to a concrete discovery.

He found that a planet's nearest approach to the Sun (perihelion) and its farthest distance from the Sun (aphelion) were approximately in the same ratio to each other as the values of the frequencies of the musical scale (Table 1). Furthermore, he found that neighboring values, comparing the minimum of one planet to the maximum of the one just closer to the Sun, were harmonious intervals.

Even more astonishing, Kepler identified the position of the asteroid belt, which was not to be seen by astronomers until the beginning of the 19th century, as occurring at the note value F# of his musical scale. As sopranos know, when the tuning is done properly—with middle C at a frequency of 256 cycles per second—they will experience a registral shift at precisely this point, between the notes F and F#. An alto will experience a register shift between the E-flat and E. (Every singer has three primary singing voices, a low, medium, and high range, and two points of registral shift. Trained singers have an additional high fourth register. The configuration of the singer's throat and the way he or she focuses breath change according to the register.)

Kepler's discovery of the musical relationships between the maximum and minimum angular velocities of the orbiting planets (in other words the degrees per interval of time that they rotate as they travel around the Sun) was a truly extraordinary discovery. He took the first approximation of simple conical geometry, a family of circular orbits around the Sun, and transformed it into an elliptical geometry coherent with the musical scale, by describing the creation of

Table 1
KEPLER'S MUSICAL SYSTEM

Planet	Daily Journey	Ratio	Musical Note Value
Sun	874.2	9.087	F#
Mercury			
Per.	380.01	3.95	E
Ap.	165.07	1.715	C#
Venus			
Per.	97.53	1	E
	(arithmetic mean, 96.22, is used)		
Ap.	94.90	1	E
Earth			
Per.	61.14	.6356	G#
Ap.	57.18	.5944	G
Mars			
Per.	38.09	.3959	C
Ap.	26.19	.2722	between F#-F
Jupiter			
Per.	5.50	15.3631	D
Ap.	4.53	12.6536	B
Saturn			
Per.	2.24	5.2570	B
Ap.	1.80	5.0279	G
Uranus			
Per.	.772	2.1564	E
Ap.	.642	1.7933	C#
Neptune			
Per.	.364	1	D#
	(arithmetic mean, .358, is used)		
Ap.	.352	1	D#
Pluto			
Per.	.408	1.1397	F
Ap.	.148	.4066	C

Kepler's method for establishing the coherence of the planetary orbits with the musical scale is elaborated here. The inner planets are normalized to the nearly circular orbit of Venus. Their velocities at aphelion and perihelion (given in terms of daily journey in arc minutes) are stated as ratios with respect to Venus. The value used for Venus is the arithmetic mean of its aphelion and perihelion velocities.

The outer planets, starting with Jupiter, are handled similarly, but are normalized to the nearly circular orbit of Neptune. The planets move down the scale as they become more distant from the Sun.

the planets according to geometric resonance principles. This is a maximum/minimum principle, like Cusa's isoperimetric principle of circular action, but of a higher order. It shows us that the same principles that govern astronomy and atomic physics, also govern man's mind—since music, like poetry, is a unique celebration of the ability of man to create.[2]

The Musical Scale

A musical composition, of course, is far more complex than the geometry of a simple scale, yet even the simple scale contains a highly concentrated interplay of different geometries. Typically, one is taught a pragmatic view that the scale is a compromise between obtaining a maximum resonance between notes that are sounded together, or played in sequence, such as the first and fifth note of any musical key. One is also taught the desirability of being able to travel among different keys, in order to vary a composition. Traditional wisdom points out that simple tuning to maximize harmonies creates sour tones in what are called distant keys. For example, if we begin with the key of C and travel to the key of A, then the fifth note E, tuned to harmonize perfectly in that key, will not be the same as an E tuned as the third tone in the key of C, and so on.

Table 2
THREE TUNINGS COMPARED

Tone	Just Tuning	Equal Tempering	Golden Mean Tuning
C	256	256	256
C#	273.06	271.20	271.5
D	288	287.35	288
D#	307.2	304.43	304.43
E	320	322.54	320
F	341.3	341.71	341.23
F#	360	362.04	360
G	384	383.57	384
G#	409.6	406.37	407.13
A	427.52	430.54	429
A#	455.1	456.14	455.1
B	480	483.26	483.4
C	512	512	512

In equal tempering each successive pitch is determined by multiplying the previous one by the 12th root of 2. Twelve such tones constitute one doubling, or octave. Just tuning is based upon the geometry of the ellipse (see text and Figure 5). The frequencies are given in cycles per second to two decimal points.

The solution to this problem is supposed to be found in the discovery of *equal tempering,* which defines the frequency of each tone as the product of the previous frequency and the 12th root of 2, so that the intervals between notes are the same, whatever the key (Table 2). This notion is fundamentally flawed, because it presumes that the musical scale is determined by the purity of sensation between notes that are juxtaposed.

The beauty of a musical composition is not located in a hedonistic pleasure principle, but in the way it can explore the mind's ability to invent lawful sequences of transformations—the simplest examples of which are variations on a theme. These may be rhythmic or tonal, they may be played in a succession of different keys, and so on; until finally, from the first theme a second is born, which can be played in counterpoint to the first—thereby creating further potentials for variation. In this way, man comes closest to the Creator himself.

Several geometrical principles are embodied in the simple scale. First, we hear the stepwise progression from one note to the next, as if each note were increased by some frequency rather than by the expansion of frequency. For example, a note three octaves higher than a given note is actually sounded at a frequency eight times greater—since each octave is doubled in frequency—but that is not how we hear it. In this sense we hear the logarithm, the exponent of the expansion. On the other hand, we also are cognizant of the difference in the amount of work necessary to produce two notes. In this case we do perceive the actual difference in frequencies.

The scale itself is created by combining certain crucial intervals into one overriding geometry:

Every octave is composed of an interval of five notes, the fifth, and one of four notes, the fourth (Figure 4). The octave from C to C′ is thereby cut at the G. (C′ is a C one octave higher than the first C.) The interval from C to G includes C,D,E,F, and G; while from G to C′ includes only G,A,B, and C′. These intervals of the fifth and the fourth are the primary cuts in the octave. From F to C′ is itself an interval of a fifth. These two fifths can be put together: start with a fifth below the C′, that is, F, then move to C′, and then to G′ above C′.

Next, we divide the interval from C to G, by the third to get C, E, and G. The interval from C to E is larger by a half step than that from E to G. To see this, take into consideration half tones that are not in the key of C itself. Thus, the interval from C to E is composed of the four half steps C-C#, C#-D, D-D#, and D#-E; while the interval from E to G is composed of only the three half steps E-F, F-F#, and F#-G. There is no E# (or F-flat); the interval E-F is only a half step. The larger interval is known as a major third, and the smaller interval is a minor third.

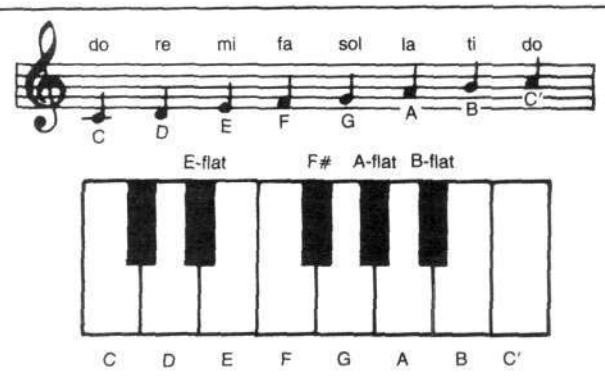


Figure 4
THE DIATONIC SCALE AND THE KEY OF C

The 12 tones of the diatonic scale (a) are C, C# (or D-flat), D, D# (or E-flat), E, F, F# (or G-flat), G, G# (or A-flat), A, A# (or B-flat), and C, which brings us to the completion of one full cycle. These are all the white and black keys of one octave. The diatonic scale is divided in half by F#:

C C# D D# E F F# G G# A A# B C

The key of C in the major mode (b) is played on the piano by striking only the white keys. The key of C in the minor mode is played by replacing E with E-flat. The minor mode is variable in that A may also (optionally) be replaced by A-flat and B may also (optionally) be replaced by B-flat.

