Italy's role in the coming scientific revolution

Giuseppe Filipponi, physicist and director of Italy's Fusion Energy Foundation, traces the Italian hydrodynamics school from Beltrami's vortices to the hypersonic airplane of Ferri.

What follows is the speech Dr. Filipponi delivered to the conference on "From Leonardo da Vinci to Hypersonic Flight: Italy's Contribution to Economics and Defense," on April 29, 1986. The conference was held in Rome under the co-sponsorship of the Schiller Institute and the Fusion Energy Foundation.

As is clearly shown by the role of Leonardo da Vinci in the Italian Renaissance and Leibniz's activities between the 17th and 18th centuries, the European hydrodynamic school is historically linked to political activities directed toward the constitution of republican states based on scientific and technological progress, and hence on the cultural advancement of the citizens.

This is precisely the case of the great hydrodynamic school that developed in Italy in the middle of the 19th century with the decisive contribution of Bernhard Riemann, who moved from Göttingen in Germany to Italy and spent the last years of his life between Pisa and Lago Maggiore.

Enrico Betti, Francesco Brioschi, Eugenio Beltrami, Felice Casorati, Luigi Cremona, Mossotti, and Carlo Matteucci were the main spokesmen of this school, which played a decisive role in the political and military battles of the Risorgimento that led to the formation of the Italian nation-state.

It is no accident that between 1840 and 1860 the "Annual Congress of Italian Scientists" became a focus of patriotic conspiracy, so dangerous that in 1850 two orders were issued, one by the Austrian governor of the Lombardo-Veneto territory, and the other by the Vatican Curia, forbidding their subjects to participate.

This was the period in which the Count of Cavour had imposed a program of forced industrialization on Piedmont, the so-called Cavour Decade. This program, tenaciously pursued despite the opposition of the ruling House of Savoy, put Piedmont in the position of being able to militarily sustain the campaign to unify Italy.

Hence, despite the history books which continue to claim that Italy was liberated from foreign domination and unified by gnostic freemasons like Mazzini or by Garibaldi's military prowess, the truth is that the modern Italian state was founded thanks to the combination of the political capacities of Camillo Benso di Cavour and the aspirations of this network of republican scientists, whose ideas were made accessible even to the most humble strata of the population by the music of Giuseppe Verdi.

Betti, Cremona, Casorati, Brioschi, and the others not only organized corps of volunteers from all over Italy in support of the Piedmontese army, but they themselves, when the need arose, became military leaders, organizing the famous "Five Days of Milan," the defense of Venice, and distinguishing themselves in the most violent Risorgimento battles and insurrections. Their role was especially crucial after unification, when, as Cavour said, "having made Italy, we must now make the Italians."

Cavour's plan was to build up, after unification, the main educational centers, and hence start the accelerated industrialization of the country, basing it on the use of the most advanced technologies of the time, such as electrical energy. "Italy has more energy in the power of its waters falling from the Alps than England has with the coal in its mines," Cavour said in his celebrated speech to the Piedmontese parliament in 1855, the occasion when he announced the great project of the tunnel of Moncenisio. These scientists were exactly the people who could turn Cavour's plans into reality, putting together educational, research, and industrial centers, and thus making Italy the first country of the world to generate electrical energy industrially. The contribution the Italian scientists made in those years to the development of the technology of electricity was decisive; it is because of them that an energy source, previously used only for lighting, became available as a power source for industry.

It is said that the then very young Antonio Pacinotti, a student of Mossotti in Pisa, had invented, during the Battle of Goito of the Piedmontese against the Austrians, the so-called Pacinotti Ring; that is, the collector that permits an efficient transformation of mechanical energy into alternating electrical energy. Since the principle of the transformer was already known, alternating electrical energy produced by hydroelectric or thermoelectrical power, could then be efficiently transported even to a distance of several tens of kilometers, but still missing was an efficient system to retransform such alternating energy into motor power. The motors developed were all very inefficient, and it was also not found very fruitful to retransform electrical energy from alternating to direct current for use. For this reason, electricity was used only for lighting.

The various attempts to develop an efficient electrical motor were also often impeded by strident arguments. Lord Kelvin, for example, opposed any research in this direction, stating that all use of alternating current other than for lighting, would be harmful to the human body—the same objections that today's ecologists raise against nuclear energy. Despite the technical difficulties and the backwardness of the scientific world of the day, an Italian scientist, Galileo Ferraris, a student of Enrico Betti, thought up the concept of the rotating magnetic field, from which was derived the technology that made it possible to build an efficient motor fed by alternating electrical energy—the modern electric motor.

