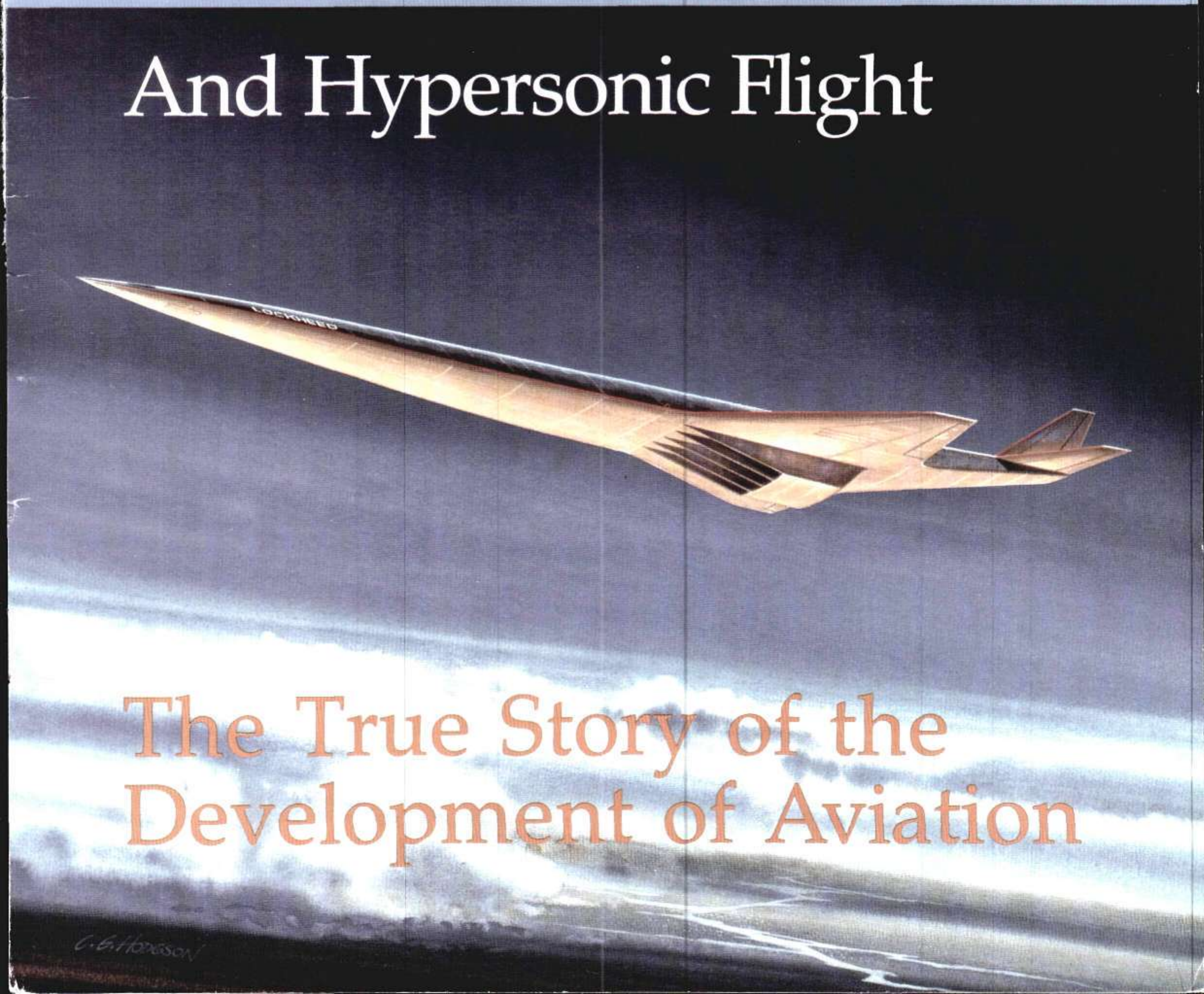
Beam Report
SDI CRITICS REFUTED

FUSION

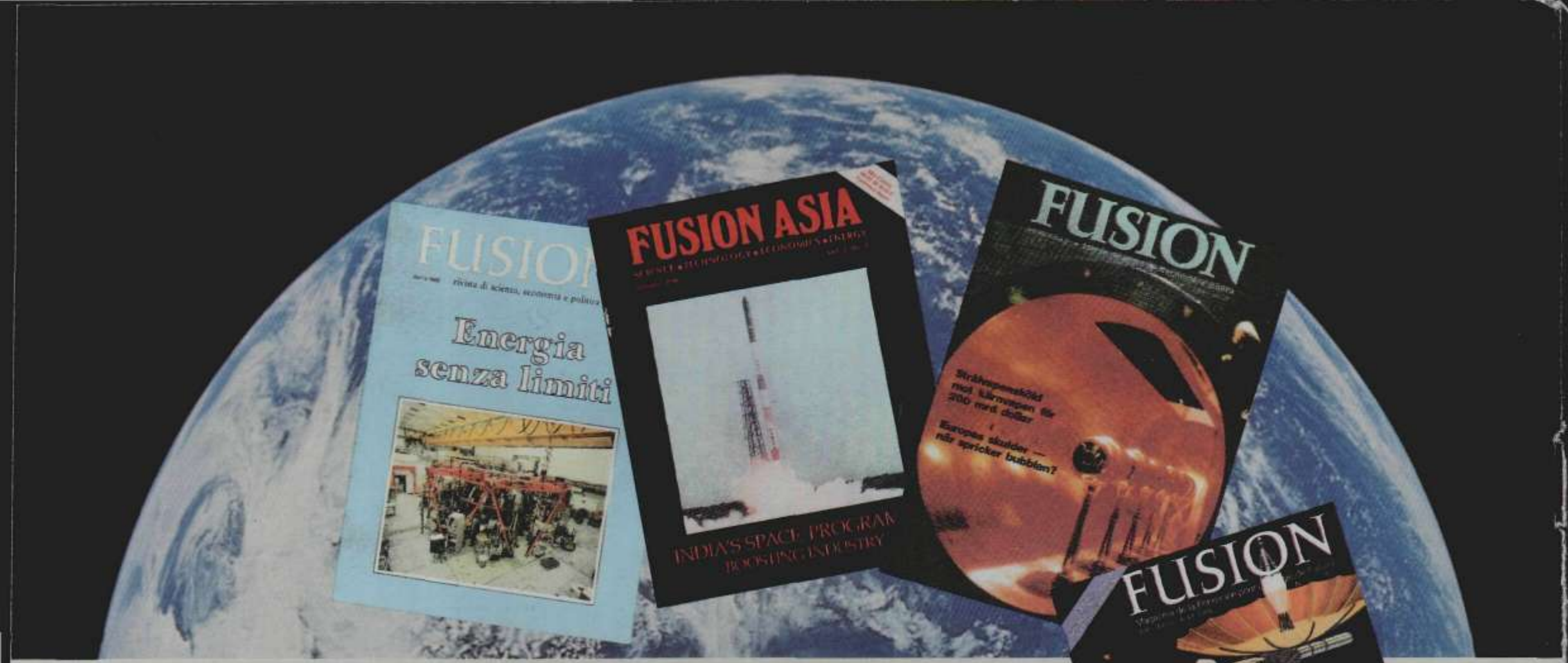
SCIENCE • TECHNOLOGY • ECONOMICS • POLITICS
January-February 1986
$2.50 $2.75 CANADA

Leonardo da Vinci

And Hypersonic Flight



The True Story of the Development of Aviation



Expand the world's view!

Join the Fusion Energy Foundation.

Subscribe to Fusion magazine.

Enclosed is:

- ☐ Sustaining membership $250
- ☐ Individual membership $75
- ☐ Corporate membership $1,000
  (All memberships include 6 issues of *Fusion*.)
- ☐ 1-year subscription to *Fusion* $20 (6 issues)
- ☐ 2-year subscription to *Fusion* $38 (12 issues)
- ☐ 1-year subscription to *Fusion* (airmail foreign) $40

Now you can subscribe to *Fusion* in 5 languages

☐ *Fusion* in Spanish, French, Italian, German*, or Swedish or *Fusion Asia* in English—$40 (4 issues)

* 6 issues per year.

Name____________________

Address____________________

City__________ State________ Zip________

MasterCard, Visa accepted

Credit card__________ Exp. Date________

Card number____________________

Signature____________________

Contributions to the Fusion Energy Foundation are tax deductible.
Make checks payable to Fusion Energy Foundation. Gift cards available on request.
Please print gift subscription names and addresses on a separate page.

Mail order form to: Fusion Energy Foundation, Box 17149, Washington, D.C. 20041-0149

Telephone orders: (703) 689-2490

FUSION

SCIENCE • TECHNOLOGY • ECONOMICS • POLITICS

January-February 1986 Vol. 8, No. 1

Features

News

Departments

FUSION (ISSN 0148-0537) is published 6 times a year, every other month, by the Fusion Energy Foundation, P.O. Box 17149, Washington, D.C. 20041-0149. Tel. (703) 689-2490. Dedicated to providing accurate and comprehensive information on advanced energy technologies and policies, FUSION is committed to restoring American scientific and technological leadership. FUSION coverage of the frontiers of science focuses on the self-developing qualities of the physical universe in such areas as plasma physics—the basis for fusion power—as well as biology and microphysics, and includes ground-breaking studies of the historical development of science and technology.

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

Subscriptions by mail are $20 for 6 issues or $38 for 12 issues in the USA; $25 for 6 issues in Canada. Airmail subscriptions to other countries are $40 for 6 issues.

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

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

ISSN 0148-0537 USPS 437-370

On the cover: Lockheed's design for a hypersonic aircraft. Cover design by Dave Hall; photograph courtesy of Lockheed.

What the New Year May Bring

According to medical experts, the number of people contracting AIDS or Aquired Immune Deficiency Syndrome virus is doubling every six months. The Atlanta Center for Disease Control estimates that there are now 12,000 victims of the disease in the United States. If the disease continues to spread unchecked at this rate, by January 1993 the entire population will have been infected. And at this point, the disease leaves no survivors.

The idea that AIDS will limit itself to certain "target" groups—drug users, homosexuals, and hemophiliacs—has now been exposed by leading medical specialists as a dangerous delusion. Dr. John Seale, for example, a tropical medicine expert in London, has documented that the AIDS virus is also found in respiratory secretions—like the airborne form of pneumonic plague, which is even more virulent than bubonic plague. In the tropics, it is already being spread by the respiratory route, Seale documents. (See this issue's Special Report.)

A Swedish team just back from Africa has reported that there is a direct relationship between economic collapse, squalor, and the rapid spread of AIDS. Twenty percent of the population of Rwanda is reported to be carrying the AIDS antibody—at minimum indicating their exposure to the disease—and medical experts estimate that this figure is probably an underestimate by a factor of 10.

The AIDS Virus Has No Civil Rights

Incredibly, the liberal lobby is defending the civil liberties of the AIDS virus, in the name of protecting the rights of homosexuals et al. to spread the disease unchecked. A child with head lice is sent home from school, yet the right of children and teachers afflicted with the deadly disease AIDS to remain in school and endanger the life of countless children is defended by organizations like the American Civil Liberties Union.

And let no one suppose that these liberals have the interest of the AIDS victim in mind. Indeed, what could be more dangerous for an individual whose immune system has been severely weakened than to be continuously subjected to the many infectious diseases that circulate in a school environment.

The Solution

AIDS is *the* political hot potato. The AIDS epidemic can be reversed only by introducing massive emergency public health measures, and this means spending money. Not only must the present trend to cut back on medical services be immediately reversed, but the level of services to which we were accustomed must be vastly increased.

At the same time the precarious situation of sanitation systems in major U.S. cities must be remedied. The elderly, the mentally deranged, and drug users must be taken off the streets, where they currently live, die, and spread disease, and they must be given proper treatment. Lastly, the present rate of deterioration of the diet of the whole of the population can no longer be tolerated. There is a strong correlation between intake of protein and resistance to disease. To fight disease, therefore, we need to increase the protein content of the U.S. diet, despite the wails of the antiprotein faction that preaches the virtues of a vegetable and grain diet.

The bottom line of this program is that in order to deal with the problem of the epidemic spread of AIDS, the government will first have to admit that the U.S. economy is a dangerous and escalating decline, not the much-vaunted recovery.

A Cultural Shift

The year 1986 must be a turning point for our nation. For too long, Americans have been bludgeoned by the mass media into tolerating cultural relativism. None too soon, people are finally recoiling from toleration of such outrageous frauds as *gay* rights, which have even included the rights of avowed pederasts to teach in the schools.

But gay rights and the virus of liberalism are only symptomatic of the cancer of our so-called postindustrial society. The present deepening depression has been justified by the Club-of-Rome Malthusians, the Venetian and Swiss International Monetary Fund crowd, who circulate the lie that mankind cannot provide for a growing population. These genocidalists have deliberately sponsored and funded the environmentalist mafia in order to destroy the nuclear industry and ensure that we will not have the wherewithal to support future generations. These oligarchs gloat as the populations of Africa, Ibero America, and Asia are savagely reduced by famine and plague. And they are joined by the Soviets, who are bending the whole of their propaganda machine to convince the West that AIDS is not a serious disease. Clearly the Soviets will not weep if the United States goes into a self-destruct mode.

We still have time, but not too much. Let us begin the New Year with the same dedication to progress, with the same cultural optimism, with which Leonardo da Vinci accomplished a renaissance in his own day.

Whom Do You Know Who Needs to Read *Fusion*?

Fusion has something special to celebrate this year—a return to a regular and timely publication schedule of six issues a year. With your help, in another year, we could return to a monthly schedule.

Here's what you can do to ensure that our subscriptions grow back to the 150,000 level: Put *Fusion* in your community and school libraries. Organize your friends and coworkers to subscribe. Give gift subscriptions to your local, state, and federal legislators, or to other people in decision-making positions who need to know what *Fusion* will tell them.

Letters

Lighter-Than-Air Vehicles for Africa

To the Editor:

I read with interest the article in the January-February issue of *Fusion* "How to Stop the Famine in Africa" (by J. Scott Morrison, p. 10).

As an additional solution to the many problems that exist, I am enclosing information on the lighter-than-air LTA 20-1 airship. With a range of 800 km, a full payload of 60 tonnes, and operational maneuverability and handling similar to a helicopter, our craft would be a tremendous asset to the African relief problem.

At present, we are negotiating the building of our first 60-tonne prototype as well as a 55-foot two-man version for Expo '86. We expect delivery of our commercial crafts to begin in 1988. I look forward to your comments on the LTA 20-1 and to discussing with you the potential for our craft in the African relief program.

Ray Trudeau
Magnus Aerospace Corporation
Ottawa, Ontario, Canada

The Editor Replies

Both Scott Morrison and Col. Molloy Vaughn, who proposed an emergency program for Africa in the July-August issue, were enthusiastic about the possibilities for the LTA. We plan to write about it at more length in a future issue.

On Nuclear Bigotry

To the Editor:

I am appalled, amazed, and angry at the magazine you edit. It is the most right wing, ridiculous, bigoted, one-sided description of facts that I have ever read. As journalists, the least you could do to help support the nuclear power industry is represent in an unbiased manner industry viewpoints. Instead your viewpoints are as prejudiced as the antinukes are on the other side.

It would be most beneficial to the nuclear industry if there were a magazine that both sides of the nuclear issue could read and become factually informed with. However, as yet, there isn't one that treats both arguments fairly. No matter how much *Fusion* believes it, one side is not *always* right.

As a supporter of the nuclear industry, you are giving us an even worse name and image than what is already perceived. Instead of condemning everyone that has a different opinion from *Fusion*, particularly those people who believe in alternatives, you should be open enough to listen and work together toward a more peaceful, healthy, and environmentally sound world.

Although this letter will be filed in the circular file once read by you, perhaps you will at least for a moment reflect on you own values and the bigotry your magazine purports.

Barbara V.E. Martocci
Brattleboro, Vt.

The writer is an employee in the nuclear power industry.

The Editor Replies

Any other comments?

Giving Credit Where Due

To the Editor:

I have always enjoyed reading your informative fusion report. I am glad you emphasized our contribution at Oak Ridge National Laboratory to the Neutral Beam Heater Developing in the September-October 1985 *Fusion* ("Multi-Beam Heavy Ion Accelerator Moves to Forefront in Fusion," p. 17). I am always proud of technology achievements performed by my colleagues at Oak Ridge National Laboratory.

However, I am sorry that you were misinformed and regret that you misinformed others. In the caption for Berkeley Laboratory's neutral beam apparatus, the statement that "Berkeley's research helped the Princeton PLT tokamak reach record temperatures in 1977" is questionable. In fact, the neutral beam heaters used to heat the PLT plasma were designed, developed, and qualified by my colleagues here at Oak Ridge.

C.C. Tsai
Plasma Technology Section
Oak Ridge National Laboratory

The Editor Replies

We are sorry to have left out Oak Ridge's major role in designing and developing the neutral beam heaters used on Princeton's PLT.

Rekindling the Spirit of The Space Program

To the Editor:

I have recently returned from the Space and Rocket Center in Huntsville, and having been a participant in the Saturn Program I was thrilled by the fact that these programs may once again be rekindled—that dynamic spirit that I felt as part of the program.

My educational background is physics, and although for the past 10 years I have pursued an industrial manufacturing career in instrumentation, I miss the creative spirit that I felt while working as a physicist.

I am currently seeking employment in the Huntsville area in the SDI program. Before making the trip to Huntsville, I was amazed to read in *Physics Today* that over 1,000 scientists have signed a petition against the SDI, including 56 Nobel Prize winners. Just yesterday I discussed with a former physics professor the pros and cons of some of the issues that have been raised. To sum it up—Mutually Assured Survival and the atmosphere that would usher in an "Age of Reason" holds forth much more promise than Mutually Assured Destruction.

Thanks to all who have had a part in opening my mind to this subject.

Wayne Hall
Mobile, Ala.

The Editor Replies

We are sure that other *Fusion* readers would also be inspired by reading the book *Colonize Space: Open the Age of Reason,* the proceedings of an FEF conference commemorating space scientist Krafft A. Ehricke. It is available from the FEF at $9.95 per copy plus $1.50 for postage.

News Briefs

Government of India

India's Fast Breeder Test Reactor

INDIA'S FAST BREEDER TEST REACTOR COMES ON LINE

India's Fast Breeder Test Reactor (FBTR) generated net energy for the first time Oct. 18. This experimental facility in Kalpakkam, Tamil Nadu, is the first breeder reactor built by a developing nation. It uses the basic French design for a liquid-sodium-cooled fast breeder, but has a unique plutonium-rich mixed carbide fuel that was developed by Indian scientists to solve the problem of India's lack of uranium reserves. The fuel is 30 percent plutonium carbide and 70 percent uranium carbide, which has a better thermal conductivity value than oxide fuel. Initially, the FBTR will run at low power for experimental use. In a year, when it is coupled with a steam generator and turbine, it will produce about 14 megawatts of electrical power.

NATIONAL ACADEMY OF SCIENCES REFUSES TO RENEGE ON FUSION

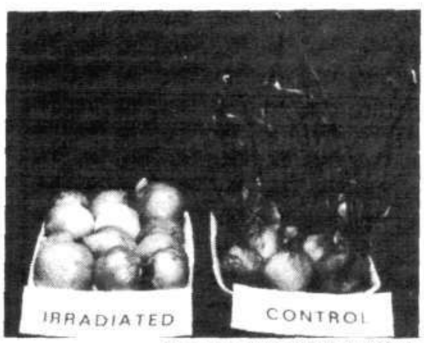
A National Academy of Sciences review committee refused to tone down its interim report on inertial confinement fusion research, which praised the national accomplishements and prospects for laser fusion. The report noted that inertial confinement was making a major contribution to the nuclear weapons program and that it was being unnecessarily smothered by top security classification. Both the White House Office of Science and Technology Policy and the Division of Classification of the Department of Energy leaned on the committee to temper its assessment. One committee member commented: "The committee has not and will not change a word in its interim report. . . . We listened to the Office of Classification's views for two hours and, when the session ended, we were more convinced than ever that we were right in criticizing their policies."

ANTINUCLEAR PROTESTERS GET MAXIMUM SENTENCE IN RHODE ISLAND

Five antinuclear protesters who damaged six Trident missile tubes in Electric Boat's shipyard in Quonset Point, R.I., were given a maximum sentence of one year in prison and a $500 fine by Rhode Island Superior Court Judge John P. Bourcier Oct. 18. The judge noted that he did not doubt the group's sincerity. "But when one strips the noble labels from where they have been pasted, one finds your acts are the first cousin to the bomb-throwers, grenade-throwers, and the airplane hijackers," he said. "They do this, break a law, because they want to propagandize a view. Adolf Hitler sincerely believed in his views and because of him there are millions of people dead."

GREEN PARTY'S PETRA KELLY DROPS LAWSUIT

West German Green Party head Petra Kelly has filed papers seeking to dismiss her June 1983 lawsuit against the newspaper *New Solidarity* alleging that it was libelous to call her a "political whore." Kelly submitted an affidavit claiming that she was not continuing her lawsuit because she was "too busy." However, her lawyers last August sought to negotiate a voluntary dismissal of the action because they admitted they could not succeed on the merits of the case. The article describing Kelly's activities was reprinted in the September-October 1985 issue of *Fusion*.



International Atomic Energy Agency

One of the benefits of low-level irradiation is sprout inhibition in onions, garlic, and potatoes.

FEF TESTIFIES AT CONGRESSIONAL HEARINGS ON FOOD IRRADIATION

The Fusion Energy Foundation testified in support of the Federal Food Irradiation Development and Control Act of 1985, H.R. 696, at hearings held by the House Agriculture Committee Nov. 18. The bill, introduced by Rep. Sid Morrison (D.-Wash.), would set up a Joint Operating Commission to coordinate research, encourage private investment, and educate the public. It would also require national uniformity in the regulation of food irradiation. The FEF recommended that the bill include the rapid commercialization of electron beam irradiation, specifically the spinoff of the beam defense program developed at Lawrence Livermore National Laboratory, and an aggressive program to transfer the technology to the developing sector. Others who testified for the bill were scientists who pioneered the technology, food industry representatives, and the American Medical Association. The environmentalists who opposed the bill called it a "boondoggle of the nuclear weapons industry."

Metropolitan Edison Co.

Workers doing scabbling work inside TMI-2. The scabbling process removes the first layer of concrete.

EXPOSURES OF TMI-2 WORKERS KEPT LOW DURING CLEANUP

Cleanup workers at the Three Mile Island 2 plant in Pennsylvania have had less collective exposure to radiation than workers at most operating nuclear plants, GPU Nuclear, the plant operator, reported this month. After six years, the risk from occupational radiation exposure has been about the same as smoking two cigarettes per year, the company said.

NEW YORK JUDGE THROWS OUT ANTINUCLEAR REFERENDUM

N.Y. State Supreme Court Judge Charles Kuffner ruled Oct. 23 that a referendum barring a nuclear-capable Navy base on Staten Island in New York City is unconstitutional, and he ordered it off the ballot. The referendum would have amended the City Charter to bar New York from selling or leasing its land for storing nuclear weapons. Kuffner's decision, upheld by the state's appellate courts, vigorously defended the basic principles of the U.S. Constitution. "The City of New York may not legislate, by referendum or otherwise, in such fashion as to hinder the effectuation of national security objectives," he wrote. "We are one people. The U.S. Constitution vests in the federal government the obligation to provide defense to the entire nation and all of its people without regard to their location. A necessary correlative to the duty imposed upon the federal government is the right it enjoys to make and effectuate decisions respecting the deployment of defense systems, within the United States, unfettered by local regulation designed to impede its effort."

FEF'S FREEMAN DISCUSSES ROLE OF GERMAN SCIENTISTS

Addressing the aerospace engineers at the third annual conference of the New Orleans American Institute of Aeronautics and Astronautics Nov. 7-8, Fusion Energy Foundation director of industrial engineering Marsha Freeman reviewed how the activities of the Apollo program, as well as today's space station, were planned as early as the 1920s by the German rocket scientists. Using slides of drawings by Hermann Oberth and paintings illustrating the works of Wernher von Braun and Krafft Ehricke, Freeman also demonstrated that the next-step industrial development of the Moon and the colonization of Mars had also been planned in broad outline over the past 50 years.

TANAPURA NAMED ECONOMIC ADVISOR TO THAI TRADE UNIONS

Pakdee Tanapura, director of the Fusion Energy Foundation in Thailand, has been named economic advisor to the Thai Trade Union Confederation, which commands some 200,000 workers in Bangkok alone.

LOUSEWORT LAURELS TO NEW YORK TIMES REPORTER PHILIP M. BOFFEY

This month's Lousewort Laurels award goes to *New York Times* reporter Philip M. Boffey for his article in the *Science Times* Nov. 26, 1985 calling fusion "an elusive dream." Noting that the Geneva summit brought "new life" to the fusion effort, Boffey then quotes unnamed skeptics to proclaim that "at this point, no one is certain whether fusion energy will ever prove possible or will ever make an important contribution to the nation's power supply." Boffey omits mention of any recent research advances.

Viewpoint

Acid Rain: The Real Story

Dr. W. B. Innes

Acid rain has been a favorite complaint of environmental extremists, starting with a media event in 1979. More recently, it has been a subject of dispute between the United States and Canada.

What is the real story? How acid is the rain and what is the trend over the years? Are fish, trees, crops, soils, statuary, and human health seriously threatened as alleged? Should very costly further controls be retrofited on Midwest power plants to solve the problem?

Based on the scientific evidence,[1] here are some answers:

First, although rain is generally acidic in the northeast United States (the pH level is 4-5 compared with 5.5 from carbon dioxide content),[2] there has been insignificant change since reliable measurements were started in 1966. However, the acidity seems to have increased prior to this both from increased SO_x-NO_x[3] emissions and from increased controls on particulate. The particulate, being alkaline, serves to neutralize the acidity.

Second, the effects of acid rain depend more on its composition than its acidity. Nitrates are rapidly and beneficially assimilated by vegetation. This produces a hydroxide ion that neutralizes associated acidity. Thus practically no soil or lake acidification is caused by nitric acid, as shown by very low nitrate levels in lakes. This is only partially true for sulfuric acid, judging from lake sulfate levels.

Third, only a few of the lakes in North America are too acidic for trout (pH level 5). These are located in the Northeast at high elevations, primarily in the Adirondacks. Documented acidic lakes in Canada appear to be limited to those downwind from the largest SO_x source in North America, the INCO nickel smelter in Sudbury, Ontario.

Canadian concern appears to be more related to future possible lake acidification than to current conditions. However, there are practically no trend data to justify such fears, and skeptics claim that Canadian policy is more related to the need to export excess hydroelectric power than to harm from acidification. Northeast U.S. nuclear power-plant policy and acid rain policy are both affected by the availability of this low cost power.

Fourth, decreased trout populations are more the result of increased fishing pressure, decreased stocking, and so on, than to acidity.

Fifth, harm to trees from acid rain is extremely questionable. The oft-cited red spruce damage at Camel's Hump, Vt. and damage to trees in West Germany's Black Forest now appear to have been very exaggerated[2] and there is no real evidence that acid rain was implicated. Recent work suggests that such isolated situations relate more to drought, disease, and ozone than to rain acidity. On the other hand, fertilizer benefits from nitrates in acid rain are substantial.

Sixth, crops and grasslands generally benefit from acid rain because of and sulfates. Acidity is rarely a problem and grasslands generally have alkaline soils.

Seventh, limestone buildings and statuary apparently are affected by local SO_2 emissions that can act to convert calcium carbonate to hydrated calcium sulfate. Resultant dimensional differences appear to effect decrepitation. However, acid rain per se tends to clean off soot and other deposits by its leaching action. In fact, acid rain removes about a millionth of an inch per year of the surface on the average at current acidity levels in the Northeast United States.

Eighth, human health effect claims from acid rain have not been documented and are based on alleged higher than normal levels of heavy metals in drinking water from acid leaching of soils.

The remedy proposed by environmentalists is the installation of even more complex control equipment on present Midwest utility sources. Continuing control measures reduced total SO_x emissions by 25 percent from 1973 to 1984. Such further controls would cost \$3 to \$10 billion per year, and their effect is expected to be minimal upon rain acidity or fishlife. On the other hand, the established remedy of simply adding limestone to acid lakes is a quick, low-cost solution. This promptly brings lake pH to the optimum value and increases levels of fishlife. The costs for so treating all acidic Adirondack lakes, as estimated by the state of New York, is \$5 million per year.

In summary, solid evidence of harmful effects from acid rain is limited to a decrease in fishlife in a few lakes downwind from major SO_2 emission sources, while there are substantial acid rain benefits. Further expensive controls on Midwest power plants are not needed since lake acidities can be readily corrected by inexpensive limestone additions.

Dr. W.B. Innes has been a consultant in the fields of catalysis and air pollution control since 1964. His work has involved thermocatalytic instrumentation for air pollutants and comprehensive analysis of the NO_2 issue. Prior to that he served as group leader and research associate in American Cyanamid's catalyst group.

Notes

1. For example, see the author's article in *Chemtech* **14**: 440-447, (1984), and P.D. Manion's article in the Journal of the Air Pollution Control Association **35**: 619-622 (1985).
2. A pH level of 7 is neutral; more than 7 indicates increasing acidity, while less indicates increasing alkalinity.
3. SO_x indicates variable amounts of sulfur dioxide and NO_x indicates mostly nitrous oxide.

How AIDS Spreads Like TB

by John Seale, MA, MD, MRCP

Editor's Note

This paper, dated Aug. 19, 1985, was originally titled "Chronic Lymphoid Interstitial Pneumonitis and Probable Transmission of Lymphadenopathy-Associated Virus (LAV/HTLV III) by Respiratory Aerosols." Seale, an expert on tropical disease from London, has been intensively studying the outbreak of AIDS in tropical areas, particularly Africa. Until the late 1970s, Seale was in the Venereal Disease Division of St. Thomas/Middlesex Hospital.

We are publishing this technical paper in order to alert readers to the grave danger of AIDS, which has been documented by scientists worldwide yet ignored and covered up by politicians and the liberal media. The normally appropriate journals irresponsibly rejected this article for publication.

The essential point the article documents is that AIDS is now found in pulmonary fluid. This means that as lesions develop in the lungs, causing the infected person to cough, and so on, AIDS can be transmitted in the same manner as tuberculosis. Note that LAV is the French name and HTLV the U.S. name for the AIDS virus.

Other research not referenced in this article has demonstrated that up to 15 percent of HTLV virus is still present in dry saliva after one week.

* * *

Lymphadenopathy-associated virus (LAV or HTLV III) was isolated a month ago by workers at the Pasteur Institute and at the Pitie-Salpetrière, Laennec, and Claude Bernard Hospitals in Paris, from bronchoalveolar lavage fluid of a 30-year-old black Haitian woman with AIDS related complex (ARC).[1] This finding may explain the observation that acquired immune deficiency syndrome (AIDS) affects men and women equally in Haiti and Central Africa. It also raises the ugly possibility that LAV may often be transmitted by respiratory aerosols in the tropics.

The woman had suffered from an-

orexia, weight loss, and intermittent fever for over two years, and from dyspnea on exertion for one year. The only abnormality detected on physical examination was generalized lymphadenopathy; there were no abnormal pulmonary signs. However, chest X-ray films showed diffuse reticulonodular infiltrates, and lung biopsy revealed lymphocytic and plasma-cell infiltration of the alveolar septa and bronchial walls, characteristic of lymphoid interstitial pneumonitis.

The bronchoalveolar lavage fluid contained 18 million cells per milliliter (comprising macrophages and lym-

The Russian Angle to the AIDS Epidemic

The 100 percent lethal disease, Acquired Immune Deficiency Syndrome (AIDS), has hit the Western world like a bombshell. If its spread is not arrested, the experts fear, its devastation will soon be worse than that of nuclear war. What is the Soviet angle in the spread of AIDS?

The coordinator of all AIDS task force work at the Geneva-based World Health Organization (WHO) is none other than a Russian named Sergei Litvinov, the assistant secretary general of WHO for Communicable Diseases. By his own admission to a European journalist, Litvinov is designated to coordinate all AIDS work globally for WHO in Geneva.

Litvinov, who was trained as an epidemiologist at the Institute of Tropical Medicine and Parasitology in Moscow, is still an official of the Soviet Ministry of Health. He is not only responsible for coordinating the AIDS activities of WHO, but also the activities of the Centers for Disease Control in Atlanta, Ga.

What is Litvinov's position on AIDS? He peddles the Soviet propaganda line. As he told a journalist, "There has been a panic and exaggeration emanating from the originating country where AIDS developed—namely, the United States of America." The Soviet Deputy Minister of Health Pyotr Burgasov made this charge more explicit in the Soviet trade union newspaper *Trud* Oct. 6. Asserting that there were "no cases of AIDS in the U.S.S.R.," Burgasov said that the reason for the high number of cases in the "degenerate" West was the sexual perversity and drug use.

—*Warren J. Hamerman*

phocytes, of which 2 million were T4 lymphocytes) without evidence of blood contamination. LAV was isolated from the lymphocytes, but appropriate staining and culture of the lavage fluid showed no evidence of pulmonary infection by *P carinii,* fungi or any virus other than LAV.

Other workers have already reported markedly increased lymphocytosis in the bronchoalveolar lavage fluid from patients with AIDS and ARC.[2] Lymphoid interstitial pneumonitis has been found in infants with AIDS[3] and in adults with ARC.[4] The chest X-rays of large numbers of patients in Zaire with ARC show diffuse reticulonodular infiltrate characteristic of lymphoid interstitial pneumonitis.

On June 28, 1985, Centers for Disease Control (CDC) belatedly recognized these observations and redefined AIDS to include histologically confirmed chronic lymphoid interstitial pneumonitis with positive serological tests for LAV/HTLV III.[5] However, the new CDC definition only applies to children under 13 years of age; the 30-year-old Haitian woman above, the thousands of her adult compatriots with the same abnormalities in Haiti, and tens of thousands of similarly affected Zairians, still do not have CDC-defined AIDS.

AIDS and the Security Of the Western World

The following are excerpts from an interview with John Seale by John Grauerholz, MD, health policy director for the Fusion Energy Foundation.

"If my hypothesis is correct, and we wait perhaps 20 years before we take drastic preventive action, half the population of the Western world will be wiped out. Meanwhile, the communist countries, sheltering behind their closed frontiers, will watch capitalism collapse in a way never predicted by Marx. . . .

"Once the AIDS virus gets into an intravenous drug-abusing community, it spreads even faster than among homosexuals. Long before even half the NATO forces and their reservists were infected with the AIDS virus, the West would be a pushover for the Soviets. Employing the AIDS virus is much less messy and self-destructive than using nuclear weapons or nerve gas. Its spread is easily prevented in a totalitarian state, unlike incoming missiles containing nuclear or chemical warheads.

"The Soviets did not deliberately start the AIDS epidemic as a form of biological warfare, but only a moron or an idiot in the Kremlin could fail to see its potential in the East-West power struggle, now that it is here. Gorbachov could easily contain the AIDS epidemic behind the Iron Curtain using methods far less draconian than those employed by Stalin in the '20s and '30s. And if he makes sure that heroin and cocaine keep flooding into the West, and the porno industry keeps pumping out propaganda glorifying ever more promiscuous and bizarre effects, he could be laughing all the way to world domination by about the year 2000. . . .

"If this was smallpox, it would be so obvious that people were infectious. The only reason it is not clear to people *how* infectious this virus is under certain circumstances is because of the enormously long incubation period. If, as with some viruses, people died after seven days instead of after seven years, the effect the virus was having in the intravenous drug-abusing community in New York would have shown up very obviously, because they would have been dying like flies. Whereas in fact only about a thousand or so have died, while about a hundred thousand are infected. But this does not mean that in 10 years time, all hundred thousand may not well be dead.

"We are dealing with a virus that certainly is as lethal as smallpox, and possibly much more lethal. Nobody in their right mind would do anything other than restrict the activities of a person with smallpox."

Pulmonary tuberculosis is often the initial clinical manifestation of infection with LAV in Haiti[6] and Central Africa.[7] Indeed, it was suggested last month in the *Lancet* that infection with *M tuberculosis hominis* should be included as a manifestation of lesser AIDS or ARC.[8] CDC remains silent on this absolutely fundamental issue.[5] A recent study by the head of the U.S. task force against AIDS and other workers from CDC and National Institutes of Health in Bethesda, Md., of patients with active tuberculosis in a sanitarium in Kinshasha, the capital of Zaire, showed that 48 percent were infected with LAV[7] compared with only 4 percent of controls.

Pulmonary infection with *M tuberculosis hominis* is characteristically transmitted via respiratory aerosols. If open, cavitating, pulmonary tuberculosis coexists with chronic lymphoid interstitial pneumonitis caused by LAV, it is inevitable that large numbers of infectious LAV virions, as well as tubercle bacilli, will be expelled in aerosols during coughing. LAV spread by the respiratory route would affect men and women equally; spouses and children of index cases would be particularly at risk, as has already been observed in Africa.[9]

It is possible that respiratory transmission of LAV may occur even without the assistance of *M tuberculosis hominis.* It is well known that LAV/HTLV III is a retrovirus genetically very similar to the maedi-visna virus of sheep,[10] and that both viruses cause progressive encephalopathy in man[11] and sheep[12] respectively. It is less well known that maedi-visna virus also causes chronic progressive pneumonia in sheep,[13] which is histologically indistinguishable from chronic lymphoid interstitial pneumonitis in man caused by LAV/HTLV III.

An epidemic of maedi-visna in Iceland, spread by respiratory aerosols among sheep crowded into shelters to protect them from the long Arctic winters, followed the importation of one infected ram from Germany in 1933. The epidemic built up slowly and unnoticed over several years (just like the AIDS epidemic has in a thousand cities across the globe) but by 1950, more than 100,000 sheep had died from the

Continued on page 64

Japan's Cannonball Laser Target Moves to Fusion Forefront

Just when budget cuts have brought the U.S. carbon-dioxide laser fusion research program to an abrupt halt—at least in the public domain—the Japanese are going full steam ahead with an advanced laser fusion target design that has great promise.

Many U.S. scientists have suggested that carbon dioxide lasers could overcome certain disadvantages by switching from direct-drive to indirect-drive configurations, and this is exactly the line of research being pursued at the Institute for Laser Engineering at Osaka University in Japan. Reports of the first experiments are encouraging.

In the indirect-drive Osaka cannonball design, laser beams are directed through small openings in a hollow chamber that contains in its center the fusion target (see figure). The laser light becomes trapped within the chamber, imploding the target.

This configuration has several general advantages over direct-drive ablation targets. High absorption and high hydrodynamic efficiency can be achieved because of the confinement of the energy in the cavity. High uniformity in implosion of the fusion fuel is also attained, because the multiple-reflection effect of the trapped laser light between the fuel target surface and the inner wall of the cannonball leads to a smooth distribution of laser energy within the cavity.

The cannonball avoids the problem of preheating found with the relatively long wavelength carbon-dioxide laser at Los Alamos National Laboratory, which used a direct-drive configuration. With direct drive, superthermal, extremely "hot" electrons are generated that can penetrate into the interior of the fusion fuel. When this occurs, the target is preheated and it is impossible to compress it isentropically to the high densities needed to produce fusion. The cannonball provides the means of controlling the hot electron spectrum by the design of its cavity structure.