We may also divide the interval from C to G to get the minor third first, and then a major third. In this instance we substitute the E-flat for the E. By doing this we are shifting from the major to the minor mode. Similarly, we have the intervals of the major and the minor sixth, which are obtained by moving from C′ back toward C, by an interval of a minor third to the A, or a major third to the A-flat. These are the most important divisions of the scale from which other geometries develop.

Two hundred years after Kepler's seminal work, Karl Friedrich Gauss developed a perfected geometric representation of Kepler's discovery, in what is today known as complex number theory, or the geometry of the Gaussian plane. The simplest form of this geometry represents the orbits as projections from elliptical cuts in a cone that are determined by the beginning and end of a 360-degree rotation of a logarithmic spiral (Figure 5). The interval of a fifth is shown to be an arithmetic mean between the bounding frequencies of the octave; two other geometric intervals, the arithmetic-geometric mean and the harmonic mean, are also shown to be important. To better understand this we must look further at how the musical scale is constructed.

As early as the Pythagoreans, in the fifth century B.C., scientists understood that the interval of the fifth was produced by plucking two strings that differed in length so that one was two thirds the length of the other. Similarly, an interval of a fourth has a ratio of three fourths to one. A major third is the ratio of four fifths, the minor third is five sixths, the major sixth is three fifths, and the minor sixth is five eighths, and the whole step is eight ninths—to one. Kepler, of course, recognized that when this relationship of string lengths is inverted, it gives us the relationship of the frequencies of the notes. Thus the string length that must be plucked to produce a G above C, will be two thirds the length of the C string, while the frequency will be three halves that of the C.

The equal-tempered scale is constructed by taking the octave and dividing it into twelve 12th-roots of 2. The values by either construction will be quite similar. Pianos today have equal-tempered tuning, although the upper registers of the piano are frequently lowered somewhat because of considerations of resonances in the piano that make this adjustment more pleasing. Neither method of tuning—just tuning by ratio values (or some adjustment of this to bring distant fifths into better harmony) or equal tempering—in itself explains the unique significance of the interval of the fifth (Table 2).

The fifth is the most resonant interval other than the octave, but we do not hear it as a resonance but as a geometric cut. Indeed, it plays the same role in dividing a musical key as the golden mean does in dividing space. The golden mean will divide a segment into two parts such that their ratio is the same as the ratio of the whole segment to its larger subdivision.

The Golden Mean

Kepler had a geometric theory of the construction of the scale according to the construction of the regular polygons; later work by Gauss and Riemann, however, has led us to elaborate his basic discovery by showing how the golden mean, the geometry of life, is also embedded in the construction of the musical scale. To see this, we begin with two different principles that govern the construction of the scale: the first is an arithmetic or elliptical geometry, the second a geometric or spiral construction.

Begin with the octave—let us say in the key of C. Represent the perihelion and aphelion lengths of the ellipse as the lengths of an instrument's strings that might be plucked or bowed to produce the tones. Then—comparing this to the velocities of the orbiting planets—the higher C will occur at perihelion and the lower C at aphelion. To divide the octave, the proper point for a first cut is at the G, the fifth note in the octave (the interval from do to sol). This G occurs at the arithmetic mean in the octave between the frequencies of C-256 and C-512; that is, at 384 cycles per second (Figure 6).

This G is the sound that occurs when you pluck the length of the semilatus rectum of the ellipse. If we repeat this process, but with a narrower ellipse whose major axis stretches over two octaves, the perihelion is again C-512, but the aphelion is at C-128 and the arithmetic mean then gives us the third tone of the octave, in this case the E. Thus we have produced the tones of the arpeggio, do-mi-sol or C-E-G. If we extend the ellipse over three octaves, it produces the note D. Thus the just, or ratio tuning, is coherent with the geometry of the ellipse, and indeed this is the geometry of the scale that Kepler used.

The arpeggio C-E-G defines the *major mode* of the key of C. To look at the *minor mode*, we must turn to a spiral geometry—the geometry of equal-tempered tuning of the scale. To accomplish this tuning, we construct a logarithmic spiral on a cone, in which the successive radial lengths represent string lengths, so that the note values attached to them will be the inverse of these lengths (Figure 7). If the cone sits on its vertex, as we proceed up the cone we are traveling down the scale.

Halfway around the cone, the spiral reaches F#—the point at which occur both the registral shift of the soprano singer and the division of the inner and outer planets by the asteroid belt. This point is both an arithmetic and a geometric mean: First, the radial length of the cone at that point is a geometric mean length between that of the bounding radii of the octave and also a geometric mean frequency between the bounding frequencies of the octave. Second, it is also a halfway point of the rotation of the spiral around the cone; in other words, an arithmetic mean rotation. Indeed a half-rotation around the spiral coheres with the fact that the F# divides the 12 notes that compose the diatonic scale in half.

(Although discussion here centers on the key of C—the primary key in the system—the other 24 keys of the musical system, 12 each in the major and the minor modes, can be derived from the key of C by simple transposition.)

The logarithmic spiral on the cone has two other unique values, at a rotation of 90 and 270 degrees. At

