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Spain

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NATIONAL INTELLIGENCE SURVEY

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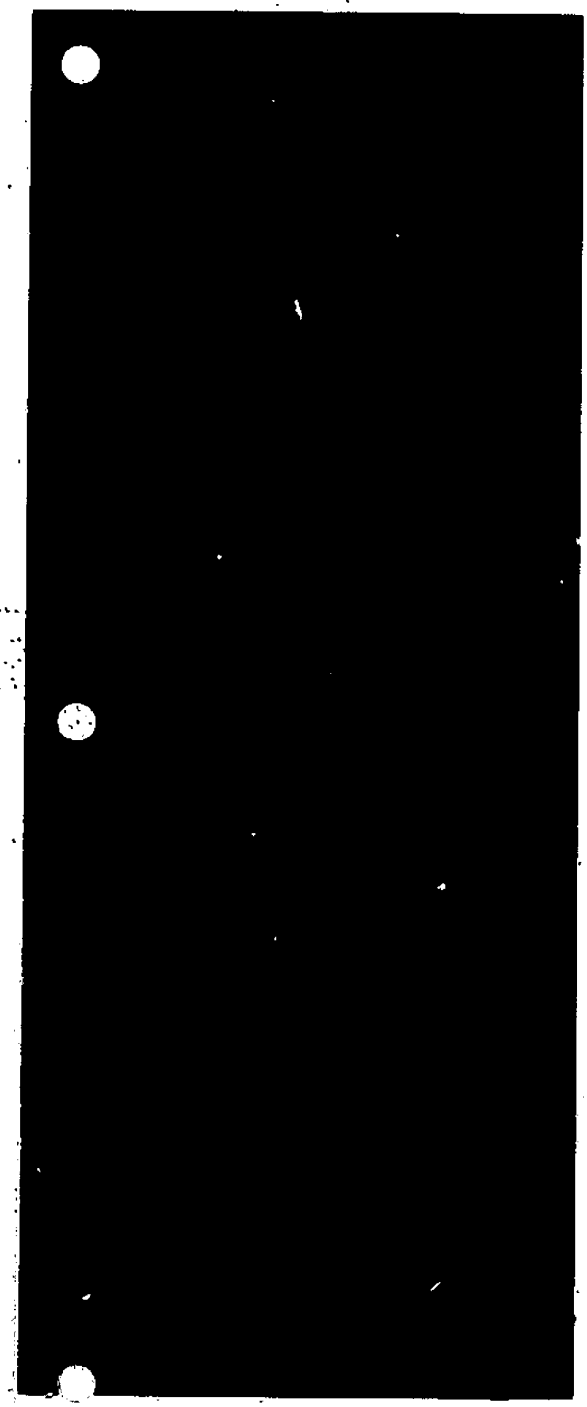

SPAIN

CONTENTS

This chapter supersedes the scientific coverage in the General Survey dated December 1970.

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FIGURES

Science

A. General (C)

Spain achieved prominence in science during the Renaissance and has shown some capability for research during the present century, but the country is now engaged in only a limited program of research and development. It has fallen far behind most of its European neighbors in the extent of its scientific and technological work and devotes less than 0.3% of its gross national product to research and development compared with about 1.5% of gross national product in France and West Germany. Under Generalissimo Francisco Franco as Chief of State, Spain has made impressive economic progress, particularly during the past 10 years and has become much more industrialized and less dependent on agriculture than formerly. In order to continue this progress, the country will be forced to depend increasingly on improved higher education and expanded scientific research and development. Currently, it is largely dependent on foreign technology for technical innovation in its industrial plants.

Several factors have impeded research, including the lack of a broad industrial base (until recently), insufficient funds for research, and a lack of equipment and trained personnel. Spain has produced a few good scientists; the most outstanding was Santiago Ramon y Cajal, who shared the Nobel Prize in Physiology and Medicine in 1906 in recognition of his researches on neuroanatomy. The isolation of Spain since the Civil War (1936-39) has had a harmful effect on science. Many scientists left the country during the hostilities and did not return. One of these is Professor Severo Ochoa, an outstanding biochemist who became a U.S. citizen and subsequently a Nobel Prize winner. A handicap to Spanish scientific research is that the great majority of research centers are too small to be effective. The universities are generally weak in research, and most of the research effort is conducted in a few government centers. Industrial research is increasing but is still inadequate.

The Spanish Government has shown a growing awareness of the importance of scientific research and development in furthering economic growth and has set up various committees to promote and coordinate research activities. One objective of the Development Plans has been to create an atmosphere favorable to technical innovation and to the improvement of the country's competitive position in world markets. To reach this goal, research and development efforts are to be concentrated in applied areas, especially agriculture, mining, and nuclear energy, but without neglecting basic research. A considerable portion of the government's research support in recent years has been for the nuclear program, which is directed toward nuclear power production.