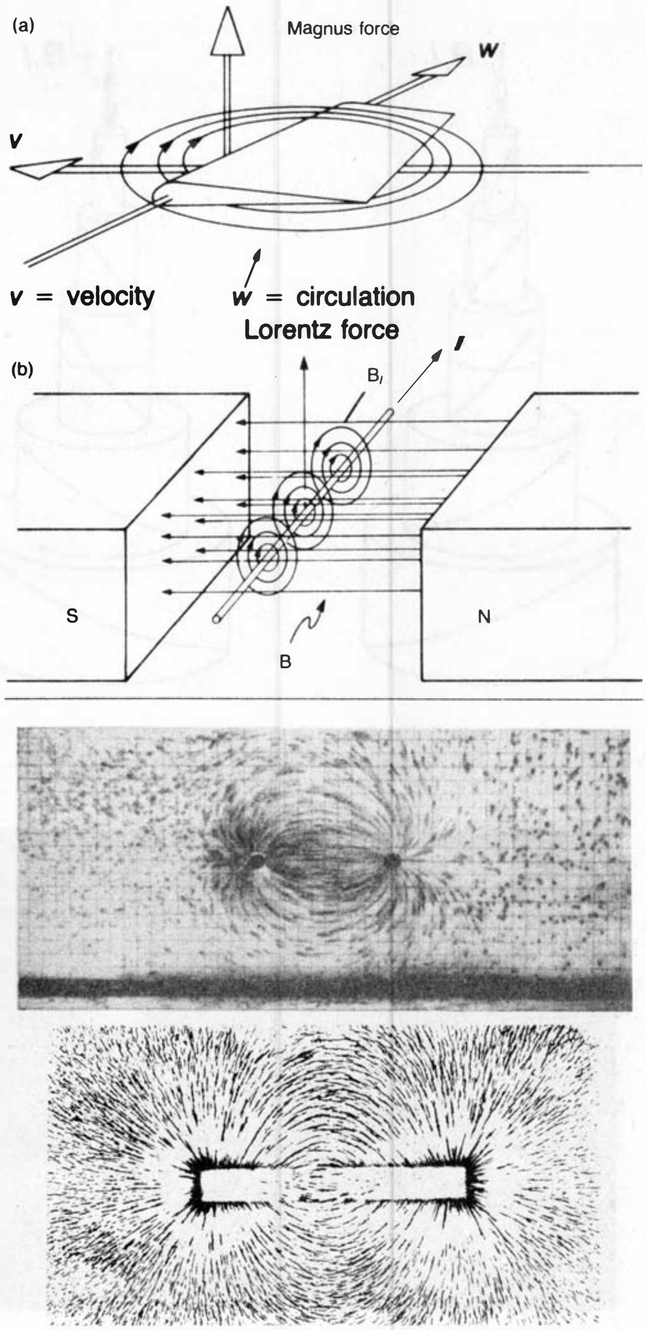
Unfortunately, because of Cavour's death right after Italian unification, the project of developing a basic steel and mechanical industry in Italy that could put the country on the level of the most advanced in Europe, failed. From the financial and economic standpoint, the new Italian state quickly fell into the clutches of the Anglo-Venetian oligarchy of the Rothschilds, who prevented any attempt at industrialization. Nonetheless, Enrico Betti soon became general secretary of the Ministry of Education and Luigi Cremona became its minister; Casorati and Brioschi were elected senators, and thus they took education policy in hand.

Under their direction, the Naples Polytechnic Institute was founded and that of Turin expanded, together with that of Bologna and the University of Pavia. Brioschi founded the Milan Polytechnic, Cremona the Engineering School of Roma, and Betti the Normal School of Pisa.

The scientific and technical potentialities created by these institutions were soon considerable; hence, when the Giolitti government in the 1890s and the first decade of the 20th century, impressed a relatively more patriotic direction on the national economy than before, the Milan and Turin Polytechnics, in particular, became driving centers for industrial and technological development. Just to give one example: In 1883 near Milan, Brioschi's successor, Giuseppe Colombo, built the first European electric power plant.

FIGURE 1

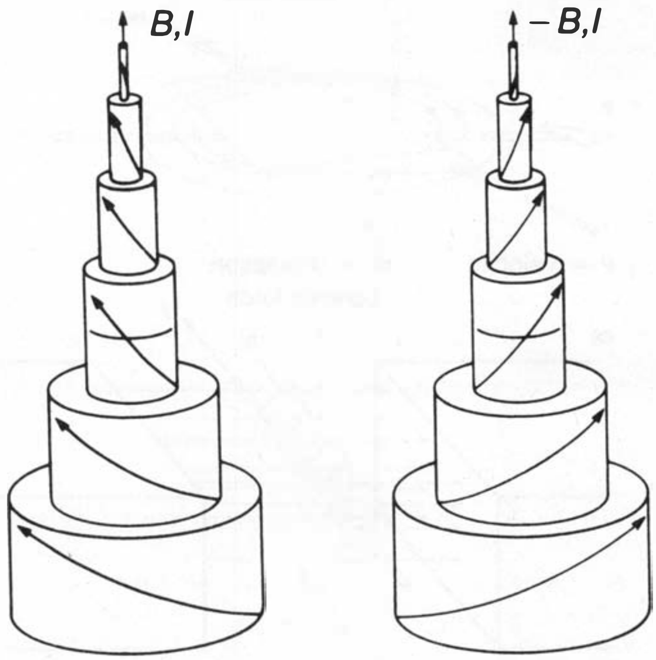
Analogy between fluid-dynamic and electrodynamic phenomena