The Japanese report experiments on Osaka's Lekko II carbon dioxide laser using planar cannonball targets. Single-sided irradiation of the planar target was effected with nanosecond or less laser pulses of 30 to 100 joules. The focal spot size was 180 microns in diameter. The beam was directed at an angle of 27 degrees with respect to the normal of the planar target.

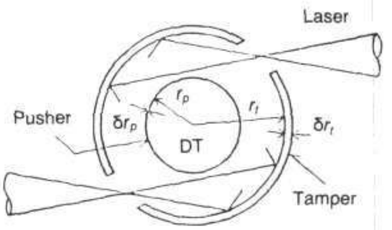
The Lekko II Experiment

In this test, the planar targets consisted of three parts, a front disk to act as a tamper, a cavity wall, and a rear foil. Fuel pellets were not used, but the foil corresponds to the pusher on a fusion fuel target that would otherwise be within the interior of the cannonball.

The hole in the front disk had a diameter of 400 microns through which the laser light was directed. A hollow aluminum cylinder formed the cannonball cavity. Aluminum was also used for the rear, a 2-micron thick foil. The front disks were varied, using in one case 10-micron thick gold, in another 10-micron thick gold with 2-micron thick aluminum on its inner surface and, lastly, a nickel wire net. The laser intensity was about 10^{14} watts per square centimeter.

A 2-micron, single aluminum foil was also used in order to compare the cannonball with a conventional ablative target. The cannonball target was found to have good laser energy absorp-

Continued on page 64



SCHEMATIC OF THE OSAKA CANNONBALL

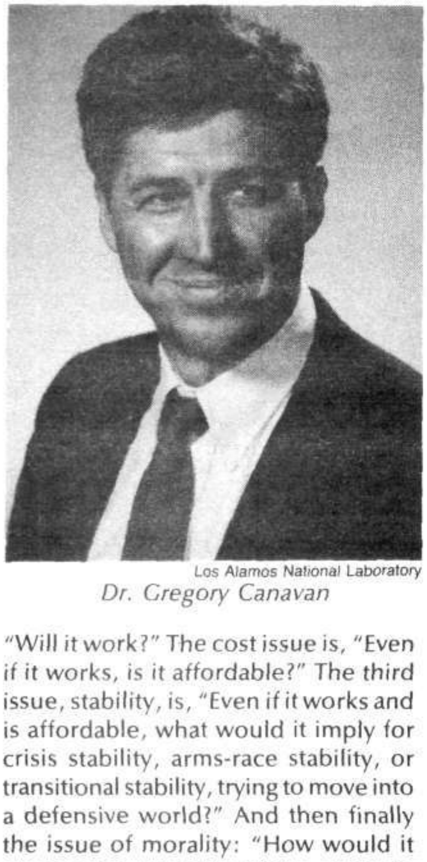
Two laser beams are shown in this cross-section view of the two-hole cannonball target, irradiating its inner wall. These openings are quickly closed off by plasma, trapping the laser beams within the interior. At the center of the cannonball is a pellet of deuterium-tritium fusion fuel with a radius r_p. The outer layer of the pellet, having a thickness δr_p, consists of a pusher material that is ablated by the trapped laser energy and thereby drives the implosion of the fuel to high densities and temperatures needed to ignite fusion.

The outer wall of the cannonball, which has a thickness δr_t, acts as a tamper that contains the trapped laser energy during the implosion of the inner fuel pellet, in the same way that a cannonball in a gun barrel contains the hot gases of an explosive charge. If the overall radius of the cannonball, r_t, is much greater than that of the fuel pellet, r_p, then most of the trapped laser light will be transformed to X-rays, and these will then drive the implosion of the fuel pellet. If r_t is only slightly greater than r_p, then the plasma emanating from the interior wall will drive the implosion instead of X-rays.

AN INTERVIEW WITH DR. GREGORY CANAVAN

An Assessment of the SDI and the Contradictions of Its Critics

Dr. Gregory Canavan, assistant division leader in the Physics Division at Los Alamos National Laboratory in New Mexico, formerly headed up the inertial confinement program of the Department of Energy's Office of Fusion Energy. He was interviewed Aug. 22, 1985 at the fifth annual scientific conference on nuclear war in Erice, Sicily, by Ralf Schauerhammer of the West German Fusion Energy Foundation and Paolo Raimondi of the weekly Executive Intelligence Review.


Los Alamos National Laboratory
Dr. Gregory Canavan

Question: One of the biggest opponents of the Strategic Defense Initiative program in West Germany, Hans Peter Dürr, wrote in a recent issue of *Der Spiegel* magazine that Strategic Defense Initiative supporters are very stupid, because they want to move a large number of very heavy satellites into space where they will only be easily destroyed by a potential offender using simple means that are the technical equivalent of throwing rocks.

You are, apparently, one of those "stupid" people who are in favor of the SDI. Why do you support the program?

I don't know Mr. Dürr and I am not familiar with the articles that he has written. I am, however, familiar with the arguments of the critics of strategic defense in the United States and I have been engaged in discussions with them ever since I participated in a study, called "The Defensive Technology Study," commissioned after the President's March 23, 1983 speech on strategic defense.

The key issues associated with strategic defense fall into four main areas, of ascending order of difficulty both to understand and to quantify. The simplest level of discussion is the technical issue, the second is cost, the third is stability, and the fourth is morality.

The technical issue is the question, "Will it work?" The cost issue is, "Even if it works, is it affordable?" The third issue, stability, is, "Even if it works and is affordable, what would it imply for crisis stability, arms-race stability, or transitional stability, trying to move into a defensive world?" And then finally the issue of morality: "How would it change the morality of the strategic posture?"

Most of the debate in the United States has centered on the more mechanical issues—technical feasibility and cost—although I believe that it is becoming increasingly clear to those who discussed the issues in the United States that these questions can be satisfactorily resolved in favor of strategic defense.

Question: Who are the main opponents and proponents in this debate?

There have been a large number of participants in the debate in the United States. The only participants who carried much weight on the first two issues, the technical feasibility and the cost issue, were the Union of Concerned Scientists (UCS) and the Office of Technology Assessment (OTA).

About a year and a half ago, both of those groups produced reports very critical of strategic defense on a variety of issues, primarily, however, on technical feasibility and cost. The technical criticisms had to do with such things as the impossibility of scaling lasers to very high energy levels, the impossibility of producing particle beams of sufficiently high brightness, or the inability of communicating with the projectile systems to enable them to intercept successfully against fast-burn boosters.

There have been a number of discussions, debates, and correspondence back and forth, which were very lengthy and very intricate, but which have had the overall impact of satisfactorily answering the objections of the SDI opponents, to the point where they have shifted their arguments away from whether these concepts would work technically.

If you listen to the chief spokesman for the Union of Concerned Scientists today, Dr. Hans Bethe, you will no longer see him arguing on the basis of simple physical arguments—such as the fact that the speed of light is finite or that the Earth is curved—that you can "prove" that strategic defense would not work. Now, he has shifted instead to the notion that perhaps the constellations of satellites would be so large as to be unattractive or cost too much.

Question: Even there, some changes seem to be taking place in the assessments of these people.

There is a very interesting inconsistency which has developed in the discussions of these technical issues and cost issues. An example is the publication a few months ago in the British science magazine *Nature* of an article by Dr. Richard Garwin of IBM, who has been one of the prominent U.S. critics of strategic defense. In attempting to argue that strategic defense could be too complicated, Dr. Garwin actually demonstrated a number of factors which do not support his case.

Chief among them, I think, was that for the nominal conditions of performance goals of the Strategic Defense initiative within the U.S. Department of Defense . . . the constellation of defensive satellites required for strategic defense against a simultaneous launch of a very hardened, very advanced force of distributed missiles is not enormous; it is not in the hundreds of thousands. In Dr. Garwin's own calculations, the number of satellites required is under 80. . . .

A key issue in all of the argumentation over the last year on the extrapolations of the performance of the SDI to very hardened threats had to do with how the constellation of defensive satellites scales with the number of missiles, or the way in which they burn out. The other report I mentioned, the one by the Office of Technology Assessment, asserted flatly that the constellation size scales linearly to the threat.

It is amusing that Dr. Garwin's calculations scale in a much more realistic way, roughly to the 0.6 power of the threat. This is much closer to the 0.5 or square root scaling that Los Alamos had produced in its initial comments on the OTA report at the time it came out last year. This is one of the inconsistencies that I was talking about, in which the critics of the SDI have now actually generally produced a large number of numerical results and estimates which support the favorable scaling of the SDI and contradict the statements of other critics of the SDI.

The most senior spokesman against the Strategic Defense Initiative in the United States is Dr. Hans Bethe. In reviewing a number of my reports over the last few months, he has now gone through calculations which corroborate the scaling that I had indicated as appropriate last year. Indeed, they show that had Dr. Bethe used a constellation altitude appropriate to the distributed threat of missiles, he would have gotten almost exactly the so-called square-root scaling that I put forward as appropriate for that case last year.

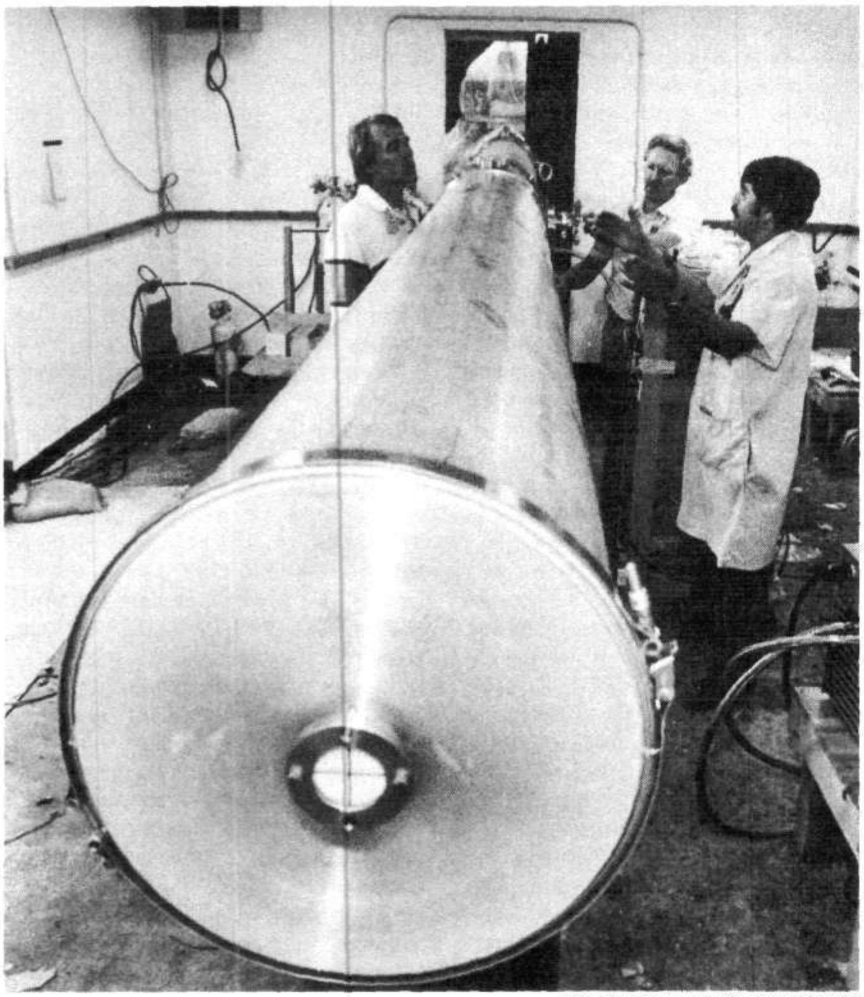
The amusing thing is that now the principal spokesmen for the Union of Concerned Scientists have produced results which broadly contradict those results which were defended by the Office of Technology Assessment of the U.S. Congress. These, amusingly enough, also contradict all the published reports of the Union of Concerned Scientists itself. . . .

Question: Technological development will probably even improve the situation for defense. I was impressed by one of the presentations here in Erice, in which Dr. William Barletta from the Lawrence Livermore National Laboratory explained how the free electron laser very rapidly developed from an exotic technology to one of the main candidates for the SDI. Is this a unique case, or can we expect more developments of this kind in the near term?

I think that people are hypnotized now by the rapid pace of technology development. Some developments have caught people by surprise, even though they have been discussed widely in the open literature. There have been some very impressive results.

There is a Lord Solly Zuckerman of Britain, who in a meeting a while back said to me that the thing that is wrong with strategic defense is that there is no new technology in it. As I was writing my letter to him after the meeting, I thought about the different technologies: lasers, particle beams, kinetic energy interceptors.

I realized that all the technologies



Fred Rick/Los Alamos National Laboratory

"Everything that is subject to debate today has been invented in just the last 15 years." Above, the test chamber where intense, pencil-thin particle beam pulses were accurately guided by a laser to a target, setting a world record of 11 feet.

that we are talking about today—space chemical lasers, the ground-based lasers, the excimer and free electron lasers, the X-ray laser, neutral and charged particle beams, and all of these non-nuclear-kill kinetic energy interceptors that are based on advanced sensors and computers—none of them had been really thought of at the time of the most recent debate on strategic defense in the United States, which was only 15 years ago. Everything that is subject to debate today has been invented in just the last 15 years.

The free electron laser has made orders of magnitude of progress in just the last one or two years. The neutral particle beam, which is worked on at Los Alamos, has developed lately as a potential intercept platform and a discrimination platform; that is, a way of finding out which objects are real weapons and which are just balloons or surrogate targets, which has been a problem of classical difficulty. The most difficult problem in strategic defense has always been in eliminating nonserious targets, so that you do not waste your interceptors.

Tremendous strides have been made on discrimination with particle beams or impulse lasers. This also has happened in just the last two years. Since the "Defensive Technology Study," there are not only new technologies but also new insights on how to use these new technologies to solve traditional problems.

Niels Bohr Library/APS

Stuart K. Lewis

Dr. Hans Bethe (left) no longer argues that SDI won't work, but that it might cost too much. The research of Dr. Richard Garwin (right) demonstrates that his arguments against the SDI are wrong.

Question: How does this technological progress reflect back to the economic effects of an SDI program?

I think you have to break the economic effects down into two parts: the near-term and the long-term issues. The near term has to do with research; the long term with a possible deployment, which is being discussed, but is not now approved.

The near-term discussion over the SDI budget is very intense, but the amounts involved are not significant for a healthy economy. The budget of a few billion dollars a year is large, but small compared to the defense budget of the United States, and does not have a direct, significant impact on the American economy.

There is an indirect impact, and that is probably positive. Historically, the Department of Defense has been a very effective developer of technology, and it is to be anticipated that this would continue and that the developments of new types of lasers, of particle generators, and, in particular, of computers, would have an enormous positive impact on the commercial economy.

As to the longer-term discussion about deployment, were it positive, we still do not have a major economic impact. If you take figures of the size that we have been talking about, even those estimated by the adversaries of strategic defense, you get numbers that appear to be only a few tens of hundreds of billions of dollars, which are figures less than, or at least comparable to, what would be spent over that period of a decade or so on alternative strategic concepts.

I don't think that the dominant issue is economic, as long as reasonable cost goals for the strategic defensive concepts are met, as it now appears they could be.

Question: There are several arguments brought up against the SDI, such as that it is immoral to build new weapons, or that one should not invest in new weapons while people are starving on Earth. Do you think that some of these arguments are valid?

These are serious questions, but most of them are not unique to the SDI. They have to do with any sort of military expenditures, and there are always those who argue that no money should be spent on military technologies as long as there is hunger in the world. I would only point out that defense and freedom are also important values, as important in some ways as material wants. And the point I stress for Western democracies is that even with their expenditures for defense, they have a much smaller proportion of material wants than do the totalitarian states from which they are attempting to protect themselves.

Sometimes these issues are amplified by connecting them with the issue of stability. There is a concern that there is not just a basic investment in testing and trying to deploy strategic defense, but that there is a possibility that we would get ourselves into an arms race, which would divert even further requirements from the unfortunate of our society. The numbers on the cost estimates we went through earlier actually show the contrary.

It has been pretty clearly explained by various spokesmen, perhaps most prominently by U.S. ambassador Paul Nitze, that if strategic defenses are cost-effective—that is, if it is more effective to develop defenses than to deploy further offenses—then one does not get into an offensive or defensive arms race. The net effect of the development and even the initial deployment of strategic defenses will be to give a positive incentive to both sides to reduce their offensive arms levels and, with them, their overall defense expenditures. . . .

Question: It is often stated that the American SDI program would automatically force the Soviet Union into aggressive opposition to defensive systems and force it to build even more missiles, and that there would be no way to go from the realm of Mutually Assured Destruction to that of Mutually Assured Survival. Is this true?

In my experience, and I think in general experience, the Soviets are, despite their rhetoric, very logical in pursuing their arms programs. If defenses turn out to be more cost-effective than offenses, then independent of their rhetoric I think the Soviets will be inclined to build defenses.

The only situation in which they could be inclined to build further offensive rather than defensive systems would be one in which defensive systems were more expensive. . . . If defenses turn out not to be cost-effective, I don't think they will ever seriously be proposed by the United States. Therefore the concern about the Soviets having a cost-ineffective defense to counter it is not a valid one.

Question: In the meeting today, Dr. Edward Teller of the United States raised the question that the U.S. press has probably been more destructive to the SDI than the KGB, because of the massive disinformation that was funneled through the Western media on the matter of the SDI. Can you comment on this?

Dr. Teller is a very colorful fellow. He certainly has more experience with the American media than I have. . . . The history of interaction has been that the critics of strategic defense have gotten along better with the press than the supporters and even neutral observers of the program. . . . My impression is that the critics received so much applause from the press because they very quickly organized, put out a series of reports—some by very senior scientists with a number of very crisp arguments, such as that strategic defense could not work because of the finite speed of light and because the Earth is curved. These were arguments that were simple, that were crisp, and that were *wrong*. But at that time, they seemed plausible and people could make good headlines of them.

The Department of Defense, because it is a big, slow-moving body, took a long, long time to put out a statement of its own. In addition, its arguments were not terribly direct and quotable. . . .

Question: What you think the SDI program means for Europe? There have been suspicions that the SDI might "decouple" Europe from the United States by shielding only America and leaving Europe out.

Not enough thought has been given to the impact of strategic defense on the theater. I personally had not given much thought to it, until a few months ago, when Dr. Fred Hoffmann, who had led the policy panel in response to the President's speech, asked me to address this particular issue. . . .

As I thought about it and worked through it and wrote on the subject, I came to a series of conclusions, which were quite unconventional a few months ago, but which are becoming now much more widely accepted. . . . If one would develop a strategic defense and also try to use some of these same technologies to better defend the theater, you see that the limited threat and the selective Soviet objectives in the theater provide an attractive framework for the application of the concepts. That is, there is a rational engagement that you can understand how to fight, which tends to make the concepts a bit better. In addition, surprisingly to me, almost all of the concepts—the lasers, the particle beams, the missiles—are directly applicable in the theater generally, with significant advantages in performance and survivability.

Let me amplify this. The performance has to do with the fact that in the theater it is very much more difficult for ballistic missiles to deploy effective decoys or surrogate targets. In the intercontinental engagement, the principal problem with the midcourse phase of the engagement is the presence of large numbers of decoys for each real warhead that you need to intercept.

In the theater, none of the missiles like the SS-21, SS-22, or SS-23 ever gets above the atmosphere; therefore, they cannot deploy effective decoys. So their interception is a fairly straightforward thing, with the nonnuclear concepts that have been developed and evaluated for strategic defense.

On the survivability issue, the main thing is that even in Europe, with nonnuclear concepts, it is possible to disperse many of the interceptors over wide areas; it is possible to move them at times, so that the adversary does not know where to look for them and where to take them out.

Many of the mid-range concepts could, moreover, be based either airborne or remotely out of the theater, in part on a submarine, if you will. Therefore, it is the survivability [of the antimissile weapons], which is the dominant issue in the strategic engagement, and which is of much less importance for the theater interaction.

The third point that hit me is that the impact of defensive systems for the theater on stability is generally favorable; in particular, if they are evaluated in concert with global defense. This is a point that is quite confusing for a lot of people. People have a concern that as strategic defenses are evaluated, the United States and the Soviet Union might withdraw behind their strategic umbrellas and leave the Europeans very much out in the cold. Because of fundamental technical factors, which have to do with the performance of the different concepts, in point of fact, that would not be the case.

The theater probably would tend to be protected *first*, more so than even the U.S. homeland. The point is that strategic defenses, particularly space-based strategic defenses, tend to be very sensitive to the rate of attack, the missiles per unit time. Since the number of missiles in the theater is much smaller, by perhaps an order of magnitude than what is faced in an intercontinental engagement, what that means is that a concept that was just barely sized to handle the intercontinental engagement, would be oversized by a factor of 10 to handle the theater.

Or, said another way, a system that was very marginal to handle the intercontinental engagement would be more than adequate to suppress ballistic missiles in the theater. And therefore the strategic umbrella actually would appear to be developed first over the theater.

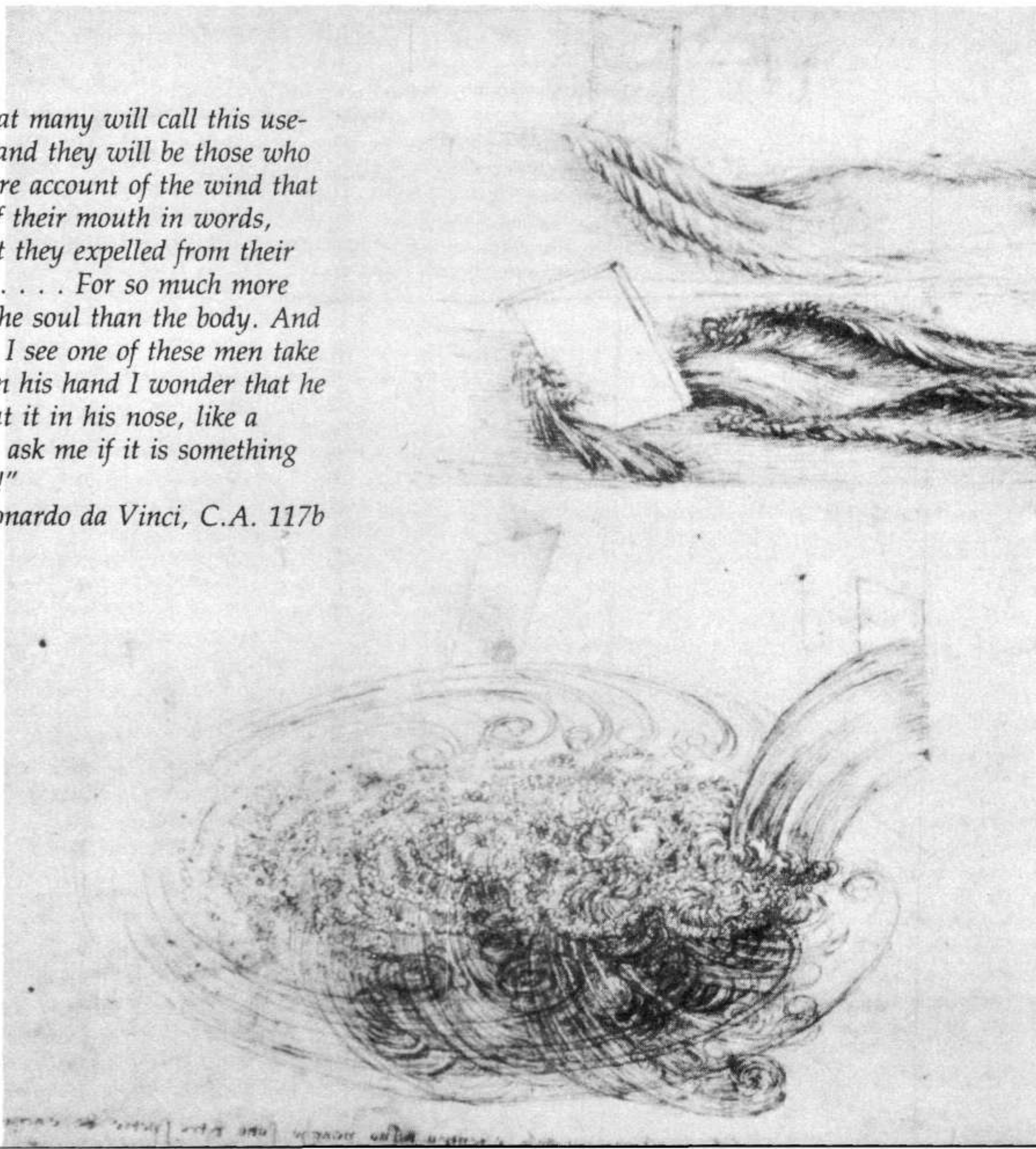
Leonardo da Vinci and the True Method of Magnetohydrodynamics

Leonardo understood the unity of wave phenomena whether electromagnetic or in air or water; more important, he identified the formation of singularities, that essence of continuing creation, which Newtonians can never fully acknowledge.

by Dino de Paoli

"I know that many will call this useless work, and they will be those who took no more account of the wind that came out of their mouth in words, than of that they expelled from their lower parts. . . . For so much more worthy is the soul than the body. And often when I see one of these men take this work in his hand I wonder that he does not put it in his nose, like a monkey, or ask me if it is something good to eat!"

—*Leonardo da Vinci, C.A. 117b*



Royal Library, Windsor 12660v.

INTRODUCTION

There is currently a renewed and much deserved interest in the work of Leonardo da Vinci on hydrodynamics. Some of the attempts are honest and worth following.[1] Others are merely trying to mystify the fact that the scientific method did not originate with Isaac Newton and the mathematical linearization of physical processes. On the contrary, the scientific method was first elaborated as a method by Plato and Nicholas of Cusa and later explicated and applied by the giants of the European golden Renaissance, most especially Leonardo and Johannes Kepler.

More recently, the work of Lyndon H. LaRouche, Jr. has inspired us to uncover the real history of Western scientific thought, looking directly at the primary sources in order to bypass the British monopoly on the history of science.[2] *Our dissatisfaction with the way in which the history of scientific thinking is normally presented stems from the epistemological paradoxes that are created if one assumes the Newtonian method as the basis for mastering the laws of the universe (that is, the laws of the real universe and not the one logically constructed by linear equations).*

In the specific case of Leonardo, we discovered something that lies before every eye able to read: Leonardo's method of thinking was scientific. Building upon the epistemological revolution of Cusa, Leonardo was able to formulate the correct questions to be asked in physics. The method of Leonardo is universal in the simple sense that it is a method of creative discovery and, as such, an example of natural law. This contrasts with the Aristotelian-Newtonian method, which classifies the given. One reflects the essence of human beings—creativity; the other reflects the outlook of a landlord—conservation of given objects. Understanding this from the standpoint that Leonardo was a master of the method that created European civilization, we have tried to look at his scattered material in a different way from that usually done. Typically, Leonardo is presented either as a mad artist who had nothing better to do than go around with a notebook and draw whatever happened to pass before his eyes, or he is described as a mysterious genius representing some mysterious symbolic tradition. (This latter description is supposed to account for his "love of spirals.")

The reason that we could be sure of our hypothesis that Leonardo's art was based upon his mastery of scientific principles (principles that have been rediscovered sometimes hundreds of years later) is found in his paintings themselves. Leonardo's art reflects more than mere painting; *it is the creative method itself that is incorporated in* his paintings. His work reflects a masterful representation of rigor and human love, and herein is the kernel of the scientific method.

Still another standpoint that allowed us to understand Leonardo was the location of his role in the republican circles of Machiavelli. This was made possible by a study of the economic content of his notebooks, bearing in mind that economic development depends upon the building of large infrastructural projects.[3] With this perspective, suddenly, all of his work, now scattered in different books, began to take a coherent shape: his technological innovations, his irrigation project, his military concerns, his research in the power of motors and the design of engines. Leonardo's outlook was that of all great humanists from Plato to Leibniz to Schiller.

Such a person would naturally be a cultural optimist, would naturally look for a way to bring man into space and to conquer the underwater depths. A man like that would normally look for the most universal principles, principles derived from the postulate that man exists and owes his continued existence to his own power to master the laws that govern his physical environment.

Such a person would not be satisfied with mere logic or technique, but would be satisfied only when he could bring real existence and its evolution to the fore. Technical development would be seen as indispensable for human existence, but such improvement could come only from the *application of universal principles, not techniques.* The motivation for his work would not be careerist but derived from Christian love, the upgrading of his fellow men by a combination of cultural and technological progress.

This is the Leonardo who was working and struggling to *make new advances, to find new means of development*—enjoying it all with the joy of a pure infant, making mistakes, constantly seeking new approaches, redrawing the same plan many times until it was sufficiently rigorous to meet his own standards, so that he was satisfied with the answer. *It is this human being who most contributed to our cultural* advancement into the industrial age. It is this Leonardo whom we wish to reinstall in his rightful place. Readers should look anew at his published drawings, this time getting into Leonardo's mind and seeing what he was seeing and thinking, enjoying science as only the cultural optimist who is a creative being can. The historical Leonardo has already been presented in other published accounts.[3] Here we wish to focus upon how his method, applied to fluid dynamics, not only is still valid but also is the only way that we can understand the real fluids that make up 99.99 percent of the universe.

The present debate in plasma physics, in meteorology, and in astrophysics, even if technically detailed, is precisely the same debate that Leonardo faced. Can we account *causally* for the evolution of new singularities? Are singularities a physical reality? Does their existence have implications for the way in which the universe as a whole is organized?

Leonardo looked at the formation of turbulence and singularities as essential and causal. Vortices would reflect not simple chaotic disorder but something more complex and ordered. *He recognized that rotation is a general property* of the universe. Yet today, this seemingly simple issue is holding back breakthroughs in modern physics. Why? Because the issue is not a simple technical question. The same kind of debate that is going on today occurred between Plato and Aristotle, between Leibniz and Newton, between the German-Italian school of hydrodynamics linked to Bernhard Riemann and Ludwig Prandtl and the English school of Rayleigh-Kelvin-Lamb. In each case, the opposition denied the real existence of shock waves and other singularities.[4] In fact, it is the outcome of the fight between these two outlooks that has determined progress or regression in scientific thinking.

We stand for the tradition of Leonardo and Riemann. We will present Leonardo's contribution to this debate in a twofold fashion, through his own material and in terms of the modern debate in fluid mechanics. Our conclusions concerning Leonardo are based strictly upon his notebooks, although we have organized and extrapolated his material for the sake of the modern debate.

A HISTORICAL SKETCH OF THE DEBATE

> . . .[I]t is Euler who is justly recognized as the father of hydromechanics. . . . But multitudinous problems of practice could not be answered by the Euler hydrodynamics; they could not even be discussed. This was chiefly because starting with the Euler equations of motion, the science had become a pure academic analysis of the hypothetical frictionless, ideal fluid. This theoretical development is associated with Helmholtz, Kelvin, Lamb, and Rayleigh. The analytical results obtained by means of the so-called classical hydrodynamics usually do not agree at all with the practical phenomena. . . . To such an important question as pressure drop or resistance . . . theoretical hydrodynamics could only answer that both pressure drop and resistance are zero! . . . Only toward the end of the 19th century a new critical spirit appeared . . . among the physicists a more realistic attitude grew up especially associated with the great name of Felix Klein, having for its object the restoration of pure and applied science.
>
> —L. Prandtl and O.G. Tietjens, *Fundamentals of Hydro- and Aeromechanics*, 1934.

This quotation from Göttingen University's Ludwig Prandtl is true only in part. Elsewhere Prandtl is more explicit that his relation to Riemann was direct, rather than through the mediation of Felix Klein. To carry the development of hydrodynamics forward, it was necessary for Prandtl to break with the English school and directly assimilate the method of Riemann.

The English school of hydrodynamics consciously rejected the Riemannian approach and thus prevented major breakthoughs in the theory of flight. Nevertheless, today this is still the school that is mainly studied. The results of this affect plasma physics and astrophysics as well; namely, there is still the tendency to consider turbulence as a purely chaotic phenomenon and vortices as something to avoid.

Not by chance, it was a student of Prandtl, Adolf Busemann, who first had the correct idea about treating vortices found within the domain of plasma physics; his insight came from his work on hydrodynamics in the tradition of Riemann.[5] Before Riemann, potential theory as elaborated by Laplace was nothing but the d'Alembert paradox expressed in dynamical equations. (d'Alembert more overtly expressed the same kind of hostility to singular phenomena that Newton had. This explains how d'Alembert naturally arrived at his infamous "paradox," whereby according to his calculations, a bird should not be able to fly.)

It is the d'ALembert theory that Prandtl had to reject in order to develop a scientific theory of flight. Leonardo, as we shall show, had precisely pointed out and partially defined the importance of the phenomena of rotation and boundary layers, elaborated by Prandtl in modern scientific terms as the basis for the theory of lift. Prandtl also engaged in a polemic against the Kelvin-Helmholtz principle of vorticity, which is discussed below. According to this view, as described by the Italian general and aerodynamicist Gaetano Crocco, "The vortex was ignored and at the same time was given by Helmholtz a mysterious and solitary existence without creation or death, like a demigod."[6]

Without the *creation* of vortices by the surface of discontinuity around a wing, there is no lift. Again this is the d'Alembert-Newtonian obsession: Birds cannot fly. But there is more to the concept of vortex creation, and before illustrating the history of Leonardo's contribution, we have to clarify this point.

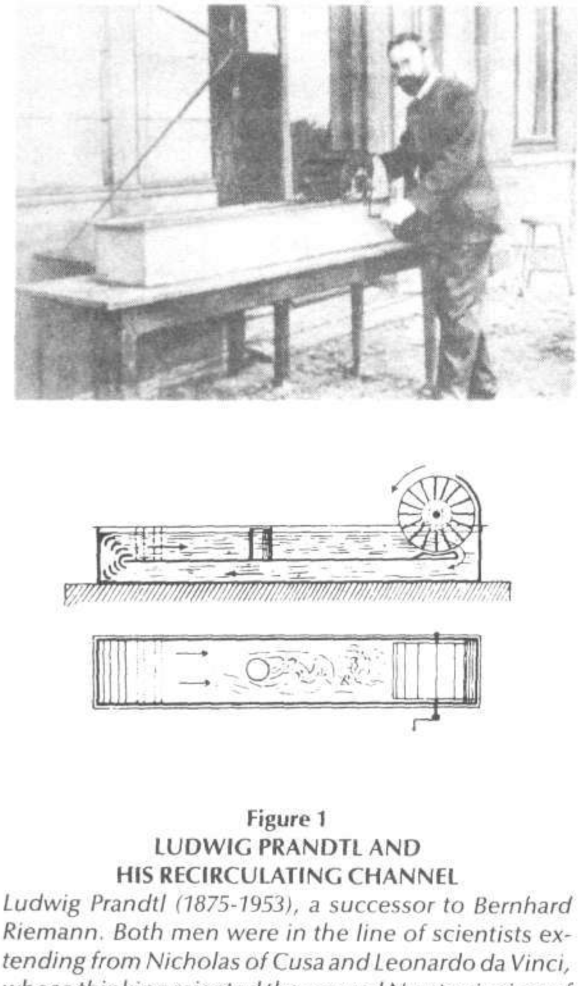


Figure 1
LUDWIG PRANDTL AND HIS RECIRCULATING CHANNEL

Ludwig Prandtl (1875-1953), a successor to Bernhard Riemann. Both men were in the line of scientists extending from Nicholas of Cusa and Leonardo da Vinci, whose thinking rejected the acausal Newtonianism of Lord Kelvin, Lord Rayleigh, and Sir Horace Lamb. Prandtl is shown here near the turn of the century with his simple laboratory device for the investigation of fluid flow.

Source: Hunter Rouse, *Laboratory Instruction in the Mechanics of Fluids* (University of Iowa, 1961), p. 4.

We can look at the universe as a continuous manifold that *creates* singularities, a universe whose continuity is redefined by such singularities. We look at the universe itself as a fluid, but from the standpoint of real Riemannian geometry; singularity formation changes the potential and the topological characteristics of the space-time manifold. Such transformation is reflected in changes of metric and "changes of state." The Riemannian hydrodynamic approach solves the apparent discreteness-continuity paradox by emphasizing the primacy of self-transformation.

Historically, this is the only way in which real breakthroughs in technological progress occur. This is the same method, although at a lower epistemological level, that allowed Schrödinger, Heisenberg, and de Broglie to introduce new and correct concepts to fundamental physics at the beginning of the 20th century.[7] This same approach has been carried forward in the realm of economy by giving a directionality to the creation of singularities, in order to define a shift in potential either entropically or negentropically.[8]

This is the only standpoint from which evolving systems can be represented.[8] The apparently local, entropic effect of the creation of a singularity is not the primary parameter; the issue is to analyze whether that singularity accomplishes a shift in the geometry of the system as a whole, so that an "entropic" effect on the lower manifold of an existing stage of development is lower than the negentropic effect for the transformed system as a whole.

Energy conservation, then, although an important topological characteristic, does not become the absolute fixed limit that it is according to the Kelvin-Helmholtz approach, which would, in effect, prevent the creation of new singularities. Kelvin and Helmholtz superimposed their own ideological interpretation of Leibniz's statement of the conservation of *vis viva*, in order to prove their mechanistic, Cartesian outlook. Stability is not synonymous with static, or even dynamic, equilibrium. Such a notion is an artificial ideological construct.[9] Energy conservation is a boundary condition for a given manifold, but it shifts precisely with the topological shift of the manifold, according to the directionality imposed by the new, real singularity formed.

In that sense, new singularities are not necessarily symptomatic of "more chaos," nor do they necessarily lead to a statistical approach. On the contrary, such singularities more appropriately approximate a Riemann-Weierstrass type of function that is everywhere dense with singularities but still continuous.[10]

The other approach to the same problem is the fake hydrodynamic school of Cauchy, Kelvin, and Helmholtz, today represented by Ilya Prigogine.[11] They present themselves as anti-Newtonian, insofar as Newton emphasized the discrete manifold—the hard-ball universe of self-evident atoms. In reality they, and Maxwell along with them, have the same approach as Newton. The do not allow for the *creation* of singularities.

For them, a local discontinuity must be accounted for by a rearrangement of a given state. This is the basis for the vortices of the Helmholtz-Kelvin theory, which creates vortex-atoms. For the hard-ball fixed configuration atoms of Newton, Helmholtz and Kelvin substitute merely more flexible, but still uncreatable vortex-atoms, found in the same Cartesian space Newton envisioned.

Both Kelvin and Prigogine are characterized by a strictly materialist-mechanist point of view, revealed by their common—and not accidental—reference to Lucretius and the Epicurean school. This is why they cannot acknowledge the concept of rotation. Without this concept of real rotation, each "new structure formation," according to Prigogine, has to be explained symbolically and as "local disequilibrium." The formation of these "new structures" then has no directionality, because the structures are the result of local condensation of atom-vortices. Hence there is no way to measure if and in which direction we have a shift in the overall topological characteristic of the field. This is the epistemology of an anarchist, which Prigogine tried first to impose on the "new physics" and now is applying to the "new economics," where the notion of directed technological progress has disappeared.