Fundamental research in Spain presents a very fragmented picture. Since fundamental research cannot be expected to show a financial profit, it has been given some support primarily to improve the prestige of scientific groups which have proven ability based on past contributions. Biological research is carried out almost exclusively in the research centers of the Higher Council for Scientific Research (CSIC) and in the university faculties of science, medicine, and pharmacy. Chemistry research is generally the sector which has been pursued the most avidly. Research in physics and mathematics is limited in scope. The physics of high- and low-energy nuclear particles is probably the most developed area. One important joint scientific group has been formed recently by the Autonomous University of Madrid and the CSIC to specialize in solid-state physics and high-energy theoretical physics.

U.S. observers of Spanish scientific centers have stated that Spain will need to invest more heavily in scientific and technological research if it is to compete on an international economic level, an assessment agreed to by the Spanish Government. Following the recent emphasis on education as the government's overriding priority, the country intends to emphasize scientific and technological development during the next decade. Scientists and the country as a whole are highly interested in foreign scientific cooperation, especially with the United States. Also, Spain realizes that it must have closer association with the industrially more advanced countries of the European Common Market. A German-Spanish scientific and

technical cooperation agreement concluded in April 1970 provided for exchange of information, exchange of personnel, joint projects, and common use of facilities.

Spain participates only moderately in international scientific affairs, and a shortage of funds has limited foreign travel. It is a member of the United Nations and several of its specialized agencies, such as the United Nations Educational, Scientific, and Cultural Organization. Spanish activities in international organizations concerned with science or education are coordinated by a Commissariat for International Scientific Cooperation under the Ministry of Education and Science. Spain is a member of the International Union of Geodesy and Geophysics, the World Meteorological Organization, the International Council for the Exploration of the Sea (ICES), the International Council of Scientific Unions, the International Hydrographic Bureau, the International Oceanographic Commission (IOC) and the European Space Research Organization (ESRO), although its financial support of ESRO is limited. Spain withdrew from the European Nuclear Research Center (CERN), because the Spaniards felt that they did not receive a sufficient return on their expenditures.

Spain has several treaties for scientific and technical cooperation with various countries. Under a 1970 United States-Spanish Agreement of Friendship and Cooperation, which replaced a narrower 1953 agreement, progress is proceeding between the two countries in several areas of scientific cooperation. The United States has provided about US$3 million for this program. The largest single grant (US$800,000) is in support of a new Institute of Molecular Biology. Other areas involved are information sciences, automation, oceanography, urban affairs, plant and animal diseases, and air and water pollution. Spain has cooperated with the United States in the staffing and operation of space-tracking facilities.

Italy, through its National Research Council, has a bilateral agreement with CSIC. Spain signed an agreement with Argentina in 1968 for cooperation in scientific research and provides limited technical assistance to Peru. Close relations in scientific affairs between Spain and France have existed for a number of years. In 1971 the Leonardo Torres Quevedo Physics Research Center and the French National Office of Aerospace Studies and Investigations signed an agreement for scientific collaboration in integrated circuits and microelectronics. Spain has signed agreements for cooperation in the field of nuclear energy with the United States, Canada, Brazil, Peru, the United Arab Republic, and Portugal. The Nuclear Energy Board (JEN) has concluded agreements for cooperation with nuclear organizations in France, India, Belgium, Italy, Argentina, and Pakistan. In early 1973 it was reported that the French Government, as an extension of its continuous efforts to develop close ties with Spain in matters relating to national defense, has agreed to provide technical assistance to the Spanish Navy.

B. Organization, planning, and financing of research (C)

Most scientific research in Spain is conducted in government research centers, especially in seven of the larger centers. Only about 7% of the nation's research in 1970 was done in the universities. Very few private firms conduct research and development on a significant scale. The government organization for scientific research and development is shown in Figure 1. CSIC in Madrid is the most important organization involved in the conduct of scientific research. Established in 1939 to promote, direct, and coordinate Spanish scientific research, it operates as an autonomous body under the Ministry of Education and Science. The CSIC includes representatives of the universities, the Royal Academies, the technical branches of the armed forces, and private research organizations. The representatives are designated by the Minister of Education and Science.