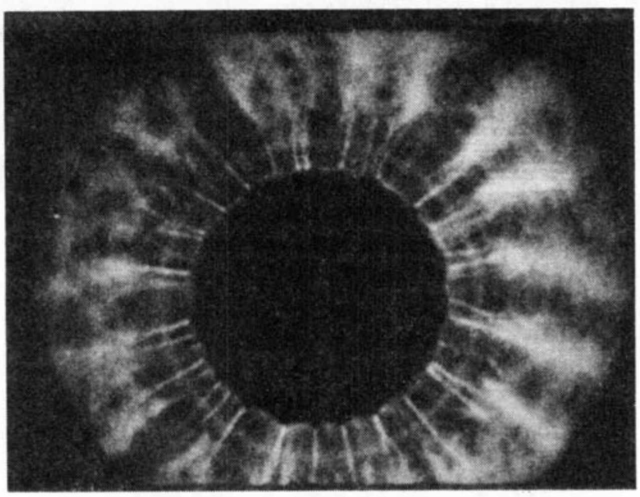


(a) Beltrami's depiction of the analogy between the action of fluid dynamic vortices (top) and the electromagnetic action of electrical currents. V is velocity, w is circulation, I is electrical current, B is the magnetic field due to the current, and B_I is the magnetic field due to the current.
(b) Photos showing the similar pattern (top) and magnetic field lines created by a magnet applied to iron filings. Crystals of potassium permanganate dropped into the water make the streamlines visible.

FIGURE 2

Formation of a pair of force-free filaments in magnetic plasma





The counterrotating pairs of vortical filaments of a plasma diagrammed here were discovered by fusion scientist Winston Bostick in 1966, and are the same as those described by Beltrami. The photo, courtesy of Dr. Bostick, shows a plasma filament in Bostick's plasma focus machine at Stevens Institute. The five-nanosecond axial-view photo shows the vortex filaments lying in the grooves of the corrugations of the current sheath.

This historical overview is important to locate the work of Eugenio Beltrami, student and then colleague of Betti and Riemann and perhaps the most gifted exponent of this school.

As Betti explicitly reports, the contribution of Bernhard Riemann to the Italian hydrodynamics school was decisive for burning all the bridges with the algebraic methods that the Jesuits had imposed on Italy's system of schools and universities. It is important to realize that the Jesuits controlled practically the whole educational system of the various states before national unity, where algebraicists like Ruffini and other personal friends of Baron Augustin Cauchy, who had corrupted the Ecole Polytechnique of Paris after Lazare Carnot was chased out, were pervasive. The role of Riemann was therefore fundamental in pushing Betti, Brioschi, Casorati, and Cremona toward synthetic geometry and mathematical physics.

Ironically, in official histories of science, Betti and Beltrami are remembered as teachers of the theory of elasticity. What is not reported, however, is that Betti and Beltrami in particular developed this theory to be able to demonstrate that Maxwell's interpretation of electrical and magnetic phenomena, like tension and pressure in an elastic medium, was wrong. In his paper "On the Mechanical Interpretation of Maxwell's Equations," Beltrami demonstrated that with Maxwell's hypothesis of elastic ether, the propagation of electrical and magnetic potential can be explained only if such potential is of the type generated by systems whose geometrical configuration can be reduced to a single (simply connected) point. For every more complicated case, however, it fails.

Thus did Beltrami dismantle Maxwell's mechanistic hypothesis of an elastic medium as a "conductor" of electromagnetic phenomena.

What is Beltrami's hypothesis on electromagnetic phenomena? The hypothesis is presented implicitly in the first researches into hydrodynamics presented by Beltrami from 1871 to 1874 at the Academy of Sciences of Bologna. According to Beltrami, electromagnetic phenomena can be explained as hydrodynamic phenomena, and vice versa.

In these papers, which are collected under the title "Researches into the Kinematics of Fluids," Beltrami develops in the three-dimensional field the theory of the potential generated by fluid-dynamic vortices and hence the analogy between the action of vortices and the electromagnetic action of electrical currents (**Figure 1**).

This conception is not original with Beltrami. Riemann developed the theory of complex-variable functions precisely to deal in a unified way with hydrodynamic and electrodynamic phenomena and those related to the transmission of heat in the two-dimensional field.

While Helmholtz in 1858 published the well-known article on vortices in which he pointed out that analogy with the electromagnetic potential of electrical currents, there is an important difference in approach between Helmholtz and Beltrami. Helmholtz developed his theory basing himself on the principle of conservation of the energy of vortical motion. He was not in the least concerned with explaining why the vortex forms and what its successive evolution is. Beltrami, however, concentrated his research on the various possible configurations which fluid-dynamic vortices may have, with the aim of investigating the principles of the functioning of such systems. In other words, Beltrami studied the hydrodynamic vortices just as the first technicians of flight experimented in water and then in air with the behavior of fluids around the profile of the wings, with the aim of identifying the laws of aerodynamics.