Rotation is not a fixed rearrangement of local atoms; it is a general topological property of our visible universe. Therefore, we do not seek to analyze it as "abnormal local behavior." What is actually abnormal is the absence of rotation. Any action in the physical universe will have to be seen in terms of the "creation of local rotation," because that is the only way action can do work in this universe. We will see later how *vorticity* or spiral forms are neither symbolic nor abnormal, but are the normal way action is shaped in our visual manifold. From galaxies to cells, space-time transformations take the form of spiral action, and it is—we may hypothesize—not a turbulent, chaotic state of matter, but probably the *most stable local state* because it is a force-free state.

The issue then is not vortices per se, just as dress is not the essence of human beings. The issue is the creation or noncreation of action; its effect in terms of potential shift will normally take spiral form when it is real action.

Kelvin, Helmholtz, and later Prigogine sought to cover up the old Cartesian approach to this basic problem with some exotic notion of "local vorticity." This is very attractive for those trained in symbology, but it negates the lawful *creation* of rotational action because that would upset their "conservation law." So the debate between Prandtl and Kelvin was not about linear motion or circular motion, but whether we are able to create action by shifting the geometry of the field. Action will normally take the form of rotation, and there will be an "entropic" effect on the previous field potential. The stream lines will appear turbulent.

The same method of thinking applied to the evolution of our own civilization has allowed us to rediscover a line of creators in science that had been ignored or obscured by the "official" schools. We are looking for evolution in scientific thinking, but measuring it against a transinvariant process of the conservation and expansion of our human species, which defines directionality in human creative activity. Truth is not measured logically. In the same way, evolution cannot be simply considered as "something new"; it must instead be measured in terms of its effect on human progress, which consequently is invariant with respect to universal natural laws. This defines the criteria for identifying a correct method of thinking from a wrong one.[12]

From Leonardo to Busemann

Before Leonardo (1452-1519), no one had really studied fluid motion as a subject in itself and with a general methodology, for reasons indicated above. We wish again to emphasize the crucial role that Cusa directly played in shaping the method Leonardo used, in particular the idea of looking upon the behavior of water, air, and light as a single phenomenon: fluid motion. This was possible only because Cusa imposed upon the humanists the injunction to seek that which is invariant in the universe as a whole. This seemingly abstract idea allowed Leonardo to use water to form hypotheses concerning air and light, with obviously astonishing results replicated only much later by Prandtl.

Newton could not grasp the same interrelation of the common properties of fluids. However, the same principle introduced to Leonardo the concept of reversibility in fluid motion: Either an object moves in water or water moves against the object—the effect will be the same. Again, this is an abstract point that allowed him major experimental opportunities. He constructed artificial birds against which he moved air to experiment with flow patterns.

Why Leonardo took on this study is apparent from his underlying motivations: the combination of his concern for irrigation projects and his sense of the necessity for man to conquer space. This optimism is the driving force of his genius. This is visible for most people through his artistic work. For the moment, the essential point in Leonardo's founding of true fluid dynamics is his unambiguous indication of the importance of the formation of singular discontinuous phenomena. These can take the form of vortices, hydraulic jumps, breakers, vortex-filaments, and so forth, out of apparently continuous wave motions. We will emphasize this tendency, this methodological aspect, and not the details of Leonardo's work. The relevance of the formation of discontinuity in a fluid is not purely a philosophical issue. It implies the creation of the right or wrong technology.

Also essential in Leonardo's method is the scarcely hidden implication that when a principle of formation of discontinuity is understood for one fluid, it must be true with some modification for other fluids too. As he emphasized, with the added characteristic of compressibility, up to a certain point the experiments in water are valid for air. In that sense Leonardo's method is still important. What he indicated as relevant phenomena in water has been verified in air with the shock wave theory and now in plasma physics. He himself projected and experimented with results he obtained in water to understand the behavior of blood circulation and tree growth with obviously astonishing "anticipation" of later scientific discoveries. Any erroneous results were caused mostly by his lack of experimental facilities rather than a deficit in method.[13]

After Leonardo, this outlook in hydrodynamics and optics was carried through, although only partially, by Simon Stevin (1548-1620), Christiaan Huygens (1629-1695), and Blaise Pascal (1623-1662). Mathematically, the importance of discontinuous processes was emphasized by Gottfried Leibniz (1646-1716) and Leonhard Euler (1707-1783).[14] With the addition of Daniel Bernoulli (1700-1782), this is the true school of hydrodynamics, which was opposed to Newton, d'Alembert, and Laplace. Historically, the work of Leonardo is known only through the distribution of manuscript copies by Dürer and Desargues, which came into the hands of Pascal, Leibniz and others in their networks. Beginning in 1798, Leonardo's manuscripts were republished in France—at least what was left of them—by the Italian physicist Giovanni Battista Venturi (1746-1822), under the direction of Monge and Carnot. Venturi himself is famous for his reexamination of Leonardo's discoveries: the Venturi tube, the importance of hydraulic jumps, and the velocity distribution in vortices.

After Venturi there was a renewed interest in real fluid motion especially on the part of Ernst and Wilhelm Weber (1795-1878 and 1804-1891).[15] The Weber brothers along with Gauss opened the way for the physical-mathematical innovation of Bernhard Riemann (1826-1866) and his school, including Felix Klein, Prandtl, and Busemann in Germany; Betti, Beltrami, Crocco, and Ferri in Italy. This school had to fight with the heirs of d'Alembert, Kelvin and friends.

While the Leonardo school would emphasize the importance of the formation of discontinuities and of rotational motion, the Newton-d'Alembert-Kelvin school would deny the formation of such discontinuities on the assumption of the conservation laws. Out of this outlook comes the attempt to look at turbulence as only a chaotic, static local phenomenon. Even if the "paradoxes" of this school have often been made ridiculous by the actual creation of technologies it claims are impossible, its outlook remains dominant in the universities.

Now let's get into the substance of fluid mechanics.

ELEMENTARY FLUID DYNAMICS FROM THE LEONARDIAN STANDPOINT

The Geometric Method: Nature Seen with the 'Artist's Eye'

Natural science was born by man's trying to answer problems posed either by the evolution of human society or by fundamental but simple and visible natural phenomena, for which he sought the causal relations. Progress in science has occurred not by giving definite and final answers, but by achieving successively better approximations to the solutions of the two categories of problems seen above. Therefore, it is not a banality to say that one side of scientific progress comes by "walking with one's eyes open." In other words, there are still a lot of everyday natural phenomena that have not yet received real explanations.

The current trend in science tends to reduce physics to pure logical-mathematical analysis. Although mathematics is a crucial aspect of the comprehension of invisible causality by the use of our conceptual powers, we must never forget whence it came and what we are looking for—that is, reality. The real world is not a simple symbol. It exists, and our own existence and evolution depend on our mastery of its laws. The point is that the objects we see are not themselves reality, but the causal processes that created them. Such objects exist as singularities, but we can grasp them only as space-time transformation. That is why geometry is the way to comprehend reality. Leonardo and then Kepler initiated what today is called topology: looking at physics from the standpoint of characteristic singularities, whether shapes or numbers. Such geometry does not need the notion of *mass* or *force* initially. We look only at which kind of transformations are possible and what the boundary conditions are that define the transfinite limit for the kind of transformation we are observing.

Why are there only certain specific forms that nature chooses in shaping its own transformations? Why the common patterns in the sky and in the water? Why the symmetry in snowflakes and crystals? Why do only certain proportions appear when growth is the primary parameter? These are the kinds of questions Leonardo posed to himself, and they are the kind of questions anyone can pose and then pursue the answers. The answers will reflect the level of scientific knowledge we have mastered, but the point of departure is that of being interested and motivated to know, and thus to pose the right questions.

There is no numerology or Masonic mystery in the forms and proportions of nature itself, or for us to employ in acting upon nature. There is no symbology in spiral forms or in the Fibonacci series. Such knowledge is not the secret of Isis or anybody else. It is only the attempt to banalize and give quick answers to deep scientific questions that accounts for the mystic currents of Sufists and others turning natural forms of growth and transformation into symbolism. Even so, if we simply look around, we will not see what Leonardo and Kepler captured in water flow, tree growth, and snowflakes, because they were looking for the causes behind these phenomena, the manifold "invisible" to the simple eye. That is the meaning of Leonardo's notion of the "artistic eye." A real artist—one who recognizes beauty as natural law—knows what to look for.

As Leonardo described his paintings, an artist does not paint lines or points. If he is a humanist, he paints *souls*—moral beautiful souls—whatever the external form. This is the infinite in the finite that we see in the best painting of the Italian Renaissance or in Rembrandt. This is the notion of aesthetic transfinite developed later by Schiller.[16]

Projective geometry was invented as the only way such infiniteness in the finite could be visualized. Beauty, then, is not simple external proportion; that is, the normal law of topological necessity obeyed by any natural transformation. Beauty instead is defined by the specific individuality, the moral individual character that is also synonymous with life. This concept of individuality—singularity—within constant proportions sparks our interest and fascination with man and nature. Natural forms may look the same, but they are never precisely the same. The stronger this individuality, the nearer we are to being real human beings. In that sense beauty is not an arbitrary notion defined purely subjectively, but is natural law, and the real artist is he alone who grasps beauty.

The geometric, artistic eye, then, although recognizing the self-similarity of natural forms, is not satisfied with the Sufist fundamentalist notion that everything is anything in nature in one big blah. The artistic eye looks for the universal processes that characterize individuation. We would look for the *soul* of natural, visible forms. This method—in theological terms the recognition of the immanence of the Creator within the created—is the specific characteristic of the Augustinian current in Christian Western civilization.

Visual manifolds. From this standpoint, Leonardo noticed and differentiated two different visual manifolds.

First, by working with Luca Pacioli, he studied very closely the topological characteristics of the Platonic solids and their proportions. We do not see these Platonic solids in nature unless we closely study crystal forms, but they represent an important geometric principle in terms of topology, limits of forms, angles, and number of existent symmetric closed forms. Such solids, according to Leonardo's point of view, represent the "residuum" of fluids, that is, semistatic crystals. In other words, the type of self-similar growth characterized by the Platonic solid is more typical of an inorganic, static growth.

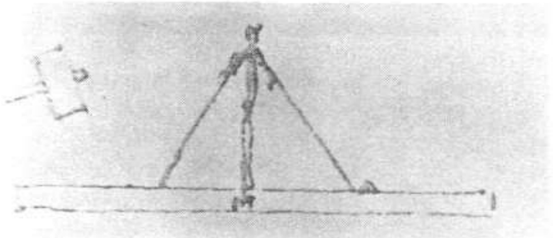
Second, Leonardo saw that the rest of the universe seemed to choose overtly to limit shapes either to pure spheres or to spiral-type circular action. Leonardo did an extensive study of such morphological growth patterns. He studied and measured flowers, trees, horns, and so on and clearly pointed out that the Fibonacci proportions seemed to be the main characteristic of life as a growth process. Leonardo also went a step further: He began to look at these patterns of transformation not only as a by-product of life, but also as a general law of fluid motion—in water, air, magnetism or "fire," as he would call plasma-type phenomena. Normally, if we look at water, we would not see what Leonardo saw and represented in his famous drawings (see frontispiece). The reason is that he was looking for patterns that he knew should be there according to his hypothesis of the geometry of transformation in the universe.

As Leonardo wrote: "If you wish to see the movement the air makes when it is penetrated by a movable thing, take an example in the water, that is, underneath its surface, for it may have mingling with it thin millet or other minute seed which floats at every stage of height of the water, and you will see the revolutions of the water which ought to be in a square glass vessel shaped like a box" (Leicester 29v).

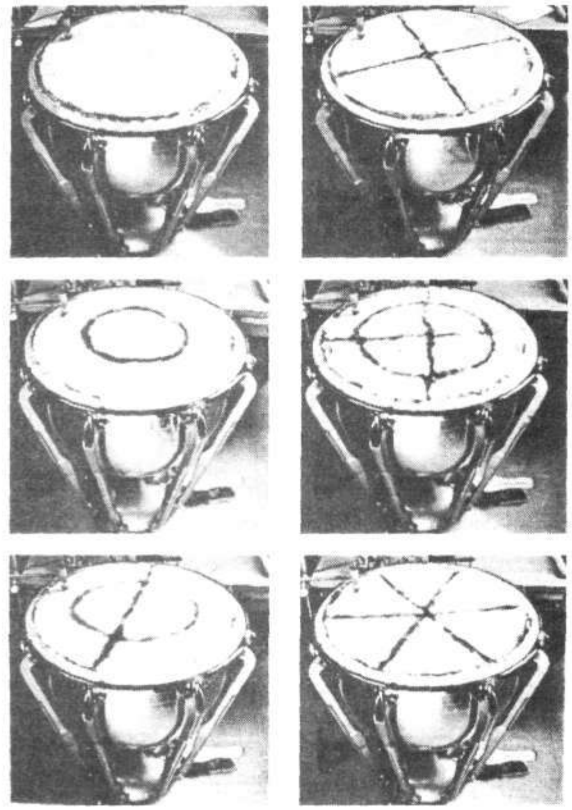
This is the first known technique of visualization of water flow patterns, to our knowledge. The importance should be obvious to anyone familiar with hydrodynamic work; only Prandtl was able again to master such an approach, which proves that this was not a simple technical issue, but a methodological issue.

Leonardo did the same thing to visualize wave motion on a vibrating plate (Figure 2). He wrote: "And when the dusty table is struck on one side, notice the manner in which the motion of the dust begins toward the creation of the mentioned mountains. . . . In the same way describe the flexible ridges of particles of dry matter, that is the creation of the waves of sand carried by the wind" (Institut de France Ms. F 61r).

Here and in other locations, Leonardo is describing what was reproduced in the 19th century by the German physicist Ernst Chladni (1756-1827): the visualization of wave frequencies on a vibrating plate by putting powder on top of it. We will describe below the implication of this precise experiment, but for the moment, let us stress the importance of the clear-cut method of visualization that Leonardo invented. Usually, this is possible only if one has in mind a hypothesis that the causal relations that shape an action are not immediately seen, but can be visualized. In this way



(a)



(b)

Figure 2
STANDING WAVES

(a) " . . . and when the dusty table is struck on one side, notice the manner in which the motion of the dust begins toward the creation of the mentioned ridges." Thus does Leonardo describe his experiments on standing wave patterns.

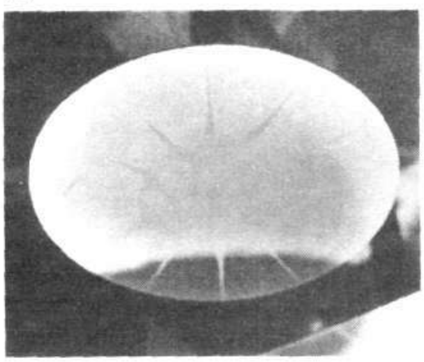
(b) The standing wave experiments were rediscovered by the German physicist Ernst Chladni (1802) and are performed here on a drumhead.

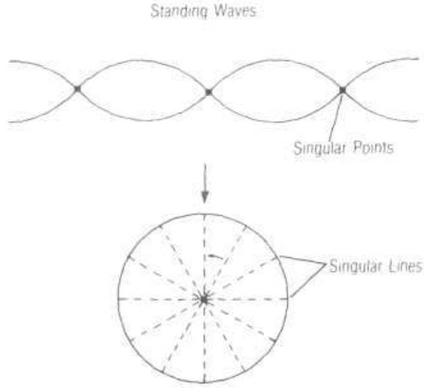
(c) The author's own results with standing waves on a vibrating plate, and a diagram of the wave behavior.

(d) Waves in a cylinder of rotating fluid.

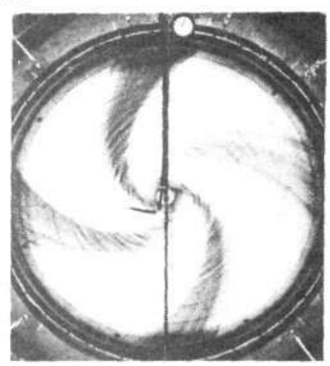
Source: Madrid Codex; H.P. Greenspan, *The Theory of Rotating Fluids* (Cambridge, 1968), facing p. 280.

(c)





(d)



one can make visual the harmony of the universe through art.

The invisible wave motion in the plate is visualized in terms of *lines*, singular lines, so *we see* singularities as the result of action and transformation of a given space. Such lines are force-free lines, and thus are stable. This is the basis of the shaping of forms.

Usually, we see straight lines only when we see a "dead" object; otherwise, other forms predominate in the biosphere and the sky. Leonardo realized that the pattern of spiral action seemed to be the one preferred in our universe, both for living organisms and for what he called *"fluids in motion."* Let us do the following experiment: Take the previously mentioned plate [Figure 2(c)] and rotate it. The lines will transform themselves according to the degree of velocity into different types of spiral forms [Figure 2(d)]! Thus, if our universe as a whole is rotating, wouldn't this mean that the normal lines of least action must be of spiral or circular forms? Is that not what happens in a living organism? Is that not the shape of "fluid in motion"? What is common to the different patterns of fluid in action, be it electromagnetism or water or air, is not that they are the same substance, but that action as transformation in space-time has the same topological characteristics (Figure 3). Transformation in space is self-similar, which allows us to project, up to a certain point, from macrostructure to microstructure; so that the outer, visible form of the growth of a tree can be projected to the organization of its cells in good approximation.

There is no mystery, therefore, in the fact that galaxies

Figure 3
THE COMMON TOPOLOGY OF ACTION

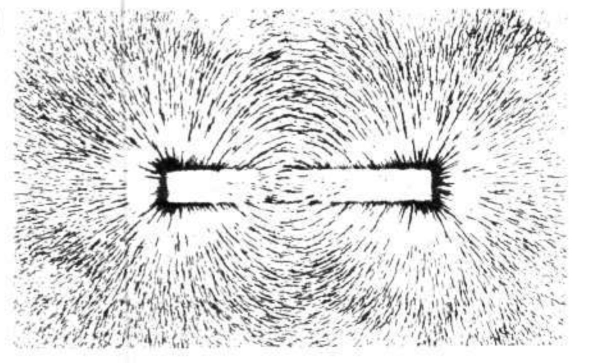
What is common to the different patterns of fluids in action—be it electromagnetism or water or air—is not that they are of the same substance, but that action as transformation in space-time has the same topological characteristics.

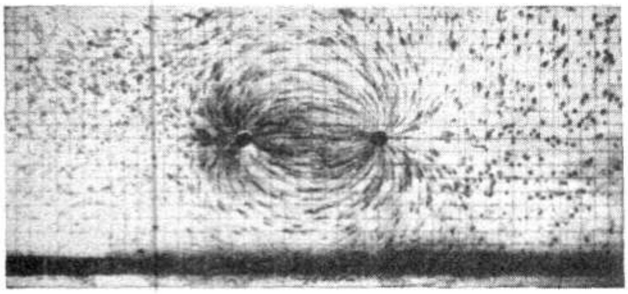
(a) The familiar visualization of magnetic field lines by means of iron filings on a piece of paper, under which a magnet is placed.

(b) Streamlines in water. The water (a few millimeters deep) flows into the pan through the left hole and drains out through the right. Crystals of potassium permanganate dropped into the water make the streamlines visible.

Source: A, G.A. Williams, *Elementary Physics*, 2nd edition (New York: McGraw-Hill, 1976), p. 188. L. Prandtl, *Essentials of Fluid Dynamics* (New York: Hafner, 1952), p. 152.

(a)





tend to shape themselves the way water does, or the way we stir milk into coffee. This is not obvious, and, in fact, the full Cartesian-Newtonian school rejects such a notion. A Cartesian space cannot allow a real rotational action to take place, as was pointed out correctly by Gauss. Yet today in astronomy, there is an open and heated debate on the rotational universe.[17] The implications are also relevant for advanced physics, especially for the theory of potential functions. The topology of a space defines the gradient of transformation; that is, a potential. Now, no singularity is producible without a rotational action that is perpendicular to the flow, because a singularity is able to act with a higher degree of freedom than the flow that generates it.

Therefore, the study of the shift in potential by the creation of singularities out of rotational action and the relative shift in topology is the basis of potential theory—not according to Laplace or Kelvin's version, but according to the Riemannian approach. The common transinvariant characteristic of the shift in topology in the physical world is that of the constancy of the rotational action of transformation. We will come back to this at the end of the article; let us first study in more detail the properties of a fluid, now that we know that fluid motion seems to have the same characteristic patterns found in living organisms.

SELF-SIMILAR PROPAGATION OF ACTION IN FLUIDS:

First Approximation: Sinusoidal Waves

Now that we have established the importance of using water as an experimental field for more important and universal phenomena, let us look at the first general law of the behavior of fluids. At first sight it would appear that water is one "object" and that its most visible aspect, the surface, would be the most simple to analyze. However, this is not the case as Leonardo realized immediately. Let us throw a stone into still water: we see ripples, waves traveling on the surface, but not immediately *inside the water* [Figure 4(a)].

As he wrote, the water surface has a very specific property: ". . . [T]he impetus of the water is divided into two parts. . . . The simple is entirely beneath the surface of the water; the other is complex—that is, it is *between* the air and the water, as is seen with boats. . . ." Here Leonardo is describing a crucial phenomenon: the effect of action transmitted by a *surface of discontinuity*: water surface. This more extensive quotation from Leonardo shows how he understood the function of a surface of discontinuity, a concept whose physical importance was grasped only by Riemann and Prandtl:

> From this it follows that points imagined in continuous contact do not constitute the line, and as a consequence, many lines in continuous contact do not make a surface, nor do many surfaces make a body. . . . The surface of a thing is not part of this thing. . . . *It must needs be therefore that a mere surface is the common boundary of two things that are in contact: Thus the surface of water does not form part of the water, nor does it consequently form part of the atmosphere. . . .* What then divides water from air? There should be a common boundary which is neither air nor water, but is without substance. . . . Therefore they are joined together and you cannot raise up or move air without the water. . . . *Therefore a surface is the common boundary of two bodies which is noncontinuous and does not form part of either. . . .* (B.M. 159v)

(a)

(b)

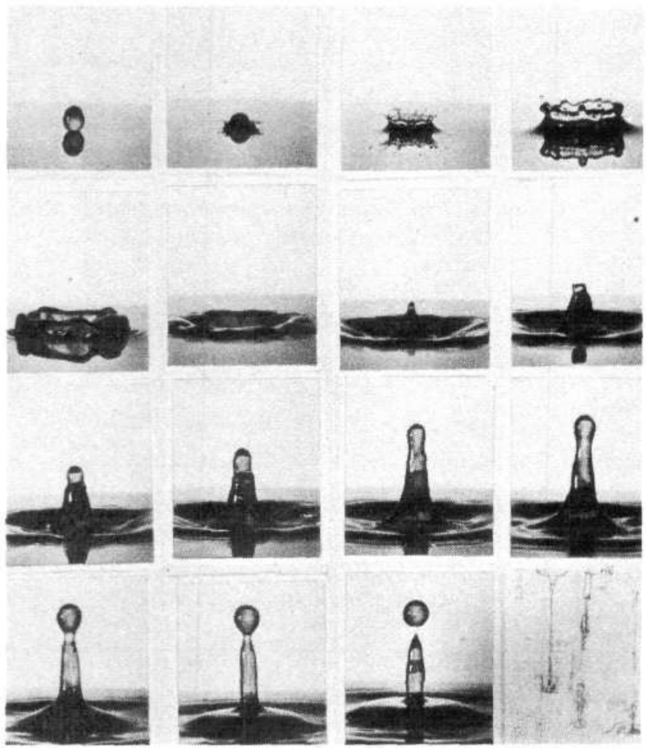


Figure 4
WAVES AT THE DISCONTINUITY BETWEEN WATER AND AIR

(a) " . . .the impetus of the water is divided into two parts. . . . The simple is entirely beneath the surface of the water; the other is complex, that is, it is between the air and the water as is seen with boats. . . ." Here, sketches by Leonardo of the surface phenomena.

(b) A drop of water strikes the water's surface and rebounds. The drop that strikes is the same that bounces back, as may be proven by using a drop of colored water against a surface of clear water. Inset is Leonardo's sketch.

Source: (a) Codex Hammer 14v; (b) Codice Atlantico 68rb.

This is not an isolated quotation from Leonardo; there are many more in the same direction, which proves that Leonardo had grasped a very important point clearly. The implications are that water surface, being a surface of discontinuity, will behave like a specific entity. It is an equipotential surface of discontinuity, if we consider the Earth and the atmosphere as a connected global geometrical entity. It is through such lines or surfaces that action acts according to the least action principles. Normally the tendency is to brush away the specific property that the water surface presents in terms of free energy, with the name "surface tension," which explains nothing and is simply an approximation of reality from a Newtonian standpoint. As one contemporary scientist, Hunter Rouse of Iowa University, put it: "For many years, the surface phenomena were explained in terms of apparent tension in an elastic skin. . . . As a matter of fact there are so many inconsistencies in the surface tension concept that the continued designation of the quantity (d) as a coefficient of surface tension is, to say the least, misleading. . . ."[18]

Before elaborating on this in conjunction with shock waves, let us look at some of the effects of such surfaces. If instead of throwing a stone into water, we throw another drop of water, what will happen? We can see in Figure 4(b) that the water drop bounces back. The photograph is made by a very recently developed high-speed technique, but the drawing in the figure is from Leonardo. You can see he was studying the same phenomenon, and his description is a very good approximation of the reality. Even if Leonardo obviously could not see that the same drop would rebound up to three or four times, he analyzed it in terms of the boundary conditions of the surface of discontinuity.[19]

Waves. What happens when we drop stones into water? We see "waves." The question Leonardo posed is, why are these waves circular? From the drawing in Figure 5, it is clear that it is not the form of the object thrown into the water that causes the waves to be circular. (Actually the waves are spherical, including air and water, but we observe only a surface.)

As shown in Figure 6, Leonardo saw a specific property of such waves: They could interpenetrate without obstructing each other. The reason is that this type of simple wave *does not transport matter transversely*. As Leonardo wrote:

> Since in all cases of motion, water has great conformity with air . . . if you cast two little stones . . . in water, you will see two separate quantities of circles . . . which growing, come to encounter, one circle intersecting the other, always maintaining for centers the places struck by the stones. The reason is that although there is some evidence of movement, the water does not leave its location, because *the opening made in it by*

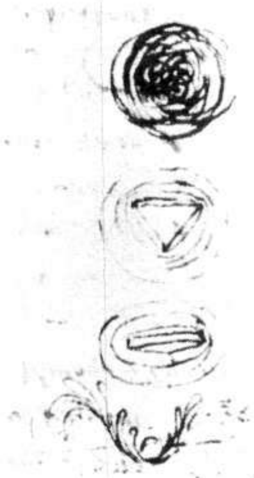


Figure 5
PRODUCTION OF THE WAVE FRONT
Why does a triangular or square object, when dropped into water, generate circular waves?

Source: Codex Hammer 14v.

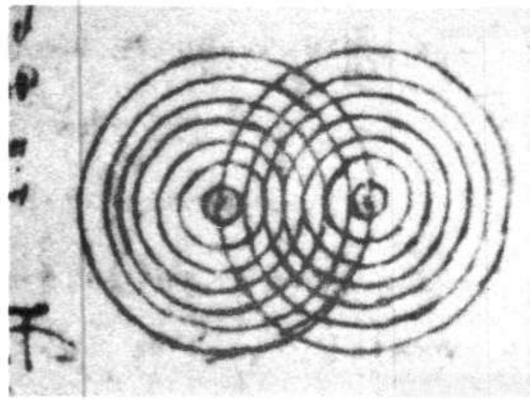
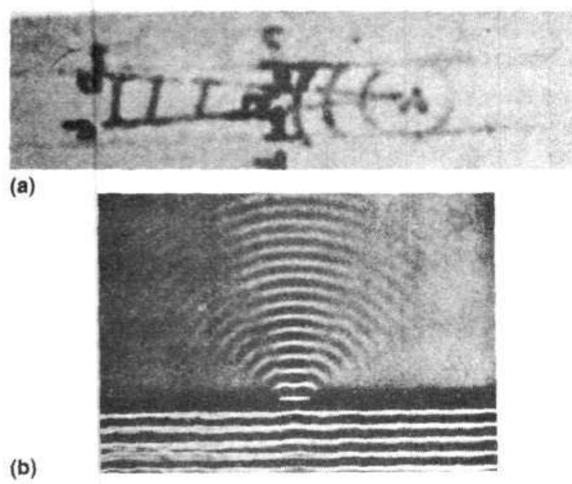


Figure 6
UNDISTURBED INTERPENETRATION
Simple waves, as Leonardo explained, do not transport matter transversely, and hence sets of such waves can interpenetrate undisturbed.

Source: Institut de France Ms. A 61r.



(a)

(b)

Figure 7
DIFFRACTION
(a) Diffraction of a wave front passing through a slit, in a drawing by Leonardo. Here he is studying vocal sound. Because of his understanding of the common behavior of fluids, he used water for the experiment. (b) Photo of straight waves undergoing diffraction in passing through an opening.

Source: Leonardo, *Anatomical Notebooks III*: 12v. G.A. Williams, *Elementary Physics*, p. 286.

> *the stones closes up again at once* and this motion made by the sudden opening and closing produces a certain shaking, which can be called trembling rather than motion. And to make what I say plainer, take heed of those straws which by their lightness stand on the water; notwithstanding the wave made under them by the coming of the circles, they do not leave their first locations. . . . (Institut de France Ms. A 61r)

Such waves then, according to Leonardo, are able to "act at a distance" without any work done.

Leonardo indicates another experiment in the same direction: If we put a flame in front of the mouth of a singer, the flame will not move, but the same sound wave could release energy on a glass and break the glass, by the effect of resonance known to Leonardo. As he wrote: "The blow given to the bell will cause a slight sound and movement in another bell similar to itself; the same for a string of a lute, and you will see this by placing a straw upon the string similar to that which has sounded" (Madrid 22v).

Leonardo continued doing extensive studies of other phenomena associated with this type of simple surface wave, which he naturally extended to sound and light waves. Here are some of the main aspects of his work:

Reflection. There are many quotes throughout his notebooks and especially in his book *On Painting*.

Diffraction, also called the Young Principle (Figure 7).

Color formation with a ray going through water.

Such waves can be represented as sinusoidal waves traveling along a cylinder even if the actual motion of the process is a transverse cylindrical action and a longitudinal double rotation of conical form (Figure 8).

Leonardo then generalized such wave motion to all kinds of action in different media (Figure 9). Here we see his comparison of sound, magnetism, light, and olfactory waves, with their properties of reflection. Leonardo asks himself the question, why do sound and smell go through a wall, while light waves do not? The answer is not given, but will be implicit in the kind of elaboration he makes later. We could express it in modern terms with the double aspect of particle (photon)-wave property of the light wave, or in terms of the self-transparency of electromagnetic waves. It is the "particle" aspect of the light that does not go through the wall.

Singularity Formations: Breakers and Hydraulic Jumps

If put in modern mathematical terms, what Leonardo is discussing would produce a Maxwell-type of electromagnetic field. Such an analogy was used by both Helmholtz and Beltrami in the 19th century, although for the opposite reason.[20] But Leonardo went further, because of his method of thinking, and began to look at the transformations from sinusoidal waves (with no mass transport) to hyperbolic types of waves (with mass transport); that is, hydraulic jumps and breakers.

Breakers. The reasons, in precise terms, for the formation of such discontinuities are not given by Leonardo, to our knowledge. But our aim here is not to present a precise historical picture of Leonardo and attribute to him everything that had to be discovered, but to emphasize the *method* of thinking that leads him to give importance to these phenomena. This method is important because the debate on the existence and formation of such physical discontinuities, as presented above, was the issue between the Riemannian and the Kelvin schools of hydrodynamics.

With breakers we see a normal sinusoidal wave that does not transport mass and does not "do work" suddenly transversally become a "mass transporter," as seen from the man surfing in Figure 10. The reason has to be looked for first in the fact that *the surface of the water is a surface of discontinuity,* and this was clear to Leonardo. This is the actual primary cause of the breaker formation, which is identical, as we will see, to the formation of internal ordered turbulences from surfaces of discontinuity once they are formed "inside" a fluid. The visualization of the formation of the discontinuity is given by the increase of the amplitude and frequencies of the wave. To generalize this, the increase in amplitude and frequencies creates in a surface of discontinuity a new singularity, which will act more like a mass-particle than like a wave. This is precisely the phenomenon Riemann identified mathematically, predicting that any compression wave will develop into a shock wave.[21]

The same must be true (and was studied in this sense by Schrödinger, de Broglie, and Heisenberg) for electromagnetic phenomena, where starting with photons we have the formation of the first generation of singularities.

Geometrically we can see the transformation to a hyperbolic geometry from the parabolic or ellipsoid type of geometry before the breaker is formed, and we are more able to analyze singularity formation. To have an immediate and simple idea of singularity on water, we have to consider the surface of water like a paper surface. As far as we can construct figures and shapes without breaking the surface, no real singularity is formed; the moment the surface is "broken," a real singularity is established. In 1932, Riabouchinsky defined the functional condition to describe a breaker with the same equation of the shock wave created by Riemann.[22]

Hydraulic jumps. These are the same phenomena as breakers, although created under different conditions (Figure 11). It is important to know that in water as in air, a "rarefaction" wave will tend to be continuous, while a "compression" wave, as indicated by Riemann, eventually must produce a discontinuity. In water a steady lowering of the water level will propagate continuously in still water of constant height (density), while the creation of a sudden elevation, by an obstacle or velocity reduction, will always lead to a discontinuity of the type like the hydraulic jump. We will illustrate this more precisely when we come back to the shock wave and the theory of its characteristics.

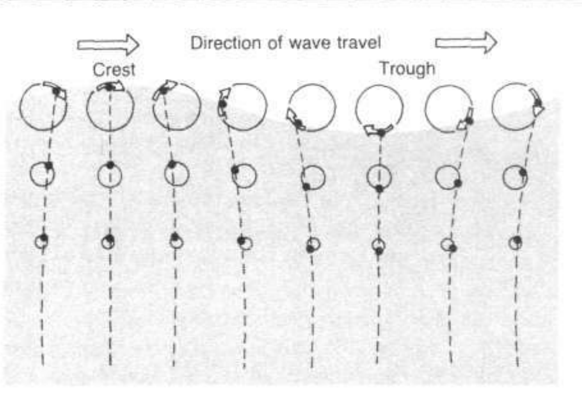


Figure 8
THE SIMPLE WAVE

The simple kind of wave can be represented as a sinusoidal wave traveling along a cylinder, even though the actual motion of the process is a transversal cylindrical action and a longitudinal double rotation of conical form.

Source: J.B. Marion, *Essential Physics in the World Around Us* (New York: Wiley, 1978), p. 212.

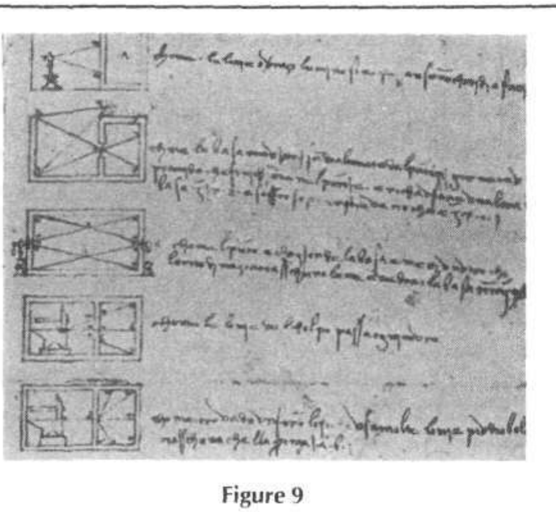


Figure 9
LEONARDO COMPARES THE CHARACTERISTICS OF WAVES

Here Leonardo compares and contrasts the characteristics of different kinds of waves—sound waves, magnetic waves, light waves, and smell considered as a wave phenomenon—with their properties of reflection. Why do sound and smell pass through walls, he asks, while light waves do not?

Source: Codice Atlantico 347.

FLUID IN MOTION OR MOTION IN FLUID

Theory of Flight Vortices—Turbulence

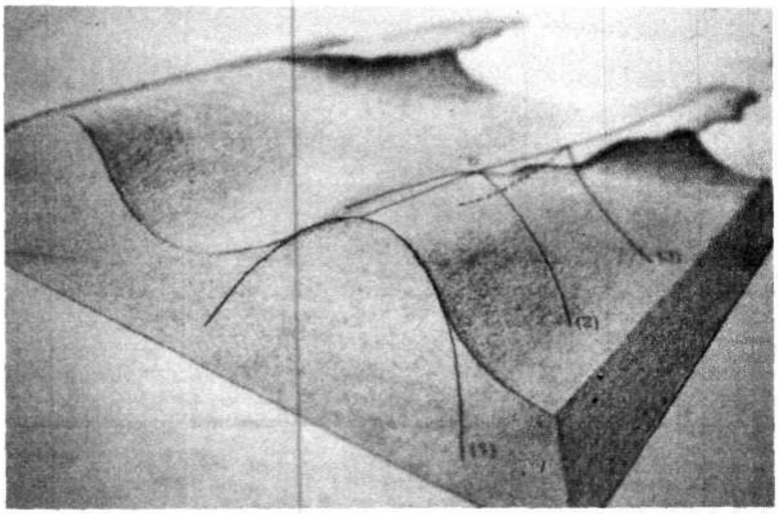
If we shift now from simple transmission of action through or in a fluid to self-motion of the fluid itself, we encounter a new set of phenomena and singularities that Leonardo studied intensively and that today is still not clearly understood—*vortices*. Again, we do not claim to provide answers from Leonardo's work, but we wish to bring his work to bear in the debate on the importance of vortices and the necessity to approach such studies from a deterministic standpoint.

The dominant current in physics, reflecting a Cartesian outlook, tends to neglect the importance of the formation of vorticity because the reductionist technicians do not want to bother with problems that are not easy. "The mere mention of vorticity or of rotation magnetohydrodynamic models," writes fusion scientist Daniel Wells, "seems to evoke an almost irrational, negative response. . . ." So also the reaction of "experts" on Leonardo, who in the face of his clearcut "obsession" with all sorts of vortices have had nothing to say but that Leonardo was "obviously fascinated with the mystery of the symbology of spirals." In reality, as we have said, Leonardo looked for the formation of vorticity in every possible place—from tornadoes to flowers, to the air, to the circulation of the blood—because he had grasped the importance and the universal characteristics of such phenomena. He went further than simple interest; he actually worked experimentally to understand their formation and function. We will review some of the main aspects of Leonardo's work, organizing it around his attempts to define a theory of flight. Only with Prandtl and then Busemann in the 20th century was the importance of vorticity and rotational fluids for the theory of aerodynamic and hydro-

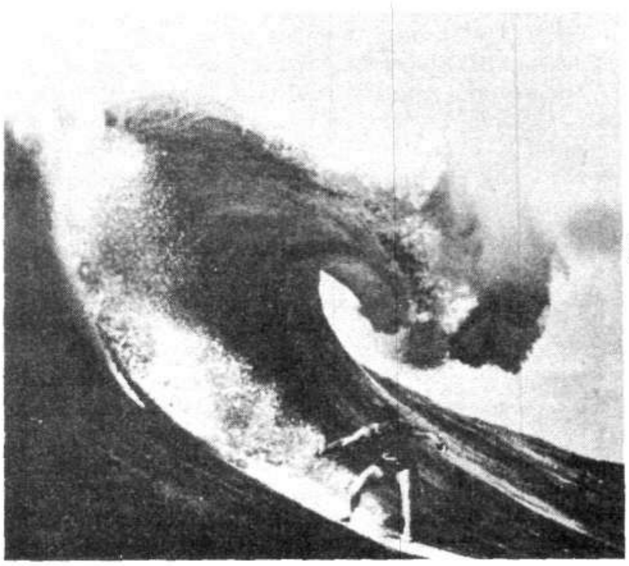
Figure 10
THE FORMATION OF BREAKERS
A normal sinusoidal wave that does not transport mass—does no work—suddenly becomes a "mass transporter," as proven by the surfer in the photo (a). Leonardo understood that this transformation is possible because the water's surface is a surface of discontinuity (b). The transformation to a hyperbolic geometry from the parabolic geometry before the breaker is formed is shown in (c).

