

Physics in France

Emerging from the scientific hiatus imposed during the first and second world wars, France has begun to reestablish her place as a leader in physics research. Liberal education and strong governmental support have provided inroads to further improvement.

by Jean Combrisson

THE STUDY OF PHYSICAL PHENOMENA and the search for their explanation by mathematical models are intellectual activities whereby France has provided a major contribution to our knowledge of the material world surrounding us. We can cite the names of discoverers at random: Blaise Pascal, René Descartes, André Ampère,

Charles Coulomb, Augustin Fresnel, Sadi Carnot; and, nearer our time: Pierre Curie, Paul Langevin, Louis de Broglie, Jean Perrin, Frédéric Joliot. Many modern inventions originated in France (for example, the metric system was introduced by the National Convention of 1792) and several international organizations

(such as the International Bureau of Weights and Measures) have chosen headquarters in Paris.

Physics and the wars

Nevertheless, we must realize that as a consequence of several factors—among the foremost of which was the destruction, between 1914 and 1918, of an entire generation of men—physics underwent a definite decline in France after 1918, a trend that reached its low point with the second world war. This war halted nearly all scientific activity and technical development: Fortunately its consequences for human life have by far not been as serious as in 1914–1918.

In 1945 French physics suffered from several maladies:

- out-of-date advanced instruction (quantum mechanics and electronics were unknown in universities)
- a shortage of qualified physicists capable of providing a foundation
- an almost complete lack of equipment (laboratories, instruments, materials)
- a wholly insufficient administrative structure for the laboratories
- a lack of scientific and technical

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knowledge that most other countries had acquired during the war (micro-waves, atomic energy).

The deep psychological shock of 1940 and the realization of great technological advances (characterized in the public mind by radar and the atom bomb) that had taken place abroad led the country to react vigorously: France took immediate steps to make amends for the lack of knowledge that not only resulted from the war but also had been a constant stigma up to that time. This reaction was far-reaching, extending from government departments to isolated scientists. It resulted in the creation and revival of research organizations, modifications of teaching methods and industrial modernization. The French, who were still inclined to live in the style of the 19th century, using methods passed down from Napoleon's era and having little communication with the outside world, decided to imitate and catch up with scientists of technologically advanced countries.

To fulfill their decision they had to form a scientific-research policy covering finance, facilities construction, the creation of large complexes of laboratories, training and additional exchange programs with scientists from abroad (in particular with the US). Those responsible for the policy had the good sense to realize that in this particular field they must form effective teams of scientists and offer attractive physical conditions as well as confidence in a future without hindrance to the progress of their work.

An example will show that this policy was not in vain: All the scientists who left France during the war returned, and, up to the present time,

France is not affected by the brain drain.

In 1967, we can affirm that France has regained her position among the leaders. She must still pedal very fast since certain weaknesses remain. But, taking into account the current abundance in the labor market resulting from the high postwar birth rate and the general prosperity of the country, there is no reason for pessimism about the future of fundamental research in France.

The historical background of physics in France has a bearing on the framework and conditions in which contemporary physicists train and work. In what follows I shall discuss the steps that one must take to become a physicist and, once that goal is reached, the various opportunities that are offered in France.

The making of a physicist

After a secondary education terminating in the baccalaureate examination (usually taken at the age of 17 or 18), two parallel and distinct courses are open to the French student who wishes to become a physicist: Grandes Ecoles, technical colleges, which give a *diplôme d'ingénieur* (not to be confused with the English word for "engineer"); science schools of a university which awards a *license*, *maîtrise* and *doctorat* (equivalent to bachelor, master and doctoral degrees).

Grandes Ecoles. Admission is by competition. There are a great many such institutions in existence, and the value of the diploma awarded on termination depends on the school. About a dozen of them are famous; most are in Paris.

Each of these schools has its own

particular characteristics, its own history, and instruction by professors who are often alumni of the school. The schools are proud of their originality and independence. They are greatly respected for the quality of their teaching, the value of their diplomas and active friendship among alumni throughout their lives. They benefit by drawing the most gifted pupils from the secondary schools. Table 1 gives a resumé of the characteristics of some of the schools.