From this standpoint, we can understand why Beltrami, instead of concentrating on the laws of conservation as Helmholtz does, is mainly interested in research into the configurations in which the fluid and, hence, the electrical currents, are subjected to the most particular and extreme conditions.

In the paper published in 1889 entitled "Hydrodynamic Considerations," Beltrami probed the hydrodynamic configurations in which the lines of flux and the vortical lines are always parallel; that is, an electromagnetic system in which the Lorenz force is zero and the electrical current, free from forces, must not do any work against the magnetic field.

Beltrami demonstrated that this case is not purely speculative but real, and described accurately the geometry of these configurations, which he called helicoid.

Beltrami's morphology of filaments is recognizable today in the magnetic geometry of the spheromak configurations and the reversed field pinch [fusion reactors—ed.]. Moreover, Prof. Winston Bostick of the Stevens Institute of Technology in New Jersey discovered the formation of force-free pairs of vortical filaments in plasma, as long ago as 1966 (**Figure 2**).

Nature thus shows that it has a high degree of capacity to organize itself according to configurations that correspond to force-free systems and operate according to the principle of least action. Research into these conditions can give us the key to understanding physical phenomena such as the electron, the proton, the neutron, and the other so-called subatomic particles, considered not as elementary particles but as complex electrodynamic systems. We can say the same thing about those phenomena such as superconductivity, in which resistance is close to zero and efficiency is maximal.

Particles as electromagnetic singularities

Beltrami's research, even though it did not lead to a general theory capable of explaining all electrodynamic phenomena, was always carried out in this spirit. In one of his first papers, in fact, "The Mathematical Theory of Electrodynamic Solenoids," Beltrami described the typical configurations of the machines that are being used to reach breakeven in thermonuclear fusion, such as the tokamaks, stellarators, and compact tori used to magnetically confine superheated plasmas.

Beltrami called these configurations "neutral solenoids" because the magnetic action is completely confined within the configuration, whereas outside it is zero. In this research, Beltrami was moved by the idea of finding all the possible analogies between electrodynamics and electrostatics. In the case of the "neutral solenoid," this analogy is obtained with the distribution of electrical charges on the surface of a conductor, for which the electrostatic action is exerted only on the outside of the conductor, while it is zero on the inside.

The search for analogies between electrostatics and electrodynamics takes us directly to what we said before on the interpretation of the so-called elementary particles as electrodynamic force-free systems, subject to least action.

In fact, by combining the work done by Riemann on shock waves in 1859, "The Propagation of Plane Waves of Finite Amplitude," with the study done by Beltrami on force-free vortices in 1889, "Hydrodynamic Considerations," we have the key to resolving the paradox between waves and particles in the theory of Maxwell.

In other words, the most scientifically interesting aspect of physical processes are the so-called singular phenomena; that is, the points in space-time in which the physical phenomenon is no longer linear.

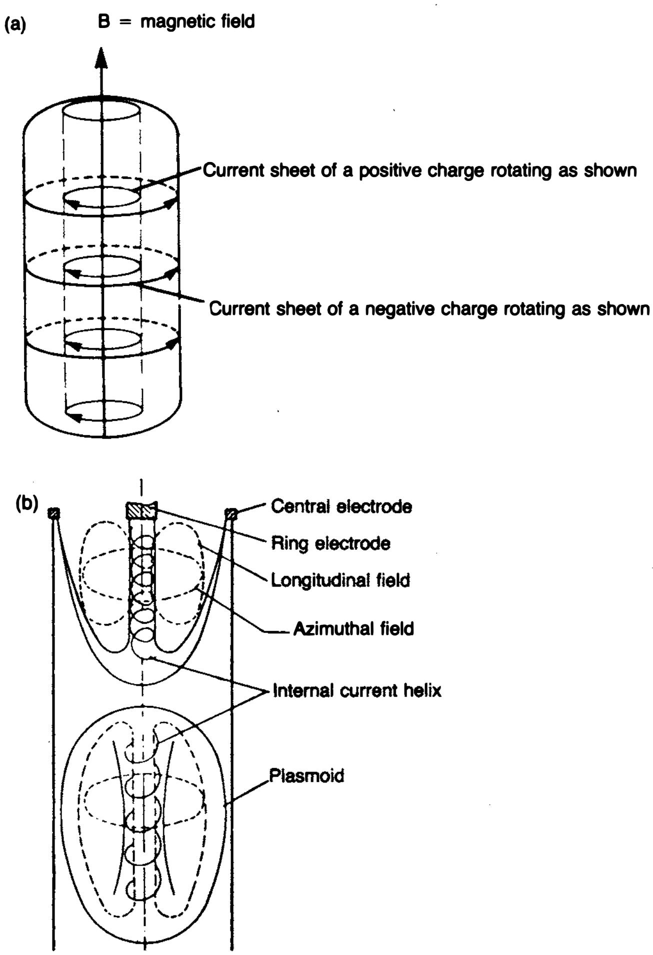
Precisely through nonlinear transformations, in fact, physical systems organize themselves according to distinct and well-defined physical-geometrical configurations, thus passing through states of greater complexity and energy density. The so-called elementary particles, such as the neutron and the electron, hence represent a certain level of organization of electromagnetic energy. Nuclei, atoms, and molecules represent a further self-organization of these particles; and even life does nothing but multiply the structural organization of such molecules in ever more complex and beautiful forms. Thus nature seems to behave in a way exactly contrary to the Second Law of Thermodynamics.