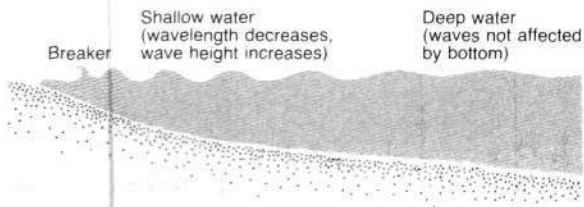
Source: Madrid Codex II; J.B. Marion, *Essential Physics*, p. 213.

(c)

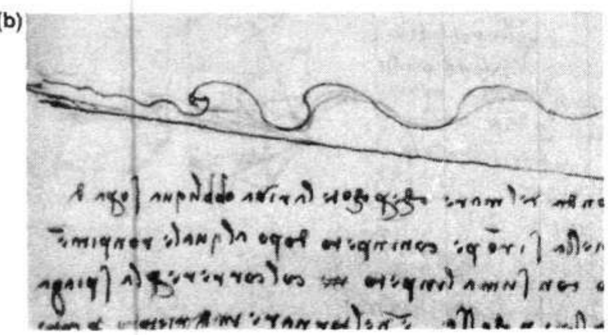


(a)





(b)



dynamic motion rediscovered—the theory being the *sine qua non* for understanding airplane lift. In the late 1940s, Busemann applied the same principle to plasma physics, in the context of hypersonic studies.[23]

Vortices. We can observe vortices daily in many places in our surrounding atmosphere; they appear without any apparent outside impetus, created by the pure self-motion of the fluid. Once they are formed, they tend to operate as "individuals" with a specific identity, so much so that we give names to hurricanes moving along or against the stream flow. One of the essential components of vorticity is temperature gradient, which generates rotational motion, the first step in the formation of a vortex being the creation of a surface of discontinuity. This motion is characterized by triple self-reflective rotation. We will see later that the concept of rotation is key for the structure and stability of vortex filaments.

(a)

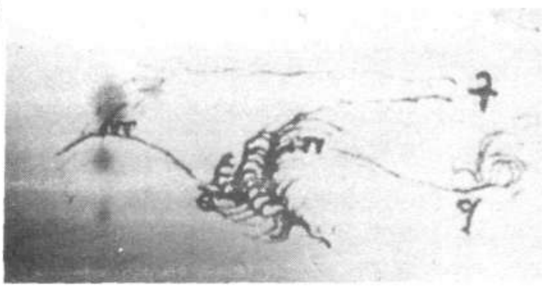


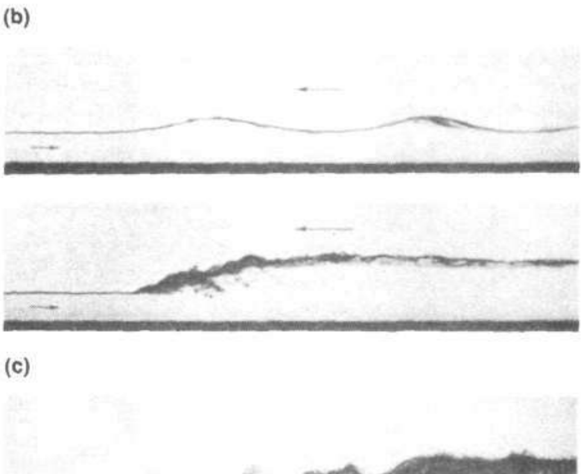
Figure 11
SURGES AND HYDRAULIC JUMPS

Surges and hydraulic jumps are essentially the same phenomena as breakers. (a) Leonardo's sketch of a hydraulic jump. (b) Surges traveling upstream against the oncoming flow—often encountered in tidal estuaries. (c) Silhouette of a hydraulic jump.

Source: A. Institut de France Ms. E 81v; B,C. Hunter Rouse, *Elementary Mechanics of Fluids* (New York: Dover, 1978), pp. 144, 146.

(b)

(c)



Leonardo intuitively understood the importance of the temperature gradient, as well as "friction" effects generated inside the fluid itself. He wrote: "*No element has in itself gravity unless it moves.* . . . Gravity is caused by immediate movement. . . . Movement is created by heat and cold. . . . The heat of the universe is created by the Sun; the movement of the elements arises from the Sun" (emphasis added, B.M. 205r).

There are two main types of velocity distribution in vortices that were also studied by Leonardo, free vortices and forced vortices. Forced vortices rotate like solid bodies with constant period but velocity increasing with the distance from the center. In free vortices, the speed decreases with the distance from the axis. Normal vortices are a combination of these two, with a fixed center, the "eye," containing a forced vortex and fluid further out spiraling with decreasing speed. But as shown in Figure 12, a normal fluid motion inside a tube tends to produce the same configuration as well as the electromagnetic motion or patterns seen in a tree trunk:

> The spiral or rotary movement of every liquid is so much the swifter in proportion as it is near the center of its revolution . . . while movement in a circular wheel is so much slower as it is near to the center of the revolving object. . . . *The motions of the air through the air are two, that is, straight in the form of a column upwards, and with revolving movement. . . . Water makes this movement downward in the form of a pyramid,* and is so much the more swift as the pyramid is more pointed. . . . (C.A. 296vb)

With the above quotations and Figure 13, we see that Leonardo is not only looking at, but experimenting with vortices.

The Theory of Flight

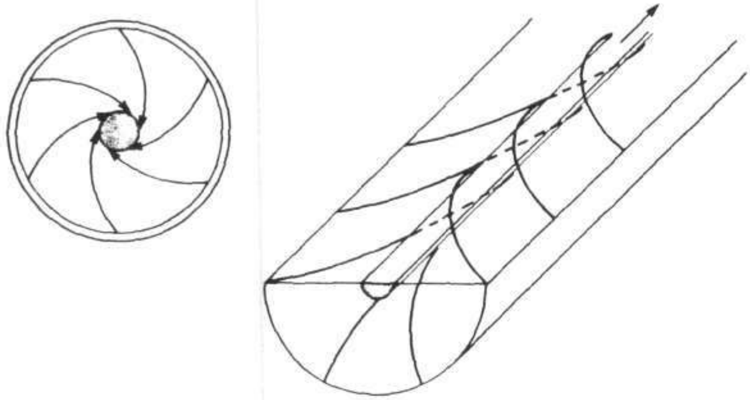
The modern theory of lift, developed by Prandtl, is based on the discovery that lift is caused by the surface of discontinuity around the wing that creates a vortex at the wing's trailing edge, and consequently an overall rotational motion around the wing that provokes the lift (see Figure 14).

This Magnus Effect (after Heinrich Magnus, 1802-1870) was finally understood only in 1902. Experimentally it was created by replicating Leonardo's method of using water flows to visualize air behavior. This had to be performed against the indications of the Kelvin-Helmholtz theories, which postulated the impossibility of creating rotation out of linear motion.

To quote Prandtl:

> . . . now according to Kelvin, no circulation can arise in the case of motion starting from rest, even in a multiply connected space. . . . In actual fact, the circulation will result from the formation of a surface of discontinuity; an eddy is formed out of the surface of discontinuity in the far edge of the airfoil, the eddies then move and leave the airfoil with a circulation equal and opposite to its own. . . . The actual lift is then due to the surface of discontinuity with a transverse discon-

Figure 12
FORCED AND FREE VORTICES
A forced vortex rotates like a solid body—constant period but increasing velocity at increasing distance from the center. In a free vortex, the speed of rotation decreases with distance from the center. The motion of water down a pipe, shown here in a diagram based on the work of Prandtl, combines the two kinds of rotation in helical form: forced rotation in the "eye" and free rotation otherwise.



tinuity in the velocity. According to the normal theory [of a perfect fluid, that is, d'Alembert, Kelvin] the velocity near the object is very high and theoretically reaches infinity in the case of a frictionless perfect fluid; in reality, the speed diminishes due to the formation of eddies. . . . We could explain this behavior by adducing the special principle that the fluid seeks to avoid infinite velocities and *forms discontinuities* instead.[24]

The implications are clear, and although we cannot elaborate here, the absurdity of Kelvin and Helmholtz is the result of their reducing Riemann's surface theory to that of Cauchy and Victor Puiseux; that is, a Cartesian version, where artificial cuts would eliminate the real notion of formation of discontinuities.[25]

In his studies of the theory of flight, Leonardo was working toward a theory like Riemann's, although by approximation, of circulation both around a wing and in the motion as a whole (see Figure 15). It is clear that Leonardo was studying lift as well as the relationship of density and temperature and overall helicoidal motion for propulsion. For example, he wrote, "I conclude that the rising of birds without beating their wings is not produced by anything other than their circular movement amid the movement of the wind. . . ." It is natural to hypothesize that Leonardo had thought through the theory of helical propulsion. We must look at his famous "helicopter" not as an actual helicopter, but as an experimental machine for helical propulsion: "If this instrument is in the form of a helix . . . such helix will be able to bring it up in the air. . . ." Leonardo added to this precise studies of the relation between the center of gravity and of resistance:

> As regards constructing the machine in such a way that in the descent, whatever may be the direction that it takes, it finds the remedy prepared, this you will do by causing its center of gravity to be above that of the weight which it carries. . . . [*Sul Volo* 13 (12)r]

The secret of Leonardo's experiments on flight is apparent in Figure 16. Leonardo had no magic powers that allowed him to "slow down the flight of birds," as someone once wrote. He simply constructed an artificial bird, with which he could experiment having both visualization of air flows and the relation between air resistance and the center of gravity. There is enough evidence to believe that Leonardo actually constructed an airplane without an engine.

After having seen the specific effect vorticity has on the wing theory, let us look at more broadly the concept of

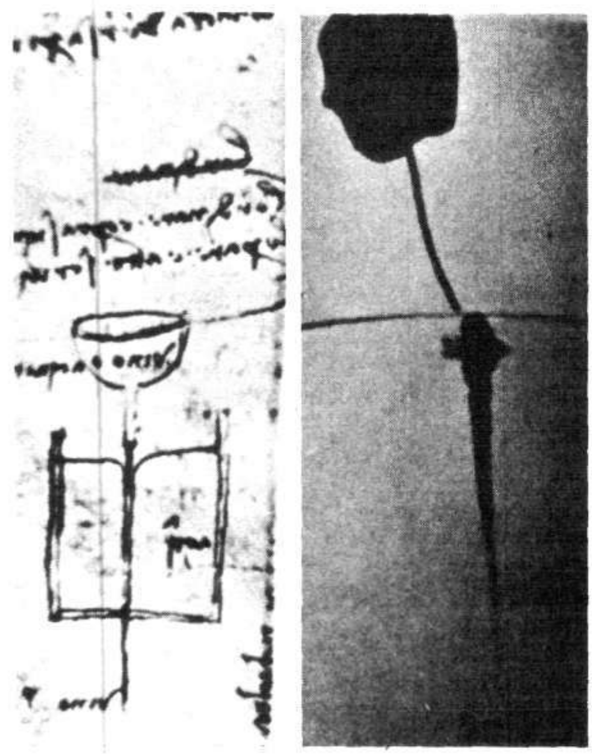
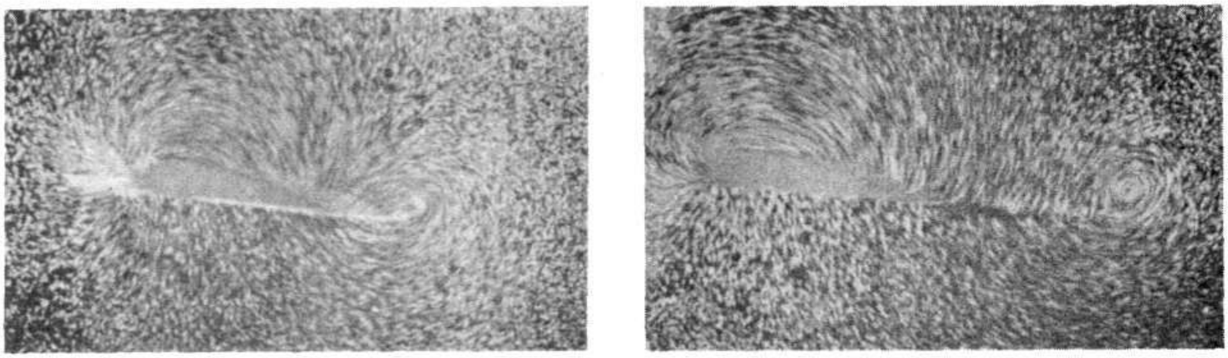


Figure 13
LABORATORY PRODUCTION OF FREE VORTICES
Leonardo's sketch, and a photo from the work of Prof. Enzo Macagno at the Institute of Hydraulic Research, University of Iowa.



(a) (b)

Figure 14
PRANDTL'S THEORY OF LIFT

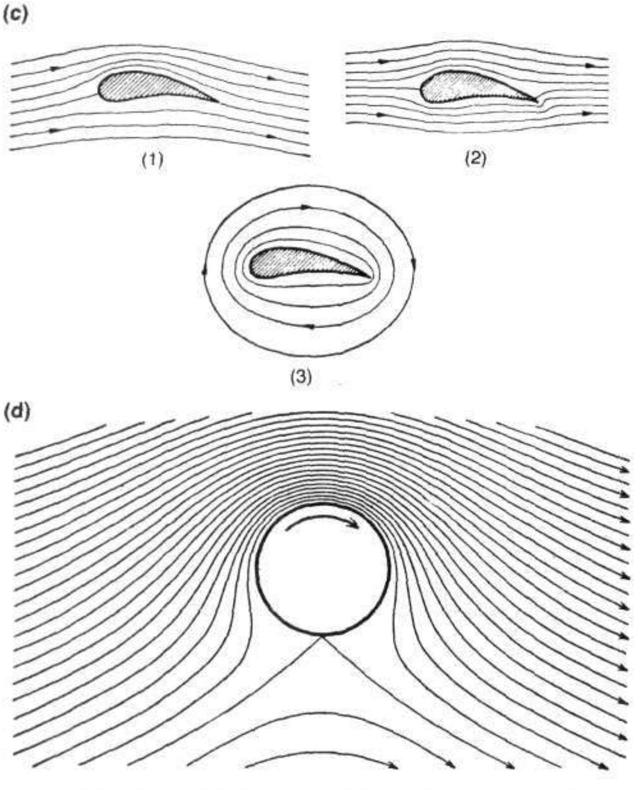
(a) Flow around an airfoil, with the "starting vortex" emphasized. The camera is at rest with respect to the airfoil. The surface of discontinuity around the wing creates a vortex at the back of the wing.

(b) Now the camera is at rest with respect to the undisturbed fluid, revealing circulation equal and opposite to the "starting vortex."

(c) Prandtl explains what is occurring: The flow around an airfoil (1) may be represented by "superposing" the "ordinary irrotational flow" (2) without circulation, and the circulatory flow of (3). Irrotational flow means that the particles in any local region of the fluid do not undergo any rotation with respect to the median line of the flow. Thus the resulting flow also exhibits circulation, which is very closely related to the occurrence of a lifting force: the circulatory flow acts with the irrotational flow of (2) above the airfoil and against it below. By Bernoulli's theorem this means that the pressure is diminished above the airfoil and increased below it; that is, there is a lifting force.

(d) The lift phenomenon is analogous to the Magnus effect involved in flow around a rotating cylinder. On the side where the two velocities are in the same direction, the speed of flow is greater. On the opposite side, where the two velocities oppose each other, it is less. A force at right angles to the flow results (upward in the diagram). This explains why a baseball to which a high spin is imparted will "pop up."

(c)



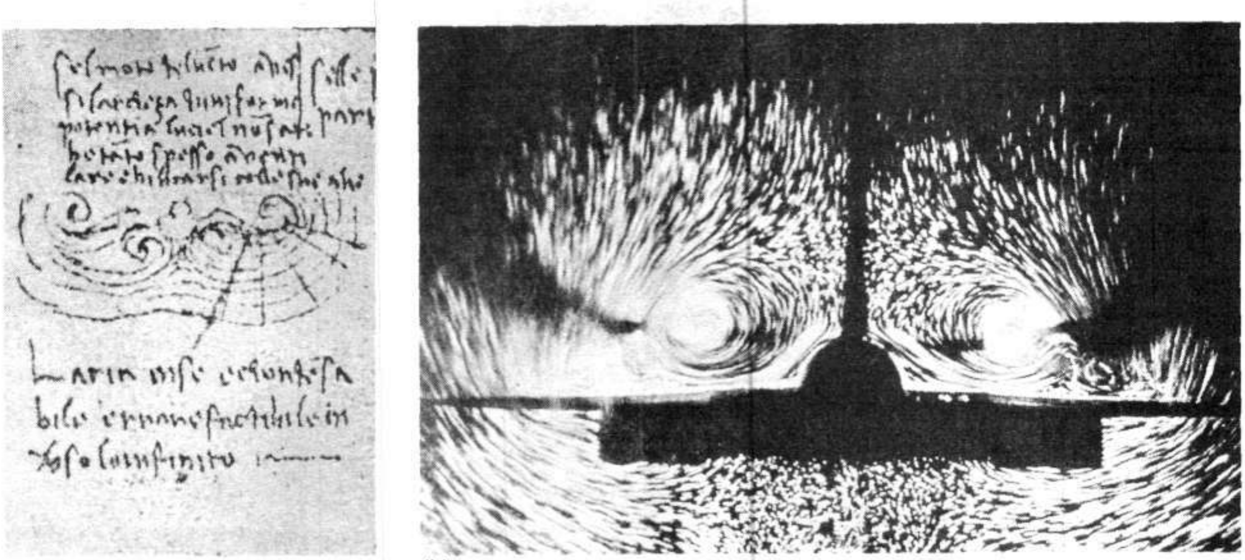
Source: (a)(b)(d) L. Prandtl, *Applied Hydro- and Aeromechanics* (New York: Dover, 1957), pp. 299, 300, 83; (c) L. Prandtl, *Essentials of Fluid Dynamics*, p. 70.

turbulent flows and the kinds of effects around a body in air or in water.

Boundary Layers, Waves, Aerodynamic Shapes

Fluids flow by themselves under certain conditions, or because a solid body is immersed in the fluid, or because the mixing of two liquids of different density or equal density but different conditions tends to create what appear at first as chaotic turbulences. A closer analysis shows that they are not necessarily so chaotic and we can analyze them as the stable formation of sets of singularities.

The experimental apparatus is very simple and can be set up easily (see Figure 17). It will show the formation of an internal line that will begin to wave around and then breaks up in apparent chaos. Figure 17 shows that at the end we have the formation of *internal breakers*! Moreover, small eddies tend to organize themselves into stable, large vortices. Other experiments have been conducted by Hopfinger and Browand[26] [see Figure 17(b)] to show that rotational action tends to organize small-scale turbulences in well-defined visible vortices. The basis for the studies of turbulence, then, as well as for the formation of breakers in the ocean, is one common matrix, the formation of a surface of discontinuity. We can do the same experiment with the



(a) (b)

Figure 15
VORTICES IN THE FLIGHT OF BIRDS
Leonardo studies vortices around a bird's wing (a). Compare this to vortices around airplane wings (b).

Source: Institut de France Ms. E 47v.

formation of smoke-ring vortices, derived from the surface of discontinuity formed around the mouth of the smoker or another opening [see Figure 18(b)]. What appears at the beginning of the photograph to be a line is most probably a small vortex filament, given that the surface of the discontinuity itself is defined by a new degree of rotational motion compared to the fluid out of which it is produced.

This theory of the formation of "turbulent" waves around bodies is obviously key in understanding flight, not only in terms of the lift effect but also for what happens around the main body of the airplane. Again, up to a certain speed, this can be experimented in water. Prandtl did this specifically for airplanes, while Leonardo did it more generally to study motion in fluid. Both Prandtl and Leonardo isolated the key aspect in the formation of the surface of discontinuity: *the boundary layer phenomenon;* Leonardo qualitatively, Prandtl more precisely (Figure 19).

It is this so-called entropic turbulence effect around bodies that in reality causes the formation of surfaces of discontinuity and finally, given certain geometrical shapes, allows the plane to fly. In the same drawing we can see that Leonardo correctly identified aerodynamic shapes for a subsonic plane or an underwater submarine. We will see later why the shape of surface boats and supersonic planes must also be similar. Leonardo understood precisely the point that for underwater motion and subsonic flight, resistance is defined from the back of the object and not so much from the front (Figure 20). Leonardo wrote:

> . . . the impetus of the water is simple beneath the surface of the water; it does not compress the water in front of the movement [that is, pressure waves are not formed] . . . but moves the water behind with the same speed as the mover has . . . (C.A. 168vb).

Newton completely missed this point. According to his theory, there is nothing interesting happening in the wake of the moving object. However, as we have indicated, the boundary layer phenomenon cannot be immediately seen unless you are looking for it from scientific hypothesis.

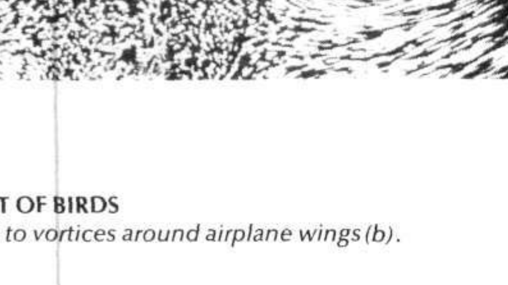
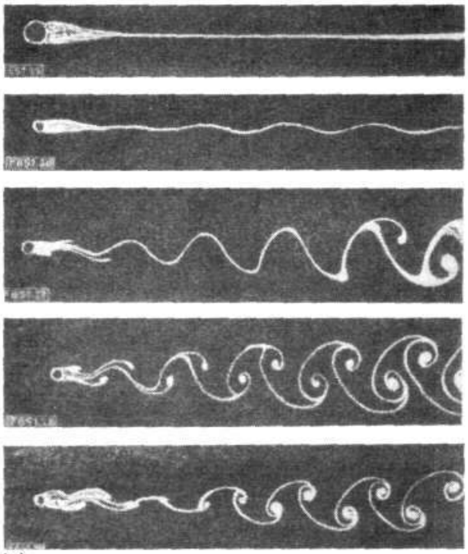
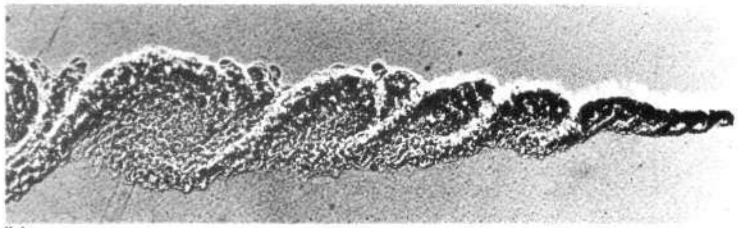


Figure 16
THE SECRET OF LEONARDO'S FLIGHT STUDIES
Leonardo had no magic power to slow down birds in flight, as someone once alleged. He grasped the concept of the wind tunnel to make experiments possible. Here is the artificial bird he built to study, among other things, the relationship between the center of gravity and the center of air pressure.



(a)



(b)

Figure 17
INTERNAL VORTICES

What at first appear as chaotic turbulences turn out to be stable formations of sets of singularities.

(a) Flow of oil behind circular cylinders at increasing flow velocities.

(b) Counterstreaming jets of helium and nitrogen. In a flow almost completely dominated by small-scale turbulence, there is large-scale coherent structure.

Source: A. Prandtl, *Essentials of Fluid Dynamics*, p. 187; B. Steven Bardwell, "Beginnings of a Deterministic Theory of Turbulence," *Intl. J. Fusion Energy* 2 (4): 27 (1981).

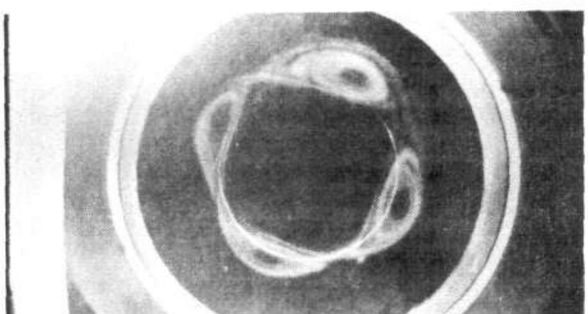
Leonardo extended this notion to contact between liquids and liquids, air and liquids, earth and air, and so on, in all cases observing that there was a *retarded fluid* phenomenon, which then caused a reverse flow piling up to form eddies. Without extrapolating very much we can see in the boundary layer concept of retarded fluid the first approximation of the "retarded potential" concept of Riemann:

> . . . As the wave of sand moves considerably more slowly than the wave of water that produces it, so the wave of water created by the wind moves much more slowly than the wave of the wind that produced it, that is, the wave of the air. The wave of the air performed the same function within the element of fire . . . and their movements are in the same proportion one to another as is that of the motive powers behind them (Leicester 23r).

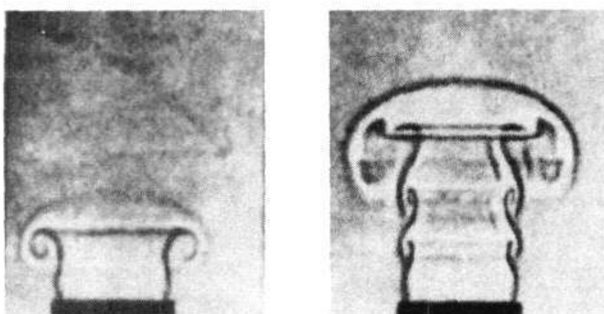
We conclude this section by demonstrating Leonardo's identification of another important phenomenon occurring in the wake of an object in fluid, the so-called von Karman vortex street, the formation of pairs of counterrotating vortices (Figure 21). This phenomenon is also very important for the study of wind instruments, in which Leonardo was also involved.

Atmospheric Three-Dimensional Vortices

Air was considered by Leonardo as one aspect of fluid



(a)



(b)

Figure 18
ROTATIONAL ACTION ORGANIZES SMALL-SCALE TURBULENCES

Rotational action tends to organize small-scale turbulences in well-defined visible vortices (a). The basis for turbulence, as for the formation of breakers in the ocean, is the initial formation of a surface of discontinuity. Smoke-ring vortices, for example, derive from the surface of discontinuity formed around the mouth or other aperture (b).

Source: *FEF Newsletter* I (6): 17.

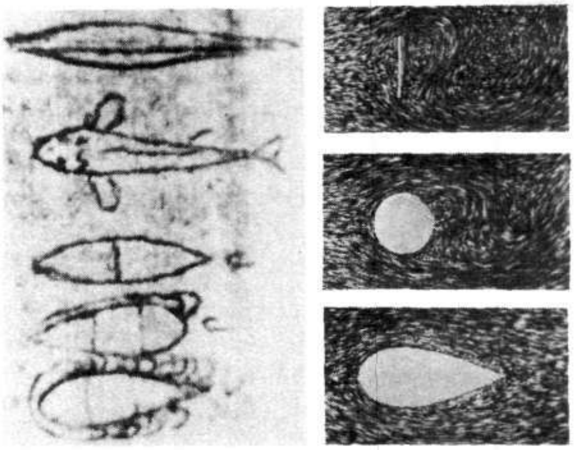


Figure 19
THE BOUNDARY LAYER

Both Leonardo and Prandtl identified the boundary layer phenomenon as the key aspect in the formation of the surface of discontinuity—Leonardo qualitatively, Prandtl more precisely.

Source: Institut de France Ms. G 50v.

motion with the specific property—in contrast to water—of being compressible. When compression results from various rotary motions, vortex filaments of the tornado type are generated in air or water spouts (Figure 22). The interesting aspect of this part of his work is that Leonardo rediscovered such three-dimensional vortex filaments in water, not inside the water as we have seen before, but as a specific transformation of the water wave at very high speed (Figure 23). Leonardo called such vortices "onde colonnali," columnar or cylindrical waves; they start like small cross waves on the surface of the water (Figure 24) which, as we shall see in the section on shock waves, are analogous to Mach lines. Such Mach lines are lines of discontinuity in the fluid; they behave with small modifications like normal waves; that is, they interfere, and so forth. At higher speeds they pile up to form "strong shock waves" or small hydraulic jumps.

The difference in behavior between water and air up to this point is illustrated with incredible precision by Leonardo:

> Air which is moved with impetus within the other air is compressed within itself as shown by the expansion of the solar rays. . . . The water in such cases cannot become compressed, and having all these like movements in its body, it is necessary for it to drive the other water from its place, so that *they may all appear on the surface*. . . .

In other words, the increased degree of freedom of the singularity in the water will show itself by increase in height because of the relative incompressibility of water; otherwise, the mechanism of the formation of water and air phenomena are the same.

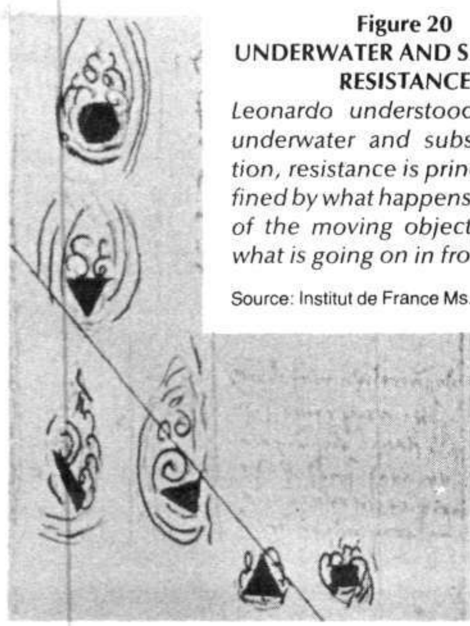


Figure 20
UNDERWATER AND SUBSONIC RESISTANCE

Leonardo understood that for underwater and subsonic motion, resistance is principally defined by what happens at the rear of the moving object, and not what is going on in front.

Source: Institut de France Ms. H 64.

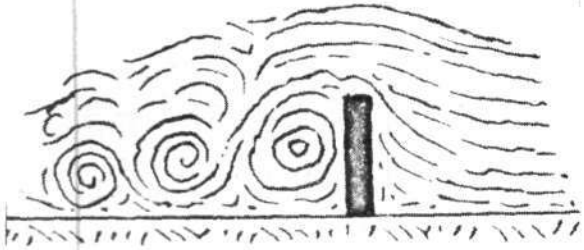
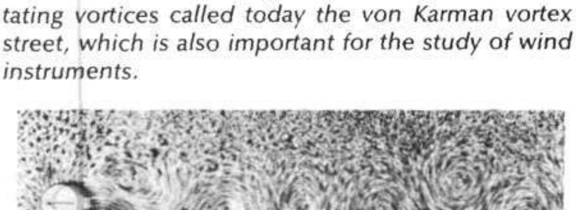


Figure 21
THE VON KARMAN VORTEX STREET

Leonardo identified the phenomenon of counterrotating vortices called today the von Karman vortex street, which is also important for the study of wind instruments.



Source: Institut de France Ms. F 89v; Rouse, *Elementary Mechanics of Fluids*, p. 241.

When the speed of such "shock fronts" increases even more, then their structuring as vortex filaments becomes visible. Such vortices or "cylindrical waves" will now tend to act not as waves but as "particles"; they will no longer interfere, but will bounce instead (Figure 25):

> When there are two unequal cylindrical waves of which the larger one comes into existence before the

smaller, this smaller wave intersects the larger and passes above it, but if the smaller starts higher in the river than the greater, then this greater follows the natural course and the smaller follows the course of the greater.

When two cylindrical waves of equal size and power clash absolutely, they each turn back completely without any penetration one of another (Institut de France Ms. 92r,v).

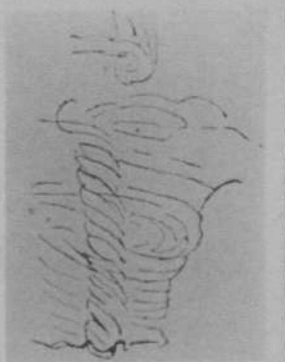
This is the same as in the formation of vortex rings of smoke, which, if they clash in the air, will tend to bounce back and enter into a vibratory motion like particles of matter. This led Kelvin and Helmholtz to the hypothesis of atom-vortices. The idea was wrong only in so far as they put it explicitly in a Newtonian context, thus negating the possibility of creation or destruction of such vortex-particles.

If Leonardo had studied only the formation and behavior of such "columnar vortices," it would have been enough to put his work in the center of the scientific debate in fluid dynamics. There is not the slightest serious comprehension today of the behavior of such intense vortex structures; moreover, experiments that tend to focus on this are suppressed.

Intense vortices have a very specific behavior that cannot

Figure 22
ATMOSPHERIC THREE-DIMENSIONAL VORTICES
Leonardo considered the specific property of compressibility of air in motion. Compression resulting from rotational motion leads to vortex filaments such as tornados and water spouts.

Sources: Codex Hammer 30v.



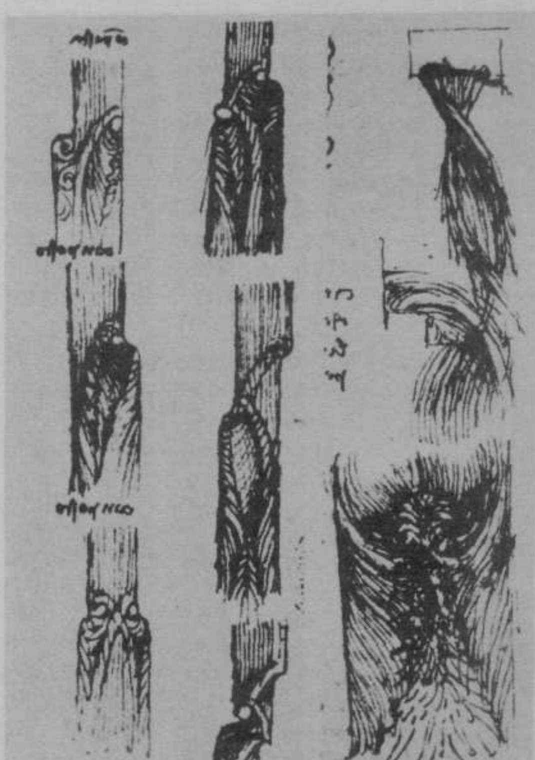
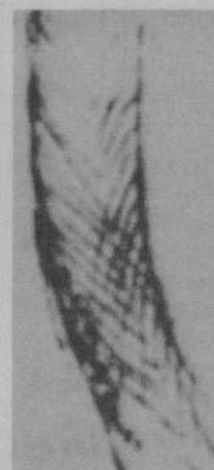


Figure 23
THREE-DIMENSIONAL VORTICES ON A WATER SURFACE
Leonardo discovered three-dimensional vortex filaments in water, not inside the water but as a specific transformation of water waves at very high speed.

Source: Institut de France Ms. F 90-93.

Figure 24
CROSS-WAVES ON A WATER SURFACE
Leonardo called the three-dimensional vortices on a water surface "onde colonnali"—columnar or cylindrical waves. They start as small cross-waves on the surface (shown here) and are analogous to Mach lines.

Source: Codex Hammer 27v.



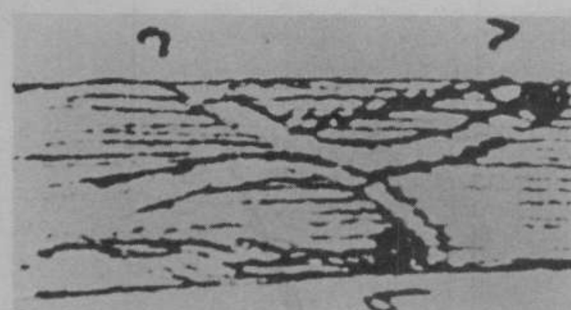


Figure 25
HIGH-SPEED CYLINDRICAL WAVES ON WATER
Cylindrical waves on a water surface have many properties of waves in air and electromagnetic waves. At high enough speed, they pile up to form "strong shock waves" or small hydraulic jumps, and will no longer exhibit interference.

Source: Institut de France Ms. F 92.

be reduced to Newtonian mechanics nor to any of its derivatives. A recent experiment on breaking up vortices shows the incredible similarity of such processes to the recombination of DNA (Figure 26).[26] Look at Figure 26(b) also from the standpoint of what is going on in the tip of a bud (seen from above) during the growth of a tree.

We could go on with many examples to show that this science is just at its very beginning. It still suffers from containment from the outside as well as self-containment because of the wrong methodological approach, which is pure sabotage.

It is also clear that the simple use of Reynolds numbers

Figure 26
INTENSE VORTICES

Intense vortices have specific behavior that cannot be reduced to Newtonian mechanics.

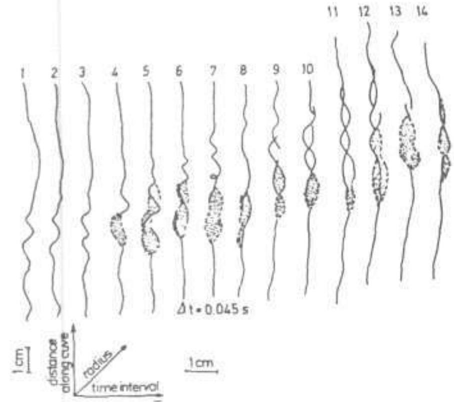
(a) A recent experiment on the breaking of vortices shows incredible similarity to the process of DNA recombination.

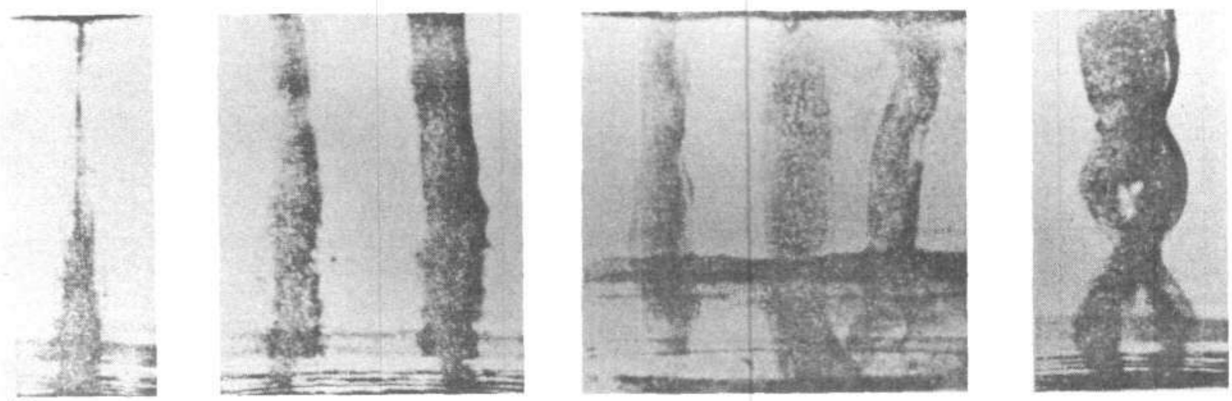
(b,c) The self-multiplication of vortices. Look at (c) from the standpoint of what happens in the tip of a bud during the growth of a tree.