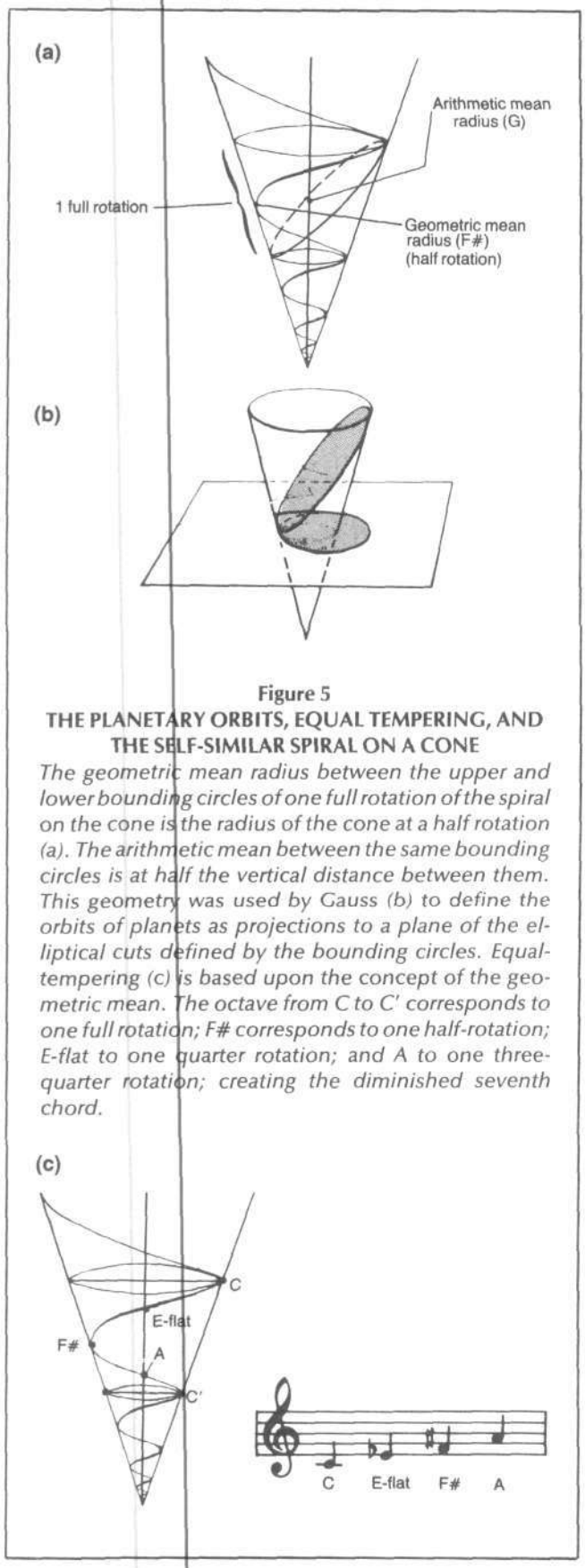


Figure 5
THE PLANETARY ORBITS, EQUAL TEMPERING, AND THE SELF-SIMILAR SPIRAL ON A CONE

The geometric mean radius between the upper and lower bounding circles of one full rotation of the spiral on the cone is the radius of the cone at a half rotation (a). The arithmetic mean between the same bounding circles is at half the vertical distance between them. This geometry was used by Gauss (b) to define the orbits of planets as projections to a plane of the elliptical cuts defined by the bounding circles. Equal-tempering (c) is based upon the concept of the geometric mean. The octave from C to C' corresponds to one full rotation; F# corresponds to one half-rotation; E-flat to one quarter rotation; and A to one three-quarter rotation; creating the diminished seventh chord.

90 degrees (starting at C and moving down the scale as we move up the cone), we have the A and at 270 degrees the E-flat. Together with the F#, these are known as the diminished seventh chord, made up of minor-third intervals. The diminished seventh is used extensively in classical music. In this way the geometry of the spiral defines the minor mode of the key of C, by indicating a succession of minor-mode intervals.

The logarithmic spiral on the cone is divided into 12 intervals according to the tuning of the equal-tempered system, so that the radii grow proportionally as the 12th root of 2. The just-tuned scale is not regular in that way. Neither scale, however, explains to us why we hear the fifth as a golden mean cut, nor does it introduce the golden-mean as a guiding principle of music. However, taking both together, and making a few minor adjustments, we can create a scale that does bring out how the golden mean indeed governs the way we hear the musical scale. We must recognize that each note in the musical system is a small quantum of action, a small circle rather than a Euclidean dimensionless point. This is precisely the same sense in which Cusa described a point.

If we wish to emphasize a golden-mean tuning, then the method described here is an adequate first hypothesis. It is not meant as a basis for a musical performance. To proceed in that direction would certainly require refining the suggested scale. The tuning depends upon determining certain note values most nearly according to the equal-tempered spiral scale, and others according to ratio values from the elliptical, just tuning. This is neither tuning by ratio

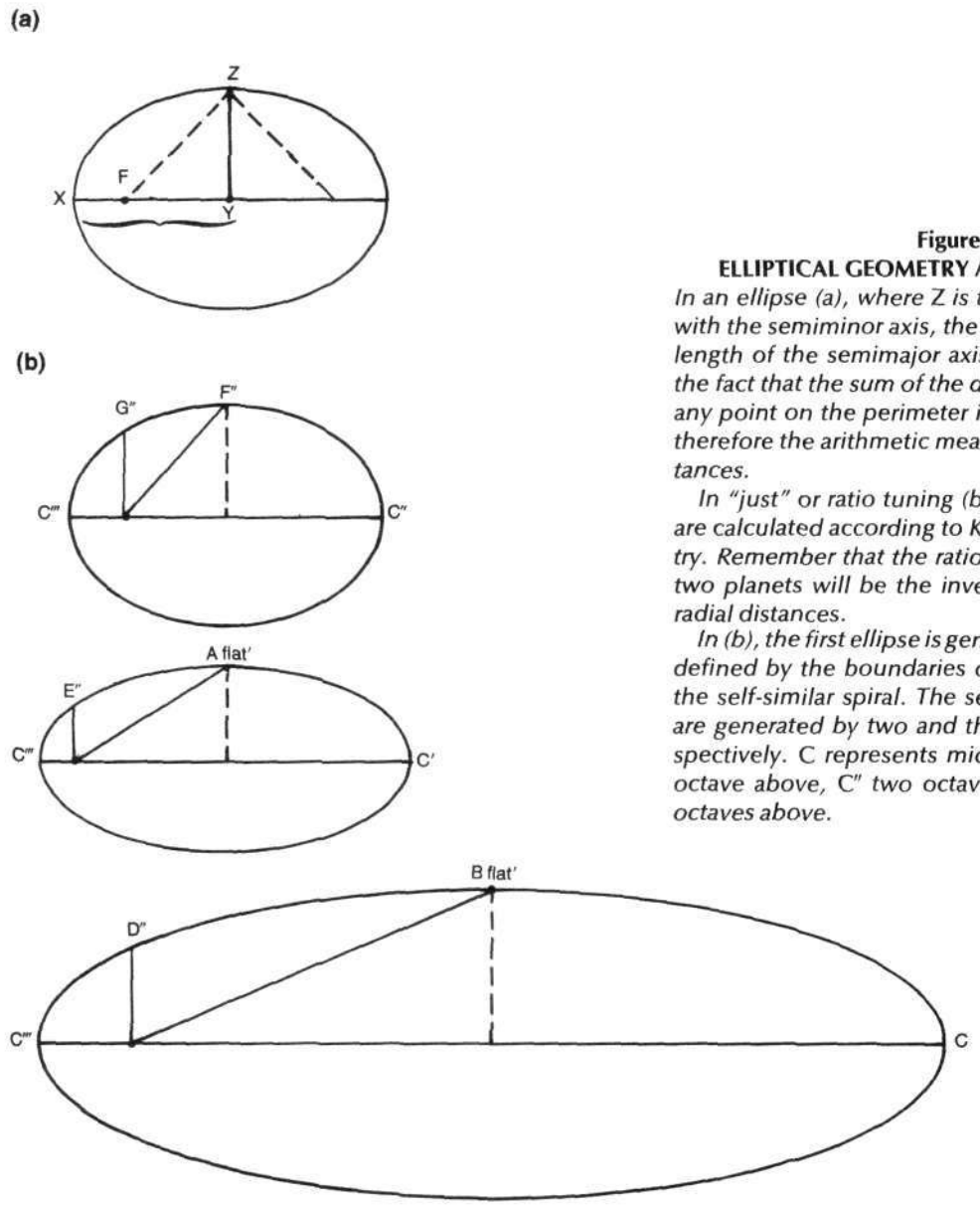


Figure 6
ELLIPTICAL GEOMETRY AND 'JUST' TUNING

In an ellipse (a), where Z is the point of intersection with the semiminor axis, the length FZ is equal to the length of the semimajor axis, XY. This follows from the fact that the sum of the distances from the foci to any point on the perimeter is always the same. FZ is therefore the arithmetic mean of any pair of such distances.

In "just" or ratio tuning (b), the notes of the scale are calculated according to Kepler's elliptical geometry. Remember that the ratio of the velocities of any two planets will be the inverse of the ratio of their radial distances.

In (b), the first ellipse is generated as a cut on a cone defined by the boundaries of one full revolution of the self-similar spiral. The second and third ellipses are generated by two and three full revolutions, respectively. C represents middle C; C′ is the C one octave above, C″ two octaves above, and C‴ three octaves above.

values nor by the logarithmic scale, per se.

The value of F# in this golden mean system must be treated as a quantum of action. It is an arithmetic-geometric mean in the sense that it defines a registral shift, as the frequency value of 256 cycles per second multiplied by the square root of 2—approximately 362 cyles per second; it is also given the lower value of 360 cycles per second. This lower value is equal to an interval of a whole tone from E, with the whole step constructed according to the ratio system as 320 multiplied by 9/8.