They confer diplomas that are independent of university diplomas, and are accepted neither as qualification for a doctorate nor as certification for becoming a university professor.

University. The baccalaureate is the only requirement for acceptance into a university; an outline of the curriculum is shown in figure 1. The *licence* corresponds to a *diplôme d'ingénieur*: It enables the student either to go into industry or to prepare for secondary-school teaching. The *maîtrise*, followed by a year of specialization—known as the "third cycle"—and subsequent receipt of the diploma for advanced studies (*diplôme d'études approfondies*—DEA), leads to research. It is essential to have a doctorate before being appointed as a university professor.

The Collège de France, an institution created in the 16th century by Francis I as a counterweight to the Sorbonne, has special standing: It confers no diploma and requires no special qualification of the professors it employs, selecting them solely on their merit and requiring them to give a different course of lectures each year. The participants in these courses are experts who attend so they can advance their knowledge. Although established four centuries ago, this precursor of the Institute for Advanced Studies is still full of vigor. The post of professor at the Collège de France is certainly one of the most highly esteemed positions in academia.

Another institution, the Conservatoire des Arts et Métiers, has a unique character: It provides evening courses offering advanced training to adults.

France has about 20 universities: Paris, Orsay, Grenoble, Strasbourg and Toulouse are the best known for physics. As a general rule in France education is completely free of cost.

Table 1. Characteristics of Some French Schools

<i>School</i>	<i>Sponsor</i>	<i>Years of study</i>	<i>Number of pupils</i>
<i>Normale Supérieure</i>	Ministry of Education	4	30
<i>Polytechnique</i>	Ministry of Defence	2	300
<i>Physique et Chimie</i>	City of Paris	4	40
<i>Centrale</i>	Ministry of Education	3	300
<i>Mines</i>	Ministry for Industry	2 or 3	70
<i>Télécommunications</i>	Ministry for Post and Telegraph	2 or 3	255
<i>Ponts et Chaussées</i>	Ministry for Public Works	2 or 3	80
<i>Supérieure d'électricité</i>	French Society of Electrical Engineering	3	100

Scholarships are provided to help those in most need.

Where is physics practiced?

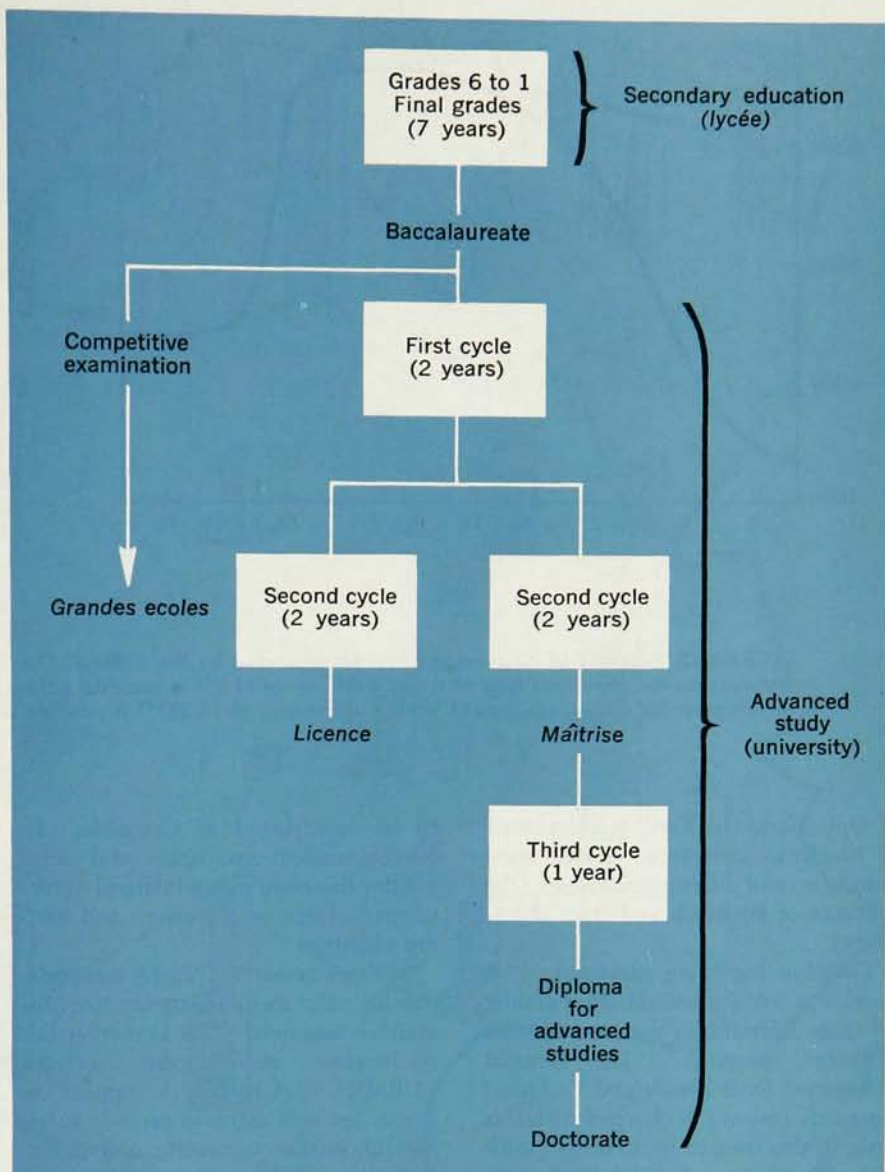
Armed with his diplomas, the young French physicist can choose a career in industry, research or teaching. Which laboratories will welcome him? Those of the universities and "Grandes Ecoles," the National Center for Scientific Research (CNRS), the large national organizations and private societies. Many young physicists spend a few years abroad (mainly in the United States).