(d) Twin vortex filaments in a tornado.

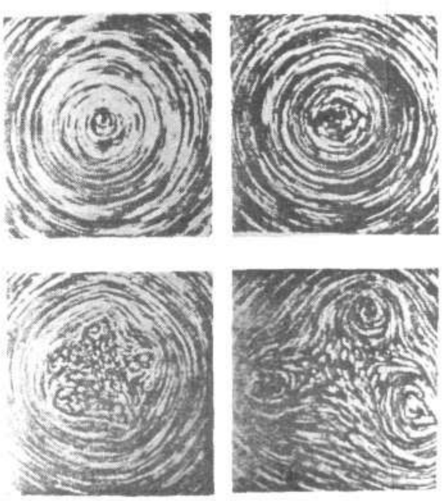
Source: (a, b, c) J. Lighthill, *Intense Atmospheric Vortices* (1982), p. 294; (d) Ralph Hardy et al, *The Weather Book* (Little, Brown, 1982), p. 114.

(a)





(b)



(c)

(d)

to measure the evolution of vorticity ceases to function when it comes to these intense columnar vortices. For example, the stability of the Red Spot on Jupiter (Figure 27) and the corresponding phenomenon on Saturn are not explicable unless we assume that high Reynolds numbers do not indicate unstable turbulence, but correspond to well-defined vortex structure, because of the presence of *rotation* or electromagnetic effects.

Let us now see, from the notion of secondary flows and cross waves, the geometrical explanation of some observable phenomena, again from Leonardo's own work.

Surface Theory of Waves: Cross Waves, Shock Waves, Geometrical Characteristics

If we limit the field of our fluid dynamic experiments to beneath the water's surface, there is a point where these experiments would cease to correspond to what happens to the airplane at high speed because of the formation in air of a shock wave. Does it mean that the similarity among fluids ceases to exist? No. We have to shift from underwater to include the water's surface phenomena in order to visualize it:

> The impetus of a movable thing within the water is different from the impetus within the air because air resists the penetration by compressing to infinity while water does not. In water, the impetus is divided into two parts: the simple one beneath the surface of the water, and the complex, between the air and water *as is seen with boats.*
>
> The simple impetus [under the surface] does not compress water *in front* of the movement of the fish but moves the water behind . . . and the wave of the water will never be swifter than the mover. . . .
>
> But the movement of the boat, called complex because it shares with the water and air, is divided into three main parts because it is carried on in three directions, namely, against the course of the river, in the direction of its current, and *crosswise,* that is along the breadth of the river (C.A. 168vb).

This analysis by Leonardo would be enough to define the full geometrical and physical analogy between air-compressed shock fronts and water-surface boat waves with their visible Mach lines or cross waves. But since "one can

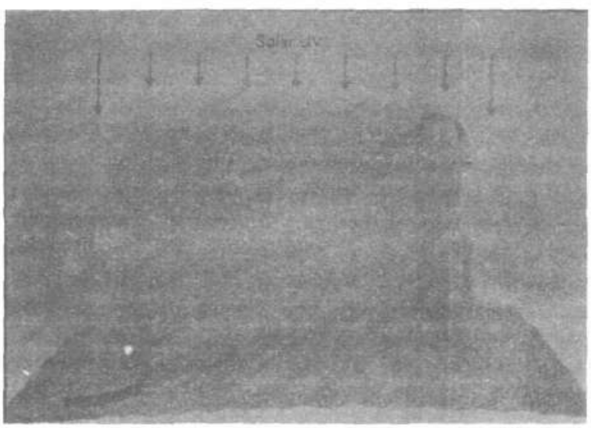
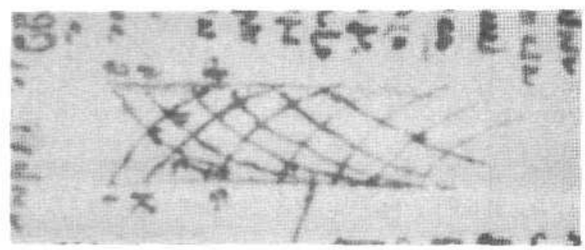
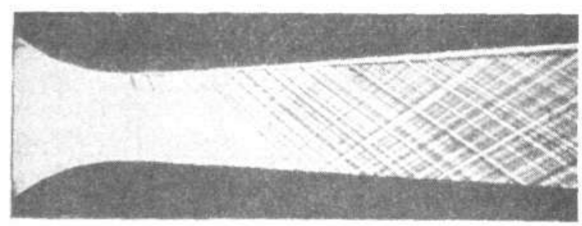


Figure 27
THE RED SPOT ON JUPITER: AN INTENSE COLUMNAR VORTEX
The stability of the Great Red Spot on Jupiter is not comprehensible unless we assume that high Reynolds numbers do not indicate unstable turbulence, but correspond to well-defined vortex structure, because of the presence of rotation or electromagnetic effects. Here, a three-dimensional drawing of the Great Red Spot.

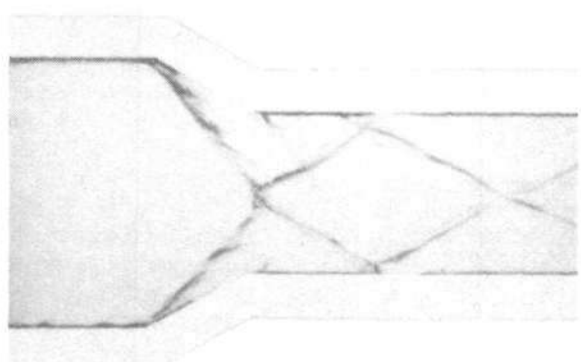
Source: NASA



(a) Leonardo's study of water.



(b) Mach lines in supersonic gas.



(c) Water experiments, the same phenomena as (b).

Figure 28
A VISUALIZATION OF RIEMANN'S WAVE 'CHARACTERISTICS'
The three pictures here show the formation in water and air of cross waves. These curves provide a visualization of the theory of "characteristics" developed by Bernhard Riemann.

Source: Royal Library, Windsor, 12660r; Rouse, *Laboratory Instruction,* p. 50; Prandtl, *Essentials of Fluid Dynamics,* p. 276.

be educated to death," as Professor Enzo Macagno says, and so lose any sense of the real world, as has happened to some of our eminent "experts" today, we have to elaborate briefly what Leonardo has grasped.

Figure 28 shows the formation in water and air of cross waves. These curves are the visualization of the theory of "characteristics" developed by Bernhard Riemann. How can we generate them very simply in water? (See Figure 29.) First, let's form discontinuities that propagate as circular waves in all directions. Second, move the objects that cause the waves, or the fluid in which the waves are propagated. Third, at a certain limiting point defined by the velocity of propagation of the first type of discontinuity (wave speed), we will get a new visible line: a surface of discontinuity at the boundary where the previous waves "pile up." Fourth, let's observe only the bent discontinuity around an object moving through water at a speed higher than wave propagation.

Fifth, observe a flow in a channel. For speeds above the wave speed, the walls create a set of discontinuities (boundary layer phenomena) that will propagate downstream along "lines" called Mach lines (for the air). Such lines will still cross each other with slight modification as normal waves. Their geometrical form will depend on the speed. They are "cross waves" or "soft shocks." Such cross waves can be caused only at supercritical speed (above the velocity of propagation of a normal wave in water), either because an object moves or because the fluid itself moves. The same happens in air [Figure 28(b)], where the cross waves span from the throat to the actual shock front; that is, they are characteristic of a supersonic regime.

The shock front is generated by the piling up of such cross waves, which are themselves a piling up of normal waves. Before elaborating this concept, let's stress one point. Everything we are looking at is essentially conceptually linked to the notion of formation and propagation of discontinuities of different orders or the formation of boundary-layer phenomena, which is the same thing. Such discontinuities again can be generated physically in many different ways, but mathematically turn out to be the same. It happens at the surface of separations: solid/fluid or fluid/fluid at different densities, or fluid/fluid at the same density but different composition, and so forth. Any fluid motion responds to such visible or invisible boundary phenomena with the formation of singularities that may or may not change the topology, that is, the geometrical characteristic—*the connectedness*—of the fluid geometry.[27] We are interested only when such geometric changes actually occur, as we shall see.

The Cartesian school, from d'Alembert through Cauchy

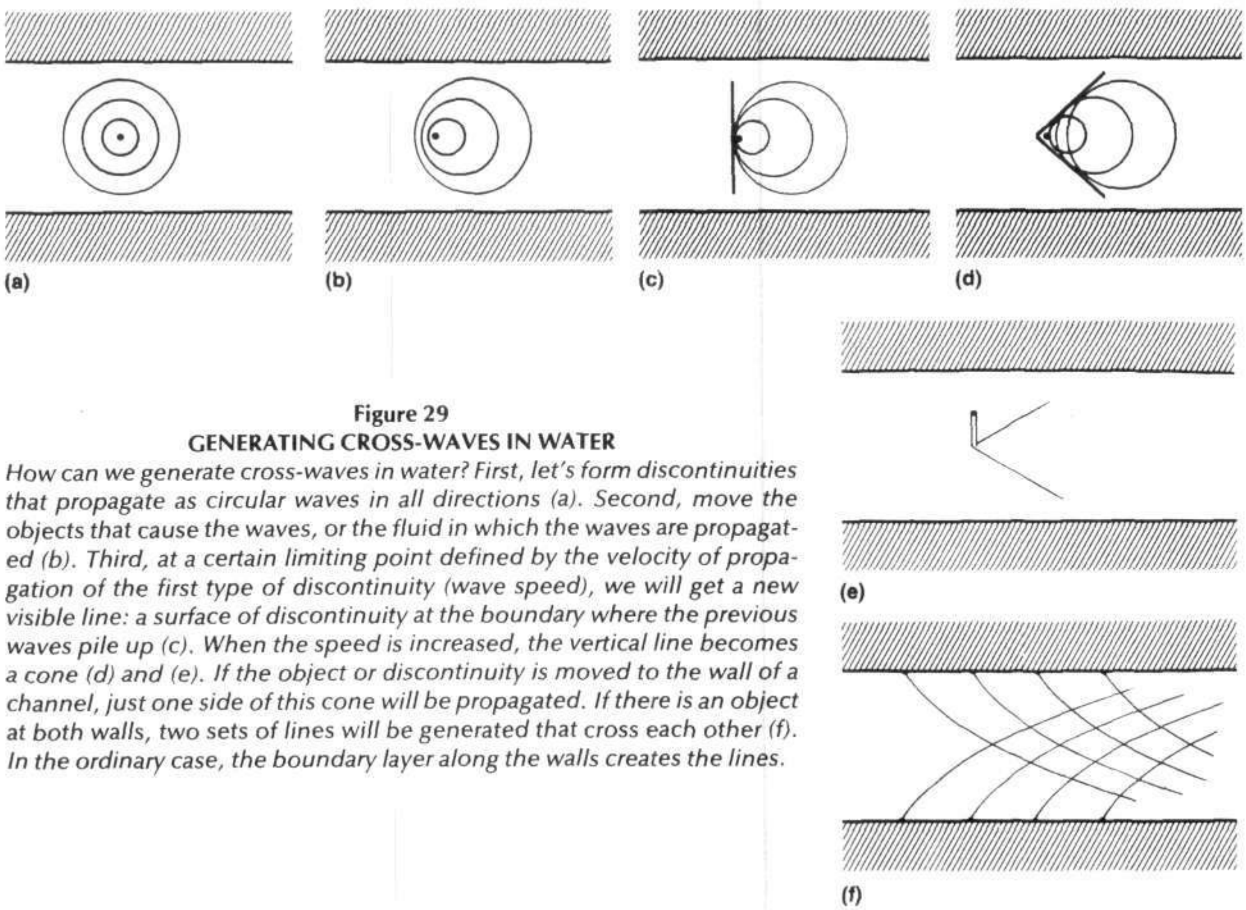


Figure 29
GENERATING CROSS-WAVES IN WATER

How can we generate cross-waves in water? First, let's form discontinuities that propagate as circular waves in all directions (a). Second, move the objects that cause the waves, or the fluid in which the waves are propagated (b). Third, at a certain limiting point defined by the velocity of propagation of the first type of discontinuity (wave speed), we will get a new visible line: a surface of discontinuity at the boundary where the previous waves pile up (c). When the speed is increased, the vertical line becomes a cone (d) and (e). If the object or discontinuity is moved to the wall of a channel, just one side of this cone will be propagated. If there is an object at both walls, two sets of lines will be generated that cross each other (f). In the ordinary case, the boundary layer along the walls creates the lines.

to Kelvin and Horace Lamb, has categorically refused to take into consideration such types of problems.[28]

Let's see how this "piling up" can generate singularities and new metrics. This will also give us an insight into the real notion of mathematical "limit," not in the sense of the d'Alembert-Cauchy limit theory for differentials but in the opposite sense of Cantor's transfinite.[29]

Assume that for a fluid (water) the main functional relation is the velocity potential. That is, we define the geometry according to the "speed of propagation" of wave discontinuities generated by a stone (see Figure 30). First, at subcritical speed (where velocity u of the fluid is lower than velocity c of the propagation of the wave), the fluid field will propagate only certain types of singularities and in a given topological shape. Second, at supercritical speed, $u > c$, that same stone will generate a discontinuity that will be propagated and can be visualized at the surface as cross lines or as small hydraulic jumps.

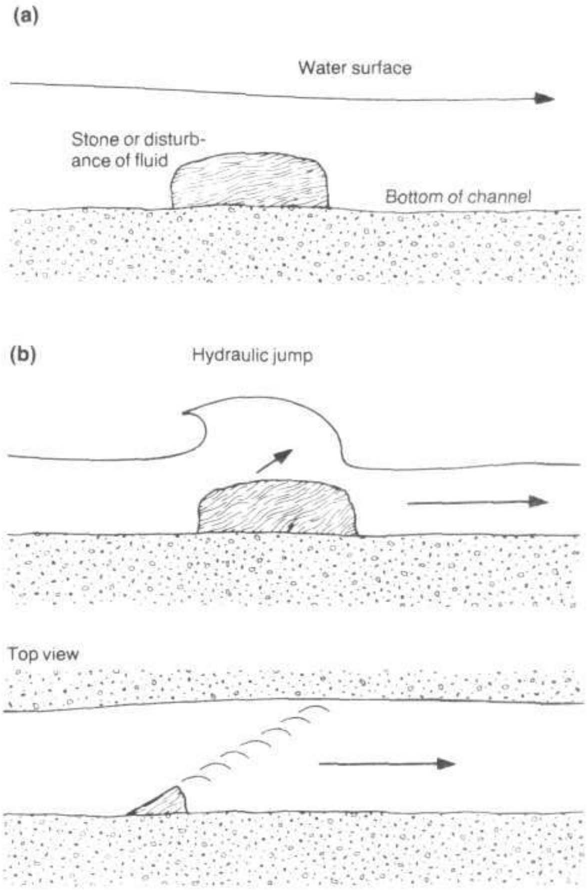


Figure 30
WAVE DISCONTINUITIES GENERATED BY A STONE
At subcritical speed (a), the fluid field will propagate only certain types of singularities, which cannot be seen. At supercritical speed (b), the same stone will generate a discontinuity that can be propagated and can be seen at the surface as cross lines or as small hydraulic jumps.

As we have seen before, the cross waves or Mach lines can be visualized as a "piling up" of normal waves or as the "limit" of normal wave speed of propagation. The limit of one pulse of action appears to be a shift to a new kind of geometrical characteristic; that is, a "transfinite." The Mach lines *themselves* can now pile up and produce strong shock discontinuities: aerial shock waves, bow waves, strong hydraulic jumps, and so forth (see Figure 31).

The cross waves or Mach lines are also called *geometrical*

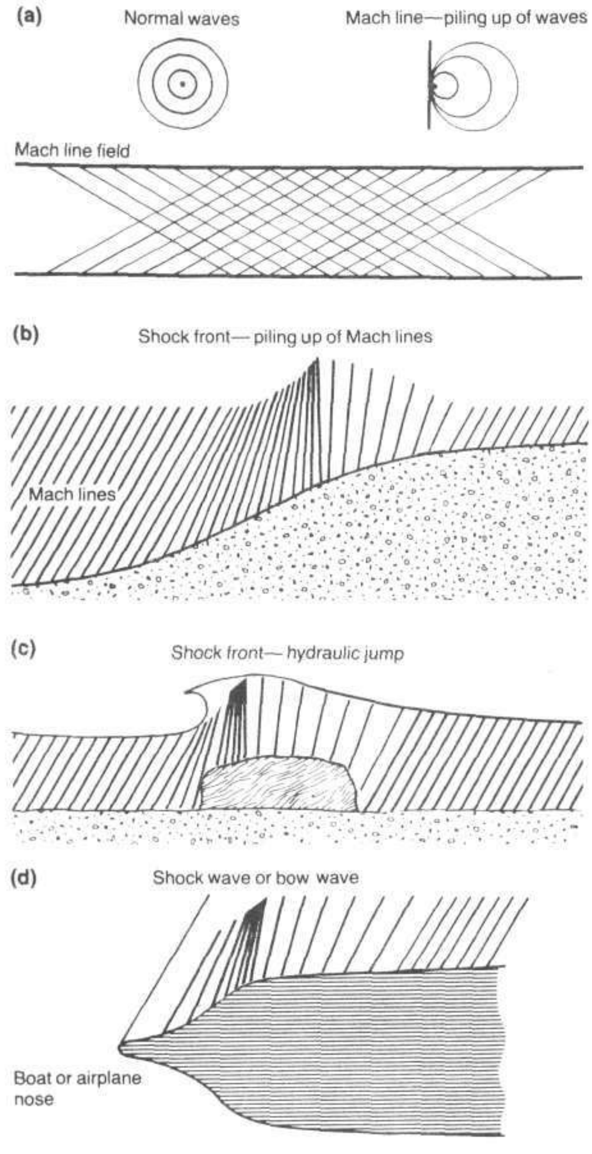


Figure 31
MACH LINES AS GEOMETRICAL CHARACTERISTICS
Cross waves or Mach lines (a) can be visualized as a "piling up" of normal waves, where the limit of one pulse of action appears to be a shift to a new geometric characteristic (b). The Mach lines themselves pile up and produce shock waves, like the hydraulic jump in (c) or the bow wave in (d).

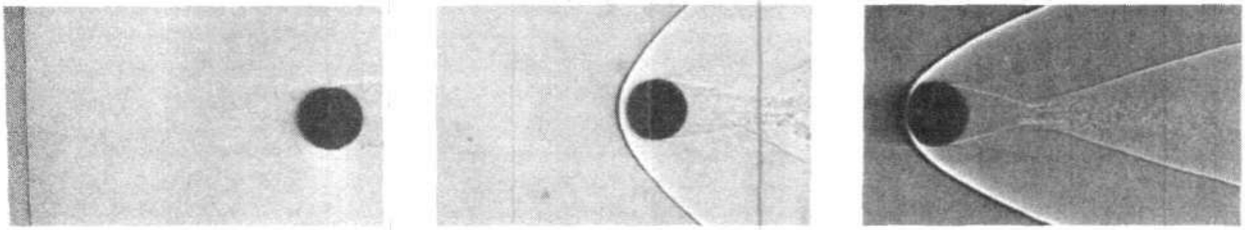


Figure 32
GEOMETRICAL VARIATION IN SHOCK WAVES AT DIFFERENT SPEEDS

The term "breaking the sound barrier" is a misnomer. Actually, increases in speed produce geometrical variations in the same type of singularity, as these photographs of an object at different speeds show. Above, sound wave silhouettes for a 9/16-inch diameter spherical projectile at 1, 2, and 4 times the speed of sound.

Source: Rouse, *Elementary Mechanics of Fluids*, p. 345.

characteristics in Riemann's work.[10] The inclination of the characteristic defines the velocity gradient in the fluid.

We are now in a certain sense at the third type of singularity generated with a simple scalar increase in the velocity potential, *but in reality we have reached a shift in geometrical property of the fluid*. The third mode is usually referred to as the "sound barrier." But there is no "going through" the barrier of sound, as we can see from Figure 32. We are in a shock-singularity-generating mode. Any action tends to produce the same phenomena with a simple scalar variation at the beginning. We see that the increase in speed *does not result in "going through," but only in generating* geometrical variation of the same type of singularity.

Leonardo did not stop here. He noticed that for still higher velocity a new shift would occur: The shock fronts would "pile up" in *helical form* to create special waves, which he called "columnar waves." Such waves would no longer cross each other, but would tend to divert, nullify, or bounce off of each other as "matter particles" (Figure 25). He saw and studied them both as actual transformations of cross waves at higher speed or as transformations of bow waves again at high speed (Figure 33).

A closer view of the high speed bow wave in Figure 33 shows that the crest of the wave is not a simple turbulent phenomenon, but the beginning of a helical cylindrical wave as noticed by Leonardo.

Let us ask ourselves, in conclusion, as most probably Leonardo did or would have done: Is there any analogue *to such visible water phenomena in gas flows? Once the* speed is increased beyond normal shock formation, do we enter into a plasma-type situation? Is there anything comparable in electromagnetic phenomena? What are the topological characteristics of fields that create such new modes of discontinuities? What makes them "stable" as in the case

(a)

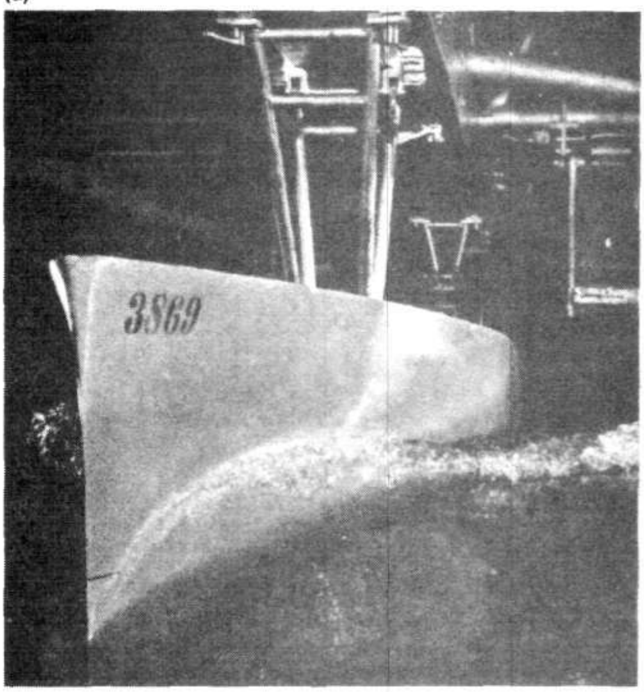


Figure 33
THE BOW WAVE

A closer look at the bow wave (a) shows that its crest is not simply a turbulent phenomenon, but the beginning of a helical cylindrical wave as Leonardo noted (b).

Source: Royal Library, Windsor, 12660v; Rouse, *Elementary Mechanics of Fluids*, inside front cover.

of water, where stabilities linked to the shift in the velocity-potential function for each mode of generation of singularities?

Dino de Paoli writes and lectures frequently on the history of technology and is working on a book on Leonardo.

Notes

1. I have drawn especially on the current work of Prof. Enzo Macagno, who is doing experiments based on Leonardo manuscripts, at the universities of Iowa and Karlsruhe (West Germany). Results of his work appear in his "La Meccanica dei Fluidi nei Codici di Madrid di Leonardo da Vinci," *Scientia* special volume (1982), p. 361.
   Valuable work has also been done by Ladislao Reti and Nando de Toni, as indicated in the Additional References.
   The work done by C. Truesdell is "delphic." That is, while using useful facts here and there, he mystifies Leonardo's method, because his aim is to prove that the scientific school of hydrodynamics is that of d'Alembert, Cauchy, and Kelvin.
2. More generally, see Lyndon H. LaRouche's book, *So You Wish to Learn All about Economics?—A text on elementary mathematical economics* (New York: New Benjamin Franklin House, 1984).
3. See my articles, "Leonardo da Vinci e la Scienza dello Stato," *Il Macchiavellico* I (1): 8-23 (Nov. 1982); "Leonardo da Vinci—Precursore della fisica moderna," *Il Machiavellico* II (1): 52-59 (Dec. 1983); "Leonardo und die Wissenschaft der Technologie," *Ibykus* II (3):15-24 (Nov. 82). See also an article in *Il Macchiavellico* on Leonardo by Nora Hamerman.
4. For the debate between the English and Continental Schools in the 19th century, see Uwe Parpart Henke, "Riemann Declassified—His Method and Program for the Natural Sciences," *Fusion* (March-April 1979), p. 24; James Burton Serrin, *Mathematical Principles of Classical Fluid Mechanics* (1957).
5. Adolf Busemann, "Relations between Aerodynamics and Magnetohydrodynamics," 1961. Air Force Office of Scientific Research Lecture in Honor of the 80th Birthday of Theodor von Karman. NASA Langley Research Center, Langley Field, Va.
6. Crocco made this remark in an article in *L'Aerotecnica* 16 (1936) titled, "L'aerodinamica in aviazione." Gaetano Crocco was of the Italian school of aerodynamics that resulted from the work of Riemann with his students in Italy in the 1860s: Betti, Brioschi, Casorati, then Beltrami and Levi-Civita. See the forthcoming article on the Italian Riemannian school in the *Int'l. J. of Fusion Energy* by Giuseppe Filipponi.
7. Jonathan Tennenbaum, "Were Gauss and Riemann Right about Electrodynamics?" *Int'l. J. of Fusion Energy* Vol. 3, No. 2, p. 4.
8. For a more comprehensive statement of the point, see Lyndon H. LaRouche, "The Science of the Human Mind—A treatise on fundamentals," *The Campaigner*, Special Supplement (February 1984).
9. A more precise account of the role of Lord Kelvin is in preparation. He shaped the generalization of the Second Law of Thermodynamics, inducing Helmholtz and Clausius to state that the universe would soon die. See Carol White, *Energy Potential—Toward a New Electromagnetic Field Theory* (Campaigner Publications, 1977) and *The New Dark Ages Conspiracy* (New Benjamin Franklin House, 1980).
10. For a more precise definition of the Weierstrass function see Uwe Parpart (Henke), "The Concept of the Transfinite," *The Campaigner* (Jan.-Feb. 1976), p. 6.
11. To grasp the full ideological implications of Ilya Prigogine's work one has to consult his masterpiece (written with I. Stengers), *La Nouvelle Alliance* (1979).
12. For elaboration, see LaRouche, "The Science of the Human Mind" (see note 8 above).
13. For a detailed treatment of Leonardo's hydrodynamic and hydrostatic investigations, see the work of Macagno published in *Scientia* (note 1 above).
14. When Euler first introduced the notion of discontinuous functions, he had to face the opposition of d'Alembert: .". . As a matter of fact when I gave my general solution for the vibration of a string, which involved the case in which the string was initially given an irregular configuration. . . . My solution was the subject of suspicion on the part of d'Alembert who maintained that in this case it was absolutely impossible to determine the motion of the string. . . . Discontinuities appeared to him always incompatible with the laws of calculus. . . ." (Euler, "On the Propagation of Sound," 1766, translated by B. Lindsay.)
15. It is highly likely that especially Ernst Heinrich Weber knew the works of Leonardo firsthand. He had been greatly influenced by the physicist and musician Ernst Chladni, a friend of the Weber family. Chladni reproduced some of Leonardo's experiments in the visualization of nodal lines of waves. Weber approached fluid dynamics through anatomy, at first studying the circulation of blood as fluid in closed pipes—Leonardo had taken the same road. See the Appendix to *Leonardo da Vinci on the Human Body*, Charles D. O'Malley and J.B. de C.M. Saunders, eds. (Greenwich House, 1982).
16. See Helga Zepp-LaRouche, address to the International Caucus of Labor Committees semiannual conference, Reston, Va., July 1985. See also Friedrich Schiller's "Aesthetical Considerations on Magnitude," in which he attacks the Kantian approach to static geometry, opening the way epistemologically for the breakthrough of Riemann directly through Gauss and Herbart.
17. Consider the possible implications, for example, of L. Carrasco and A. Serrano, "The Relation between Angular Momentum and Star Formation in Spiral Galaxies," *Int'l. J. of Fusion Energy*, (Jan. 1985) p. 57.
18. Hunter Rouse, *Elementary Mechanics of Fluids* (Dover, 1978).
19. Leonardo's text is in the Institut de France Ms. C 22r,v.
20. For the debate between Beltrami and Helmholtz, see a forthcoming article on the Italian Riemannian school in the *International Journal of Fusion Energy* by Giuseppe Filipponi. Helmholtz applied the analogy between the hydrodynamic and the electrodynamic to arrive at the Maxwellian field. Beltrami did the same—to indicate the limits of the Maxwellian approach.
21. For elaboration see Uwe Parpart (Henke) (see note 4).
22. D.R. Wells and P. Ziajka, "Production of Fusion Energy by Vortex Structure Compression," *Int'l. J. of Fusion Energy*, (Winter, 1978), p. 3.
23. I refer to the Magnus Effect, which Busemann applied to plasma physics in relation to the Lorentz Effect (see notes 5 and 22).
24. L. Prandtl, *Essentials of Fluid Dynamics* (Hafner, 1952).
25. To grasp the epistemological difference between the Riemannian approach and the Cauchy school, one has to read the works of the Italian students of Riemann: Betti, Brioschi, and Casorati. Casorati specifically defines the gap between the two schools, identifying the "Cauchy cut" as a different approach from Riemann's. Helmholtz transmitted a Cartesian version of Riemannian geometry to the next generation.
26. J. Lighthill, *Intense Atmospheric Vortices* (1982).
27. For an elaboration of the "connections" of surfaces, see Uwe Parpart (Henke), "The Concept of the Transfinite"; White, *Energy Potential*, and the writings of Riemann in English translation appearing in *Energy Potential* (see notes 9 and 10).
28. Parpart (Henke), "Riemann Declassified" (see note 4).
29. This is not an arbitrary connection. Cauchy transformed the Leibnizian theory of differentials into the d'Alembert theory of "limits." See Dino de Paoli, "Carnot et la conception humaniste de l'industrialisation," in *La Science de l'Education Républicaine—le secret de Monge et Carnot* (Campaigner Publications, 1980).
   See also Georg Cantor, "Foundations of a General Theory of Manifolds" (1883), translated in *The Campaigner*, (Jan.-Feb. 1976), p. 69.
30. We cannot elaborate the mathematics here. See Bernhard Riemann, "On the Propagation of Plane Air Waves of Finite Amplitude," *Int'l. J. of Fusion Energy*, Vol. 2, No. 3 (1980), p. 1; R. Courant and K. Friedrichs, *Supersonic Flow and Shock Waves* (New York, 1948); L. Prandtl, *Essentials of Fluid Dynamics* (Hafner, 1952).

A Note on the Leonardo Manuscripts

Leonardo manuscripts are designated as follows:
C.A., Codice Atlantico
Tr, Codice Trivulziano
A to N, manuscripts of the Institut de France; manuscript F is mainly dedicated to the study of vortices
B.M., Arundel manuscripts in the British Museum
Leicester, now renamed the Codex Hammer, but folios are numbered differently in the two designations
Madrid, Codex Madrid

In quoting from Leonardo's manuscripts, italics represent emphasis added.

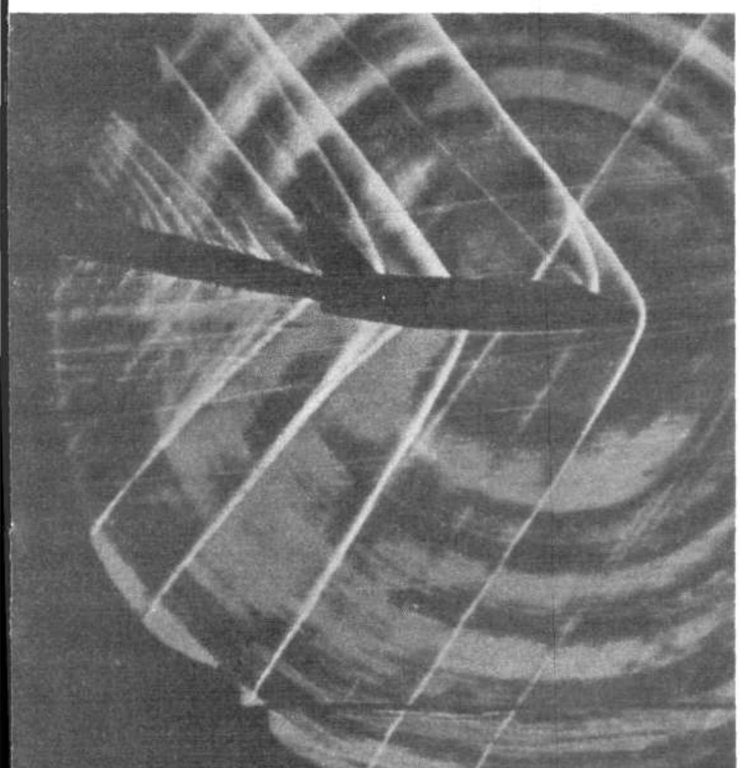
Additional References

Ladislao Reti. *Madrid Codex commentary*, Vol. 3 (McGraw-Hill).
————, ed. *The Unknown Leonardo* (McGraw-Hill, 1974).
Nando de Toni. *Leonardo e i suoi studi sull'acqua*. Manuscript, 1983.
Enzo Macagno. In honor of Nando de Toni. "Analogies in Leonardo's Studies of Flow Phenomena."
————. *Leonardo's Methodology in his Fluid Mechanical Investigations.*
Edward MacCurdy. *The Notebooks of Leonardo da Vinci* (George Braziller, 1939).
Jane Roberts and Carlo Pedretti. *The Codex Hammer of Leonardo da Vinci* (Florence: Palazzo Vecchio, 1872).
Carlo Pedretti and Kenneth Clark. *Leonardo da Vinci Nature Studies from the Royal Library at Windsor Castle* (Harcourt Brace Jovanovich, 1981).
C. Truesdell. "A Program Toward Rediscovering the Rational Mechanics of the Age of Reason," *Archive for History of the Exact Sciences*, Vol. 1, No. 1 (1960), p. 1.
————. "Vorticity and the Thermodynamic State in a Gas Flow" (Series: Memorial des Sciences Mathematiques, publié sous le Patronage de l'Academie des Sciences de Paris), Fascicule CXIX (Paris, 1952).
————. "Leonardo, Myths and Reality," 1967.

If not for the Göttingen Tradition in science, the United States could not have developed supersonic flight or rocket flight.

The Question of Scientific Method

How the Riemannian Approach Allowed the Development of Supersonic Flight



NASA/Ames Research Center

The study of vortex formation in fluid flow was pioneered by Ludwig Prandtl, whose work influenced later advances in aerodynamics. Above: photograph of air flow past a model of the Space Shuttle in a wind tunnel.

by Uwe Parpart Henke

To make programs like the Strategic Defense Initiative successful, it is absolutely critical that they have the broad philosophical outlook that there are no limits to growth. Any Malthusian thinking will necessarily lead us in the wrong direction. I want to contrast two types of approach philosphically and epistemologically to the kind of thinking that ultimately finds its way into large programs like the Manhattan Project, the Apollo Project, or the Strategic Defense Initiative program. I want to point out, in particular, that one cannot simply see these as technical organizational problems or technological problems, but one has to get some understanding of what is the broadest cultural background that defines the possibility of the successful development and execution of such large programs.

Specifically, such large-scale research programs like the Apollo Project or the Manhattan Project must have the philosophical approach to fluid mechanics and fluid dynamics exemplified by Ludwig Prandtl. Prandtl, a professor of applied mechanics at Göttingen University from 1904 to 1953 and director of the Kaiser Wilhelm Institute for Fluid Flow from 1925 on, is probably the single most significant researcher in this century in hydrodynamics and aerodynamics research.

Fluid dynamics research started at the University of Göttingen around the turn of this century, initiated by Prandtl when he came to Göttingen in 1904. He built the first sizable wind tunnel and similar apparatus that made progress in this area possible.

What enabled the researchers at Göttingen and at the universities in Berlin and Aachen to make the breakthroughs in fluid dynamics and in aerodynamics in the early part of this century that later made possible manned flight, ultimately supersonic flight, and then rocket flight, was their broad philosophical background. If a different kind of philosophical tradition had prevailed, most of the developments that we have seen in this century, especially after World War II, would have been either very far delayed or might not have occurred at all. What I will discuss is the derivation of the Göttingen Tradition with specific emphasis on the geometrical type of thinking of the individuals whose earlier scientific ideas led to the Prandtl school.

The Göttingen Tradition

At the beginning of this succession is Gaspard Monge. Monge was one of the principal researchers at the French Ecole Polytechnique at the end of the 18th century, and he pioneered a method of looking at differential equations—equations that define different types of complicated physical processes—essentially from a graphic or a geometrical point of view. These methods proved extremely successful in the early work of the Ecole Polytechnique and then led to a situation in which many of the students, not directly of the Ecole Polytechnique or Monge, but students of these ideas, perfected this and were able to make enormous progress in a very short period of time.

Perhaps the most influential and least known mind in this line of succession is Jakob Steiner. Steiner was born in 1796 and he came to the University of Berlin, which had then just been founded by his mentor Wilhelm von Humboldt. He came to Berlin without a job; he knew a great deal of geometry and was convinced of his ability to solve the most difficult geometrical problems, but he did not have the kind of formal education that would have allowed him to become a professor in Berlin at that time. He could not even become a teacher at the high school level: In order to do that, he would have had to pass a so-called state examination, and he had tried that in 1822 after he had just come to Berlin.

He had the bad fortune that one of his examiners in the field of philosophy was G.W.F. Hegel. Those who have attempted to read some of Hegel's writings will appreciate what Steiner did: Before he was examined in philosopy, he wrote a note protesting the idea that he should be examined in the kind of obscurantism that Hegel's philosophy represented. Hegel then, as one might imagine, retaliated in the examination itself and wrote a report. The quote we have is that Hegel said, "Jakob Steiner concerns himself only with entirely trivial reflections." These "entirely trivial reflections" define the conceptual basis in almost every respect of the type of work that led to the fluid dynamics elaborated by Prandtl and his collaborators.

Steiner's so-called triviality in the mathematical field was characterized by the fact that he abhorred algebra, and he was tested in algebra as well as philosophy. Steiner flunked both of these tests marvelously. The person who tested him in algebra reportedly said of Steiner that his knowledge of algebra does not appear to go beyond the solution of equations of the second degree and he does not even seem to

Gaspard Monge

Jakob Steiner

Wilhelm von Humboldt

The philosophical predecessors of the Göttingen school include Monge, Steiner, and von Humboldt. At the turn of the century, Felix Klein organized Germany's industrial muscle to push forward the frontiers of science—a model the United States would do well to follow today. He is shown here with the seal of the Göttingen Association for the Advancement of Applied Physics and Mathematics, which he founded in 1898.