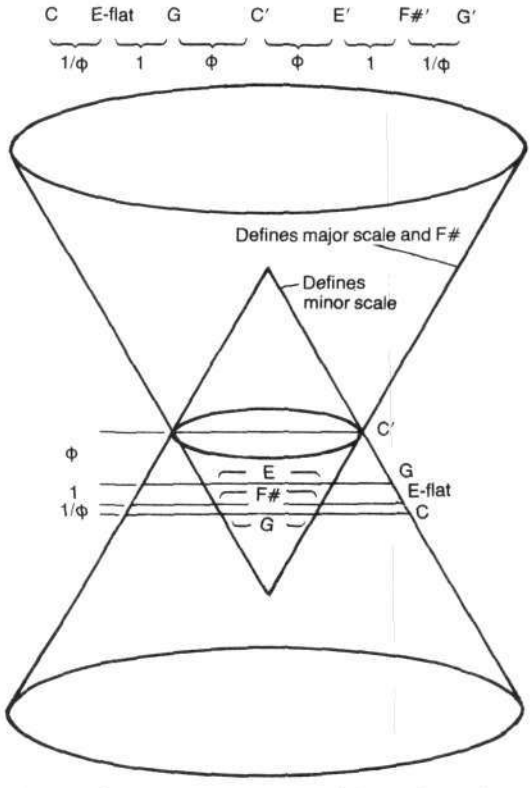
We find that we can combine middle C with the arithmetic mean, G, of the octave below middle C, and the arithmetic-geometric mean above middle C, F# (the first note of the soprano second register), into one musical-geometric construction where the C will divide the frequency differences (that is, the action) according to the golden mean ratio.

Figure 7
THE GOLDEN MEAN GEOMETRY OF THE MUSICAL SCALE

The geometry of the scale, using the amended "golden mean" frequencies, has the following relationships (where ϕ is the golden mean):

$$(F\# - C)/(C - G) = (360 - 256)/(256 - 192) \cong 1.618$$

$$(E - C)/(C - E\text{-}flat) = (320 - 256)/(256 - 152.13) \cong 1.618$$



The golden mean geometry of the scale is illustrated by two mutually inverted, intersecting cones. The frequencies of the notes (and inversely, the lengths of the strings that produce the notes) are in the ratio of the golden mean.

Sounded together with C, the upper and lower bounding notes do not produce a harmonious sounding interval, but this triad unites these three key singular cuts. (F# − C)/(C − G) gives a value of approximately 1.6, the golden mean.

Similarly, we can look at the point of registral shift for the alto singer, between E and E-flat. This determines the difference between the major and the minor modes in the key of C, and it also will give us a golden mean ratio. In this instance we take the difference between the E-flat below middle C and middle C, and that between the E above middle C and middle C, and again find a golden mean: (E − C)/(C − E-flat).

While these intervals are discordant, we do find a truly harmonic instance in the relationship between the major and the minor mode of the key of C (Figure 7). Here we see that the golden mean lays the basis for unifying the major and minor modes of the key of C. In a certain sense, we produce the F# as a singularity of the higher geometry of the two modes taken together as one key, although it appears in neither the major nor the minor mode of the key of C taken in itself. Despite the fact that F# is not a member of the key of C major or C minor, it is the unifying principle of both.

Again, we are not looking at the ratio values of the frequencies of the notes themselves, but we are taking the ratio of their differences—between C and E, E and F#, and then again between E and F# and F# and G. These differences decrease proportionally to diminishing intervals of the golden mean. Conversely, take those between C and E-flat, E-flat and G, and again between B-flat and G and G and C, and these increase proportionally as increasing intervals of the golden mean. The major and minor modes are shown to be inversions of each other in terms of the golden mean. This geometry is borne out by the following consideration. If we replicate the major key of C, but go backwards starting not from C, but from G (G, F, E-flat, D, C, B-flat, A-flat) we get a version of the minor mode.

There are many instances in the music of Mozart and Beethoven that illustrate the use of the major and minor mode taken as one key, highlighting precisely these golden mean relationships. We have shown that the fundamental key, the key of C, from which all other keys are derived and to which they refer, is essentially derived from the golden mean. Not only does the golden mean determine the principal cuts of the scale, but it is the principle that underlies the unity between the major and minor mode. By doing this we have given a final unity to Kepler's first and last law, since both can now be shown to embody the golden mean principle of all Creation in God's living universe.

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

Footnotes

1. See Carol White, "Johannes Kepler: Voyager in Space," *21st Century*, March-April 1988, p. 42.
2. See Laurence Hecht, "The Geometric Basis for the Periodicity of the Elements," *21st Century*, May-June, 1988, p. 18.

Kuiper Airborne Observatory

A Flying Telescope

by Jim Everett

Lori Stiles

The KAO lands at Christchurch, New Zealand, in March 1986 after a successful night observing Halley's Comet over the South Pacific Ocean.

Astronomy is frequently not a science that is pursued in comfort. To get the best viewing conditions, astronomers place their observatories in remote locations, usually on mountaintops. They open up their doors to the cold night air, which helps prevent heat currents from distorting the viewing—but which also freezes the astronomers.

More recently, the trend has been to attach electronic cameras to the telescopes which, besides the advantage of more sensitivity, permits the operators to sit in a climate-controlled room where they do their work looking at TV monitors.

There is one modern telescope, though, that still makes rigorous demands on those who use it.

The operating height of this observatory is 41,000 feet, 2 miles higher than the highest mountain. All those who work here must undergo special high altitude training; if a door were to pop open, they would have only 20 seconds to find their individually fitted oxygen masks. Outside, the temperature is usually no warmer than −20 degrees Fahrenheit. It's not that cold inside, but the metal walls let in some of the chill. The wind blows at a steady 400 miles per hour. That and the sound of the engines create a roar so loud that everybody has to wear special headphones to protect his or her hearing.

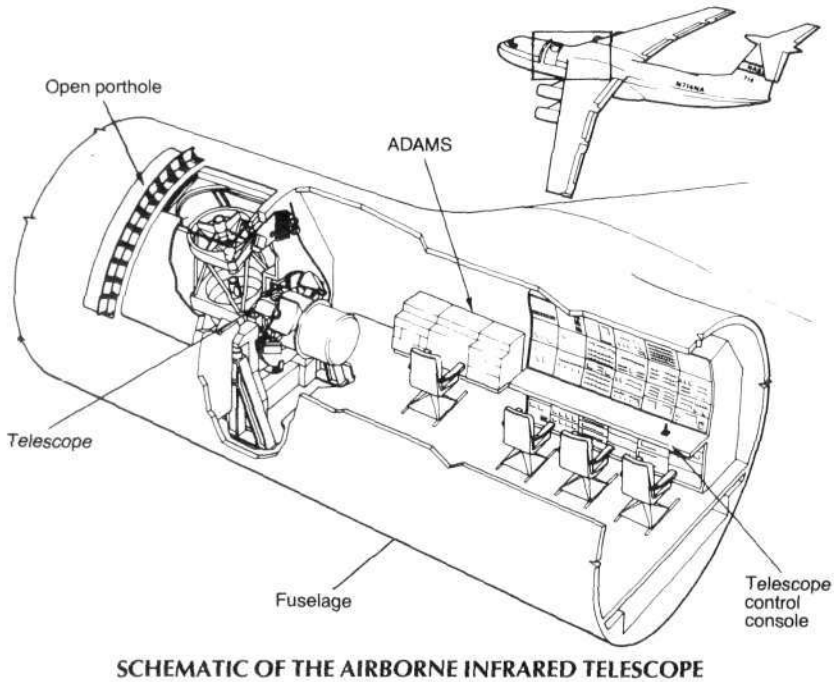
This is the Kuiper Airborne Observatory or KAO, operated by the National Aeronautics and Space Administration. The "observatory" is a Lockheed C-141 Starlifter, one of the largest planes in the world. Just forward of the wings on the port side of the aircraft lies an opening not found on any military version of this jet transport. In flight, a sliding door opens to reveal a 36-inch Cassegrain reflecting telescope.