The CSIC is organized into eight *patronatos*, or foundations, named after famous Spanish scholars and scientists. Each *patronato* has a number of institutes or research centers in specific subjects. Four of the *patronatos* are concerned with scientific and technical research and development. The *Patronato Santiago Ramon y Cajal* is concerned with research in biological and medical sciences; the *Patronato Alonso de Herrera*, natural and agricultural sciences; and the *Patronato Alfonso el Sabio*, mathematics, physics, and chemistry. The chief aim of these three foundations, frequently referred to as the Science Division of the CSIC, is to integrate the foundations concerned with fundamental research in natural sciences into a single unit. This was done to simplify administration and to coordinate research activities to promote efficiency and achieve better use of services, library facilities, and laboratory equipment and instrumentation. The main fields of interest are medicine and animal biology, agricultural sciences and plant biology, mathematics, physics, astronomy, and chemistry. The fourth foundation of interest is the *Patronato Juan de la Cierva*, which deals with scientific and technical research. These four *patronatos* supervise about 140

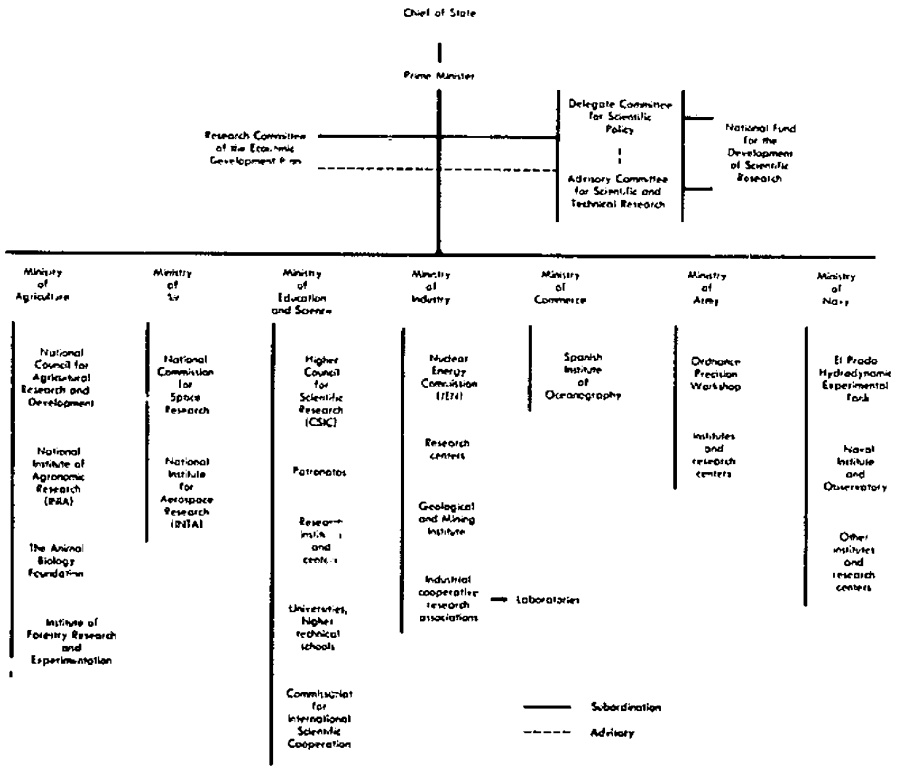


FIGURE 1. Government organization for research and development, 1973 (C)

institutes, centers, departments, and sections, which in 1970 had a total employment of 3,896 persons.

The depth and extent of the industrial and technical research with which the *Patronato Juan de la Cierva* is concerned through its institutes, departments, and sections, and its close contact with Spanish industry, give it an important position within the framework of scientific and technical research in Spain. The aim of this *patronato* is to promote and develop industrial and technical research by carrying out research work itself in its own institutes and centers or by coordinating and financing the activity of other public or private research centers. The foundation does not play a direct role in formulation of national science policy; however, it exercises an important influence on the organization and development of industrial research, both by its scientific activities and by measures which it takes to enhance the coordination and financing of technological research activities undertaken by other bodies. Coordination occurs through the existence of a Technical Advisory Council at each institute or center of the foundation. It is made up of industrialists and qualified technical personnel representing the scientific and industrial organizations interested in the particular activity of the institute or center. The foundation has about 15 research centers, mostly in or near Madrid, and numerous laboratories distributed throughout the country. The research centers of this foundation organize congresses and scientific meetings at the national, local, and international levels to consider technical questions relating to a particular specialty.

The *Patronato Diego Saavedra Fajardo* does some work in geography. Three other *patronatos* are concerned with studies in the humanities. The CSIC has a data processing center and publishes periodicals summarizing the research conducted in the various institutes. It maintains an awareness of research done in other countries and maintains extensive contacts with certain U. S. research centers. The CSIC also awards several major prizes annually for research.

A governmental decree of February 1969 was designed to strengthen cooperation between the CSIC and the universities and to provide for the establishment of joint research centers at universities. These centers were to be devoted to research in mathematics, physics, biochemistry, geology, biology, physiology, anatomy, and veterinary science.