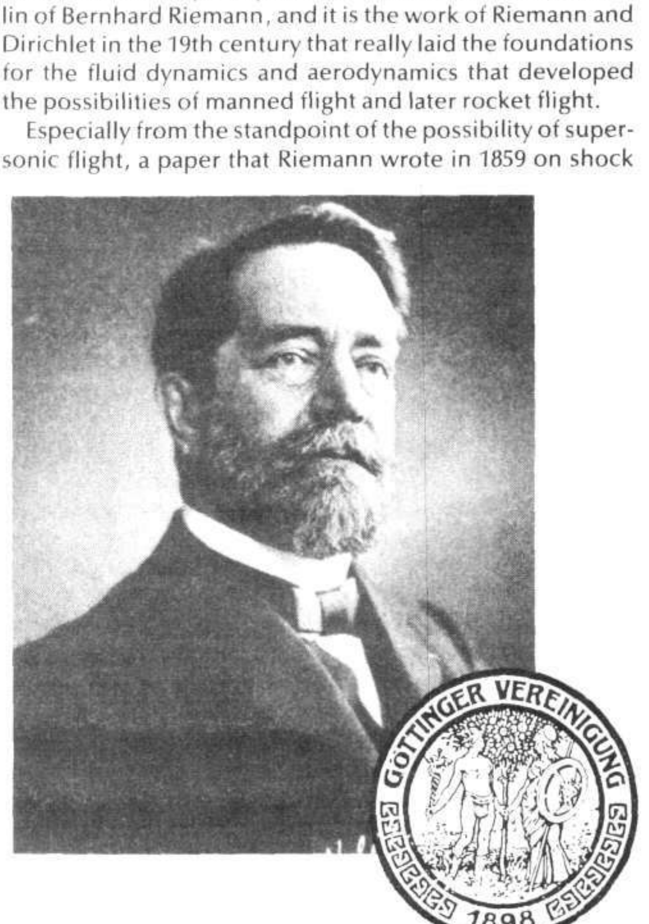
be very familiar with that. Equations of the second degree are something that now, perhaps unfortunately, people are being taught at a rather early age. In any case, Steiner's genius in geometry was perhaps first recognized by Wilhelm von Humboldt, who founded the University of Berlin and was the minister of culture of Prussia for a while.

Humboldt had his youngest son educated in private by Steiner after Steiner had been denied official certification as a teacher. The first book that Steiner wrote on geometry, which became the principal textbook in geometry at the University of Berlin later on and in many of the German universities and high schools afterwards, was dedicated to von Humboldt and his method of thinking.

What Steiner always stressed in teaching his students was that there is a very close relationship between the kind of creative playfulness that we apply in geometrical constructions and our ability to develop entirely new concepts. Algebra, on the other hand, puts the mind into the kind of straitjacket that does not enable the student at a later point to apply himself creatively to new types of problems.

In 1834, Steiner finally got his appointment at the University of Berlin because it was recognized that he was an obvious genius in his field. The opinions of Hegel and of some other mathematicians who initially examined him were thankfully ignored at that point and he was made a professor. His efforts to become a professor were supported by Crelle, by Bessel, by Dirichlet, and by Jacobi, who were then the greatest mathematicians in Europe. In 1847-1848, Steiner became a principal teacher at the University of Berlin of Bernhard Riemann, and it is the work of Riemann and Dirichlet in the 19th century that really laid the foundations for the fluid dynamics and aerodynamics that developed the possibilities of manned flight and later rocket flight.

Especially from the standpoint of the possibility of supersonic flight, a paper that Riemann wrote in 1859 on shock waves—the kind of waves that are formed in a compressible fluid, be it a gas or any other kind of compressible fluid—proved extremely influential. It was one of the most important things considered when supersonic flight was contemplated in the period of World War II and afterwards. Contrary to many of the critics of Riemann, it was precisely the case that he discussed so-called isentropic compression shocks in his 1859 paper, which proved to be most important and influential in the theory of supersonic flight. Prandtl's training in Germany was very much in the tradition of Riemann and, in fact, in some of his first papers, he quotes Riemann in detail.



Prandtl had a student, whose name perhaps is not known to many readers, Adolf Busemann, who worked in Germany during World War II, then came to the United States after World War II. His ideas were the essential ideas that made supersonic flight possible by October 1947, when the first Bell X-1 plane crashed the so-called sound barrier. (A lot of things could be said about this notion of sound barrier; there really is no such thing, and the idea of a barrier in fact implies all the wrong things and precisely that wrong kind of thinking that we should stay away from.)

The Opposing Tradition

Counterposed to the geometrical tradition reaching from Monge to Busemann is the tradition of the people, who if their ideas had prevailed, engineers or other inventors might have invented airplanes and done various kinds of things with them, but physicists and mathematicians would have been able to prove quite rigorously that manned flight or flight heavier than air was impossible.

One of the people on this list is Theodore von Karman, who in his very early career, just about one year before the actual first heavier-than-air flight by the Wright brothers, proved to his own satisfaction (not to the Wright brothers' satisfaction) that flight heavier than air was impossible. This was based on the theory of air resistance, of so-called drag, a resistance of any fluid against an object being moved through it. This is the so-called impact theory, or resistance or drag, due to Newton and later on developed in more detail by Lagrange. One could perhaps say, somewhat ahistorically and facetiously but nonetheless correctly, that Newton was the first to prove that flight heavier than air or any kind of flight was impossible. In fact, it is not even clear how birds could fly under Newton's theory.

Prandtl makes the point in his famous textbook (this was actually written by Tietjens on the basis of Prandtl's lectures) by saying that if it were the case that drag or resistance increases with the square of the velocity, then under those circumstances it is extremely difficult to see how flight of any kind is conceivable. The way Newton arrived at this is on the basis of this so-called impact or collisional model; that is, thinking of an airfoil or even a plate injected into an airstream and simply computing the impact and the forces of impact of the molecules that hit this particular airfoil or any kind of object put into the flow. This way of thinking, and von Karman's calculations that led him to believe that flight heavier than air was impossible, were based on that kind of impact model. Essentially, von Karman said, the molecular pressure would prevent takeoff. This kind of

Carlos de Hoyos

Prandtl's student Adolf Busemann developed the ideas that made supersonic flight possible. Here Busemann (center) receives an award from the Fusion Energy Foundation in November 1981.

thinking was quite pervasive even at a point when von Karman later on became one of the celebrated people who allegedly had a lot to do with the development of aerodynamics.

I want to emphasize that this collisional and essentially statistical model of computing physical events on the basis of certain averages—averaged over particles and groups of particles and molecules statistically—is proved one of the most important barriers to a satisfactory development of theory not only in the areas that we are discussing here, fluid dynamics and hydrodynamics, but also in the equally important areas of quantum theory, plasma physics, and so on, which are essential to the possibility of thermonuclear fusion.

These collisional and statistical models do not work, and it is only and precisely to the extent that they were explicitly rejected by the Göttingen school that these areas can be regarded as possible and developable.

Prandtl's Method

The essential idea that Prandtl had in 1904 is that if one were to try to directly describe the possibility of flight using the very difficult differential equations that govern the flow of so-called viscous fluids (fluids that have internal friction), the so-called Navier-Stokes equations, then one would be faced with an impossible problem. One could experimentally perhaps define and determine the possibility of flight, but one could never quantitatively explicitly calculate the actual conditions that make flight possible. Rather than looking at an airfoil subjected to a stream of air as an airfoil injected into a viscous fluid, which mathematically is impossible to handle, Prandtl separated the problem into two parts. He did this from the standpoint of the geometrical type of thinking that introduces as an essential characteristic of the geometrical continuum the singularities in this continuum. On the one hand, Prandtl said, we can look at the flow far away from the airfoil, the so-called free flow, on the basis of the very simple potential equations according to Laplace. These are trivial and relatively easy to understand differential equations, which have an immediate geometrical interpretation in the context of so-called conformal mapping theory.

Prandtl said the only area in which we have to consider flow that has internal friction is in the immediate vicinity of the airfoil itself, in the so-called boundary layer. This is the little white layer that can be seen in the photographs of Prandtl's experiments (Figures 1 and 2). In this area, we can no longer ignore viscosity or the internal friction of the fluid, in particular. This is not because we know on the one hand that directly at the surface of the airfoil the flow is zero; that is, the air or the water—or whatever it is—actually sticks at the surface. A very small distance away from this, it is clear that it has already attained a velocity equal to the free flow velocity. What we must look at is this critical boundary layer, what Prandtl called the surface of discontinuity, in which, a very, very large difference in velocity is attained over an extremely thin layer—a layer that can, in fact, be thought of as arbitrarily thin. If we think of this boundary layer as a surface of discontinuity, under these circumstances we can simplify the Navier-Stokes equations quite significantly, and are therefore able to give a quantitative solution to the problems of drag, lift, and all of the other aerodynamical problems that are critical to discuss the possibility of flight.

Without the kind of work that Prandtl did—first published in 1904 and discussed by him prior to his coming to Göttingen, when he was a teacher at the Technical High School in Hannover—without these kinds of discussions of the boundary layer problems, it is generally acknowledged today that a quantitative discussion of the possibility of flight would not have been available.

One of Prandtl's most important colleagues was Runge, a mathematician who developed many of the mathematical methods for calculating the problems in aerodynamics that Prandtl raised.

The Role of Felix Klein

Felix Klein was the teacher of many of the students in the late 19th and early 20th century in Germany in mathematics and in physics, and at the same time was one of the most accomplished organizers of the total scientific, technological, and industrial enterprise in Germany. Klein had earlier made a name for himself by developing some very interesting and significant work in elliptical function theory, and in the 1890s he came to Göttingen as a professor and made it his task to try to define a research program for the entirety of the technical and scientific disciplines at the university. Particularly important, he worked in close collaboration with Wilamowitz, the senior faculty member in the field of *Altphilologie*, ancient languages with specific emphasis on Greek. Klein and Wilamowitz jointly defined an outlook on research and education, which I think is uniquely responsible, in terms of its philosophy, for the advances that were made in Germany in that period. At the same time, Klein enlisted and in a certain sense forced German industry into

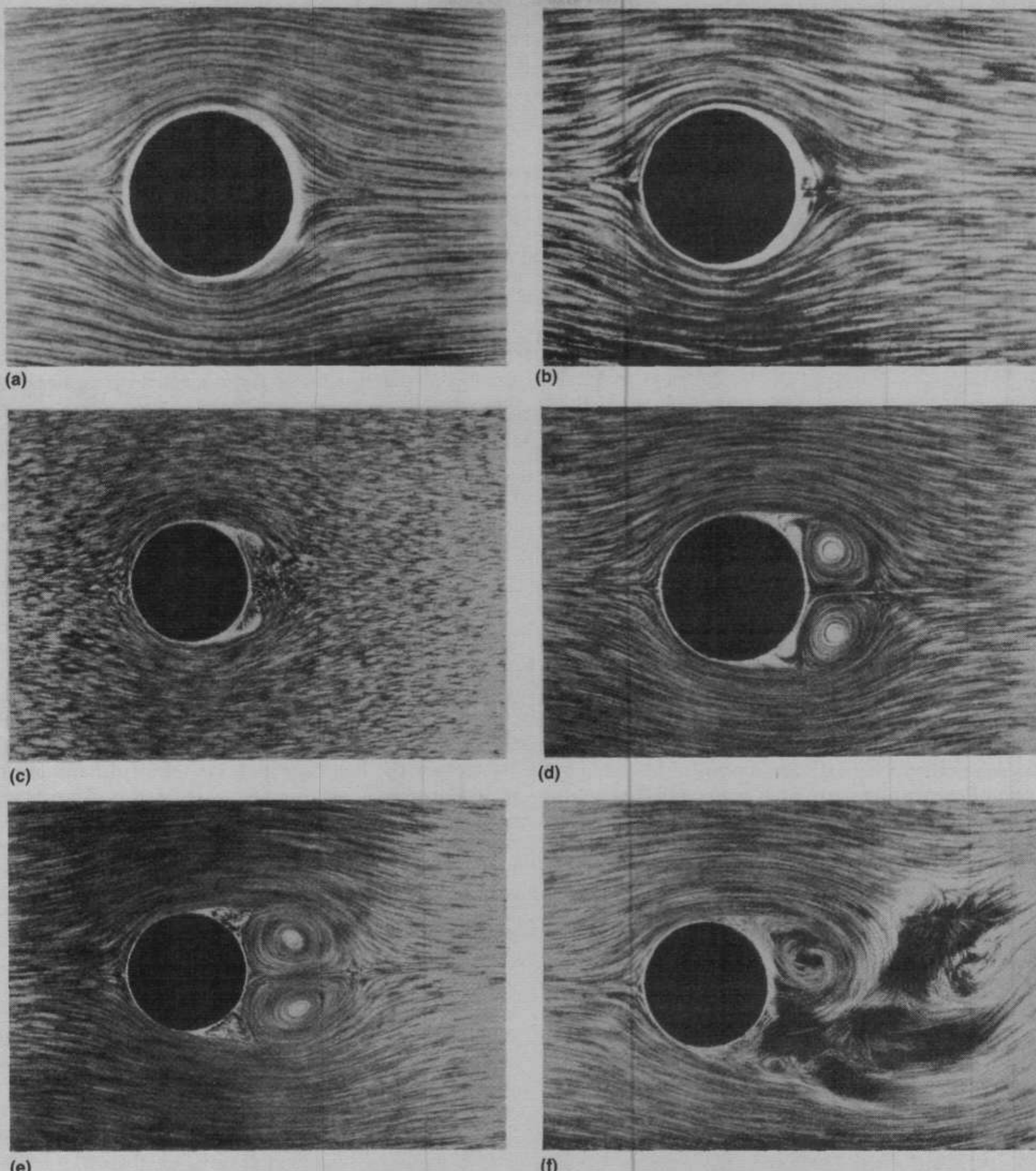


Figure 1
PRANDTL'S APPROACH TO FLUID DYNAMICS

As director of the Kaiser Wilhelm Institute for fluid flow at Göttingen, Prandtl photographed and filmed experiments on the generation of vortices in water flows to demonstrate to students the characteristic features of fluid dynamics. The illustrations here are from Prandtl's films.

Photos (a)-(f) show water streaming around a cylinder. Fine aluminum particles enable the streamlines to be visible to the camera. You can see the actual vortex formation, which becomes large-scale after a short period of time. The boundary layer is the light, surrounding mass around the dark cylinder. This boundary layer rips off and develops the fluid vortex.

Courtesy of California Institute of Technology

Theodore von Karman shortly after his appointment as director of the Guggenheim Aeronautical Laboratory

Bettmann Archive

Robert Millikan posing with the 10-foot wind tunnel at Cal Tech in 1930.

supporting this kind of research both by financially supporting the research institutions that were being built at the German universities, and at the same time creating inside their own companies and allocating up to 20 percent of the total profits of the company for research and development.

Klein founded the so-called Göttingen Association, the *Göttinger Vereinigung*, in 1898. This was the group of professors at Göttingen who collaborated with the principal people in German industry. The Göttingen Association mandated that any industrial company that wanted to get the top students from the disciplines of physics, mathematics, or the engineering sciences into their companies, could not get that unless they could demonstrate that more than 20 percent of their profits had, in fact, been allocated to research and development. They were otherwise not found worthy of being supplied with that kind of manpower.

Klein, because he had a very close working relationship with the Prussian minister of culture, Althoff, was able to quite rigorously control this situation, and was able to force those companies that did not want to comply into a situation where their competitiveness was, in fact, severely hampered.

Now, whether or not one wants to use that kind of model in the United States today is something that might be debated. In any case, the basic point is very clear: Industry must make its contribution not only in the form of financial donations, but also in terms of an actual, in-depth commitment to research and development, in order to be able to collaborate with the most advanced scientific institutions, so that there is not a tremendous and unnecessary gap between theoretical and applied research. This was Klein's principal purpose.

He was able to enlist the heads of *all* of the large companies, from Krupp, to Siemens, to MAN. Any company of any size in Germany in the period before World War I became, at one time or another, a member of the Göttingen Association and collaborated in this program. This is what made possible the developments in aerodynamics in the 20th century.

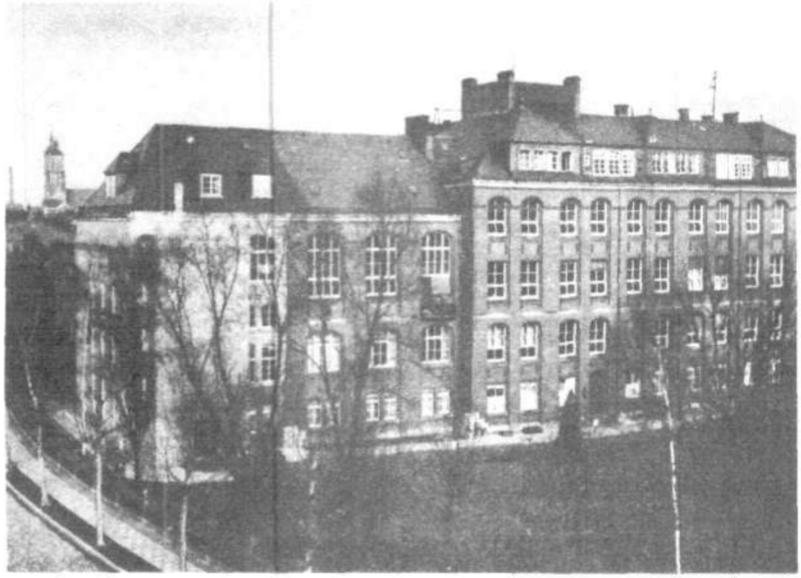
Von Karman As a Villain

In contrast to this tradition is another group of people, including prominently Theodore von Karman. Those of you who have worked in the airplane industry and the space program not only may be surprised, but also perhaps offended by the fact that I single out Theodore von Karman as one of the villains in this story, even though he admittedly made some significant contributions in certain areas.

Von Karman, Hungarian by birth, was a student of Prandtl at Göttingen, and Prandtl was instrumental in providing him with a professorship at the technical university in Aachen, in the westernmost part of Germany. In the initial years, still directly under the influence of Prandtl, between 1908 and 1911, von Karman did quite excellent work there. In fact, much of the type of work on so-called vortex streets, vortex formations behind objects, and fluid flow, is due to the early work of von Karman. During World War I, he was drafted into the Hungarian Air Force and he then returned to Aachen in 1920 to resume his post.

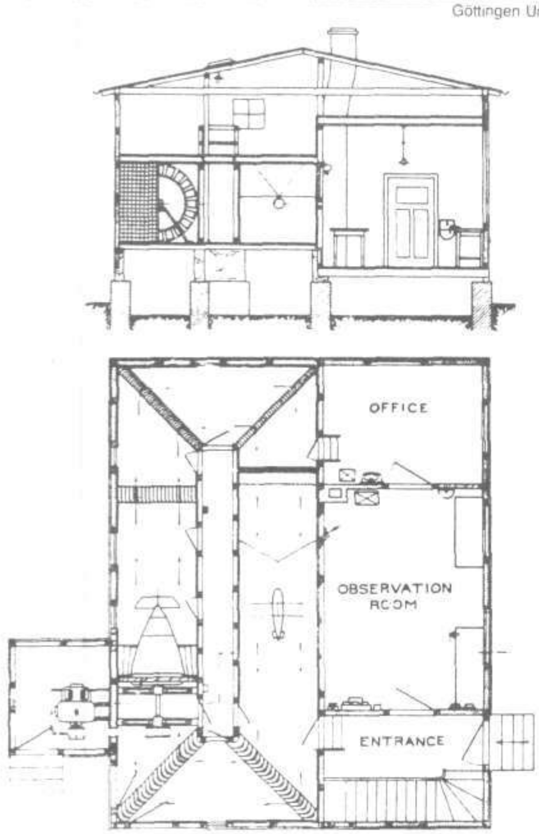
It is not quite clear what happens to one if one is drafted into the Hungarian Air Force, but whatever happened to von Karman was not very good. The actual scientific developments and the scientific initiatives that he took after his return to Germany are, by and large, to be judged quite negatively.

In 1922, he and others organized a conference at Innsbruck, Austria, in which he was the first to propose a statistical approach to the theory of turbulence—directly in opposition to the geometrical approach of Prandtl. It was



Göttingen University

Ludwig Prandtl (above) is probably the single most significant researcher in this century in hydrodynamics and aerodynamics research. Above right: Göttingen University and (below) diagram of the first wind-tunnel laboratory at Göttingen.



as a result of the disagreements that arose out of this—they did not really come very much to the surface or very much into the open. At least in these kind of disputes scientists often tend to be polite, perhaps *too* polite, rather than bringing out these differences for everyone to see. But in any case, Prandtl quite strongly disagreed with this approach. It was directly contrary to his own way of thinking, and to his own insight into what had allowed him to succeed.

Prandtl blocked the appointment of von Karman to a professorship in Göttingen in the early 1920s. At that point, a different development occurred in the United States.

Millikan and More Villains

After World War I, it had become quite obvious that airplanes and similar kinds of high technology devices had already had a very significant influence in the war and might, in fact, become decisive if a new war were to break out in the future. At that point, various organizations of industry, as well as military organizations in the United States, realized that the actual level of physical science and of engineering science in the United States was abysmal, and they attempted in the relatively shortest possible period of time to remedy that situation. One of the principal protagonists—and there should be no question that he had the proper purpose, though, I think, badly executed—was Robert Millikan, who in 1923 won the Nobel Prize for physics for his experiments with electron theory.

Millikan, at that point or slightly later, became the leading physicist and, in fact, the leading organizer of the research at the California Institute of Technology. He collaborated very closely with Daniel and Harry Guggenheim for the purpose of making money available for the development of research institutes, and also for the possibility of attracting researchers primarily from Europe and with emphasis on Germany, in order to remedy the backwardness of the United States situation.

In one way or another, it became known to Millikan that von Karman was getting disenchanted with his position in Germany, and by 1926 negotiations started between Cal Tech and von Karman. Initially, von Karman acted as a consultant in the construction of the wind tunnel at Cal Tech, and then later, in 1930, he actually permanently moved to the United States.

Millikan himself did some useful experimental work, but his philosophical outlook on scientific enterprise was essentially diametrically opposed to the kind of outlook that I have ascribed to Prandtl and others. His autobiography—mind you, this is not a biography but an autobiography, so it reflects his own way of thinking—starts with recounting a little story about when he is four years old. He is playing with his two-year-old brother under their porch in the dirt. He says, my younger brother picked up a bunch of dust and told me, "Well, *eat* it. One can eat this." And Millikan says, I didn't believe that, and I told him it's not possible, but my younger brother, at age two, did not want to believe me, so I told him, "Well, why don't you eat it yourself?" And the two-year-old picked up the dust and ate it, and then ran, screaming, to his mother.

That, says Millikan, is how he became a physicist. That is how he was first convinced of the value of the experimental method. Well, if I wanted to slander the man, I might have *invented* this story, but in fact, it is the first paragraph in his autobiography; so therefore, presumably, he was deeply impressed by this and somehow *believed* this kind of nonsense. This is not how you become a physicist, or anything else; it's how you become a fool.

Later on in his autobiography, Millikan has a little list of those whom he regards as his scientific heroes. He regards as the greatest genius in the history of science, Maxwell. He then lists Kelvin, Rayleigh, Helmholtz, Boltzmann, and J.J. Thompson. Now, mind you, this is a man speaking in the 1940s. There is not a single mention here of people whom, I think, we rightfully should regard as the greatest scientific geniuses of the 19th and 20th centuries.

The problem is that the scientific enterprise in the United States—even at a point when quite correctly it was realized that it was backward—then came under the guidance of an individual who had done valuable experimental work, but whose entire outlook and way of looking at the scientific enterprise was so slanted and so wrong, so badly misguided, that there is no real surprise that his programs, in fact, did not prove particularly successful.

Millikan and Guggenheim decided that they needed to find "a scientist of ability, bordering on genius." They wanted to find such a scientist, give him some money, and let him develop aerodynamics in the United States. And the one they found was von Karman. Why did they hit upon von Karman, rather than Prandtl? Here's the actual quote from a letter: Harry Guggenheim had gone to Germany at that time in order to look for such a genius. He had gone to Göttingen and seen Prandtl's work, and for whatever reason, Guggenheim was impressed and said to Millikan, "let's get Prandtl."

Millikan responded, "Dear Mr. Guggenheim . . . with respect to the suggestion which you made as I left your house, that we try to get Prandtl over here for a short time, I have talked the matter over at length with Epstein and Bateman. Both of them think that in view of Prandtl's advanced age [he was five years older than von Karman] and his somewhat impractical personality, he would be far less useful to us than von Karman."

And then, later on, a little footnote is added, where he makes some remark about G.I. Taylor and Britain. In fact, they preferred G.I. Taylor as well. That may not mean much to many readers, but to some of us who know about G.I. Taylor's work, it means something. In any case, the Millikan letter says: "The other thing that speaks for von Karman, by the way, is that he is Hungarian in nationality. We have between us reached the conclusion, partially because of von Karman's nationality, that he would be the better person than Prandtl."

One of the most famous quotes that I have from Millikan is also in his autobiography. This was right after World War I and perhaps is understandable in the heat of the argument. Millikan said, what we can't have in the United States is the "German barbarism reflected in World War I," and we can't have people associated with scientific work in Germany at that time—which was true for Prandtl who had a great deal to do with the development of airplanes. Then he said: "We Anglo-Saxons have overcome these tendencies toward barbarism. The British Empire, after ridding itself of some of its worst excesses, has become the veritable model of freedom and development in the world today."

So this was the person who brought a genius to the United States.

The outcome of this could be seen at the end of World War II. From 1930 on, von Karman was effectively in charge of all aerodynamic research in the United States. There was really nobody who could have in any way challenged or influenced what von Karman wanted to do.

In 1935 there took place in Rome the so-called Volta Congress on aerodynamics and fluid dynamics, in which the primary presentations were made by Adolf Busemann and General Crocco, one of the principal aerodynamics researchers in Rome. Von Karman went to that congress after he had been in the United States for five years and had gotten more money for developing aeronautical research at Cal Tech than that allocated to the entirety of the European institutes. He came back with the impression that the Europeans were far ahead. And he made a report to this effect, but he couldn't figure out why the Europeans were ahead. He said, we seem to be doing what we should be doing, but somehow we don't seem to be succeeding.

In particular, von Karman was quite rightfully impressed with the fact that after four years of trying at Cal Tech, they had built a wind tunnel that was operating at speeds of several hundred kilometers per hour, and something like 5,000 horsepower. In Rome in 1935, however, he found a supersonic wind tunnel operating at twice the speed of sound and with 20,000 horsepower. So he came back somewhat shocked and he made the determination that all energies must be mustered to develop this work better in the United States. Nothing came of his effort.

In 1938, the question of jet propulsion was first investigated in the United States. There was some suggestion that jet propulsion should be a good way of driving airplanes. A committee was called together by the National Academy of Sciences, under the leadership of von Karman and Millikan, with the able assistance of Professor Marks of Harvard University, and they delivered their report on June 10, 1940. The report said, in essence, gas turbines are no good for flight because they're too heavy. Well, several months be-

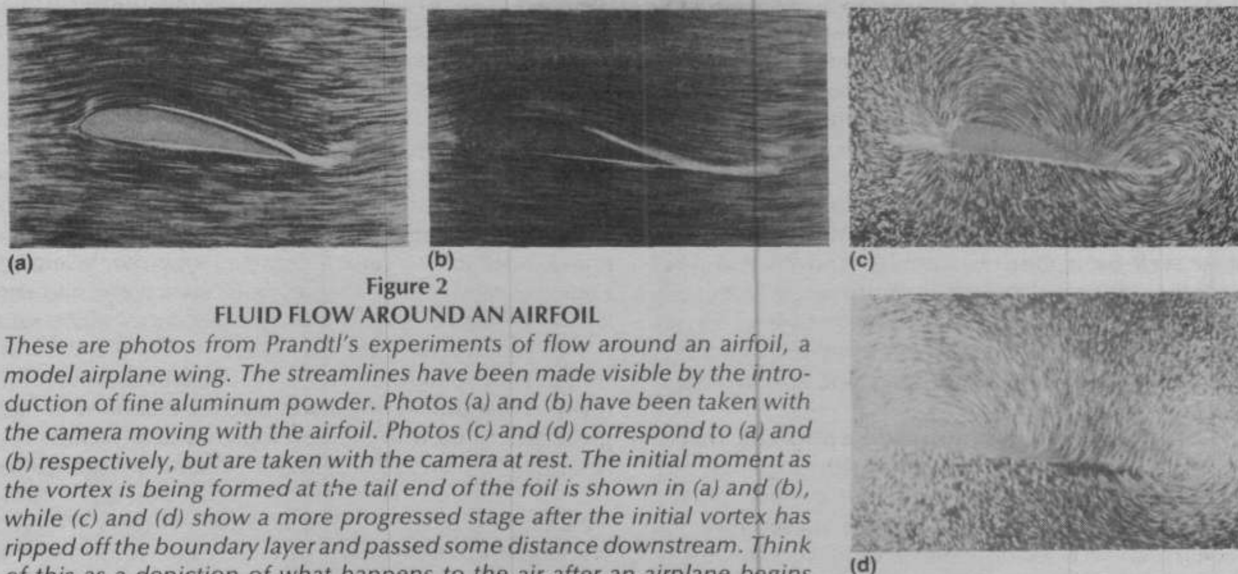


Figure 2
FLUID FLOW AROUND AN AIRFOIL

These are photos from Prandtl's experiments of flow around an airfoil, a model airplane wing. The streamlines have been made visible by the introduction of fine aluminum powder. Photos (a) and (b) have been taken with the camera moving with the airfoil. Photos (c) and (d) correspond to (a) and (b) respectively, but are taken with the camera at rest. The initial moment as the vortex is being formed at the tail end of the foil is shown in (a) and (b), while (c) and (d) show a more progressed stage after the initial vortex has ripped off the boundary layer and passed some distance downstream. Think of this as a depiction of what happens to the air after an airplane begins flight. If you have ever been in an airport close to a 747 taking off, you know that these vortices hit you quite hard. In fact, smaller planes cannot take off in the wake of a large jet.

fore that, the first model of the Messerschmitt 262, the actual German jet fighter of World War II, had already successfully flown and gone through much of the testing routine.

Von Karman delivered a report of the impossibility of jet propulsion for aircraft at the time when such aircraft were already flying in Germany! He later apologized and said that he just put his signature to this report; he didn't really read it. And then he said that when the report was issued in 1938, he was in Japan. He in fact was in Japan in 1938; however, the report was not delivered until 1940, so this explanation doesn't make much sense.

In 1945, the Army Air Force was quite shocked at what they found in Germany in the aerodynamics field. Several people had been sent over to Germany to investigate what was going on. Von Karman was one of them. He and another researcher from Cal Tech questioned Prandtl for long hours in detail about what he had been doing, and they questioned Adolf Busemann in detail about his ideas on supersonic flight.

After von Karman came back, he was asked by the National Advisory Committee on Aeronautics (NACA), as well as by the Air Force, to deliver a report, and he wrote a report that said we weren't really very impressed with what we saw in Germany. In fact, in many cases, the German work was good, but it certainly was not spectacular. Many of the things that have been praised, we were ourselves thinking about, he said.

The Air Force did not issue the report. One of the top people in the NACA, Hunsaker, wrote a letter to von Karman saying that this seems to be a rather self-serving and nonsensical report, and you will make yourself a laughingstock of the world if you issue it. For your reference, said Hunsaker, I will list to you precisely those areas in which the Germans *were* ahead in 1945, and in which we did virtually nothing. Then he went through it, just listing those areas in the field of aerodynamics: supersonic research, missile research, rocket research, jet propulsion, sweptwing design, and so on.

So this report was not issued, but von Karman was promptly charged by the Air Force to write another one, outlining the next 50 years of aerodynamical research for the United States. I don't know if that was ever written, or maybe it's a classified document. I hope it's so deeply classified that nobody will ever see it.

The Question of Method

This brings us to the fairly obvious conclusion: There's no question that the financial and material means at the disposal of the German effort in aerodynamics and related fields during and before World War II were in no way superior. What was superior and different was the type of outlook and the basic method that I have stressed here.

Von Karman is associated with the statistical turbulence theory and with the idea of using classical hydrodynamic theory, but making certain linear adjustments in it in order to get away from the nasty singularities that plague this kind of research. He is associated precisely with the outlook which, if it is adopted in principle, will not allow any significant advances in the physical sciences, and has never, in fact, been responsible for the development of such advances. This is the very simple fact that we have to face.

It has nothing to do with Germany versus the United States, or anything of that sort. It has something to do with *method*. These points of method were shared by the people of the Ecole Polytechnique in France, they were shared by the group around Riemann, they were shared by the great hydrodynamicists of Italy in the tradition of Riemann, and they were shared by all of those researchers whose names I already mentioned, most notably, Prandtl and Busemann in Germany at that time. It is not a point, as Millikan says, of nationality.

Let's look at some of the important developments of the postwar period. First, there is the so-called sound barrier (Figure 3). I object to the word "barrier" because it implies *precisely a kind of collisional approach. It has nothing to* do with barrier; there is no barrier, there is nothing there. There is just air, like anywhere else. The point is, that if you get near the speed of sound to about 0.7 Mach, then under those circumstances the drag coefficient on the airfoil increases very steeply, exponentially, until you in fact reach the speed of sound.

The reason for this is that through the development of shock waves, which affect the airflow over the airfoil, a certain amount of the lift energy is converted into shock formation. That energy is taken away from the lift capability of the plane, and under those circumstances you experience various kinds of instabilities and difficulties with the plane itself, which have to be countered simply from the standpoint of understanding the problem. You have to make the kind of geometrical adjustments in wing design, or anything else, that are necessary to do that.

One of the principal adjustments in wing design that can be made was invented by Busemann, the so-called swept-wing design, the arrow design. You can see (Figure 4) how the critical zone for the development of shock waves that influence flight and lift negatively is at the 0° angle; that is, if the wing is at right angles with the fuselage, you get the onset of the critical area at 0.7 Mach and then the drag coefficient declines afterwards.

If you have a 60° angle of the wings, then not even half *the drag coefficient develops and you get it also at a much* later point; namely, beyond Mach 1. And if you have a 70° inclination with the fuselage of the wings, then you get to a point where you get a very low, very late onset of the critical phase. Also, the amount of reduction in lift or the amount of increase in the drag coefficient is not very substantial. It is there, it will always be there, because shock waves form.

Shock waves are real, as was certainly determined by these methods of research in aerodynamics carried out in the 1930s and 1940s in Germany primarily under Busemann's direction in Braunschweig. They are not what Rayleigh had said, when he criticized Riemann's 1859 paper. He said, shock waves do not exist. What exist, are singularities in the mathematical formulation of the wave equations, but we cannot assign any reality to such singularities. All it means, is, that we have failed to come up with a solution.

As Riemann said, these things *are* real, and he said it 50 years before Rayleigh made that idiotic criticism. It was precisely because of the realization that the shock waves are real that they were taken into account when supersonic

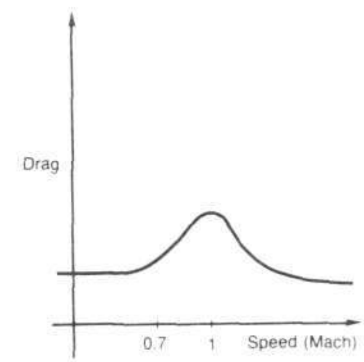


Figure 3
THE SO-CALLED SOUND BARRIER
The sound barrier has nothing to do with a barrier. When a plane gets near the speed of sound to about 0.7 Mach, the drag coefficient on the airfoil increases very steeply because shock waves develop that affect airflow over the airfoil.

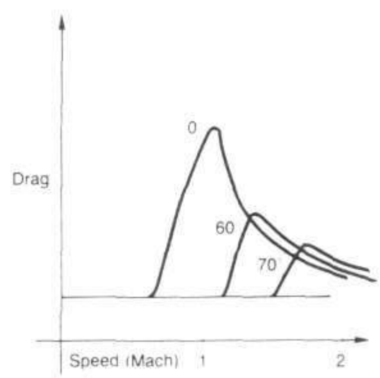


Figure 4
SHOCK WAVES THAT INFLUENCE FLIGHT
The critical zone for the development of shock waves that negatively influence flight and lift is at the 0° angle. If the wing of the plane is at right angles with the fuselage, you get the onset of the critical area at 0.7 Mach. But if the wings are at a 60° angle, then not even half the drag coefficient develops. With a 70° inclination, there is a very low, very late onset of the critical phase.

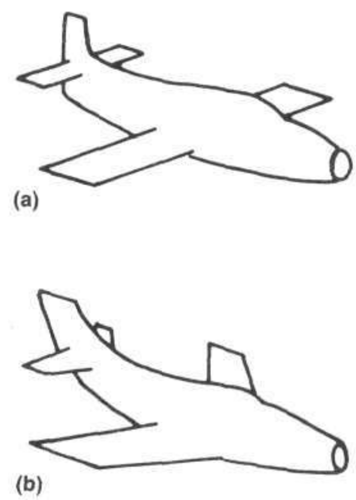


Figure 5
THE D-558 DESIGN BEFORE AND AFTER BUSEMANN
The Douglas D-558, which was developed simultaneously with the Bell X-1 as a supersonic design in 1945, had a conventional straight wing (a). After von Karman and others visited Germany and interviewed Adolf Busemann, their design was modified to his swept-wing design (b).

flight was studied in supersonic wind tunnels in Göttingen and Braunschweig, and later on in Munich and Lake Kochel.

An interesting example is the Douglas D-558, which was developed simultaneously with the Bell X-1 as a supersonic design in 1945 before the von Karman mission went to Germany and interviewed Busemann and others. Figure 5(a) shows their design before the trip to Germany: a straight wing sticking out, so you have the 0° angle situation of before and a tail end that sticks up, just as in the old designs of aircraft in the subsonic range.

Then von Karman and others came back to the United States in the summer of 1945, and after that the D-558 looked like Figure 5(b). All of a sudden it became a swept-wing model with a swept-tail configuration.

Several years ago when I was visiting a scientific conference in Moscow, a Russian researcher showed me a picture of one of the models for a supersonic passenger jet type that the Russians had acquired when they moved into the eastern part of Germany. "What do you think that is? he said. I said, "Everybody knows, that's the Concorde." But it was not the Concorde, it was a model built by Busemann for a supersonic jet—in the late 1930s—to which the Concorde design is identical.

There is no mystery of any kind involved here. It is a simple and straightforward story. It's a question of method, both scientific method and method of organization. It's a question of assembling the kind of scientific team that is capable, on the basis of the right kind of methodological approach, to find the mode of organization most appropiate to its goals. And these goals have to be set never with regard to so-called state-of-the-art designs, but in fact as far beyond as you can possibly do.

To the extent that you do that, you will be capable of changing this so-called state of the art rather than being stuck with it. What we have to do in any program, whether it is a crash technological development program or a basic research program, is to set our sight on the kind of goals and tasks that are way beyond what we initially anticipate the most immediate goal of the program to be. If that is not done, then we will not confront ourselves with the type of challenge that is necessary in order for the scientific enterprise to succeed.

The lesson to be learned is that we do not need state-of-the-art programs; this is nonsense and leads to precisely the wrong approach. The cheapest programs are not state-of-the-art assembly programs; the cheapest programs will always prove to be those crash programs that look as far ahead as possible in order to accomplish the immediate task. This may appear to be quite expensive in the long run, bringing in basic research and technology and design together into a program, rather than just doing the state of the art on the basis of what is on the shelf. The latter is going to be the most expensive and the least workable approach, and I am afraid, to a significant extent, when we are talking about the SDI today, it is precisely that kind of approach to the situation, that is most problematical.