Why place a telescope in an airplane? Not only is the environment uncomfortable, even dangerous, it is in most respects not a good platform from which to operate a telescope. The airplane vibrates and is subject to pitch and roll. The air rushing over the telescope creates such turbulence that the resolution is five times worse than if it were ground based. And it's expensive to operate: more than $150,000 a flight.

However, the KAO has one advantage that makes up for all the drawbacks: It works in an environment that is above more than 99 percent of the water vapor in the Earth's atmosphere. This is especially important to one branch of astronomy, that which observes in the *infrared* portion of the spectrum.

Infrared light is invisible to the eye, though we can feel its heat on the skin if it is intense enough. We are, in fact, most familiar with it as radiant heat. Infrared light reacts readily with molecules of all types, but water molecules are particularly efficient absorbers in the infrared.

As we shall see, astronomers are very



SCHEMATIC OF THE AIRBORNE INFRARED TELESCOPE

This cutaway view shows the telescope, located just forward of the aircraft's wing. The tracking and control units are adjacent to the telescope. ADAMS, the Airborne Data and Acquisition Management System, helps the operator find the target in space.

interested in looking at planets, stars, and galaxies in the infrared light that they emit. But because most infrared light from space gets absorbed in the atmosphere, this branch of astronomy has lagged behind. Astronomers have sought to overcome this infrared "blindness" by building special telescopes high on mountaintops; one of the finest is on top of Mauna Kea in Hawaii.

Another option is to place an infrared telescope in space. In 1983, NASA launched such a satellite, called IRAS for Infrared Astronomical Satellite. It performed beautifully, but after a year IRAS lost all of the coolant needed to keep the detector sensitive. In the next decade another infrared telescope is scheduled to be launched. This one will be serviced by the Space Shuttle crew, so it will have a long lifetime.

Gerard Kuiper: Astronomy Pioneer

Flying a telescope in an airplane is just another way to get above most of the water in the atmosphere. Airborne infrared astronomy was pioneered by Gerard P. Kuiper, in whose honor the KAO is named. (Kuiper, known as the father of modern planetary sciences, had many firsts. For example, in 1944 he discovered that Titan, Saturn's satellite, has an atmosphere, and in 1948 he discovered the fifth moon of Uranus, Miranda.)

In 1965, NASA began an experimental program that was to culminate in the commissioning of the KAO in 1975.

NASA chose the C-141 military transport plane because its huge size can handle a large telescope, along with the supporting computers, instruments, and staff needed to operate the telescope. Its size also makes it a relatively stable platform for the telescope, since air turbulence does not cause it to bounce around a lot. The C-141 is also powered with turbofan jets, which vibrate the plane less than older jet engines did.

To further reduce vibrations, the telescope is mounted on pneumatic shock absorbers, not unlike those found in cars. These shock absorbers are mounted, in turn, on a 16-inch ball bearing that is cushioned by a thin film of air kept at high pressure. In addition, gyroscopes and motors attached directly to the mount instantaneously move the telescope to compensate for momentary motions of the airplane. The result is a highly stable mount, not much worse than if it were on solid ground.

Lori Stiles

A KAO crewmember examines a computer-generated star map.

Using the Telescope

When the door opens on top of the airplane, the telescope is exposed directly to the atmosphere. Turbulence is kept to a minimum by air foils that channel air into the telescope cavity, so that a constant pressure is maintained.

Finding and locking in on the target is the most technologically difficult task in airborne astronomy. Since the "dome" over this telescope is the airplane itself, the telescope is pointed by turning the entire airplane. More precise pointing is done by small motors on the telescope mount.

The task of coordinating the piloting of the airplane with finding the target in space is given to a very sophisticated computer called ADAMS, Airborne Data Acquisition and Management System. ADAMS has a star map in its memory that contains 250,000 stars. If an astronomer has a hard time figuring out which stars he or she is seeing through the telescope, then ADAMS helps out by displaying a detailed star map of the area.

Once the astronomer has found the observation target, ADAMS takes over the job of piloting the airplane. It takes into account all the motions of the star or planet as it moves across the celestial sphere during the night. ADAMS then constantly directs the plane's autopilot as to the proper course to take.

Some KAO Firsts

What have astronomers discovered using the KAO? On Dec. 21, 1986, a group of NASA and university astronomers using the KAO infrared telescope were the first to detect water in Halley's Comet. Thirty-five years earlier, the astronomer Fred Whipple had hypothesized that comets were "dirty snowballs." But astronomers were not able to test this hypothesis until now. Using a device called an infrared spectrometer, they looked for the special "signature" of water.

On the night of the 21st, the scientists saw four of the ten predicted spectral lines of water. On Dec. 23, they saw all ten. Earlier attempts to detect water in comets had failed because everyone was looking in the wrong place; they were looking in the ultraviolet part of the spectrum.

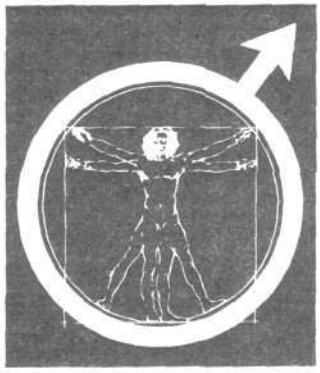
This was not the first time the KAO had detected a molecular compound in space. Astronomer Harold Larsen has used the KAO telescope to look at the atmospheres of Jupiter and Saturn. His group discovered that the characteristic yellow and brown bands are colored in part by phosphine, a compound of phosphorus and hydrogen.

On March 10, 1977, the KAO took off from Perth, Australia, for a historic look at Uranus. The astronomers, led by James Kerr, had plotted a course that carried them far into the southern Indian Ocean, where an eclipse of a star by Uranus was calculated to be visible. Their mission was to study the starlight in the brief moment that it passed through the atmosphere of Uranus. Changes in the starlight could help decipher the content of the Uranian atmosphere.

Unexpectedly, just before and just after the eclipse of the star, their instruments recorded a string of blips. They immediately guessed that the starlight was being eclipsed by something in orbit around Uranus. Later analysis gave definite proof that they had seen the rings around Uranus. This brilliant discovery was fully confirmed by the Voyager flyby in January 1986.

The KAO was also probably the first

THE CASE FOR MARS



AN AMERICAN ASTRONAUTICAL SOCIETY PUBLICATION

The Case for Mars III, This three-part set, based on a conference held July 18-22, 1987, Boulder, Colorado, will be published late 1988. Prepublication price for Part I (general) is $20 (soft cover), Parts II & III (technical) $60 (soft cover, both parts). No discount on these. Write for more information.

The Case for Mars II, Ed., Christopher P. McKay, 1985, Second Printing 1988, 730p, Hard Cover $60; Soft Cover $40 ($4 postage & handling)
This book provides a blueprint for manned missions to Mars and a continued presence on the planet's surface, including what technology is required, and what kinds of precursor missions and experiments are required for this undertaking. The material is based on a conference held July 10-14, 1984, Boulder, Colorado.

The Case for Mars I, Ed., Penelope J. Boston, 1984, Second Printing 1987, 348p, Hard Cover $45, Soft Cover $25
Included in this volume are mission strategy, spacecraft design, life support, surface activities and materials processing, social and political aspects.

Also numerous books on space published for the American Astronautical Society or distributed for other publishers are available from Univelt Inc. Write for a free catalog.