Spain has three authorities which are concerned formally with scientific activities at the national level: the Delegate Committee for Scientific Policy, the Advisory Committee for Scientific and Technical Research, and the Research Committee of the Economic Development Plan. These committees are important in establishing scientific policy and in the allocation of funds for research and development. The Delegate Committee for Scientific Policy was established in April 1963 to guide and coordinate government action in a manner that would promote and encourage scientific and technical research, to formulate integrated long range plans, and to prepare decisions on budgetary allocations for research according to the provisions of the Economic Development Plan. The Delegate Committee is presided over by the Chief of State. Members include the Deputy Prime Minister, the Ministers of Finance, Interior, Public Works, Education and Science, Agriculture, Industry, and Commerce, and the Under Secretary attached to the Prime Minister's Office. The Research Committee of the Economic Development Plan, established in 1962, is important with respect to scientific activities, because it is a part of the Economic and Social Development Planning Commission, which decides on the amount of funds to be allocated to research under the plan.

The Advisory Committee for Scientific and Technical Research is a service of the government and is neither financially nor administratively autonomous. It aids in the formulation of government science policy and plays a consulting role for the Delegate Committee for Scientific Policy and the Research Committee of the Economic Development Plan, both of which rely heavily on the Advisory Committee in arriving at decisions. The Advisory Committee has no laboratories of its own, but it may recommend institutes and research centers in which research programs are to be conducted, it also suggests suitable coordination methods. The Advisory Committee has an added responsibility of proposing measures to encourage industrial research. The president and deputy president of this committee are appointed from among the members of the CSIC. The other members of the committee are representatives of the Ministries of Finance, Interior, Public Works, Education and Science, Agriculture, Industry, Commerce, and Housing, and representatives of important agencies and organizations concerned with research. The Secretary of the Advisory Committee is the General Secretary of the CSIC.

A National Fund for the Development of Scientific Research, set up in 1964, is administered by the Delegate Committee for Scientific Policy and the Advisory Committee for Scientific and Technical Research. This fund provides financial support for extraordinary purchases of scientific instruments for government and university research centers, provides funds for cooperative scientific research programs outside of the CSIC, and makes loans for research projects conducted by private firms in collaboration with government research centers.

Several government ministries are involved in research. The Ministry of Education and Science, in addition to its responsibility for the CSIC, is responsible for scientific education and research in the universities. In December 1968 the Minister of Education and Science reorganized the Directorate General of Higher Education and Research to provide subdirectorates of higher technical instruction and of scientific research and coordination and an office of scientific research and promotion. The latter office is concerned primarily with encouraging research in higher educational institutions.

The National Commission for Space Research under the Ministry of Air Force, promotes and coordinates space research. The Esteban Terradas National Institute for Aerospace Research (INTA) at Torrejon[1] de Ardoz is an autonomous agency that uses the facilities of the Ministry of Air Force but is governed by a board that includes the Ministers of Air Force, Army, Navy, Industry, and Education and Science. The Ministry of Industry is responsible for the Nuclear Energy Commission, the Geological and Mining Institute in Madrid, and the Industrial Cooperative Research Associations. A National Council for Agricultural Research and Development,

[1]For diacritics on place names see the list of names on the apron of the Summary Map and the map itself in the Country Profile chapter.

under the Ministry of Agriculture, advises the ministry on the direction and coordination of research in agriculture and forestry. The Ministry of Agriculture is responsible for the National Institute for Agriculture Investigations (INIA), the Animal Biology Foundation, and the Institute of Forestry Research and Experimentation. Considerable research related to agriculture is done also in CSIC laboratories. The Ministry of Commerce has under its supervision the Spanish Institute of Oceanography, but the work of this institute is directed by the navy. Military research is the responsibility of the Military Research Board, which also provides coordination between the CSIC and the research facilities of the Ministries of the Army, Navy, and Air. The Ministry of Army directs the Ordnance Precision Workshop in Madrid. The Ministry of the Navy has the Naval Institute and Observatory at San Fernando and the El Prado Hydrodynamic Experimental Tank. The Center for Technical Studies of Special Material (CETME), Madrid, established under the Ministry of Industry, is concerned with the plans and projects pertaining to weapons and munitions.

JEN is responsible for the Spanish nuclear energy program. It is dependent directly on the Ministry of Industry and is governed by a board of directors, including ministerial representatives and outstanding scientists and industrialists. Its principal objectives are to promote and supervise investigations involving application of nuclear energy for national purposes, particularly as directed toward the production of nuclear power. JEN has a staff of about 2,000, including 300 university graduates. Most Spanish nuclear research is carried out in the research centers of the JEN, particularly the Juan Vigon National Center of Nuclear Energy near Madrid. Some nuclear research is conducted in the universities.

The several royal academies constitute the Institute of Spain. The academies do not engage in scientific research themselves, since their function is only to promote science in general and to encourage its development. The academies of importance to science are the Royal Academy of Exact, Physical, and Natural Sciences; the Royal National Academy of Medicine; and the Royal Academy of Pharmacy. The Royal Academy of Exact, Physical, and Natural Sciences is basically a government consultative body. Beyond providing information to the government when it is requested, it takes no part in the formulation of national science policy. Administratively and financially, it is dependent upon the Ministry of Education and Science. The academy awards three scholarships each year and supports two university chairs—one for mathematical programming theory and the other for nuclear reactor theory. In addition, it awards eight prizes each year. Although the academy has research personnel in the form of scientific workers and technicians, most of them work in university laboratories or in the laboratories of the CSIC.