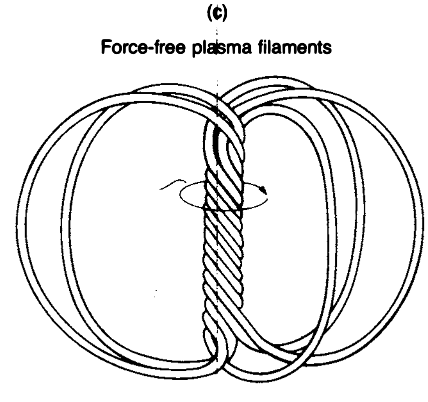
Riemann, in the cited work, demonstrated that such passages from one stage to the next are in general nonlinear and that the singularities created by this discontinuous process, are not ephemeral but profoundly real, just as the shock wave created by a jet in supersonic flight is real.

Beltrami then showed, in his "Hydrodynamic Considerations," the geometric form that such singularities generally assume: a geometric form, however, which has a very important physical meaning, by allowing the self-organization of the physical system according to a force-free system subject to the principle of least action. Hence, a configuration in which the electrical current and the magnetic field are parallel or such that, as in the case of fluid dynamics, it is the speed of the flux that is parallel to the axis of rotation of the flow itself.

A proof of the validity of the conceptions both of Riemann and of Beltrami was only given as late as 1936, when Prof. Luigi Crocco, having built the supersonic wind tunnel at Guidonia with Antonio Ferri, set about studying the formation of shock waves around various wing profiles. In his 1939 work, "A New Function of Current for the Study of the Rotational Movement of Gas," Crocco showed that the or-

FIGURE 3
Electrodynamic model of the neutron





In (a) the two flows of positive and negative charges are very close and move in opposite directions. Since their magnetic momenta are parallel, they are added together, while the total charges is zero. It would be important to investigate the characteristics of the neutron according to a force-free, least-action system. Such a system is shown in (b) and (c), which are examples of plasmoids that self-form in the hot plasma. Such an investigation can give us a deeper knowledge about phenomena like beta decay and nuclear physics in general.
In (b) the circulation of the cells produced by a "fountain-like pinch." The cells of circulation are thought to be force-free configurations. In (c), a plasma nodule, a toroidal solenoid is wrapped in a force-free wire.

ganization of air generated by a supersonic shock-front is that of a vortex, with its axis of rotation parallel to the speed of the flow of the air itself—a vortex, therefore, similar to the one described by Beltrami.

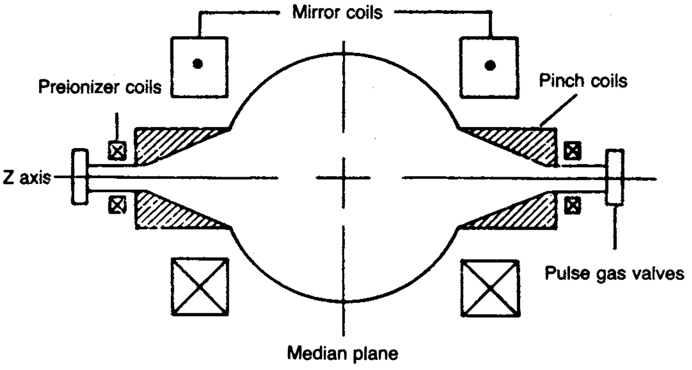
The first significant attempt to explain the formation of the so-called elementary particles according to the conceptions of Riemann and Beltrami, was made by Dr. Winston H. Bostick, in the *International Journal of Fusion Energy,* Vol. 3, No. 1, January 1985. Bostick's study, titled "The Morphology of the Electron," provides the basis on which an electron is depicted as an electrical Beltrami vortical filament, whose mass is made up of the confined electrical energy. Bostick showed that all the properties and characteristics of the electron are explicable with such a model. Following his example, one could develop a model also for the neutron and the other "particles."

The idea of developing a model of the electrodynamics of the neutron, among other things, is also not completely original. Right after the neutron was discovered in 1932, in fact, various indirect experiments on "scattering" were carried out, with the goal of determining its form. Although the entire scientific community thought the neutron could be described through the usual banal model of Rutherford—the positive charge in the middle and the negative one circulating around it—the experiments quickly showed that there was no charge in the middle of the particle, but empty space. For this reason, some effort was made to develop an electrodynamic model of the neutron, as exemplifed by the essay by Donald J. Hughes, "The Neutron Story." This attempt was abandoned when the esoteric methods of statistical mechanics and quark theory got the upper hand.