Among available books are:

Space and Society - Challenges and Choices, Volume 59, Science and technology Series, Eds., Paul Anaejinou, Nathan C. Goldman, Philip J. Meeks, 1984, 442p, Hard Cover $55; Soft Cover $35.
Subjects included are American government and space, political economics and space, foreign space programs, space applications, and the future. Index.

The Human Quest in Space, Volume 65, Science and Technology Series, Eds. Gerald L. Burdett, Gerald A. Soffen, 1987, 312p, Hard Cover $55; Soft Cover $45.
As the title suggests, the human role in the space program is stressed. Emphasis is placed on medical problems in long-duration space flight and the development of closed ecological systems including the pioneer work being conducted on Biosphere II in Arizona.

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to obtain a spectrum of the supernova in the infrared. On April 16, 1987, a near-infrared spectrum was obtained revealing one very strong hydrogen line with twin peaks, Paschen α, the meaning of which is not yet known, and a strong absorption feature possibly indicating that dust of clay-like minerals may surround the supernova envelope. These lines will help in understanding the supernova process. More KAO flights involving several teams of scientists have since been devoted to the supernova.

Other Favorite Targets

The total solar eclipse on March 17-18 of this year—visible 600 miles northwest of Guam—was another special opportunity for the KAO. Astronomers studying the solar atmosphere were interested in the few seconds at the beginning and end of the eclipse, when only a sliver of the Sun was visible from behind the Moon. Measurements at those moments will contribute to a model of the temperature and height distribution of the chromosphere, the middle section of the solar atmosphere.

Other favorite targets of infrared astronomers are the cool clouds of gas and dust that are just beginning to coalesce into stars. KAO studies of these protostars in the constellation Orion and elsewhere show that many of the dust grains are coated with ice and organic materials.

An important part of the KAO work is the study of galaxies, both our own and others. KAO astronomers have done pioneering work in imaging globular clusters, spherical star systems containing typically 100,000 of the oldest stars in our galaxy. In distant galaxies, KAO spectral studies show that much of their infrared radiation comes from massive stars just forming in the heart of giant molecular clouds.

Finally, with new detector improvements, the KAO can now be used to observe quasars, the most distant objects visible in the universe.

The Kuiper Airborne Observatory has proved so successful that a new version is being planned for the 1990s. This one will be housed in a Boeing 747 and will include state-of-the-art equipment of that decade.

The Galaxy and the Solar System

Roman Smoluchowski, John N. Bahcall, & Mildred S. Matthews, eds.

"...an important work that will make a valuable and long-lasting impression on our understanding of how galactic processes affect the solar system... it should (and will) be read by all those interested in the possible galactic connection between mass extinctions and other terrestrial processes. In addition, individual papers provide excellent surveys of areas of astronomy that are often not well covered elsewhere." —*Science*

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Environment

Continued from page 11

tion—around 200 joules/gram in time less than 0.1 second, preferably in times approaching 0.1 milliseconds or less—acoustic shock wave generation will occur and a nonlinear decrease in energy is required to produce death as a result (steam generation, if you will)."

In the "proof-of-principle" experiment, such energies could not be applied because of the limitations on peak pulse power of the 10 kilowatt magnetron used, and because of the relatively low coupling of applied power to the insect. The frequency used was not near the resonant frequency of the insect.

We have hypothesized that it is more than feasible to couple into biological or physiological frequencies. Future experimental work could determine the species-specific and tissue-specific resonances that are most efficient. While the power is absorbed on a total surface area, it may be concentrated on specific focal points in the biological organism.

An Inside Look

The Space Station: A Personal Journey
Hans Mark
Durham, N.C.: Duke University Press, 1987
264 pages, $24.95

There have been numerous books published about the U.S. space station over the past four years, but many are either simplistic or too "imaginative."

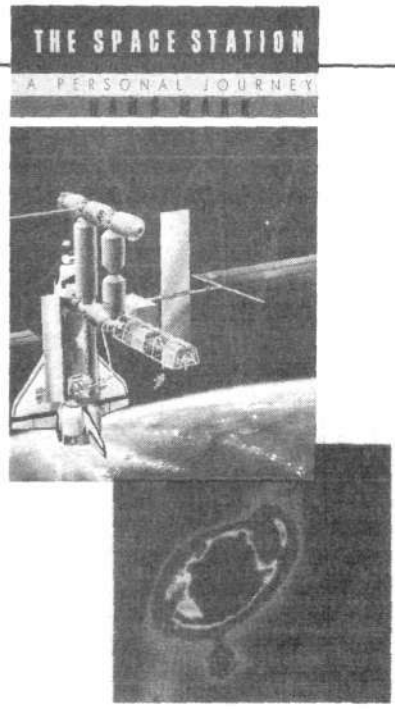
This one, however, sheds light on the reasons that the space station program is in the state it is in (see article page 14), and is an excellent contribution to political space history.

Its author, Dr. Hans Mark, was deputy administrator of the National Aeronautics and Space Administration (NASA) during the years that NASA was trying to persuade President Reagan to start the project.

Mark presents an important inside look at the decision-making process in the administration, the political opposition to the station program, and the lobbying to which he and NASA administrator James Beggs were forced to devote time in order to get the White House go-ahead.

Mark describes in detail the "interagency process" that delayed the decisions on space policy, the "zero-sum game" approach of science adviser George Keyworth, and the opposition of the military.

—Marsha Freeman



Redshift Controversy

Quasars, Redshifts, and Controversies
Halton Arp
Berkeley, Calif.: Interstellar Media, 1987
Hardcover, 198 pp., $19.95

Astronomer Halton Arp has studied galaxy-quasar associations since 1966. These associations disprove the accepted, simple relationship between the amount of redshift of an object and its recessional velocity and distance, since low redshift galaxies are associated with high redshift quasars.

This well-designed and illustrated book is a history of the observations—and the attacks, counterattacks, and suppressions of Arp's work—since 1966. The emphasis is on presenting the evidence, and in a form useful for both specialists and nonspecialists. It includes the related study of quantized redshift values that are also inconsistent with the accepted view.

Arp lost access to the Palomar 200-inch telescope in 1983. The committee allocating telescope time informed him in writing that his pursuit of galaxy-quasar associations was without value. Apparently, Arp had refused to conform his observations to the committee's rules for the universe. The following year, in which his access to the Carnegie Observatory at Las Campanas was terminated, he received the Alexander von Humboldt Senior Scientist Award.

Arp is currently on the staff of the Max Planck Institute for Physics and Astrophysics in Munich.

—David Cherry

The Largest Roadmap

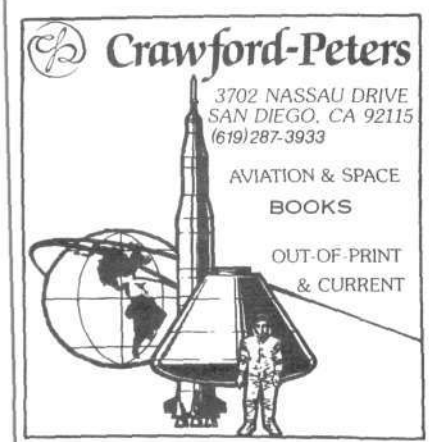
Nearby Galaxies Atlas
R. Brent Tully and J. Richard Fisher
Cambridge University Press, 1987
Spiralbound, 8 pp. and 23 color foldout plates, $59.50

This is the only atlas of nearby galaxies that even comes close to reflecting the extent of today's knowledge. Its most complete predecessor reflects the state of knowledge 20 years ago.

The 2,367 galaxies known in 1978 with redshifts corresponding to recessional velocities of 3,000 kilometers per second or less are included. The galaxies are first shown in two-dimensional sky maps, and again in a three-dimensional presentation.

The authors, both radio astronomers, believe that the atlas demonstrates more structure than is generally appreciated. The plane of the Local Supercluster, they say, is more extensive than has been thought, and nearby clouds of galaxies tend to align themselves parallel to it.