The total amount of scientific research undertaken by industrial organizations in Spain is small. Most companies cannot support research and development on a significant scale. An exception is the Madrid ITT laboratories of Standard Electric de Espana. Its 1970 budget was US$1.7 million, and the amount was expected to rise to US$2.5 million when its new laboratories were completed. A major portion of expenditures for industrial research in Spain is in such industries as electrical machinery, automobiles, chemicals, and pharmaceuticals. Some progress has been made in establishing Industrial Cooperative Research Associations, which function under the direction of an executive council composed of representatives of member firms. They are financed up to 50% by the government through the budget of the *Patronato Juan de la Cierva*, and industry supplies the rest of the support. Private industry supports some research through contracts with the institutes or centers of the *patronatos;* the *Patronato Juan de la Cierva* derives a substantial portion of its income from such contracts.

Several problems have arisen in connection with the expansion of Spanish research and with integration of research into the Economic Development Plan. Scientists generally have not been invited to participate broadly in the planning process. Spanish scientific personnel criticize industry for its unwillingness to support research. Industry, on the other hand, has a generally low regard for the scientific and technological capabilities of Spanish research and development centers and looks to foreign countries for technological innovations. In actuality, importation of foreign technology has played an important role in stimulating the recent Spanish economic and industrial development. The Spanish scientific community has been disappointed in the fact that only about 15% of the funds requested for scientific activities for the Second Development Plan were actually included in the plan. It is expected that the Third Economic Development Plan (1972-75) will mark a turning point toward substantially greater Spanish Government support for scientific research and development. Emphasis is expected to be placed on utilization of natural resources and on applied industrial, agricultural, and biomedical research.

The total expenditure for research and development is inadequate and has not kept pace with the growing economy. Substantial increases in funding are being made, but it is estimated that in 1971 expenditure for research and development was US$70 million, or less than 0.25% of the gross national product. A breakdown of government expenditures on research and development for 1967 is as follows: agriculture, 17.4%; nuclear energy, 23.1%; industry and mining, 41.9%; science division of CSIC, 5.0%; other ministries, 7.5%; and higher education, 5.1%. The total CSIC budget has risen from $13.9 million in 1964 to $20.3 million in 1970. In 1968 the JEN had a budget of $12.5 million, which was distributed as follows: 24% for fundamental research, 46% for applied research, and 30% for development work.

The major portion of the research and development requirements of Spanish industry is met by importing foreign technology through purchase of licenses and by participation of foreign corporations in Spanish firms. In 1968 the excess of technological payments over receipts by Spanish companies amounted to US$97.8 million. Payments increased from US$109.2 million in 1968 to $132.9 million in 1969. Thus the amounts paid by Spanish industry for foreign technology are about double the country's total research and development expenditures.

C. Scientific education, manpower, and facilities (S)

Scientific education is readily available in Spain, primarily at the 16 government-supported universities, at several higher technical schools, and at a few private universities. During the past 10 years engineering education has changed considerably. Many of the former highly selective special schools (*escuelas superiores*) for engineering have become part of the universities. Student enrollments have increased to the extent that there is a surplus of engineers in some fields. The quality of scientific education is reasonably good but not outstanding. The Spanish universities are weak in research and graduate education. The universities have little money for research, and the professors are to engrossed with teaching duties to devote much time to research. Graduate education in most disciplines is poorly organized and poorly financed.