The first electrodynamic models of the neutron were mainly based on the flow of two parallel electrical currents, one of positive charges and the other negative, around a toroidal configuration. According to this configuration, the electrical and magnetic fields completely encircle the outside of the toroidal configuration with the exception of the axis of the torus, where the magnetic momenta of the two currents

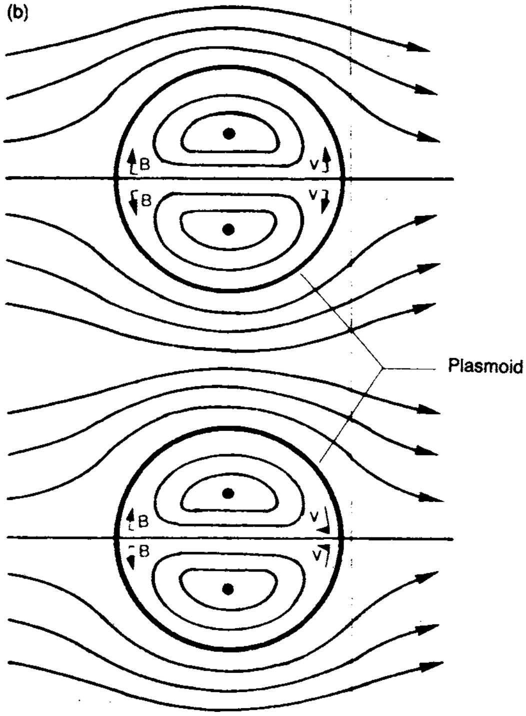
FIGURE 4
Schematic of a theta pinch machine and corotating and counterrotating vortexes

(a)



A schematic drawing of the TRISOPS II experiment.

(b)



Counterrotating vortex traveling to the right
Corotating vortex traveling to the left

(a) Schematic of the TRISOPS II theta pinch experiment machine designed by plasma physicist Dan Wells. (b) Vortical rings of force-free plasmas, one corotational and the other counterrotational, produced in the central part of the machine TRISOPS II.

are added together. The neutron, in fact, even though electrically neutral, has a magnetic momentum (**Figure 3**).

Aerodynamic approach to plasma physics

The main difficulty plasma physicists run into is that of not being able to put in the right light the vortical phenomena that occur in a hot plasma. In the plasma we find combined both fluid-dynamic and electrodynamic phenomena, resulting in the formation of vortices that are free from both Magnus and Lorenz forces. Such phenomena, however, are generally treated as unimportant "marginal effects," principally because the education of modern physicists, based on quantum mechanics and quantum physics, often literally does not allow them to "see" such processes, which nonetheless have a considerable physical importance.

Thus, just as Prof. Luigi Crocco demonstrated that a shock wave generates a vortex, similar to the force-free Beltrami vortices, in a hot plasma these kinds of vortices are very frequent and are generated by the phenomenon called theta pinch. This "pinch" in the column of plasma, even though it is still a controversial phenomenon among physicists, is reported to be due to the electrical currents in motion in a plasma in opposition to the electrostatic repulsion, such that the faster the charges, the stronger the pinch is, and such that at the speed of light the pinch would equal the electrostatic repulsion.

Since such a pinch effect generates vortical structures in the plasma similar to those described by Beltrami, free of either Lorenz or Magnus forces or both, a study would be necessary to investigate to what point such a pinch could be assimilated to a discontinuity such as that of a shock wave in aerodynamics (**Figure 4**).

For these studies on plasma physics to proceed adequately, it would be important not only for the physicists to acquire a certain familiarity with aerodynamic problems, but also for a certain number of skilled aerodynamicists, accustomed to dealing with vortices and shock waves, to concern themselves with plasma physics.

Just to give one example: One of the best treatises on the generation of vortices is a critical essay of 1936 by Gen. Gaetano Arturo Crocco, one of the founding fathers of Italian and world aeronautics. In this essay, "Aerodynamics in Aviation," Crocco treats in a masterly way the formation of vortices around a wing in subsonic flight, the circulation, and then the harmonic generation of vortices in the opposite direction at the tail. Crocco also showed the formation of a Beltrami vortex on the end part of a wing in flight, something to which only marginal importance is given, even today. The construction of an airplane, according to Crocco, should give maximum consideration to the generation of vortices. "It often has occurred," he reports, "that the tail of an airplane in flight was suddenly destroyed because its structure was resonant with the regular generation of vortices behind the wings, and hence it acquired part of their energy in the form of vibrations."

Today in plasma physics, we need such an attention, such a capacity to intuit and resolve problems from a fluid-dynamic standpoint, as we saw before in the physics of elementary particles.

Again in the paper "Aerodynamics in Aviation," Crocco said, "Aerodynamics has pulled down from Olympus and humanized, by studying their generation and extinction, the vortices that Helmholtz had described as eternal Gods, without birth and without death." We could say the same thing today for the elementary particles and plasma physics, using the ideas of Riemann and Beltrami.