The Grandes Ecoles, the Collège de France and the science schools of the universities maintain large and varied laboratories financed both by their own funds and CNRS support. The standing of these laboratories depends to a great extent on the professors who run them: An example of a laboratory with considerable reputation is Alfred Kastler's laboratory at the Ecole Normale Supérieure in Paris.

CNRS, created after the war, has a certain similarity with the National Science Foundation. It is an organization that possesses its own laboratories (among them the Bellevue laboratories), thus enabling researchers to follow a scientific career free from teaching commitments. These scientists are supervised by a director and a committee elected by a majority vote of the group of scientists in their particular specialization. These committees are also responsible for allocating funds to the laboratories.

CNRS numbers about 5000 scientists in all disciplines: The titles that they can hold in the course of their career are *attaché*, *chargé*, *maître* and *directeur de recherches*.

Big national organizations. The necessity of making a special effort in certain directions has led the government to create national organizations endowed with considerable capital and managed in the same way as big industrial enterprises. The possibility of undertaking a good career and the material means offered there have drawn top personnel. The National Office for the Study and Research of Aerospace (ONERA), the National Center for Space Study (CNES), the National Center for the Study of Telecommunications (CNET) and the Atomic Energy Commission (CEA)



ORGANIZATION of university studies.

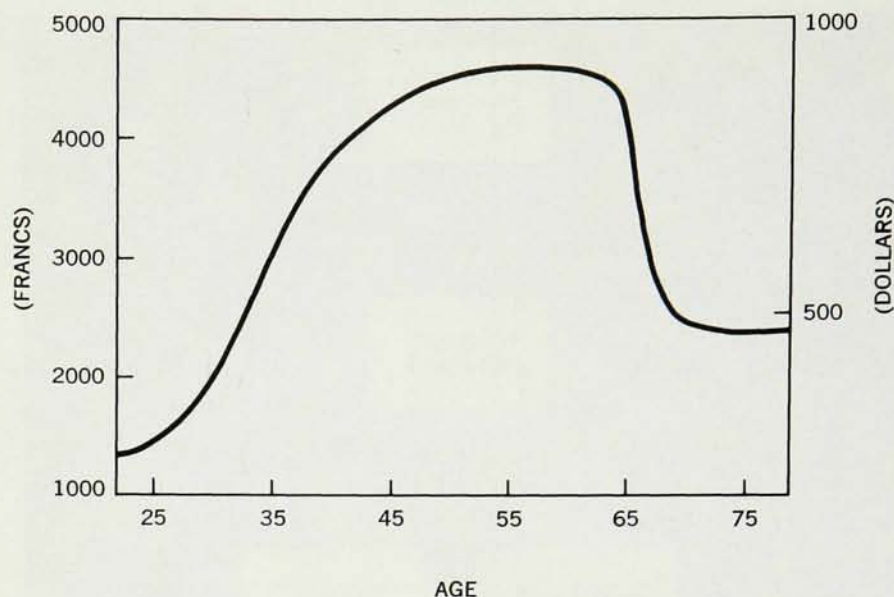
—FIG. 1

are some of the leading national organizations. Without doubt, fundamental research in physics has found its greatest scope in the Atomic Energy Commission. The centers for nuclear studies at Saclay, Fontenay-aux-Roses and Grenoble produce a large share of French scientific literature.

All the national laboratories (universities, CNRS and national organizations) are closely connected through their contracts and, in particular, through the many professional contacts among their scientists. There is no great difference between the laboratories insofar as credit and salaries are concerned.

Private laboratories. Many physicists work in industry where, as with research workers all over the world, they range from those with short-term and urgent objectives to those with much longer-term programs. It is, however, a fact that the size of French enterprises, and therefore of the capital to which they have access, is small and rarely enables them to subsidize sizable research laboratories where scientists can form large teams and not be distracted by the need to work on urgent industrial projects. Industrial laboratories often seek the advice of university professors.

Certain laboratories are shared by universities and industry (the Institute



AVERAGE SALARY of an average physicist estimated by the author. Depending on the physicist's type of work, a difference of $2^{\pm 1}$ is possible. Depending on the employer's type of work, a difference of $(1.25)^{\pm 1}$ is possible. —FIG. 2

of Optics and the Central Laboratory of Electrical Industries) or are common to several different industries (the Institute of Research and Iron Metallurgy).

Coordinating organizations. A need was felt for coordination among all those laboratories that come under different ministries. The General Delegation for Scientific and Technical Research (DGRST) is charged with this task; it also tries to let industry profit from the work carried out in the university laboratories and to initiate concerted action for the development and strengthening of certain disciplines. A special committee formulates five-year plans that outline investment programs. The fifth five-year plan covers the years 1966–70.

Collaboration with other countries. Many French physicists go abroad to increase their knowledge; an even greater number of foreign physicists from all over the world come to France, either temporarily or permanently. In elementary particle physics, some research is carried on at CERN, and a collaboration with the Soviet Union has also been initiated. Plasma research is carried on within the framework of Euratom. Solid state research will be conducted with a Franco-German high-flux reactor which is going

to be constructed at Grenoble. In telecommunications, space and aeronautics there are many bilateral agreements in force with western and eastern countries.

Military research. To be complete, this list must include organizations for military research. The Direction des Recherches et Moyens d'Essais (DRME) is essentially a support organization and exists to provide funds for subsidizing university and industrial research laboratories. All other military activities have their own laboratories. Special mention should be made of the Organization for Military Applications of the CEA, which has been responsible for the country's atomic weapons.

Employment and salaries

So far physicists have not been faced with an employment problem. The overall absence of unemployment, together with the rapid expansion of research, has often resulted in a lack of qualified scientists that has proven to be a greater bottleneck than the lack of funds. Although it is impossible to state a physicist's precise salary, the curve in figure 2 gives the salary range of an average physicist before deduction of taxes amounting to about 20%. Fluctuations of -25% (teaching) to

$+25\%$ (industry) are quite possible.

Stability in employment is the general rule. Most physicists remain with one or two employers during their entire careers. Apart from the United States, France probably offers its physicists the best salaries. In universities, Grandes Ecoles and research laboratories conditions for men and for women are identical.

Difficulties

The most fundamental difficulties occur entirely because countries the size of France find it increasingly difficult to satisfy the needs of modern physics.