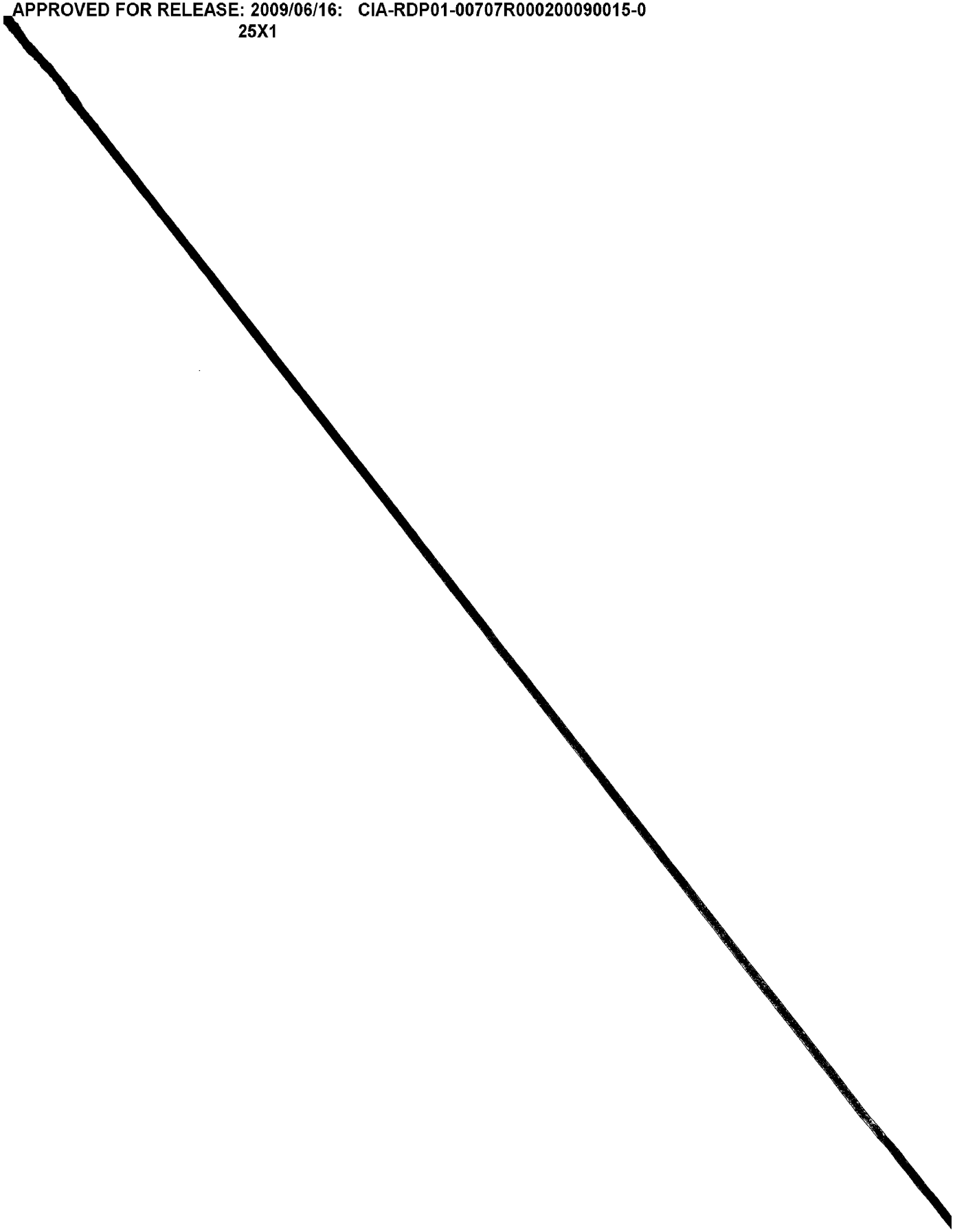
The educational system at all levels in undergoing reforms, but progress is slow. University professors, or chair holders, have great independence and exert considerable power over their assistants. A 1965 law was directed toward introduction of a departmental system, but changes have been resisted by the professors. The newly established autonomous universities of Barcelona and Madrid have succeeded in introducing reforms more effectively than the traditional universities. All state universities have faculties of science which are divided into sections: physics, chemistry, mathematics, and natural sciences. Most of the science faculties have been established during the 20th century.

The percentage of students enrolling in scientific studies is much smaller in Spain than in most other West European countries. Enrollments in the higher technical schools have increased, particularly in such fields as industrial, architectural, and civil engineering. Only a few doctoral degrees are awarded in the sciences by the universities. Some of the institutes of the CSIC participate in postgraduate programs by providing special courses and laboratory facilities where students can work toward their doctoral degrees. During the 5-year period ending in 1970, a total of 1,135 doctoral theses was completed in the centers of the *patronatos* of the CSIC. The Leonardo Torres Quevedo Physics Research Center, Madrid, of the *Patronato Juan de la Cierva* offers courses in electronics, solid-state physics, and plasma physics.

There appears to be an overabundant supply of scientific and technical manpower for the limited research and development program. Only about 2% of the scientists and engineers are employed full time in their professional fields. The number of personnel employed in research centers increased only from about 7,700 in 1964 to 8,000 in 1967, an increase of approximately 4%. The salaries of research workers holding government positions are low, but the salary levels of university teaching staffs have improved in recent years.

Spain has about 200 official research centers which belong to 14 different ministerial departments. Official research centers are generally very small, and only 2 of them employ more than 250 scientists and engineers; 7 employ between 50 and 250, and 47 between 10 and 50. The remaining 145 centers are nearly all dedicated to the humanities and social sciences. Research in industrial companies is carried out in about 300 laboratories of various types, of which only 6 employ a staff of 50 or more scientists and engineers; each of the remainder has fewer than 20 graduate staff members.