Von Neumann's Cost-Benefit Nonsense

I have to mention one other villain who had something to do not so much with the scientific side of these developments, but had a tremendous influence on this organizational side, John von Neumann. Von Neumann was another Hungarian-born mathematician who studied at Göttingen and later came to the United States in the 1930s.

In the minds of most, von Neumann is associated not so much with his mathematics and physics, but rather with his ideas in economic theory. In particular he wrote a book along with Morgenstern called *The Theory of Games and Economic Behavior,* viewing economic development essentially as a kind of competitive game between players much like a poker game. In fact the first paper von Neumann wrote on so-called economics in 1928 was "The Theory of Parlor Games."

The next thing he studied in order to be able to model economic development in the late 1920s was poker, and he invented a simplified version of stud poker and abstracted from a simplified version of stud poker his basic ideas of economic development. Don't underestimate the influence of this nonsense. What has come out of that is the Rand Corporation, the Air Force Systems Command, and every single bit of so-called cost-benefit analysis optimization nonsense that we are suffering from today. It is one of the principal problems that we have to solve in order to define and push through the kind of crash program for the SDI that is desirable.

The other thing that has come out of von Neumann's poker theory is the famous Robert McNamara way of "winning" the Vietnam War. You remember what that was: the body count method—cost benefit analysis applied to military strategy and tactics. Most of you were probably treated to this every night on TV: You had a body count, so many Vietcongs, so many North Vietnamese killed, so many Americans killed; the ratio looks good.

The McNamara crowd made detailed analyses of how many people exist in each age group in Vietnam to see how many people were being eliminated per day, and then asked the question, how many troops do we have to put in to win on the basis of cost-benefit analysis? How much do we get out of it if we put so many soldiers, so many tanks, so many this and the other things in. From the standpoint of linear programming and optimization analysis, how do we win? You can't win that way.

The principal strategic problem in military terms and otherwise in politics is the principle of the flank. The principle of the flank defies by its very definition the idea of cost-benefit analysis, and this has precisely to do with the unexpected—to put a tremendous amount of cost into one area where it is unexpected, in order to be able to then succeed as quickly as possible. The very opposite of the kind of thinking so much associated with von Neumann and much of the Pentagon thinking today is what is called for under these circumstances.

If we keep that in mind, and let that be reflected in our political approach to these questions, we may have a chance.

Uwe Parpart Henke is the director of research for the Fusion Energy Foundation. This article is adapted from his presentation at the Krafft Ehricke Memorial Conference in June 1985, sponsored by the FEF and the Schiller Institute.

"After we have made Italy, we must make the Italians." It was in this spirit that the 19th century scientists of the Italian Riemann school played a decisive role in the formation of the Italian nation state.

Hydrodynamics and the

Courtesy of Adolf Busemann

Scientific Foundations of the Modern Italian Nation

by Giuseppe Filipponi

The role of Leonardo da Vinci as father of the Italian Renaissance and the political activity of Leibniz during the late 17th century clearly demonstrate that scientific advancements are historically born of the political activity required to build republican states committed to scientific, technological, and cultural advancements.

This is exactly the case of the great hydrodynamic school that was developed in Italy during the mid-19th century with the decisive contribution of Bernhard Riemann. Riemann came from Göttingen University to Italy to spend his last years in Pisa and Maggiore Lake. Enrico Betti, Eugenio Beltrami, Felice Groiti, Francesco Brioschi, Luigi Cremona, Masotti, and Carlo Matteucci were the principal representatives of this hydrodynamic school, and they had a decisive role in the political and military struggles that directly led to the formation of the modern Italian state in 1860.

Participants at the 1935 European aerodynamics conference at Volta, Italy, a milestone in the development of supersonic flight. Ludwig Prandtl is fifth from left, first row.

In fact, during the period 1840-1860, as a result of the work of some of these scientists, the Annual Congress of Italian Scientists, which brought together scientists from throughout the Italian peninsula, became one of the centers of the patriotic conspiracy. The Congress was considered so dangerous that two orders were issued in 1850—one by the Austrian governor of Lombardo-Veneto and the other by the Vatican Curia—banning the future participation of scientists from those regions, which were then independent states.

This was also the period during which the Count of Cavour imposed a crash program for the industrialization of the Piedmont region, (then ruled by the King of Savoy) based on steel production and agricultural development. This crash effort provided the essential logistical means for sustaining the military offensives leading into the national unification of Italy.

The Creation of the Italian Nation

Despite the misrepresentations found in the official history texts to the effect that the Italian state was formed by a cabal of Masonic gnostics like Giuseppe Massini and Giuseppe Garibaldi, the truth is that the Italian nation was actually created by the combination of the Cavour political leadership, the above-mentioned network of patriotic scientists, and the music of Giuseppe Verdi.

Betti, Cremona, Brioschi, Masotti, Matteucei, and Felice Casorati, not only organized the volunteer corps from all of Italy to support the Piedmont army, but they themselves were military leaders, colonels, who fought in the major battles of the "Resurgement." Their role, however, was much more important after the unification of Italy. As Cavour put it, "After we have made Italy, we must make the Italians."

The Cavour project employed this network of scientists to establish the major educational centers of the new Italian nation and to initiate an accelerated industrialization of the country based on the most advanced technology of that time—electrical energy. Unfortunately, because of Cavour's death in 1862, only the first of these two goals was fully realized. The financial and economic policies of the new Italian state fell into the hands of international bankers like the Rothschilds, under the direction of the Anglo-Venetian oligarchy. Thus any significant attempt at industrialization was prevented.

Nevertheless, immediately after the unification, Betti became a senator and general secretary of the Education Ministry, while Casorati, Cremona, and Brioschi became senators and took control of educational policy. Under their direction, the Napoli Polytechnique was founded and the Pavia Bologna and Turino universities were greatly improved. Brioschi personally founded the Milan Polytechnique; Cremona, the Engineering School of Rome; and Betti, the Normale School of Pisa—all on the model of Göttingen University.

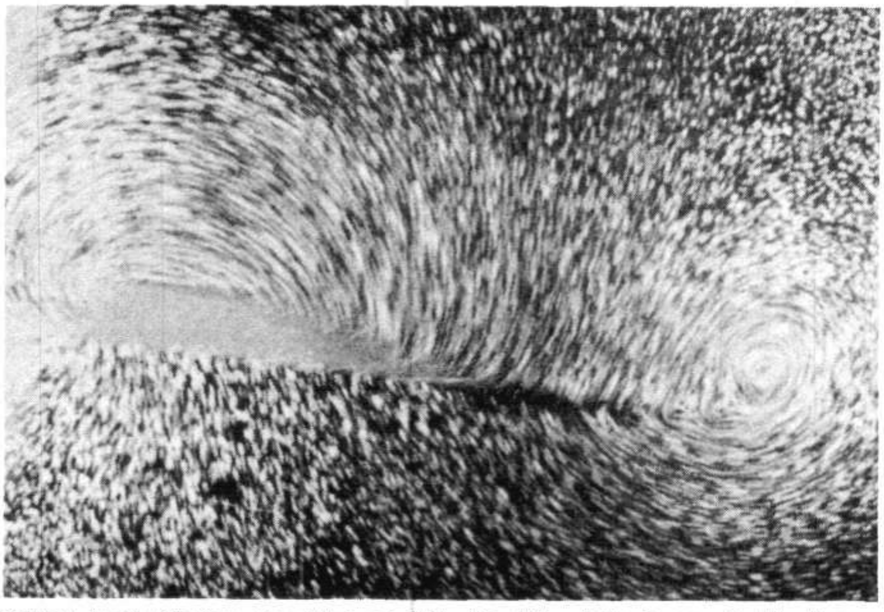
The theoretical and scientific potentialities rapidly matured and were realized in the economy after the Giolitti government came to power in 1880. In particular, the Milan and Turin Polytechniques became key centers for the development and transmission of industrial and technological developments. An outstanding example of this was the construction in 1883 of the first European electric power plant near Milan, during the same period that Edison built the first electric power station in the United States. Later, after a student of Betti, Galilio Ferreri, invented the electric engine based on rotating magnetic fields, electric energy was widely applied throughout the northern Italian economy.

From Hydrodynamics to Aerodynamics

In spite of World War I, the disastrous fascist regime, and the continual opposition of the gnostic Masons and Jesuits, the Italian hydrodynamic school was able to survive, centered in these educational institutions, in the form of the modern aerodynamic school. The aerodynamic school in-

VORTEX FORMATION AROUND AN AIRPLANE WING

Air flow around an air foil or a single airplane wing forms two vortices. The relatively fixed vortex around the wing can be seen in the front part of the wing. The second vortex has just detached from the trailing edge of the wing where other vortices will be created and detach. The counterpart to this vortex on the plane's other wing is rotating in the opposite direction.



Source: L. Prandtl, "The Generation of Vortices in Fluids of Small Viscosity," in *Gesammelte Abhandlungen* (Springer-Verlag, 1961), p.767.

cluded General Gaetano Crocco and Antonio Ferri in Rome, Carlo Ferrari in Turin, and Enrico Pistolesi in Pisa. In 1935, this school founded the Aerodynamic Research Center in Guidonia, near Rome, where Ferri built the most advanced supersonic wind tunnel in the world. At the beginning of World War II, the Guidonia Institute had five wind tunnels (four subsonic and one supersonic), a water flow facility for testing boat configurations, and a stratospheric tunnel.

It was at Guidonia that the Busemann zero drag, zero lift supersonic biplane was first experimentally investigated. The Italian school at Guidonia was intimately connected with the Prandtl-Busemann School in Germany, and after 1945, Antonio Ferri and Adolf Busemann worked in close collaboration at Langley Air Force Base in Virginia.

A 1936 report by Gaetano Crocco, "L'Aerodinamica in Aviazione," in the journal *L'Aerotecnica*, recounts the intellectual history and roots of the modern Italian hydrodynamic school. In particular, Crocco attacks both the French school of d'Alembert and the English school of Newton.

Today, real hydrodynamics—as exemplified by the pioneering work of Leonardo da Vinci and in modern times by both the Riemann-Prandtl school in Germany and the Riemann-Italian school—is not presented in the ordinary university curriculum. Instead, today students are taught that fluids are of two types. There are perfect fluids, which have no viscosity—inviscid fluids that are therefore much more amenable to representation by smooth, singularity-free mathematical functions. And there are viscous fluids, like those developed by Newton, involving "real" forces such as molecular drag and friction (that is, viscosity) on the microscopic level. The first type was championed by d'Alembert of France and the second by the English Newtonians.

Crocco notes that the d'Alembert inviscid fluid leads immediately to a paradox: Any body set in motion in such a perfect fluid does not encounter any opposition and therefore continues on infinitely along the same line. Ironically, this would seem to fulfill Newton's most cherished proposition of the so-called law of rectilinear inertia: Once a body is set in motion it continues in a linear manner until disturbed by some external force.

D'Alembert improves upon the primitive Newtonian case because it is no longer necessary to make the absurd assumption that space consists of a perfect vacuum. Instead, d'Alembert fills space with a perfect fluid. As with a Newtonian fluid, the paradox arises even in the case of d'Alembert's resistance-free, perfect fluid. This was demonstrated by Lord Kelvin, and reiterated by von Karman in his early works. According to them, human airflight was an impossibilty; even the flight of birds could not be explained.

The reason for this in the case of d'Alembert's perfect fluid, is that no work can be done by a body in motion through fluid against the fluid itself, nor vice versa; the fluid cannot do work on the body in motion. This is an inherent characteristic of the perfect fluid. It should be noted that the viscous Newtonian fluid arrives at the same result—the impossibility of flight—through the opposite door, so to speak. In this case molecular drag makes passage through the fluid virtually impossible, and almost infinite amounts of energy must be expended to achieve any significant lift.

Crocco's Contribution

Having rejected both the Newtonian and d'Alembert fluids, Crocco asks, how then can we begin to describe the real situation? After all, birds have been seen to fly!

First, there must indeed be viscosity in order to have flight: The plane must do work on the air in order to pass through it. The action of viscosity, though, cannot be reduced to simple molecular drag. Rather, its action must be located within the overall organization of the fluids that are encountered. The question of flight can then be reformulated in terms of asking how the wing organizes the air—all of the air—in order to create those conditions that will permit the passage of the wing through the air with the minimal exertion.

Crocco points out that a wing achieves flight—net lift—not simply based upon its interaction with the air in its immediate vicinity—that is, the boundary layer surrounding the wing—but rather on the basis of the organization of all of the flow (circulation) around the wing (see figure). As can be seen, the air is organized both in the front and the back of the wing. There are two vortices, first, the relatively fixed vortex of circulation around the wing, and second, a pair of counterrotating vortices produced off the trailing edge of the wing. Although the vortex of the second case can apparently be fixed (or stationary) for a steady flight speed (steady air flow), changes in the flow speed will cause the vortex to detach from the wing and form a new vortex on the trailing edge. The two vortices combine to give zero net vorticity, like the zero field situation given by two counterwound and concentric Beltrami solenoid coils.

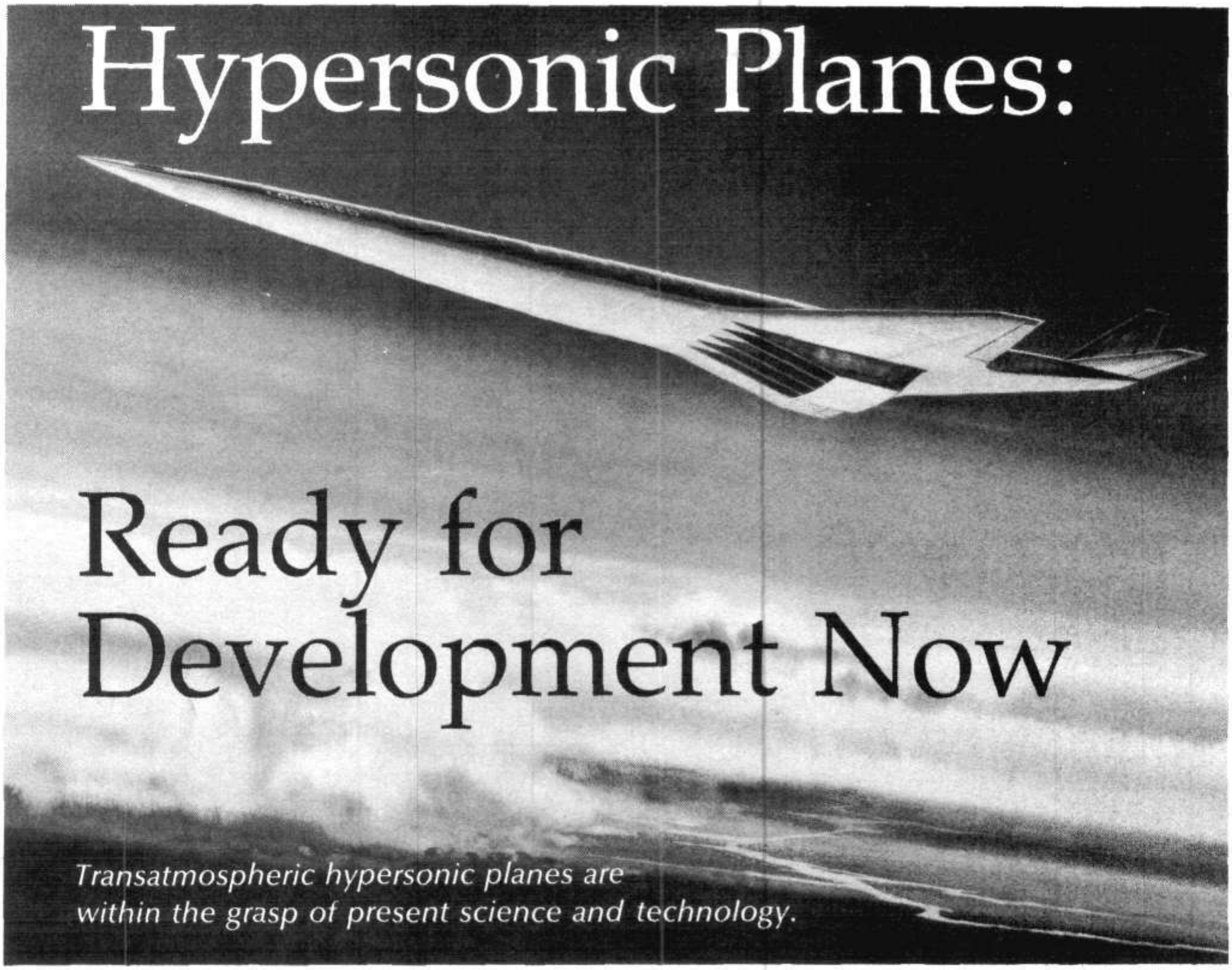
Crocco does not remain satisfied with the concept of a simple "stationary" global organization of the air flow around the wing. In fact, he polemicizes against such a concept put forward by Hermann von Helmholtz in his 1859 paper on vortices. Crocco points out that for Helmholtz vortices are "like Olympian gods who neither are born nor die, but are eternal." Crocco then identifies that the central question both for the science of flight and for modern hydrodynamics is precisely that of the birth and death of vortices.

Like Prandtl and Busemann, Crocco emphasizes that the generation and death of vortices are crucial for understanding flight. In the case of Prandtl and Busemann it is the formation of boundary layers that constitutes the same essential line of attack. It is not the laminar flow or rotational flow per se, but the formation process that is key. Both cases are similar to the shock wave that creates, through its formation, the basis for transport beyond the sound barrier—a sort of self-induced transparency.

Crocco solved a mystery that is instructive along these lines. It was observed that aircraft calmly flying along would suddenly lose their tails. Crocco found the explanation in the process of vortex formation off the trailing edge of the wing. This trailing vortex would form and detach from the wing and intercept the tail of the plane like a directed electromagnetic wave packet.

Giuseppe Filipponi, a physicist, is the director of the Fusion Energy Foundation in Italy and the editor of the Italian-language magazine Fusione.

Hypersonic Planes: Ready for Development Now



Transatmospheric hypersonic planes are within the grasp of present science and technology.

by Charles B. Stevens

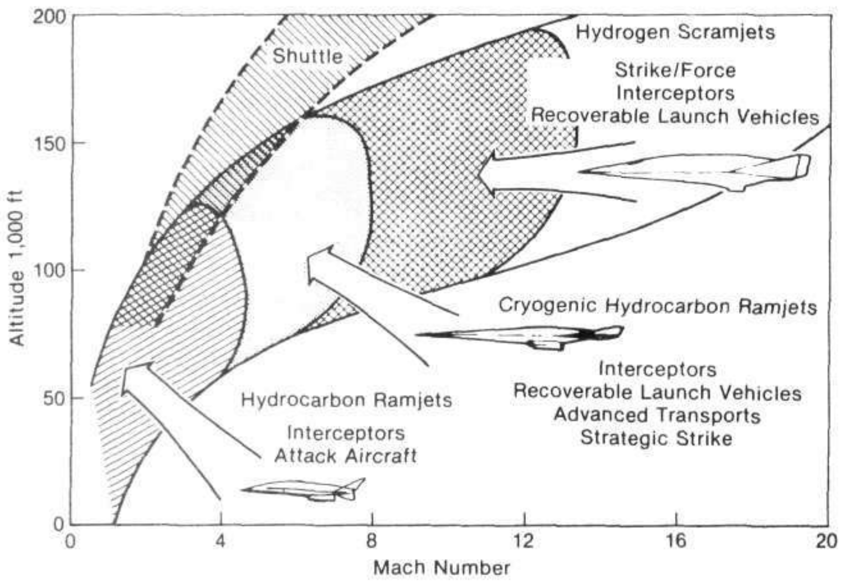
Los Angeles to Tokyo in 2¼ hours? This is not science fiction. Although almost a decade has passed since the United States abandoned the effort to develop such supersonic transport, we have at hand the technology necessary to perfect aircraft that fly at 12 times the speed of sound. Recently, presidential science advisor George Keyworth, the Defense Advanced Research Projects Agency (DARPA), and the Air Force called for development of hypersonic aircraft with speeds capable of reaching near-earth orbit. By leap-frogging the supersonic stage, transatmospheric hypersonic planes would provide essential contributions both to national defense and civilian air transport.

In making the case for hypersonic flight, NASA deputy administator Hans Mark noted that hypersonic aircraft were crucial for realizing President Reagan's Strategic Defense Initiative to make offensive nuclear missiles obsolete. In his testimony to Congress, DARPA Director Charles Buffalano reported that the technology offered both a means of reducing the cost for delivering materials into orbit and for 2 to 3 hour flights to the Orient, which would give a significant impetus to the economic development of the Pacific basin—a point also emphasized by Keyworth.

U.S. research on hypersonic flight was mothballed in the late 1960s at the same time that the NASA program was curtailed, when the Air Force cut hypersonic engine research back from a requested $100 million to $4 million. In a message to the members of the American Institute of Aeronautics and Astronautics, the late Dr. Antonio Ferri, the Italian-American pioneer of supersonic flight, characterized the Air Force decision as "foolish." Ferri cited

Figure 1
LOCKHEED'S HYPERSONIC SCRAMJET PASSENGER LINER
This Lockheed design for a hypersonic passenger transport would fly at more than 100,000 feet and cruise at 4,000 miles per hour speeds. The supersonic combustion ramjet engines—known as scramjets—are able to carry 200 and more passengers a distance of about 5,750 statute miles. Such an airliner could fly from Los Angeles to Tokyo in 2 hours, 18 minutes, which includes subsonic climb and approaches in compliance with existing airport noise and navigation regulations.

Figure 2
AERONAUTICAL SYSTEM OPERATION REGIONS
Shown here are operational altitudes versus aircraft velocities (in terms of multiples of the speed of sound—the Mach number) for existing and future supersonic and hypersonic craft. Note the necessarily higher operational altitudes needed for maintaining sufficiently low drag at higher speeds. Existing types of hydrocarbon-fueled ramjets operate in the region up to Mach 4. Cryogenic hydrocarbon ramjets would operate in the next region up to Mach 8. Cryogenic hydrogen-fueled scramjet designs have been tested in wind tunnels and are currently projected as operating up to Mach 12.



just a few potential benefits of hypersonic flight: A mobile fleet of hypersonic aircraft, similar in strategic value and relative invulnerability to nuclear submarines, he said, could fly 1,000 miles at Mach-12—that is, 12 times the speed of sound—in as little as 10 minutes. A reusable orbital transport powered by a combined turbo-ramjet/scramjet could attain orbit and then skip in and out of the atmosphere at Mach-25 speeds.[1] And large hypersonic transports would be more economical than subsonic, long-distance aircraft.

Technology Ready

The technology needed for development of hypersonic aircraft is now available at low risk, a point stressed by Keyworth and DARPA. Despite the budget cuts of the 1960s, continuing advances in jet propulsion engines, advanced aeronautics, and materials science have provided the essential basis for realizing transatmospheric vehicles, called TAVs. An airturboramjet, for example, has been under development at Aerojet Corp. for nearly 20 years; Lockheed has designed a TAV resembling the Space Shuttle; and Rockwell has designs for a TAV that would be lifted to high altitude by a jet-powered carrier aircraft. NASA, which has continued its research in hypersonic flight since the 1960s at Langley Air Force Base in Virginia, plans the construction there of a viable hypersonic wind tunnel along the lines of those first built by Antonio Ferri.

In a recent report to Congress, NASA outlined a 15-year, billion-dollar program that would lead to a Mach-12 transport capable of carrying 300 to 500 passengers. This TAV would take off like a conventional aircraft, cruise and be highly maneuverable within the atmosphere, and enter and leave orbit on demand. For a such a vehicle, no single conventional propulsion system could operate efficiently from takeoff to hypersonic cruise. Thus hypersonic research has concentrated on multiple propulsion systems. The separate engines necessary would include a turbojet for speeds through Mach 3 and a ramjet from Mach 3 to Mach 6. NASA considers a hydrogen-fueled scramjet as the most appropriate propulsion system for speeds above Mach 6.[2] A combined system might include an integrated turboramjet engine and turboramjet rocket.

The basic feasibility of building a TAV, according to NASA, was demonstrated by 1983, but combining the technologies involved is a major challenge. Advanced materials must be used in the engines and structure, and advanced avionics, aerodynamics, and propulsion systems have to be developed.

Propulsion Evolution

In 1965, NASA created the Hypersonic Research Engine Project at Langley Air Force Base. Since that time, a handful of aerospace scientists and engineers have devoted their work to demonstrating that an air-breathing engine can achieve 10 times the performance of simple rocket propulsion. The reason for this potential 10-fold advantage is that a rocket must carry most of the weight of its fuel supply in the form of oxygen. In contrast, air-breathing engines simply scoop the necessary oxygen out of the atmosphere. These air-breathing aircraft need carry only hydrogen, which can be in the form of jet fuel hydrocarbons or cryogenically cooled liquid methane. Without any oxygen aboard, there is a 10-fold savings in weight. In addition, an air-breathing engine is far more efficient and durable than a rocket for hypersonic flight within the atmosphere, up to about 200,000 feet.

Today the turbojet is the most widely used air-breathing aircraft engine, operating efficiently up to speeds of about twice the speed of sound—Mach 2. It contains a turbine that increases the flow of air through the engine to ensure that sufficient oxygen is present for efficiently burning the hydrocarbon fuel. Above Mach 2, the forward speed of the aircraft is high enough to "ram" air through the engine at the required rate without need of a turbine. At the higher supersonic velocities, the "ramjet" makes for a lightweight, more efficient propulsion than that of the ordinary turbojet.

Beyond Mach 6, aerodynamic considerations dictate that hypersonic aircraft operate at altitudes higher than 100,000 feet. The specific reason for this is that aerodynamic drag is a function of the density of the air. By going to higher altitudes at which the air density decreases exponentially, drag is decreased to a minimum while sufficient aerodynamic lift is maintained. However, the low air density leads to a substantial reduction in the rate at which oxygen can be rammed through the engine.

The solution to this aerodynamic-propulsion dichotomy of divergent requirements was provided by Antonio Ferri and his collaborators: the scramjet (Figure 1).

In the scramjet design, most of the underside of the aircraft is utilized to scoop air into the engines. Early ramjet design concepts sought to keep the combustion process at subsonic speeds. By disturbing the airflow in front of the engine, the incoming oxygen could be drastically slowed. But at greater than Mach 6 hypersonic speeds it becomes extremely difficult to slow the air inflow below the speed of sound. Even if this were possible, the resultant slowing process heats the air to 4,000 degrees F. At these temperatures the air molecules dissociate, making the combustion process far more inefficient. Additionally, there is the problem of the turbulent shock wave created when the air passes below the speed of sound.

The scramjet therefore is predicated on achieving combustion with air intakes at supersonic velocities. NASA Langley scientists, in fact, succeeded in developing a dual mode scramjet engine. The innards of the scramjet are honeycombed with fuel injection outlets. Half of them face toward the rear and the other half are at a perpendicular angle to the airflow.

At low Mach numbers, most of the fuel is injected parallel to the airflow to prevent the combustion process from occurring too far forward. As speeds increase, more and more fuel is injected perpendicular to the airflow in order to maintain efficient burning.

The Langley dual-mode scramjet module was tested up to speeds of Mach 7. The only reason it did not achieve even higher speeds was that Mach 7 was the limit of the wind tunnel. NASA states that its current scramjet can attain Mach 12 speeds, and in its recent report to Congress NASA reported, "The upper limit of speed for useful airbreathing

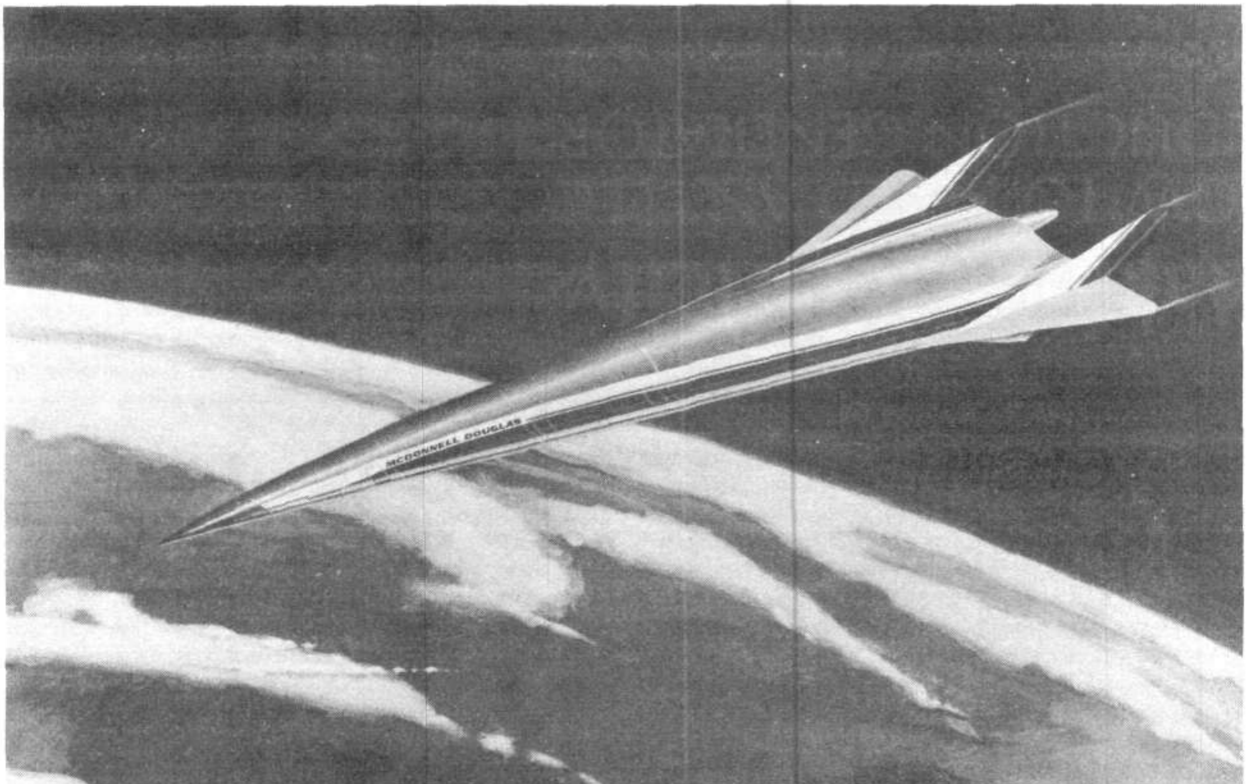


Figure 3
MCDONNELL DOUGLAS'S MACH 5 ORIENT EXPRESS
This methane-fueled "Orient Express" is based on state-of-the-art technology. It would carry 300 or more passengers to the Far East within a few hours, operate with minimal sonic boom, and would not disturb the ozone layer.

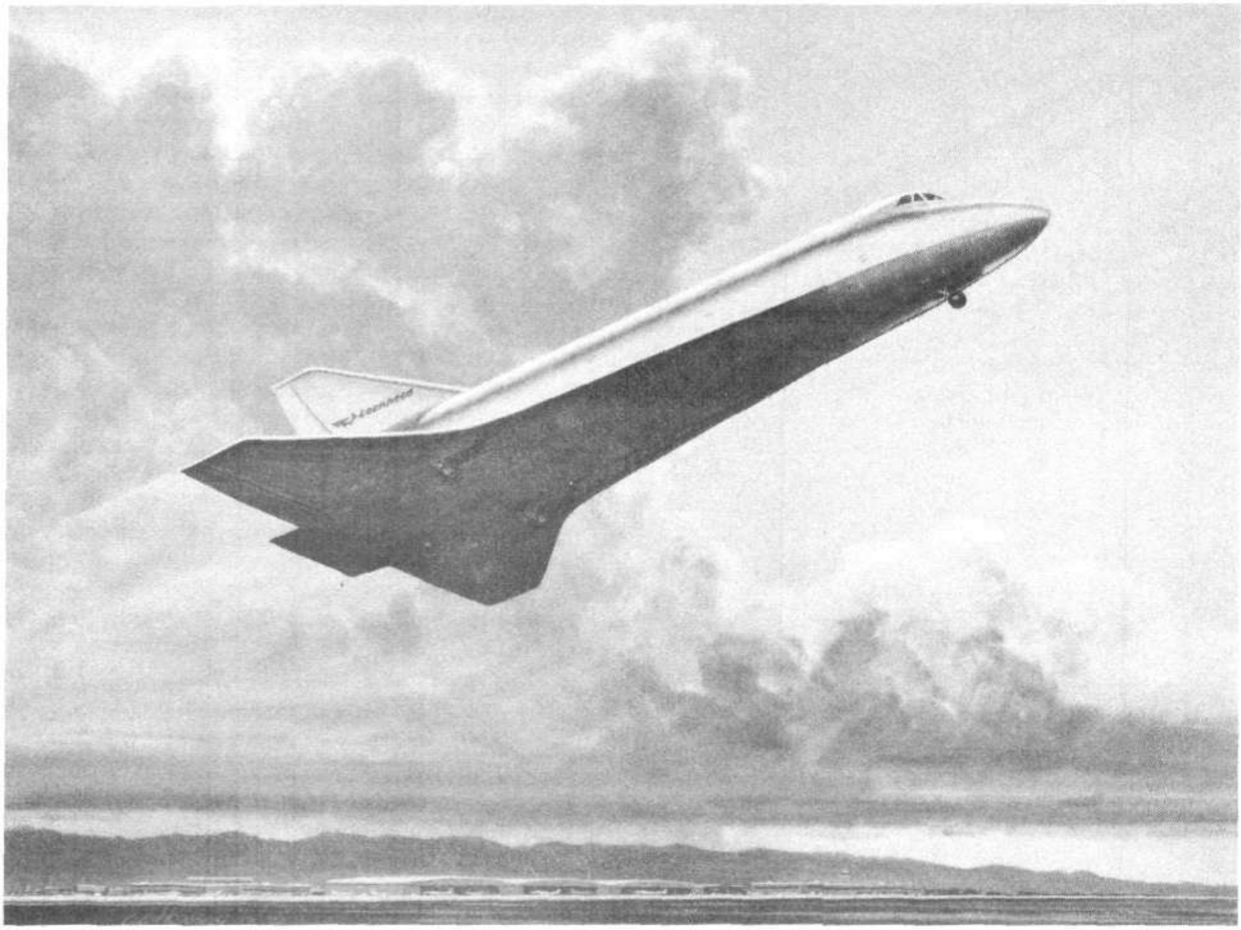


Figure 4
LOCKHEED'S NEAR-TERM TAV
This Lockheed design for a near-term transatmospheric vehicle would be capable of operating at speeds from the subsonic to Mach 30. Powered by a combination of turbojet and rocket engines, this TAV could be a second-generation Space Shuttle delivering payloads to space as well as a hypersonic air transport.

propulsion has not been determined."

Survey of Operating Regimes

The operating regimes for various existing and future supersonic and hypersonic aircraft are shown in Figure 2. Existing types of hydrocarbon-fueled ramjets operate in the region up to Mach 4. Note the necessarily higher operational altitudes needed for maintaining sufficiently low drag at higher speeds. Cryogenic hydrocarbon-fueled ramjets would operate in the region up to Mach 8. Such hypersonic craft could function in various missions as fighter interceptors, recoverable launch space vehicles, intercontinental passenger transports, and strategic defense platforms. Cryogenic hydrogen-fueled scramjet designs have been tested in wind tunnels and are currently projected as operating up to Mach 12.

Hypersonic aircraft designs have been developed for each of these operational regimes. A McDonnell Douglas design for a cryogenic methane-fueled Mach 5 transport, which is based on existing technology, is shown in Figure 3. This has been dubbed the "Orient Express" and could carry more than 300 passengers to the Far East within a few hours. Its combined aeronautic and propulsion characteristics make this concept the easiest to attain with existing technology and the easiest to operate at the highest efficiencies. The 80,000-foot-plus cruise altitude leads to minimal sonic booms—less than half those produced by the existing Concorde—in addition to the least disturbance of the Earth's ozone layer and the most efficient aerodynamics for economic fuel utilization.

Lockheed has proposed another approach that combines a turbojet engine drive with conventional rockets in a craft that looks very similar to the existing Space Shuttle (Figure 4). This transatmospheric vehicle or TAV would use ordinary turbojets for landing and takeoff at conventional airports, and rockets would be used to lift it into near-space orbit. The dual-powered TAV would be a combination spacecraft and conventional air transport, designed to operate equally well on transcontinental routes or at the fringes of space. It could achieve far more economical delivery of payloads to space than the existing Space Shuttle.

Technology Integration

The TAV cannot be viewed as a simple amalgam of unrelated components. Performance requirements are so high that every aspect of the design must be integrated with every other. The very shape of the aircraft must meet the needs of the propulsion system. Dr. Lee Beach, who heads up the hypersonic flight work at NASA-Langley, put it this way: "In our terminology, the undersurface of the vehicle, all of it, is the engine. The forebody precompresses the flow coming into the propulsion system. The aft surface of the vehicle is the nozzle, designed to divert exhaust smoothly. In hypersonic vehicles, an integrated airframe design is not just a performance increment. It's absolutely essential."

The need for cryogenically cooled liquid fuels can also be seen from this perspective. Before being burned for power, the liquid fuel, which has been cooled to cryogenic temperatures near absolute zero, is used as a coolant. Sustained hypersonic flight means that the wings must operate at high temperatures. Cryogenic cooling systems will be used throughout the TAV to reduce heat at the most critical points.

The most important element in the integrated design of a TAV is the science of hypersonic flow—engineering shock waves. At high Mach numbers, the shock waves created by the aircraft cannot be treated with conventional fluid mechanical concepts. The hypersonic shock produces plasma—ionization of the air—and the plasma dynamics of these hypersonic shock waves play a crucial role in the operating characteristics of the TAV.

It is not coincidental, therefore, that hypersonic pioneers like Adolf Busemann and Antonio Ferri initiated and pioneered research in the 1950s into the hydrodynamics of energy-dense plasma configurations. Today this line of investigation has led to the development of many advanced nuclear fusion concepts, including the spheromak, reversed field pinch, and compact tori. After the shutdown of most NASA projects in the late 1960s and the almost complete disappearance of significant hypersonic aircraft development, however, this highly productive cross discipline collaboration between aeronautic and plasma-fusion scientists was disrupted. Hopefully, the reinitiation of serious TAV development will lead to the rapid resurrection.

The Nuclear TAV

One of the original concepts for fueling advanced TAV transports was the use of nuclear fission reactors. Detailed designs were actually developed decades ago for safe, clean nuclear powered aircraft. The TAV has sufficient size to utilize nuclear power, and significant advances in nuclear reactor technology make its potential incorporation into advanced TAVs feasible and desirable. The introduction of nuclear-powered TAVs would make transport into near-space orbit sufficiently economical to support large-scale colonization of space, the Moon, and nearby planets.

The other area that the TAV will revolutionize is materials. The TAV will operate in a highly stressed environment and must be durable with a minimum of maintenance problems. The structure for the aircraft must be lightweight as well as relatively simple to permit inspection with standard nondestructive techniques. TAV materials under consideration range from advanced metal alloys, such as the quasicrystal metallic glasses being researched at the National Bureau of Standards, to advanced composites and ceramics. Two recent developments in resin matrix composite materials include the new classes of carbon fibers capable of being used in mass production and the new tough resins like elastomer modified epoxies and polyetheretherketone, a thermplastic. This particular material, called PEEK, makes a good laminating resin and when so used will give composite materials an interlaminar fracture toughness that is an order of magnitude higher than that of existing epoxy resin-matrix composites.