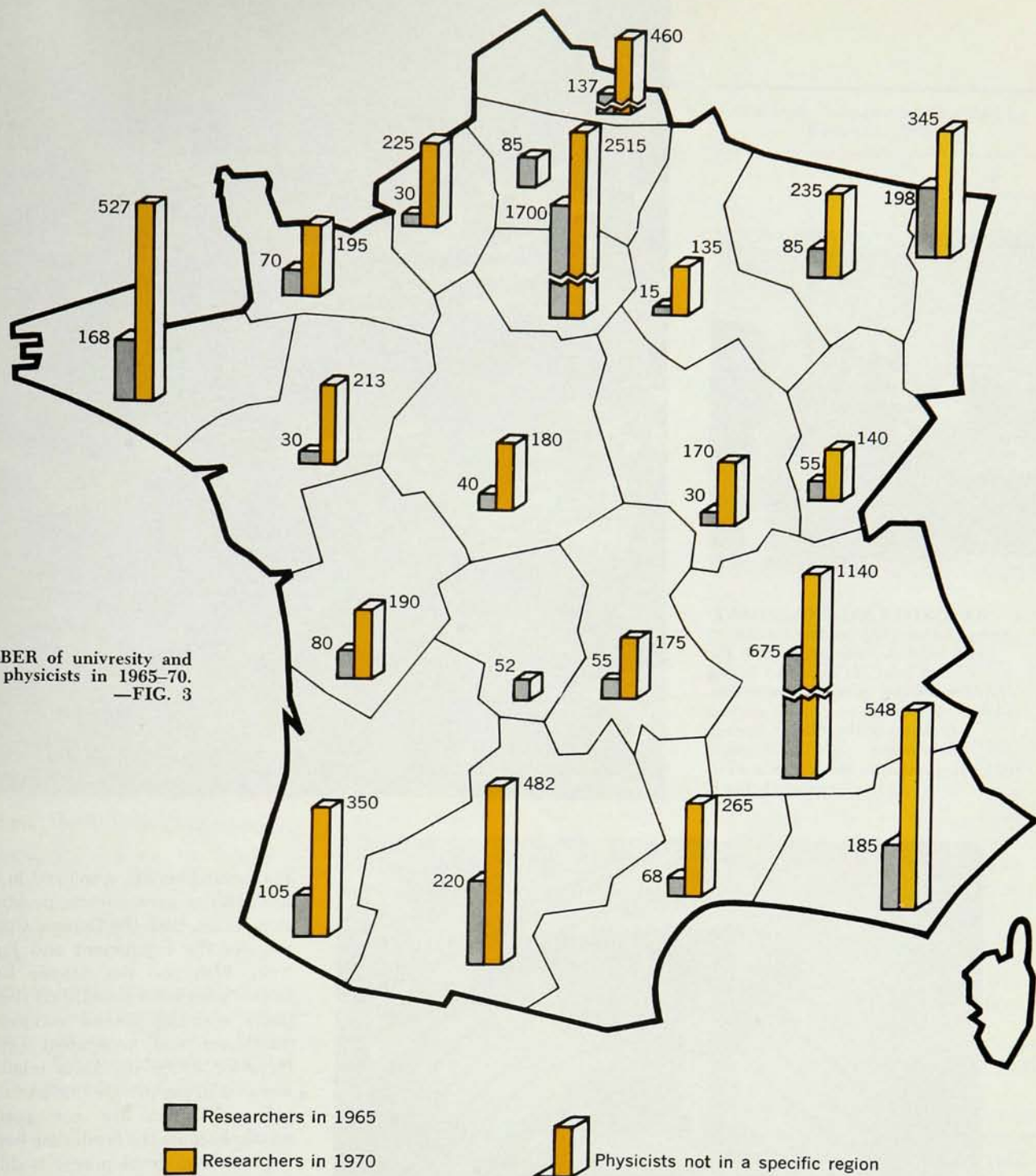
Publications. Publication is difficult although the French scientist has access to a means of publication which, owing to its flexibility and speed, is unique in the world: This is the *Comptes-Rendus à l'Académie des Sciences* which publishes an article in less than a week. The *Journal de Physique* is devoted to more profound articles, but suffers, like other specialist journals, because the French physicist is forced either to publish in his mother tongue at the risk of remaining unnoticed by his contemporaries abroad or to publish in English, that is, to express himself less effectively and to accentuate the decline of the French language.

Editors of scientific publications come up against another problem: The limited market forces them to charge high prices for their books, thus further reducing the market.

Apparatus. The French industry for physics equipment, which lacks the capital, laboratories and markets to which the US has access, finds great difficulty in remaining or becoming competitive in up-to-date apparatus. This problem will no doubt remain unresolved until societies amalgamate on a European scale.