Spain has a few good research facilities. Outstanding is the Juan Vigon National Center of Nuclear Energy, which is of excellent design and is



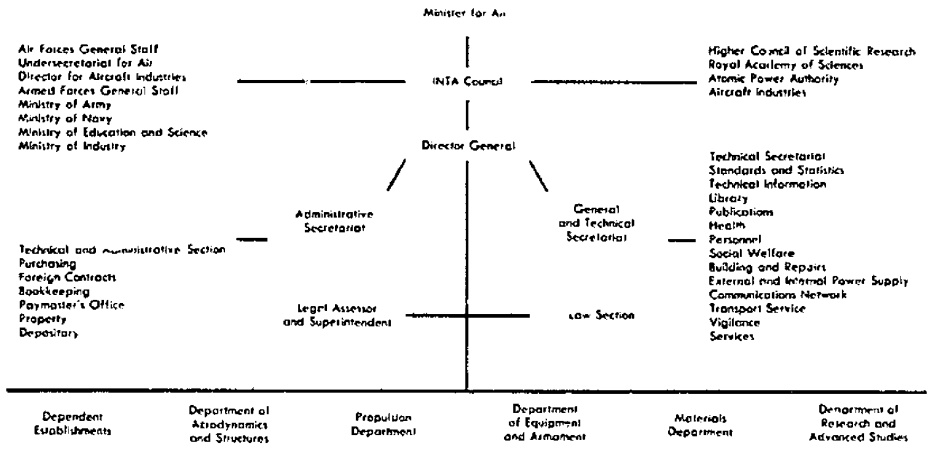


FIGURE 2. Organization of the National Institute of Aerospace Technology (U/OU)

receiving systems support launch operations from the site. The site has meteorological support facilities, which include a 100-foot observation tower, a balloon shelter, and radio facsimile equipment. Another facility operated by INTA is the Grand Canary Space Station at Maspalomas. This station is equipped with a 1-meter parabolic antenna that has been used to track and communicate with U.S. spacecraft in NASA's Mercury, Gemini, and Apollo programs. Although operated by INTA, station maintenance is performed by U.S. technicians.

Ground weapons research is concentrated on shoulder weapons and rocket development rather than on tube artillery weapons. Spain has done research on rocket grenades, a combination hand grenade-mine, a plastic antitank mine, and does work on weight reduction of 60-, 81-, and 120-mm mortars. By 1966 the Spanish had developed and experimented with a series of five surface-to-surface rockets, which they designated models C, D, E, R, and S. Three different launchers were constructed and rocket regiments were armed with six batteries of the C rocket and three batteries each with the D-2 and E-2 rockets. The Spanish have maintained an active program to modify and improve their systems and as a result have not stockpiled a great quantity of single items for the armed forces. Progress in artillery rocket system development will continue but the country is not expected to advance in rocket development or employment.

Although Spain continues to rely primarily on foreign research and development for progress in modernizing the army's armor inventory, ground weapon production technology has improved as a result of the agreement of military cooperation signed by Spain and France in June 1970. This agreement provides for coproduction of the French AMX-30 (105-mm gun) tank (Figure 3), which has stimulated some research and tooling projects for development of capabilities and expansion of facilities necessary to carry out this program. Several plants, entirely or partially owned by the government, and some elements of private industry are participating in the preparations for manufacture and testing of components and for assembly of the Spanish Army's new main battle tank. In addition, because of the anticipated slow pace of AMX-30 tank production, the country is exploring interim measures, e.g., dieselization of the army's M-47 tanks, to modernize the armor inventory.

No significant research is done on quartermaster, engineer, or transportation equipment. Automotive plants have laboratories and testing facilities but motor vehicle research is minimal.

FIGURE 3. An agreement permitting production of this French AMX-30 tank, which has a 105-mm gun, has stimulated some research and tooling projects (U/OU)

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Naval research and development are of minor consequence. They consist mainly of exploiting foreign technology to meet local needs. Such work is confined to the construction of frigate or smaller size vessels. The only indigenous research known to be underway on naval weapons is directed to the development of small caliber deck armament.

2. Biological and chemical warfare (C)

No research on offensive or defensive biological warfare is known to be carried on in Spain. The country depends on the neighboring NATO member nations to keep it informed on advancements in basic research and in the latest technological and scientific developments. There is only a limited capability for the development of chemical warfare defensive equipment, and there is no program for research in offensive materiel. Scientists are aware of the nerve agents tabun, sarin, and soman but have not conducted research on them.

3. Nuclear energy (C)

Spain has established a nuclear energy program devoted to research, the utilization of nuclear raw materials, and the applications of nuclear energy, particularly for power. The country has been dependent upon some foreign assistance but is increasing its capabilities for industrial participation in a growing nuclear power program. Although Spain has not signed the nuclear Non-Proliferation Treaty, it has no plans to expend any effort on the development of a nuclear weapon program.