The basis for supersonic flight

"It was 1903 and the Wright Brothers had not yet flown, but in Italy General Moris in Rome had already set up the first aerodynamic wind tunnel. In 1914 then, the big double-return wind tunnel was built on Lungotevere Michelangelo in Rome. Out of its mouth, 2 meters in diameter, came a wind of 200 kilometers an hour. No airplane had ever flown yet at that velocity. It became the object of visits by technicians from all over the world, who, when they came to Rome, used to note down its address in their notebooks together with that of St. Peter's and the Colosseum." So wrote Gen. Gaetano Arturo Crocco in an essay on the history of aeronautics in Italy, to demonstrate the international supremacy of Italy in aerodynamic studies in those years and up to the Second World War.

In 1919, 1920, and 1921 Italian hydroplanes repeatedly won the international Sneider Cup for high velocity. Together with Ferrari in Torino and Pistolesi in Pisa, Gaetano Arturo Crocco was the father of the Italian aerodynamic school, which, together with that of Ludwig Prandtl and Adolf Busemann in Germany, laid, in the 1930s, the bases for supersonic flight.

In 1935, Gaetano Arturo Crocco organized the Volta Congress on high velocities in Rome, to which the greatest world experts in aerodynamics came. Prandtl spoke of lift in supersonic flight, Busemann presented the supersonic wing, "slender as a Gillette razor blade," reports Crocco.

The centerpiece of the conference was the visit to the Center of Aerodynamic Studies and Experimentation of Guidonia (near Rome), where the Italian Air Force, under the direction of General Crocco, had just completed the outfitting of the world's most important center of aerodynamic research, as it was then recognized internationally.

In the Center there were four big subsonic wind tunnels, a stratospheric tunnel, a big hydrodynamic tank, other smaller tunnels, and—the crowning touch—the most powerful supersonic wind tunnel then existing in the world. That tunnel had been built on the model of the Hackerett Tunnel of Zurich, but with a continuous electrical current motor of about 2,850 kilowatt power, while the one in Zurich had a maximum power of only 900 kilowatts.

The wind tunnel had been built by Antonio Ferri and Luigi Crocco (the son of Gaetano Arturo Crocco), and Ferri ran experiments at it until 1943, when as a result of the war, the center was closed and subsequently dismantled.

In those years, Ferri utilized the supersonic wind tunnel in Guidonia to study the various supersonic wing profiles, with very interesting results. He found, in fact, that the classical theoretical scheme of the formation of a shock wave systematically failed to agree with the experimental data, and he showed that this discrepancy vanished when one corrected the theory on the basis of the 1936 study by Luigi Crocco on the generation of a global vortex of the fluid generated by the shock wave.

Few in Italy today realize how important the participation of Italian scientists and technicians was to the development of world aeronautics. But the Americans knew it very well—so well that Luigi Crocco was immediately invited to teach at Princeton University, and Antonio Ferri moved in 1945 first to the aeronautics research center in Langley, Virginia, and then to Brooklyn Polytechnical Institute in New York City.

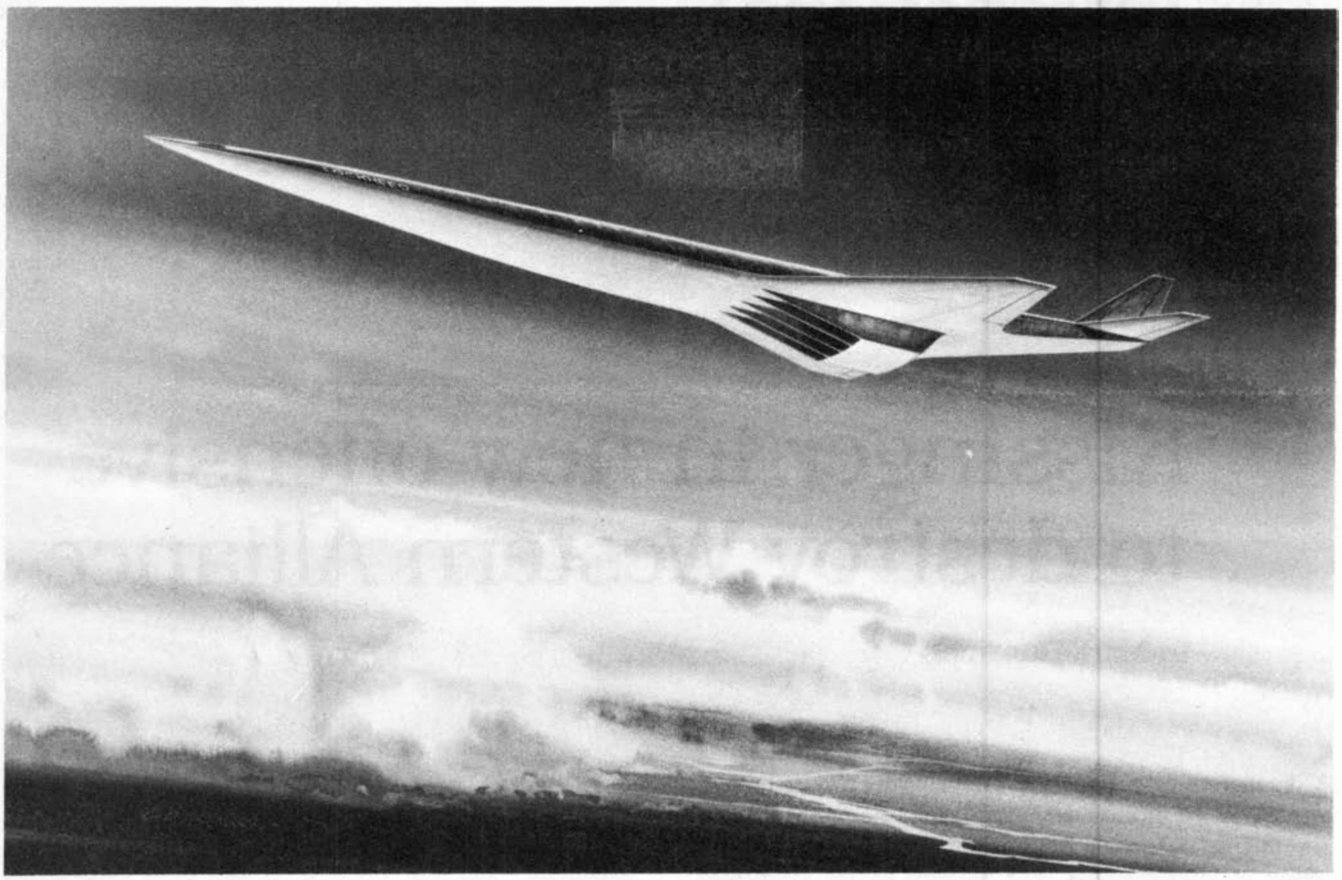
In the United States, Ferri found a situation somewhat behind in the aerodynamic field, and so he immediately went to work writing what was then the world's first book on supersonic flight, *Supersonic Aerodynamics,* making great use of the experiments done with the Guidonia wind tunnels, which are reported in the book by the dozen. He then imposed on the Americans—not without having to overcome considerable resistance—the construction of discontinuous supersonic wind tunnels, thus giving the U.S.A. world supremacy in aeronautics for years to come.