Finance. Very large investments (accelerators, research reactors, satellites), even if they are consistent with the budget of a country like France, necessitate decisions and contracts at a government level, which are thus out of the sphere of the physicist. Collaboration among several countries (as at CERN) indubitably resolves certain problems but poses others, particularly because emigration among European countries remains a serious difficulty.

NUMBER of university and
CNRS physicists in 1965-70.
—FIG. 3



Personnel. Even though France can now count on enough well trained physicists and on an equally adequate number of technicians, one problem remains: lack of mobility of personnel. The fault lies with housing difficulties, a tradition of stability in employment and residence, social laws that guarantee security to all employees and a lack of openings for research physicists in applied research, teaching and administration. If the

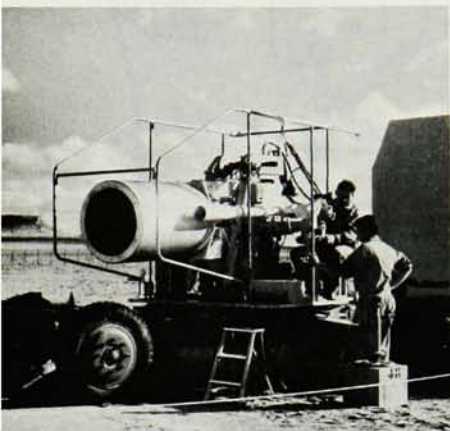
present period of expansion and the trend toward a freer exchange between countries continues, France will find solutions to these problems that are at least as satisfactory as those for the US and the USSR.

France is characterized by an extreme centralization of its activities in the Paris region, to the extent that one could refer to the rest of France as the "French desert." If this state of affairs creates problems for the govern-