—David Cherry



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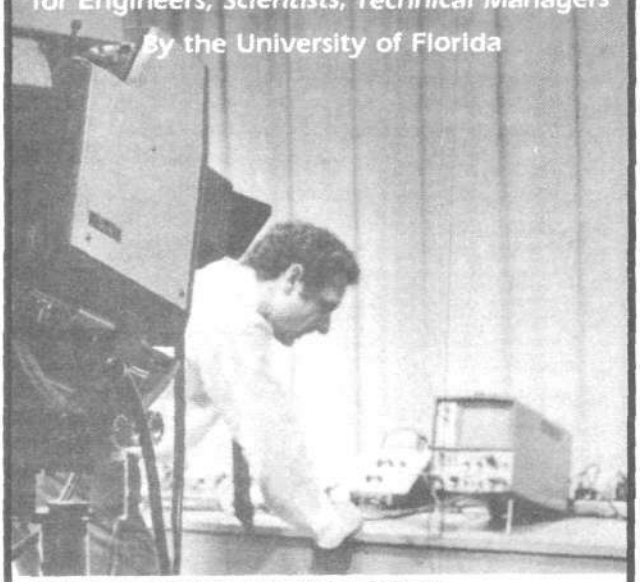

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—Cambridge University Press—

Meteorites and Their Parent Planets

Harry Y. McSween, Jr.

"...Of the shower of meteorites books that has hit the shops in the past few years, this is probably the best."
—***New Scientist***

"...an easy-to-read introduction to the science of meteoritics that cogently integrates the many disparate lines of evidence concerning these samples of our solar system and their origins. It can be read with profit by those who wish to expand their general knowledge and may, it is to be hoped, tantalize some young people into pursuing careers in this intriguing field."—***Science***

Intended for the nonscientifically trained reader, *Meteorites and Their Parent Planets* provides a comprehensive and readable introduction to the study of meteorites and their significance. Unlike all other books on the subject, which merely classify meteorites, this book explores their origins by tracing meteorites back to their parent bodies—the sites of various geological processes. In this way, the author uses his subject as a key to unlocking the secrets of the orbiting worlds, such as asteroids, planets, and the moon, from which meteorites are thought to originate.
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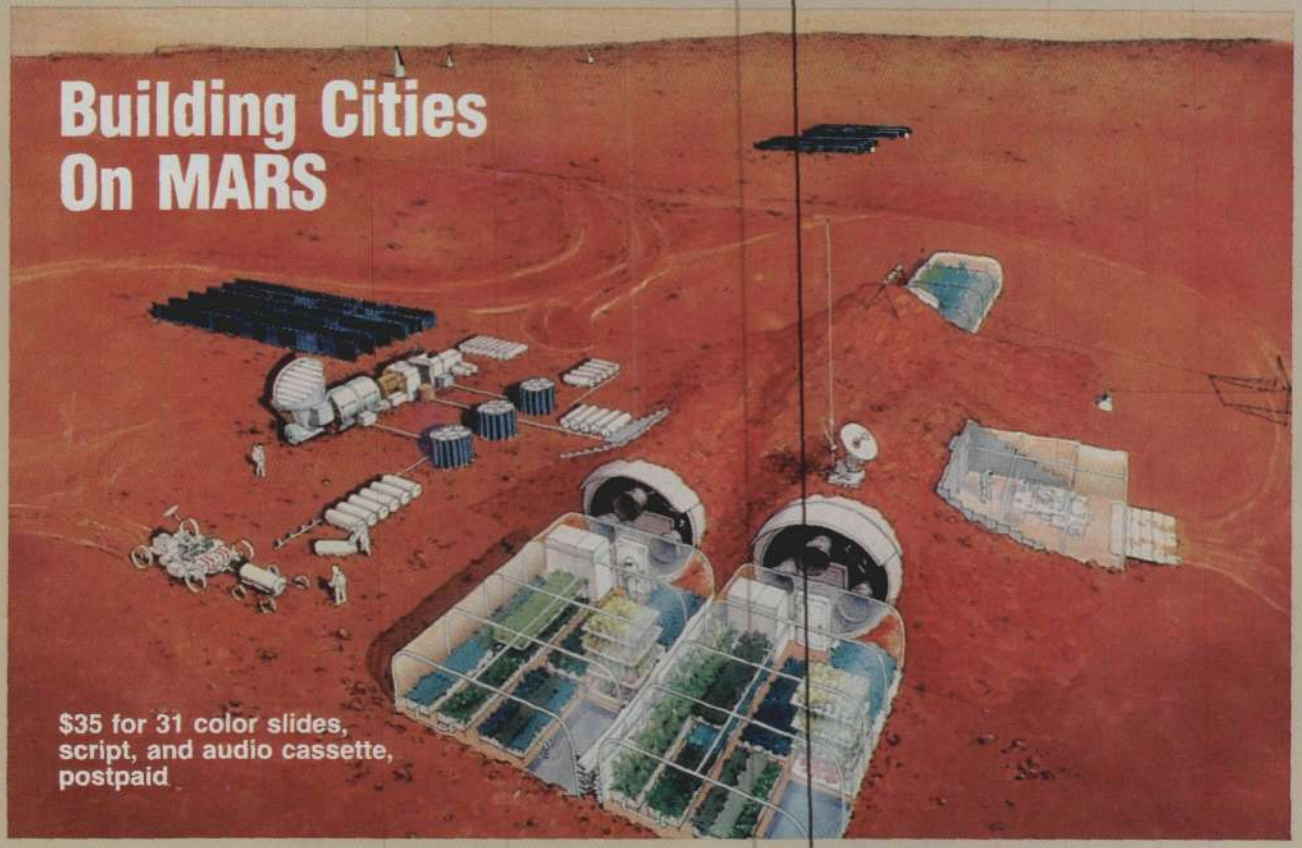

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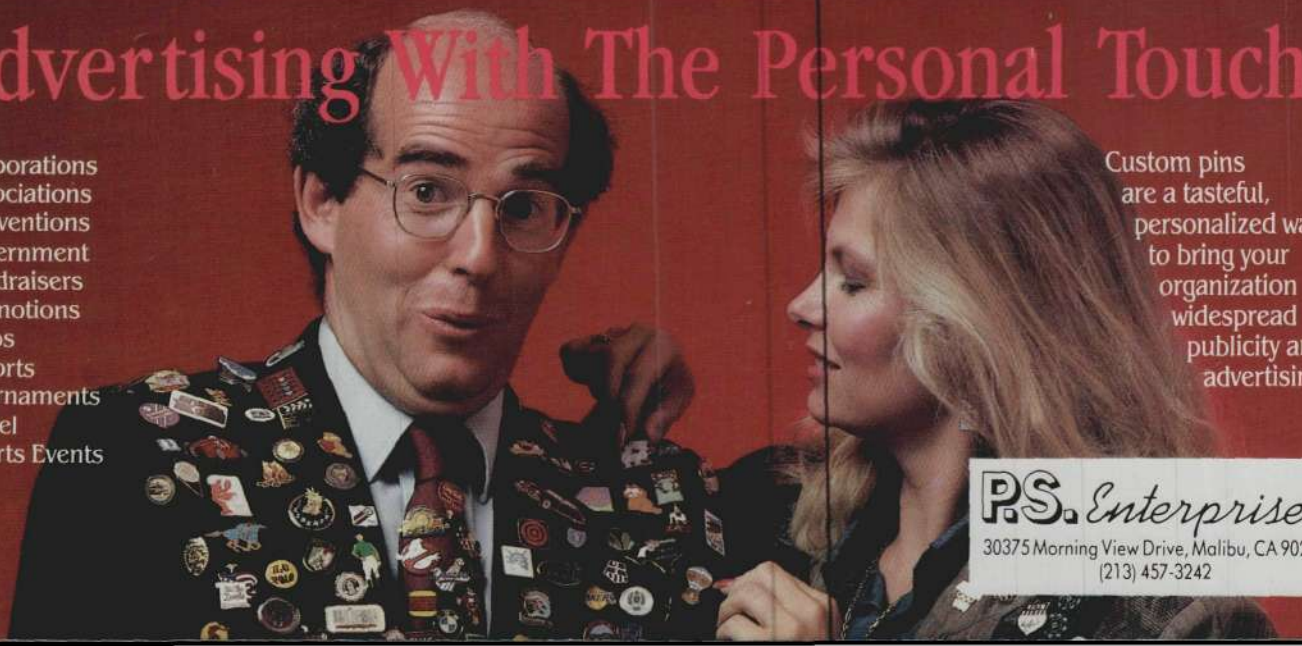