At the end of the 1960s, Ferri engaged in a new battle to convince NASA, the Pentagon, and other American governmental institutions of the need to fund a project to develop a transatmospheric aircraft capable of reaching hypersonic speeds up to Mach 12—the plane that would have given the U.S.A. aeronautic supremacy even into the 21st century.

Such an airplane, according to Ferri's project, would have had to operate both inside and outside the atmosphere, and, propelled by small rockets, also reach the lower Earth-orbits. As Ferri summarized in a speech to a conference of the American Institute of Aeronautics in 1975, such a hypersonic airplane, capable of landing and taking off horizontally like a normal airplane, of reaching to the lower orbits, and flying from Tokyo to Washington in two hours, could offer innumerable benefits both civilian and military:

1) The construction of a fleet of hypersonic bombers which at Mach 12 could traverse 1,600 kilometers in 10 minutes, carrying a load of megatonnage far superior to any fleet of missiles, would be a very important deterrent weapon

FIGURE 5



At the end of the 1960s, Antonio Ferri proposed to U.S. authorities the development of a supersonic airplane, which would have assured the United States supremacy in the aerodynamic and space field into the next century. The illustration shows a Lockheed design for a passenger airliner of the sort Ferri proposed. The concept includes a dual propulsion system with both conventional turbojet engines and supersonic combustion ram jet engines fueled by liquid hydrogen. The flight time from Los Angeles to Tokyo would be 2 hours and 18 minutes.

vis-à-vis the U.S.S.R.

2) The full accessibility from Earth to the space stations deployed in low orbits, as well as the reduction of flying times from the present air transports on trips of 7,000 to 9,000 miles, from 18-20 hours to about 2-3 hours.

The main motivation with which Ferri supported his project before the U.S. government, Congress, and public opinion, was based on cultural optimism.

In the previously cited speech of 1975, Ferri presented a graphic showing that most of the world population lives at a distance of 7,000 to 9,000 miles from the United States in the very poor zones of Asia, Latin America, and southern Africa. In the future, Ferri said, industrialization and the economic development of these areas would lead to an exponential increase in travel between these nations and the United States. Think of India with 800 million people, think of China which is about to surpass a billion, he said. Therefore, the project for a plane that would shorten these trips from 20 to 3 hours, even if initially very costly, would be in the medium and long term extremely profitable. In short, good business, in the best tradition of the American economic system, and proposed, obviously, by a first generation Italo-American!

Unfortunately, the American government found Ferri's plan incompatibile with its budget, and therefore what was adopted as a result was a much more economical and obviously limited version—the Space Shuttle as we know it today.

Despite the advantages the Shuttle offers relative to traditional launching rockets, it clearly cannot be compared to what Ferri proposed in terms of possible civilian and military applications. Anyway, recently, after two American governmental agencies, the Defense Research Projects (DARPA) and the President's Office of Science and Technology Policy, had maintained the need to develop a hypersonic plane in the framework of the Strategic Defense Initiative, President Reagan in his 1986 State of the Union message in early February announced the launching of the project (**Figure 5**).

So, Ferri's ideas have also won their last battle.