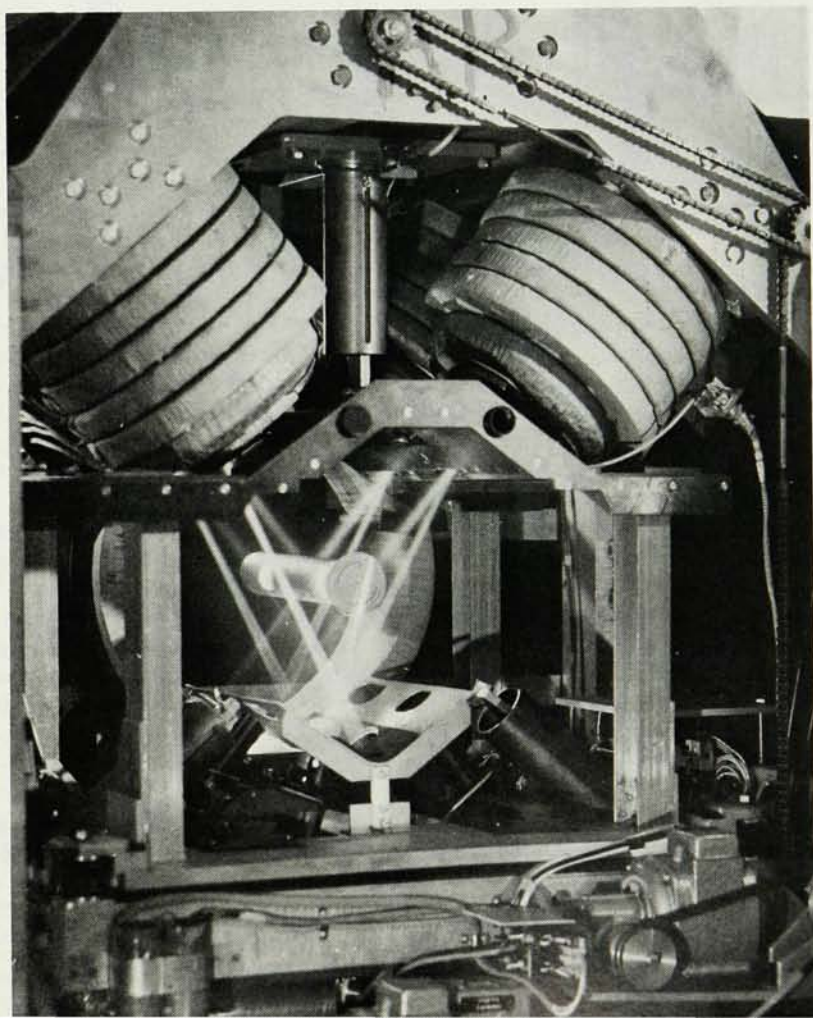
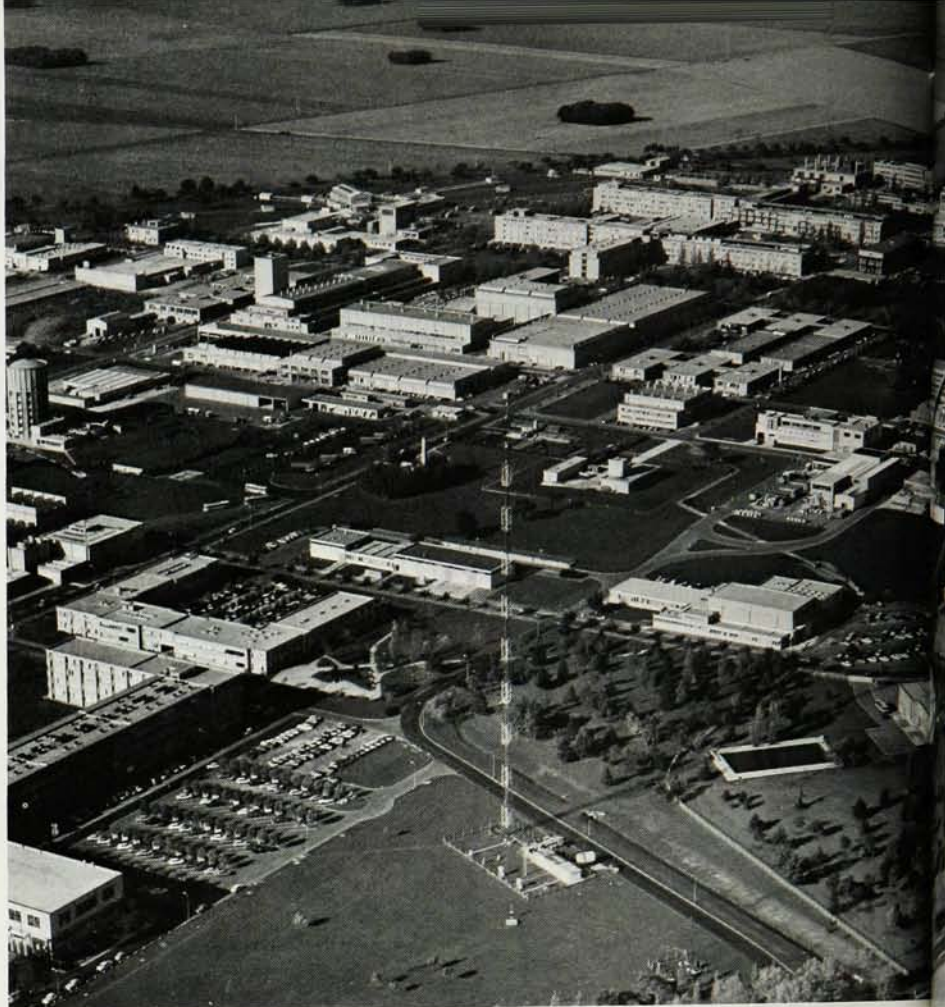
ment from the point of view of transportation, housing and employment, it does not displease physicists. Quite to the contrary, they find in the Paris area a center of intellectual and industrial activity comparable with, if not better than, the largest cities of the world.

Manpower and capital

In 1963 DGRST began a census of researchers in the public sector (80% of



FACILITIES AND EQUIPMENT.
ONERA telemetric laser turret (above)
being used in conjunction with the
French satellites *Diadème* during
intercontinental geodesic operations.
Saclay—one of the centers for nuclear
research of the Atomic Energy
Commission (right). Magnetic
suspension of models in a wind
tunnel (below).



the researchers are employed in CEA, in CNRS or as university professors). In addition, both the General Commission for the Equipment and Productivity Plan and the Atomic Energy Commission have established five-year plans enabling precise estimates of manpower and investment expenditures for 1966-70. Data relative to research in the private (industrial) and military sectors are not available, mainly because the borderline between research and development is difficult to define.