Other materials concepts are being harnessed for more advanced propulsion systems. For example, it has been suggested that metastable helium can be produced in a solid-fuel form by aligning the helium atoms and bonding them together to produce an excited but stable state. A strong bonding of the atoms will then provide a solid with a high melting temperature and have a useful life of up to eight years. Its energy content is projected as being 100 times greater than conventional chemical fuels.

SDI Missions

The TAV would make essential contributions to the SDI program. It could provide a cheaper means for deploying and repairing satellites in space and could provide certain rapid deployment capabilities not possible with alternative systems. According to the Air Force, "The TAV allows us to consider new missions for which no capability existed before, while providing an alternative way to perform existing missions."

Keyworth's Office of Science and Technology Policy has presented a plan to implement many features of the TAV proposal prepared by NASA. The plan would combine federal R&D work on advanced aeronautics to take into account civilian hypersonic transport, increase basic research at universities, increase federal support for advanced aeronautics research, and begin to work out now how TAV will function in future air traffic control systems.

It is clear that the science and engineering to perfect hypersonic aircraft are possible in the immediate future. So with the proper funding, we may soon be able to board the hypersonic Orient Express and in less than three hours arrive in Tokyo.

Charles B. Stevens is director of fusion engineering for the Fusion Energy Foundation.

Notes

1. A ramjet has a specially shaped duct open at both ends in which the air for combustion is compressed by the forward motion of the engine, mixes with the fuel, and burns; the exhaust gases issue in a jet from the rear. A scramjet is a supersonic combustion ramjet.
2. Ramjets utilize high flight velocities to produce the necessary air flow through their engines; turbojets use turbines to generate this air flow.

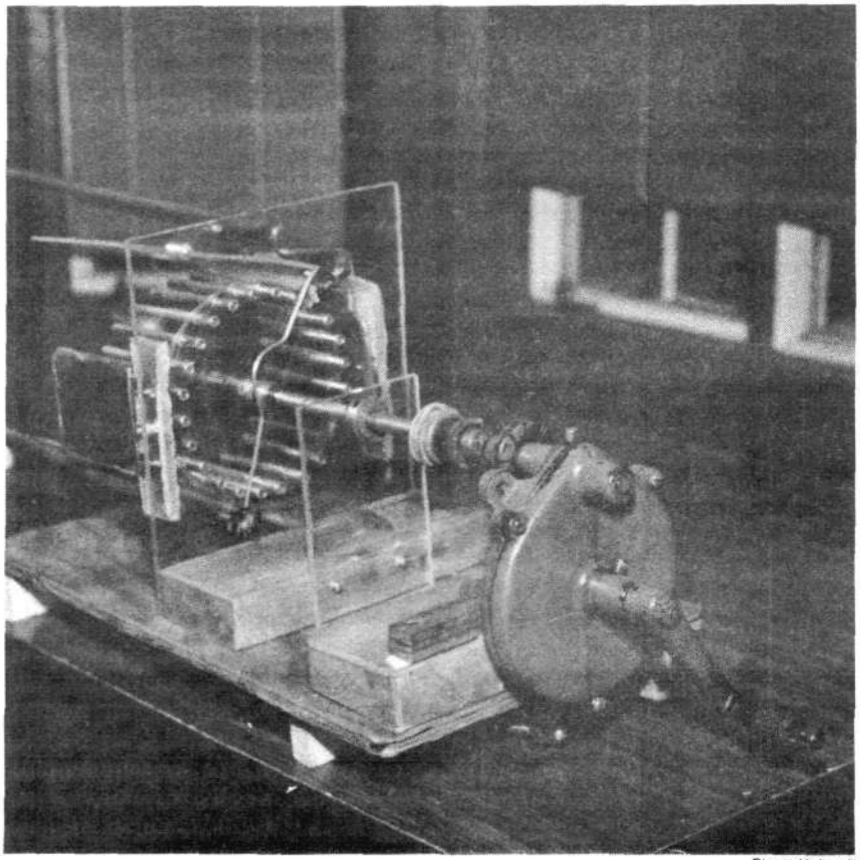
The Young Scientist

Making Electricity

HOW TO BUILD AN ELECTROSTATIC INDUCTION GENERATOR by Thoula Frangos

The first observation of electrostatics probably occurred with the cave man, who noticed that if he stroked fur it would get "charged," and that in the dark he could observe sparks on the fur. By at least the year 600 BC, the Greeks of Thales observed that rubbing amber caused it to be "charged," attracting dust and other light particles.

A scientist, however, must do more than just observe; he must make hypotheses and experiments. William Gilbert was a scientist in this sense. While a physician to Queen Elizabeth in about the year 1600, Gilbert became the first to do extensive research in magnetism and electrostatics. He wrote the famous book *De Magnete*, but he had no machine for collecting charge and making electricity.



Stuart K. Lewis

Dirod 2 as built by Dr. Robert Moon of the Fusion Energy Foundation.

The first electrostatic generator was invented in 1660 by the ingenious Otto von Güricke. It was a friction-type generator where the experimenter produced charges by rubbing his hand on a smooth sulfur ball mounted on a shaft. It was not until the next century, in 1753, however, that induction of charge was discovered by the English scientist John Canton. His experiments showed that an object that collected charge would induce the opposite charge in another object. Canton was also the first scientist in England to verify Benjamin Franklin's hypothesis on the nature of electricity.

In 1787, another English physicist, Abraham Bennet, invented the first electrostatic induction generator, called "Bennet's Doubler." After that, there were continuous improvements on this device, each capable of producing greater voltage, or energy, than the previous ones.

A Modern Induction Generator

More recently, A.D. Moore, an American professor, designed a simpler device using Bennet's principle. He called it Dirod 2 because its basic parts were a disc and rods. Dirod 2 was designed especially to teach students the basics of electricity and engines.

The experimenter generates electricity when he rotates a crank, causing each of 12 metal rods to pick up charges from the inductors and transmit them to collector plates via conductive tape, called brushes. The voltage of charge builds up on the collector plates.

To see how this device generates electricity look at Figure 1. The disc, *D*, is made of Plexiglas, a high-grade insulator (an insulator is a nonconductor of electricity). The rods, numbered *R1* through *R12*, the two collector plates, and the two attached inductors, are made of metal. There is a neutral wire (or chain), *N*, that has conducting brushes on each end, which are now touching *R12* and *R6*.

As you can see, the conducting brush touching *R12* has a positive charge, while the conducting brush touching *R6* has a negative charge. There are also conducting brushes attached to the collector plates that are now touching *R10* and *R4*.

Now where does the initial charge come from to start the build-up of voltage? The experimenter's handling and touching of the plexiglass by working with it will put enough charge on the surface to "induce" charges on the collectors.

Since unlike charges attract each other, the minus (negative) charges on inductor 1 will attract plus (positive) charges and cause them to appear on rod *R12*. The opposite occurs for inductor 2 and rod *R6*, where negative charges collect. The charges on *R12* and *R6* are called induced charges, and these rods will now become charge carriers. The rods rotate and touch the conducting brushes that stick out from the collectors. In this manner they deposit most of their charge (about three-fourths) onto the collector plates, which build up charge with each rotation.

It might seem as though the machine could continue to accumulate charge up to millions or billions of volts. Actually, the machine will reach only 90,000 volts, because any additional voltage over this limit escapes the metal collectors, forming a corona in the air around the collectors. You can see this corona—bright spots near the conducting brushes—when you operate your machine in the dark.

What You Will Need

To build Dirod 2, you will need equipment that is found in a school machine shop or a mechanic's shop. This is a good project, in fact, for a class that has access to a machine shop. Here is the shop equipment you will need:

Lathe
Reamer
Drill
Bandsaw or jigsaw
Belt sander
Center punch
File
Triangles for measuring
Solder

Here are the materials you will need. You may be able to find much of this second-hand.

- **7 pieces of Plexiglas (¼-inch or ⅜-inch thick)**
  - **1 major plate, 9″ × 9″**
  - **1 minor plate, 9″ × 7″**
  - **2 corona shields, 7″ × 7″**
  - **2 supports for shields, ¾″ × 3″**
  - **1 disc, 6-inch diameter**
- **12 aluminum rods (¼-inch diameter), 5 inches long**
- **2 aluminum or brass plates, 3″ × 4″ × ⅛″**
- **6 feet heavy copper wire, ⅛″ rod stock**
- **1 mechanical crank**
- **1 metal shaft**
- **1 plywood (for base), about 20″ × 20″**
- **24 screws, 8-32 machine screws**
- **12 Allen screws**
- **epoxy glue**
- **kerosene (small amount)**
- **silver conducting paint (small amount)**
- **tracing paper or vellum for drawing**

Building Dirod 2

If you have never built anything as ambitious as Dirod 2, this will give you invaluable experience with the nature of materials and how to adapt them to your needs. You will also learn how to use hand methods and simple machine processes to complete your project.

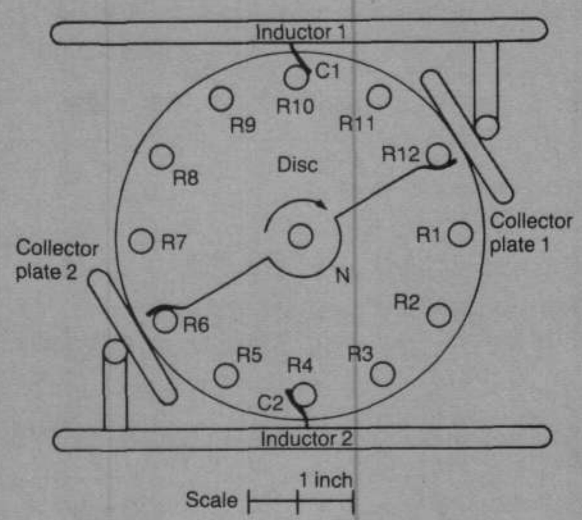


Figure 1
FRONT VIEW OF DIROD 2 SHOWING DISTRIBUTION OF CHARGES
The negative (−) and positive (+) charges on the inductors are picked up by the rotating metal rods, numbered R1 through R12, and deposited on the collector plates.

Here is how to put Dirod 2 together: First, look at the drawings to familiarize yourself with the device. Front and side views are shown in Figures 3 and 4, while Figure 2 shows how the entire apparatus comes together. Before you start building, it is a good idea to make full size drawings of Figures 3 and 4 on heavy tracing paper or vellum; it will help to avoid mistakes.

The Main Parts

A wood base supports both the generator and crank that operates it. The two main vertical parts attached to the base are Plexiglas plates; the minor one supports the shaft that connects the disc with the crank, and the major one supports the disc itself, corona shields, and collector plates. The collector plates in turn support their own inductor.

The corona shields are epoxy-glued to their Plexiglas supports (3/4" × 3"), which are screwed into the major Plexiglas plate at a 30° angle. The inductor is brass or aluminum, 1/4-inch in diameter and attached to the collector plates by epoxy joint with silver paint. The inductor will bend over, but not touch the corona shield.

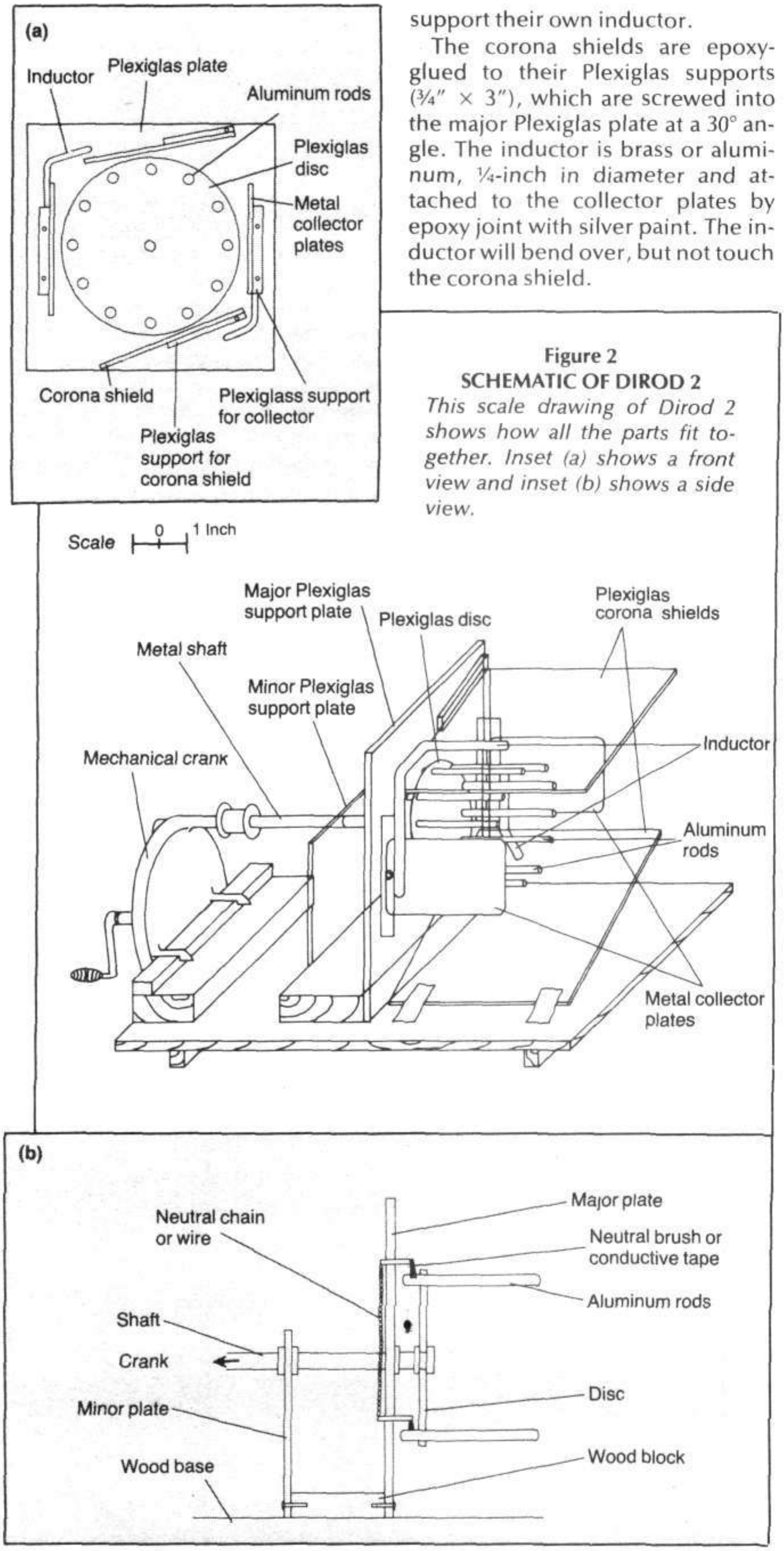


Figure 2
SCHEMATIC OF DIROD 2
This scale drawing of Dirod 2 shows how all the parts fit together. Inset (a) shows a front view and inset (b) shows a side view.

Working with the Plexiglas. All the Plexiglas pieces should be 3/8-inch or 1/4-inch stock. Another trade name for this is lucite. Plexiglas melts when overheated, so drill it very slowly and carefully. Mark outlines accurately with scratch lines. We found it best to cut the Plexiglas with a jigsaw and then file the edges, but you can also rough-cut the piece on a bandsaw and then smooth the edges on a belt sander or disc sander.

Use a sharp drill, low speed, and slow feed to drill the Plexiglas. The danger here is overheating, resulting in scoring. I recommend dry drilling and light pressure; go in 1/8 inch and back out; then go farther. Remove chips from the drill as needed. In drilling for an accurate fit to a shaft or bar, drill the hole undersize and follow with a reamer.

Threading holes. To tap a hole for machine screw threads, always use kerosene.

Making the disc. Drill the shaft hole first. Use a center punch to make an indentation. Start with a small drill to enlarge the indentation; then enlarge this with a larger drill. Follow with the 3/8-inch drill. The reference side must be down.

Marking the disc. Next scribe (that is, scratch or mark) the disc edge where the 12 rods will be placed. We taped our full-scale drawing to the disc and marked the disk from the drawing. Use the center punch for rod holes after marking locations using 45° and 30-60° triangles. Drill rod holes.

Epoxy-glue the disc to the shaft.

Rounding the rod ends. Using a lathe, chuck the rod in a collet. With high speed, use a file to bevel the end at about 45°. Shift file to reduce the two ridges.

Mounting the rods. Here again, your drill may give anywhere from a tight to a too-loose fit. If tight, use the drill press as a press to force rods in—but with moderate pressure. Too tight a fit may stress the Plexiglas, in which case you should polish down the rods. If too loose, fix rods into holes with epoxy.

Preparing the collector plates. These 4" × 3" aluminum or brass plates of 1/8-inch thickness have rounded corners with a 1-inch radius. Add corona trim to the plates using heavy copper wire or ⅛-inch rod stock. Apply it to edge and epoxy-glue it to plate. We found brass easier to work with, and we soldered the trim to the plates.

Preparing the inductors. These are aluminum or brass with ends rounded and polished. (You could also use copper tubing.) Epoxy-glue them to the collector plate, using silver conducting paint to bridge the epoxy. You can also solder the inductors to the plate.

Making the brushes. Use slipknot semiconducting tape, which serves as shielding to reduce stress around irregular points in high-voltage power cable splices. Make the brushes ½ inch wide and 1 inch long by folding the tape over once. You will need four such brushes, two neutral brushes connected to the neutral chain and two others connected to the collector plates.

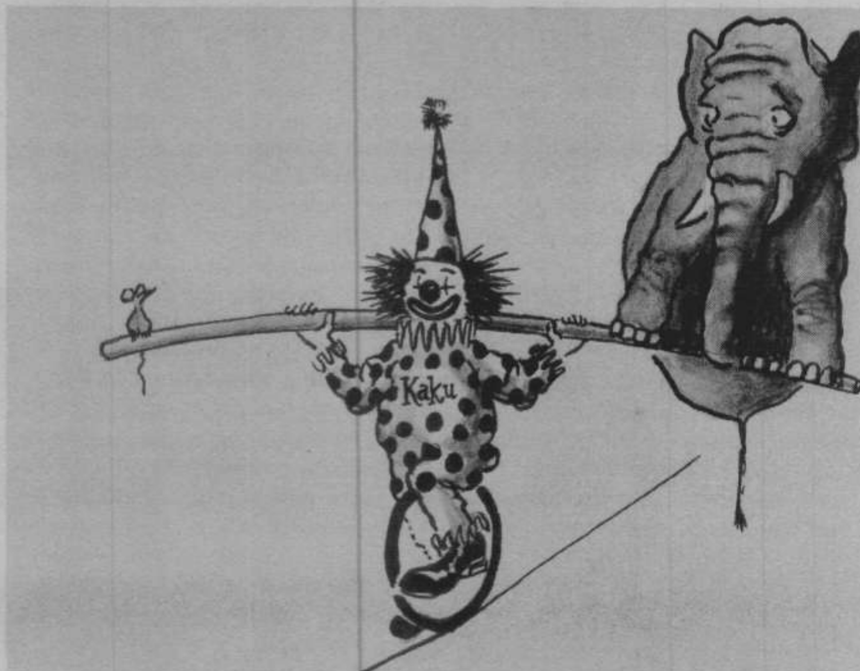
A note on the screws. Except for the wood screws, all are 8-32 machine screws and roundheaded or Allen screws. Allen screws have no heads; they are hardened steel setscrews for holding parts on a shaft.

The Corona Test

Once you have assembled the Dirod 2, try a corona test. Take the Dirod 2 into a completely dark room and turn the crank to run it. At first, only four little discharges at the brushes are seen. As your eyes become adapted to the dark, more and more corona appears. Try everything. Draw sparks. If it is corona-balanced, you will find that the corona will shift around in odd and spectacular ways. If good corona fails to develop, observe close by from all angles. A sharpness somewhere may have been overlooked. The appearance of corona there gives it away. Cover the sharp edge with conducting tape.

Here is what Professor Moore wrote about his invention: "Let me predict. Build the Dirod 2 in your youth. Put it away in a closet, go out in the world to make your way. When you retire 50 years later, come back, take it out, and run it. It will welcome you with sparks. This story is wrong in one respect: You will never put it away."

Books



P.T. Barnum Was Right

by Howard Hayden

Nuclear Power: Both Sides
by Michio Kaku and Jennifer Trainer
New York: W.W. Norton & Company, 1982
$6.95 (paperback)

Physicist Michio Kaku's plan for this book is simple enough: Get pronuclear and antinuclear people to contribute essays on both sides of various topics, write brief introductions to each topic, and market it. The result is a book that is "balanced" in the same sense that a debate between one perpetual-motion-machine nut and one physicist is balanced: both sides are presented; Amory Lovins gets equal time with nuclear scientists.

Obviously wanting to present the very best antinuclear case, he has chosen fellow experts like "unsafe-at-any-speed" Ralph Nader, "soft-energy-paths" Amory Lovins, and "Chicago-Seven" David Dellinger along with the nuclear disestablishment representatives John Gofman and Karl Z. Morgan. About these latter two hazards-of-radiation experts, Judge Patrick F. Kelly of the U.S. District Court in Kansas recently wrote, "The court rejects the opinion testimony of Dr. Morgan and Dr. Gofman because they both evidence an intellectually dishonest invention of arguments to protect their opinions. . . ."

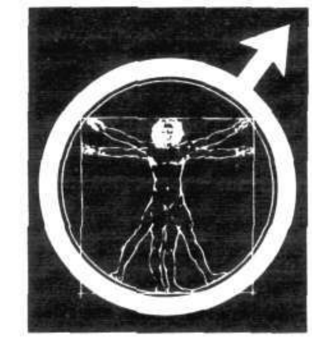
The book's subtitle is "The Best Arguments For and Against the Most Controversial Technology," but if these are the best antinuclear arguments available (and they are the best I have seen), there is no controversy!

Recent research has shown that the scientific community is overwhelmingly pronuclear, increasingly so as expertise in energy matters increases. This places the burden of proof on the shoulders of the antinukes. This review, therefore, addresses their arguments, although it should be noted that the pronuclear arguments are well written and interesting.

Health Effects of Radiation Exposure

There seems to be no quarrel with high-dose data on radiation exposure and cancer. If a population is exposed to 10,000 person-rems (with individuals receiving on the order of 100 rems each) one fatal cancer will result. The linear hypothesis is that the same population dose is required if all individuals receive low doses (on the order of rems or less). That is, the same 10,000 person-rem exposure will result in a single cancer if 10,000 people each receive 1 rem. This is the view that prevails among health physicists, although it is believed to overestimate low-dose hazards.

The Mancuso study on radiation and cancer, frequently cited by the antinukes, is a farce and has been discounted by all scientific groups that have studied it. In the book, Nuclear Regulatory Commission health physicist Allen Brodsky describes his firsthand experiences with the Mancuso group and leaves no doubt that their procedures were unscientific at best.



Nevertheless, antinuke expert Karl Morgan uses the Mancuso study to bolster his own case that a cancer dose is only 120 to 140 person rems when individual doses are low. He defends this view with the following invention: Leukemia allegedly dominates over myelomas (bone marrow tumors) when individual doses are high and other medical stress is great, and the opposite is true for low doses. Curiously, however, no medical teams have reported that the leading cause of death in high radiation areas is myeloma!

John Gofman has the courtesy to tell the reader that everybody is out of step but John Gofman. Scientists and academia, we are told, are supposed to "provide the mantle of credibility" for the government and utilities who "work hand in glove" to provide us with pernicious technology. He evidently regards himself as the Lone Ranger, singularly capable of independent thought and action. His discussion is backed up by (you guessed it) Gofman's own testimony in the *Congressional Record* and Gofman's own antinuclear book.

Containment of Radioactive Species

On this subject, Jan Beyea, a physicist for the Audubon Society, speaks for the antinukes. He agrees that all is well with nuclear power plants and would continue to be well if the probability calculations were correct—but he distrusts them. They are not based on experience, he says.

An entire reactor was built and tested just to see what happens when a large failure loss-of-coolant accident occurs, but apparently Beyea doesn't agree that some direct experience was gained here. He is also worried about a steam explosion, which could in principle breach the containment building, as though methods of handling steam are an unexplored, frontier technology. Even less credibly, he implies that at this point in the 20th century, we have no experience with pipes and valves. Ever been to a nuclear power plant?

Beyea is also inclined to believe that we have a "flat learning curve," learning nothing from experience, contrary to all experience in all industries. In conclusion, he says, nuclear power is just too dangerous and we won't learn anything.

Waste Disposal

Introducing the section on nuclear waste, editor Kaku asserts that "reprocessing removes only plutonium," thus obscuring what reprocessing is all about—turning the vast majority of the so-called waste from nuclear plants into usable fuel.

Nuclear by-products do not leave in smoke or settle out as ash, but rather remain with the fuel and in fact only comprise a few percent of the volume. They are intensely radioactive. Reprocessing is a procedure for removing this waste from the fuel (plutonium and U-235) and potential fuel (U-238). It is reasonable to use the fuel and to dispose of the small amount of waste.

Another antinuclear spokesman, Robert Pohl, is very worried about radwaste. Citing a list of possible uses for salt domes, he asserts that it is extremely likely that some future unsuspecting culture will come upon a radwaste depository and proceed to die by the millions. Are we to assume such overwhelming stupidity on the part of our descendants?

Somehow, these folks are supposed to be messing around in salt domes but fail to notice that (1) there is funny-looking glass and stainless steel around; (2) people who work with it get burns and get sick, sometimes fatally; (3) the most dangerous salt tastes funny; and (4) people who eat the salt get sick.

Also, civilization must have considerably declined because (5) there are no geiger counters, and (6) there are no tourists whose film is fogged by the radiation.

Nuclear Economics

Editor Kaku's greatest contribution may be that of not regarding Ralph Nader as an expert on nuclear physics. In true institutional fashion, he has kicked Nader upstairs and declared him an expert on economics!

In Nader's view, nuclear technology is impossibly expensive, and as proof he cites the 14 years it takes us in the United States to build a nuclear plant. Humbly he takes no credit for the delays, and fails to mention that in the rest of the world it takes about 6 years for the same American manufacturers to build an identical plant.

Then there are the economics of Mr. and Mrs. Amory Lovins. The two Lovins are offended whenever electricity is used for heat, and therein make a moral case against nuclear power. Perhaps they haven't heard that reactors produce heat. Princeton law professor Richard Falk then does his best to convince us that nuclear power and nuclear weapons are strongly linked. He misses the essential point: The military has for decades successfully built nuclear weapons without bothering to generate electricity in the process.

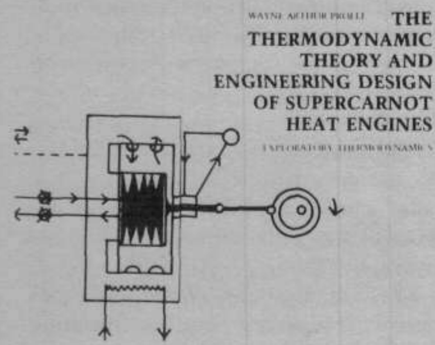
Finally, we have on the antinuclear side, David Dellinger. His essay is devoid of references, but instead tells of firsthand experience "from people downwind and downstream of the plants—farmers, veterinarians . . . parents of children born dead or defective. . . ."

☞ P.T. Barnum was right!

Howard Hayden is an associate professor of physics at the University of Connecticut at Storrs.

Refuting the Second Law

The Thermodynamic Theory and Engineering Design of Super Carrot Heat Engines
by Wayne Arthur Proell
Las Vegas: Cloud Hill Press, 1985
439 pages, $200



After reading through the author's fulsome acknowledgements and dedications, as well as his preface—all of which suggest that this book is a major philosophical attack upon entropy theory—the reader is left more than a little bemused by its contents.

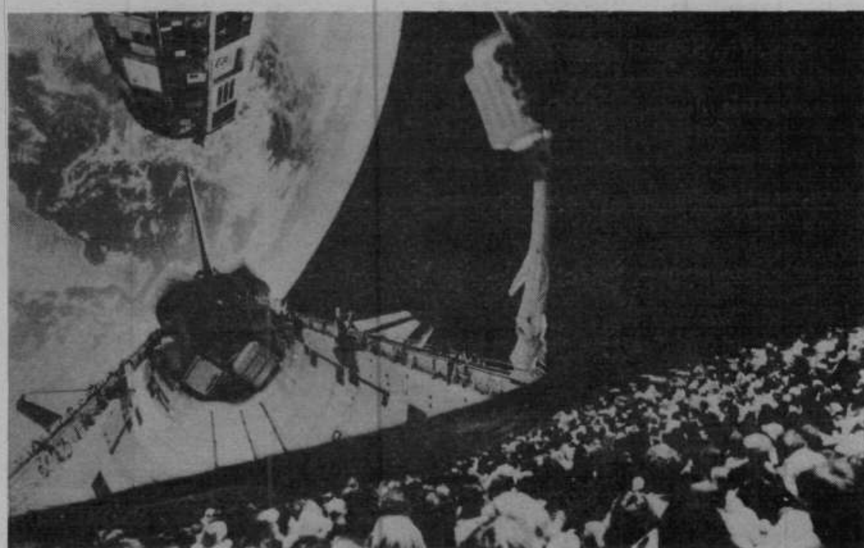
This reader, at any rate, admits to being unable to read more than half of the book, which is tediously full of thought experiments about impractical engines, worked out in overbearing detail. As far as we could see, with a peek at the ending, the author is giving us a theory of refrigerators. It escapes us how an increase in local negative entropy, challenges the Second Law of Thermodynamics.

The author's mistake lies in thinking that he can use the methods of thermodynamics to challenge thermodynamics. The Second Law is wrong, precisely because thermodynamics is fundamentally wrong in its assumptions. The kinetic energy of molecules that exhibit apparently random motion al-

Continued on page 64

NASA's 'Spacetacular' Film

"The Dream Is Alive"
Produced and directed
by Graeme Ferguson
37 minutes, June 1985



Smithsonian Institution/Lockheed Corporation

Theater viewers watching the Space Shuttle Remote Manipulator arm in action on a giant screen.

Every *Fusion* reader should see NASA's new film "The Dream Is Alive." If anything, NASA's own description of the film is an understatement. The promotional reads: "Get a window seat aboard the next Space Shuttle. 'The Dream is Alive' offers an insider's view of America's space program.

"The film features spectacular inflight footage shot by 14 astronauts on three separate missions. See astronauts at work both inside and outside the spacecraft; the deployment of scientific and communications satellites; the dramatic capture and repair of the 'Solar Max' satellite and the first space walk by an American woman astronaut, Kathy Sullivan.

"Experience a thunderous Space Shuttle liftoff from atop the launch pad tower. Sense the weightlessness of a zero-gravity environment and view the Earth from more than 200 miles out in space."

The film was produced and directed by Graeme Ferguson of Imax Systems Corporation for the Smithsonian's National Air and Space Museum, and is narrated by Walter Cronkite. It was funded by Lockheed Corporation and the museum as a public service, and will open at more than 40 huge-screen IMAX theaters in 1985 and 1986.

Would that television achieved this quality of excitement and adventure. The film is especially a must for children.

—*Carol White*

Cannonball Target

Continued from page 9

tion—above 50 percent—and a high hydrodynamic efficiency in the range of 16 percent. The numbers of hot electrons emitted from the rear of the first type of cannonball target were found to be less than those seen in the single-foil ablative target. This tendency was even more noticeable for the second type.

Overall, the energetic hot electrons are mainly absorbed by the cannonball cavity wall. Their energy is thus converted into plasma generation and heating, which then effectively drives the implosive acceleration of the inner surface representing the fuel target surface in this experiment. Furthermore, low-energy hot electrons in the cavity also become useful in driving the implosion of the inner surface.

It was found that the formation of the cavity structure of a plane foil can modify the energy distribution of the hot electrons. This modification of the hot-electron spectrum appears to depend on the cavity materials and geometry. Therefore, proper design of spherical cannonballs can suppress the hot-electron preheating of pellet fusion fuel otherwise seen in direct-drive, long-wavelength laser fusion.

Osaka is also continuing work on cannonball targets with other types of inertial confinement fusion drives such as short wavelength lasers and particle beams. By exploring various cannonball configurations with a wide range of different drivers, they plan to demonstrate the science needed for high gain inertial fusion energy generation.

—*Charles B. Stevens*

Second Law

Continued from page 63

lows us to measure certain global features of the electromagnetic action of which the motion is a by-product; but all causal action must be fundamentally hydrodynamic in character rather than randomly statistical.

The true refutation of the Second Law begins with the existence of the author. Since life exists, and it can not exist upon the premises of entropy theory, then it is that theory—rather than life—that is wrong.

—*Carol White*

Aids Spreads Like TB

Continued from page 8

disease[14] as a direct result of the introduction of just one infected animal.

It seems probable that in the prosperous West, LAV is still only transmitted by per-cutaneous inoculation, or by anal intercourse, but that in the tropics it is already being spread also by the respiratory route with or without the cooperation of *M tuberculosis hominis*. The prospects for the less prosperous inhabitants of the crowded cities and villages of the world beyond the next decade are bleak.[15]

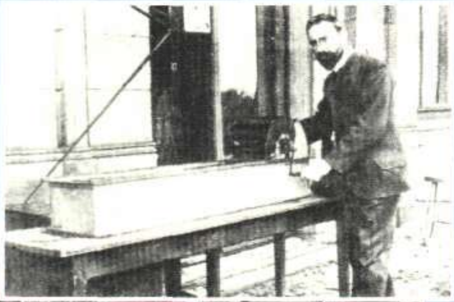
References

1. J.M. Ziza, F. Brun-Vezinet, A. Venet, et al. "Lymphadenopathy-associated virus (LAV) isolated from bronchoalveolar lavage fluid in AIDS-related complex with lymphoid interstitial pneumonitis." *N Engl J Med* **313**: 183 (1985).
2. J.M. Wallace, R.G. Barbers, J.S. Oishi, H. Prince. "Cellular and T-lymphocyte subpopulation profiles in bronchoalveolar lavage fluid from patients with AIDS and pneumonitis." *Am Rev Respir Dis* **130**: 786 (1984).
3. G.B. Scott, P.E. Buck, J.G. Leterman, F.L. Bloom, W.P. Parks. "AIDS in infants." *N Engl J Med* **310**: 76 (1984).
4. P. Solal-Celigny, L.J. Couderc, D. Herman, et al. "Lymphoid interstitial pneumonitis in AIDS-related complex." *Am Rev Respir Dis* (in press).
5. CDC. "Revision of case definition of AIDS for national reporting—United States." MMWR **35**: 373 (1985).
6. A.E. Pitchenik, C. Cole, B. Russell, M.A. Fischl, T.J. Spira, D.E. Snider. "Tuberculosis, atypical mycobateriosis, and AIDS among Haitian and non-Haitian patients in South Florida." *Ann Intern Med* **101**: 641 (1984).
7. H. Francis, J. Mann, R. Colebunders, J. Curran, P. Piot, T. Quinn. "Utility of the HTLV III ELISA assay in the diagnosis of AIDS in Central Africa." *Proceedings of the 6th International Meeting of the International Society for STD Research*, Brighton July 31-Aug. 2, 1985 (in press).
8. J.J. Goedert, S.H. Weiss, R.J. Biggar, et al. "Lesser AIDS and tuberculosis." *Lancet* **2**: 52 (1985).
9. T. Jonckheer, P. Henrivaux, J. Levy, et al. "HTLV III infection in African families." *Proceedings of the 6th International Meeting of the International Society for STD Research*, Brighton July 31-Aug. 2, 1985 (in press).
10. M.A. Gonda, F. Wong-Stall, R.C. Gallo, J.E. Clements, O. Narayan, R.V. Gilden. "Sequence homology and morphologic similarity of HTLV III and visna virus, a pathogenic lentivirus." *Science* **227**: 173 (1985).
11. G.M. Shaw, M.E. Harper, B.H. Hahn, et al. "HTLV III infections in brains of children and adults with AIDS encephalopathy." *Science* **227**: 177 (1985).
12. H. Thormar, P.A. Palsson. "Visna and maedi—two slow infections of sheep and their etiological agents." *Perspect Virol* **5**: 291 (1967).
13. G. Querat, V. Barban, N. Sauze, et al. "Highly lytic and persistent lentiviruses naturally present in sheep with progressive pneumonia are genetically distinct." *J Virol* **52**: 672 (1984).
14. P.A. Palsson. "Maedi and visna in sheep." In R.H. Kimberlin, ed. *Slow virus diseases of animals and man*. (New York: North-Holland Publishing Company, 1976) p. 17.
15. J. Seale. "AIDS virus infection: prognosis and transmission." *J Roy Soc Med* **78**: 613 (1985).

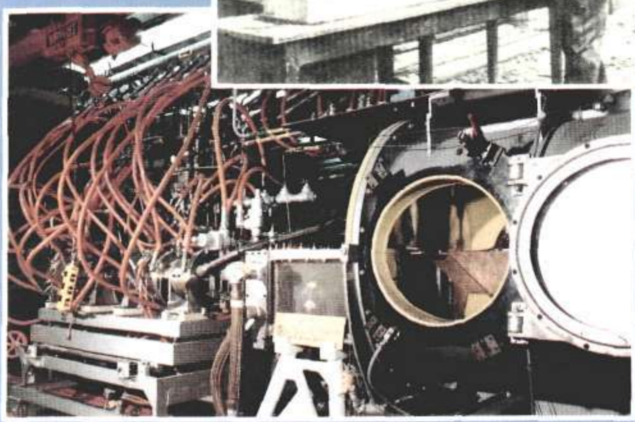
In This Issue

A page from Leonardo's notebook with a self-portrait and some studies of water flow.

The Royal Library at Windsor Castle, 12579.



Hydrodynamicist Ludwig Prandtl with his simple laboratory device for the investigation of fluid flow.



NASA

The wind tunnel facility at Langley Air Force Base in Virginia, where NASA is testing a Mach 7 Scramjet. Air is heated to 3,400° F. by the electric arc at left. Shown in the open window is the front of the scramjet engine model. NASA has outlined a 15-year, billion-dollar program that would lead to a Mach-12 transport capable of carrying 300 to 500 passengers.

LEONARDO, THE GÖTTINGEN SCHOOL, AND HYPERSONIC FLIGHT

As the feature articles in this issue demonstrate, without the scientific method of Leonardo da Vinci and the later work of the Göttingen School in Germany, supersonic flight, rocket flight, and other achievements of modern science would not exist at all.

- Science historian Dino de Paoli makes it clear that Leonardo's work on hydrodynamics not only is still valid, but also is the only standpoint from which we can understand the action of the real fluids that make up 99.99 percent of the universe.

- FEF research director Uwe Parpart Henke elaborates on the Riemannian geometrical method of the Göttingen School, highlighting the hydrodynamics work of Ludwig Prandtl and contrasting this successful approach to the dead-end outlook of the opposition, exemplified in this country by Theodore von Karman.

- Italian FEF director Giuseppe Filipponi provides a capsule history of the Riemannian tradition in Italy, demonstrating how this led to the rapid Italian progress in aerodynamics in the 1920s and 1930s.

- Fusion news editor Charles B. Stevens reviews the current status of hypersonic flight, describing how the United States could leap-frog the supersonic stage and right now develop aircraft that fly at 12 times the speed of sound.