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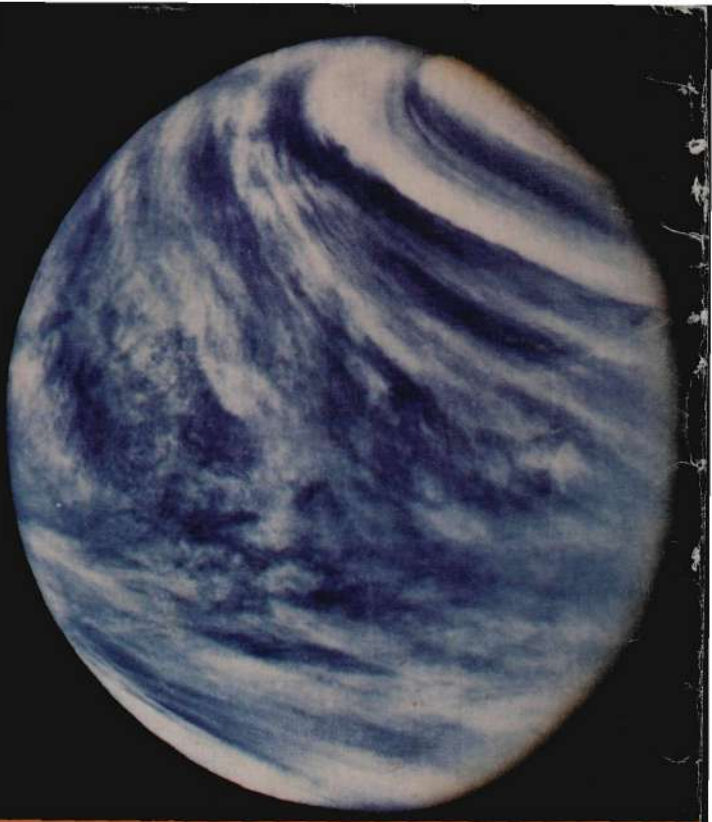
In This Issue:

CREATING A SOLAR SYSTEM IN SPACE AND IN THE LABORATORY

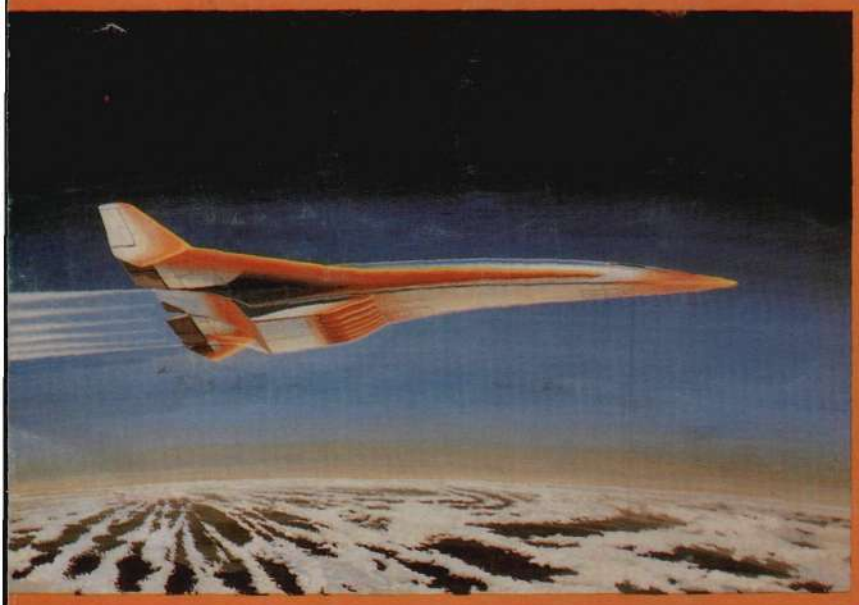
Fusion scientists have worked hard to create a fusion reactor in the laboratory that mimics the work of the Sun and the stars. Now Daniel Wells shows how the creation of fusion plasma vortices in the laboratory tells us how the solar system was formed. As Wells demonstrates, our solar system began as force-free plasma vortices, a set of concentric cylinders that looks like a jelly roll. Each layer of the roll contracts to a ring, which then contracts to form the mass of a planet. Like Kepler, Wells derived his theory from the physical geometry of the planets and the Sun, independent of any "forces" assumed to act at a distance.



Venus: In Wells's system, the mass of the planet began as one ring in a vortex cylinder that collapses into a disk. The planet's orbit follows that of its original ring.

NASA

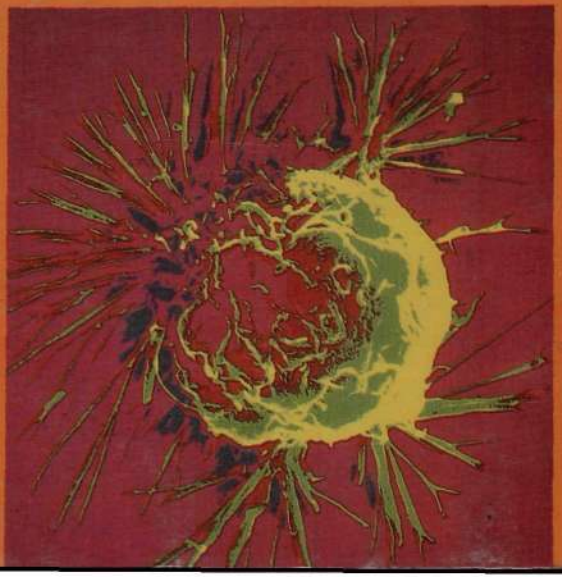
Leslie Bossinas/NASA



SPEEDING THROUGH THE 21ST CENTURY IN AIR-BREATHING SPACE PLANES

Here and in Europe, designs are on the drawing boards and in the engineering stage for new vehicles that will transport 21st-century man between the continents on Earth and between the planets in space. Charles B. Stevens reviews the rapid progress of the U.S. program, which expects to launch a prototype of the air-breathing X-30 space plane before the end of 1994. The $3.3 billion project promises not only speed but economy, carrying 100 times more payload at a cost nearly 100 times less than that of current space transportation.

This artist's concept of the space plane shows the aerothermal heating effects caused by friction as the vehicle flies hypersonically through the atmosphere.



National Cancer Institute, NIH

Scanning electron microscope view of a human breast cancer cell showing its overall shape and the intricate details of its surface.

EXPLOITING ELECTROMAGNETIC PROPERTIES OF LIVING MATTER

What do locusts, cancer cells, and the AIDS virus have in common? They are all life-threatening scourges that man can eradicate with the use of properly tuned electromagnetic energy. For locust swarms, the specifics of such killer pulses are already known, as Warren Hamerman outlines. For cancer and AIDS, the specifics are not yet completely known; however, as Wolfgang Lillge and John Grauerholz report, new directions in optical biophysics research presage better diagnosis and treatment for both deadly diseases.