Therefore the figures given below represent only the public sector—certainly the most important insofar as fundamental physics is concerned. (It is certain that a fraction of the sums spent by the state is not used in its own laboratories but goes toward contracts for training in private laboratories.) These figures should be taken only as an order of magnitude because of the uncertainty about the qualifications of researchers and the definition of a physicist.

Manpower. Researchers in France number about 15 000 (excluding medicine and pharmacy) and can be di-



vided into the following categories:

mathematics	8%
physics	31%
chemistry	25%
geological sciences	7%
biology	29%

Of this total 20% are women (physics 15%). 4% are foreigners residing in France, of whom 50% hold French degrees. The continental origins of these foreigners are as follows:

Europe	50%
Asia	30%
Africa	14%
America	6%

Large numbers of foreign scientific researchers come to France for one or two years; for example, in 1967 the Saclay center comprises 270 foreign workers (of whom 85 are physicists) out of a total manpower of about 6000 (figure 3). 80% of the scientists (physicists, 90%) speak English and 40% German. 68% of the researchers (women, 72%) are under 40.

As regards physicists in particular, in 1965 it was estimated that they numbered 5000. We expect this

Table 2. Investments Classified by Activity: 1966-70

	\$ (millions)
Astrophysics—plasmas	24
Physics of elementary particles	180
Nuclear physics	
Optics	16
Atomic physics	
Physics of solids	72
Electronics	
Mechanics—acoustics	30
Thermodynamics	
Public works	4
Miscellaneous (biophysics, oceanography, theoretical physics)	34
Coordinated action under DGRST	40
Total	\$400

number to double by 1970. It is interesting to know where these physicists received their training, in what regions they work and by whom they are employed. The subsequent tables give this information. They do not include physicists engaged in activities of a military nature or those in private industry laboratories.

Type of training

Grandes Ecoles	2000
university	1800
various (unidentified)	1200

Region in which physicists work (see also figure 3)

Paris	2400
Lyons-Grenoble	800
Toulouse	300
Strasbourg	250
Marseilles-Nice	250
Rennes	250
Lille	200
Bordeaux	150
(Amiens, Nantes, Poitiers)	
Montpellier, Besançon, Dijon, Nancy, Clermont)	400
Total	5000

Employed by

CNRS	1300
CEA	700
university	2000
various	1000

The association to which most physicists belong is the French Society of Physics (2500 members). With the help of CNRS the society publishes *Journal de Physique*. Eight issues per year are devoted to fundamental physics, four to applied physics and four to

Table 3. Investments Classified by Regions: 1966-70

	\$ (millions)
Paris	114
Lyons-Grenoble	40
Toulouse	10
Strasbourg	10
Marseilles-Nice	5
Rennes	9
Lille	1
Bordeaux	1
Other regions	10
Miscellaneous, not localized	80
Coordinated investments under DGRST	40
Investment in France	320
International investments	80
Total	\$400

the proceedings of national and international meetings.

As regards the industrial sector, it is nearly impossible to separate research from development. A census taken in 1965 gave these manpower figures:

Power (gas, coal, electricity)	1200
Petroleum	1000
Nuclear engineering	450
Iron metallurgy	430
Nonferrous metals	350
Mechanics	720
Aeronautics	3650
Automobiles	600
Electrical construction	1000
Electronics	5100
Miscellaneous	500
Total	15 000

Since only one third of the above can be assumed to be physicists, the 1965 total would be about 5000.

Finance. Only estimates for investment expenditures have given rise to detailed study. The plans for 1966-70 allotted \$400 million to physics. If one estimates the operating costs (salaries and expendable materials) at \$800 million, one realizes that France expects to spend \$300 million a year on physics research in the public sector. Relating this sum to the 5000 physicists gives \$60 000 a year per physicist. (Two or three assistants—technicians, administrators, documentalists, etc.—are allocated to each physicist.) It is interesting to note how the \$400 million is allocated by activity and region in France. Details are in tables 2 and 3. □