The nuclear energy program was begun in 1948, when a special commission was created to study the application of nuclear energy in Spain and to initiate training programs. This led to the establishment of a Nuclear Energy Board in 1951 to carry out actual development; JEN is under the Ministry of Industry. The functions of JEN include advising the government on nuclear matters, exploiting nuclear raw materials, training personnel, producing and distributing radioactive isotopes, and constructing and operating pilot plants and prototype facilities. One of the most important tasks assigned to JEN is to promote a nuclear industry. With the growth of nuclear power, in 1972 the Spanish Government promulgated a new nuclear code, giving the Ministry of Industry the central role in licensing and regulating nuclear power stations and related industrial, scientific, and professional activities.

Spain is a member of the International Atomic Energy Agency and EUROCHEMIC; the latter is a fuel reprocessing facility built and operated by the members of the Nuclear Energy Agency of the Organization for Economic Cooperation and Development. Spain was a member of the European Organization for Nuclear Research (CERN) but was forced to suspend its membership for economic reasons. In 1972 Spain joined EURODIF, the French-led group which is studying the possibility of building a uranium isotope separation plant in Europe using the gaseous diffusion process. Spain is also a member of the Association for Centrifuge Enrichment (ACE), which was established in May 1973 to study the centrifuge process of enriching uranium.

JEN established a national nuclear center, *Centro Nacional de Energia Nuclear Juan Vigon*, near Madrid. The work of JEN is divided into 12 divisions devoted to all aspects of nuclear research. The divisions are grouped into five directorates: Geology and Mining, Reactor Physics, Isotope Chemistry, Pilot Plant and Industrial Applications, and Engineering and Health Physics. The principal research facilities of the Juan Vigon Center are a US-supplied, 3-megawatt (MW) swimming pool type reactor, JEN-1, which went into operation in 1958; CORAL-1, a zero power fast breeder critical experiment; and JEN-2, a 10-kilowatt (kW) pool type reactor. Both reactors went into operation in 1968. Two 10-kW argonaut-type research reactors were constructed at the center and installed at the Industrial Engineering Schools at Barcelona and Bilbao in 1961 and 1962, respectively. The center also has pilot plants for uranium ore processing; production of heavy water, nuclear-pure graphite, and uranium metal, oxide and carbide; the fabrication of fuel elements; and the reprocessing of irradiated fuel. These facilities give Spain research and development experience in most phases of reactor construction and operation. There are extensive plans for nuclear power. Figure 4 gives locations and tabulated data.

While the first uranium deposits in Spain were discovered in 1939, a program for the exploitation of radioactive materials was not started until the late 1940's. An extensive prospecting program is being carried out by JEN, and promising uranium ore deposits have been located in a number of areas. Spain is estimated to have reserves of about 8,500 short tons of recoverable uranium at less than US$10 per pound.

A uranium ore concentration plant, *Fabrica de Uranio General Hernandez Vidal*, went into operation in 1959 at Andujar, province of Jaen. Approximately half of the known Spanish uranium ore reserve is located in a cluster of deposits near Ciudad-Rodrigo. The government decided that the Ciudad-Rodrigo

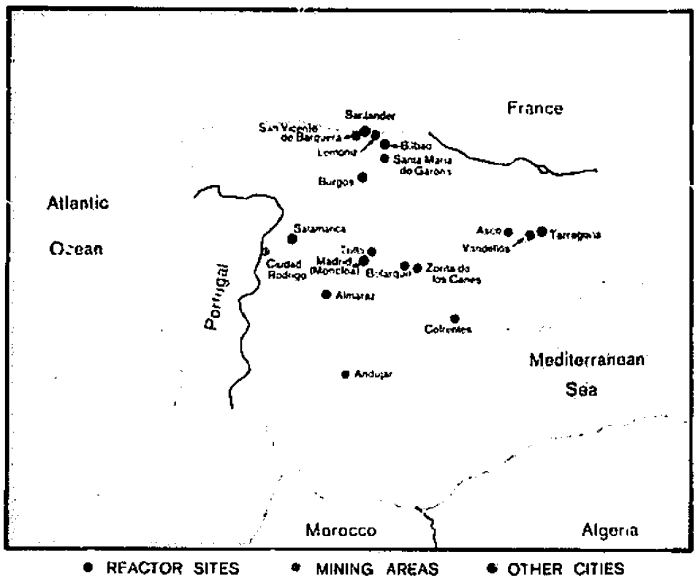

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FIGURE 4. The Spanish nuclear power program (C)

Figure 4. The Spanish Nuclear Power Program

Station Name	Power	Date	Status
	(*M We*)		
Zorita I (Jose Cabrera)	153	1968	In operation
Santa Maria de Garona	460	1971	*Do.*
Vandellos	500	1972	*Do.*
Almaraz-1	900	1976	Under construction
Lemoniz-1	900	1977	*Do.*
Asco-1	900	1977	*Do.*
Almaraz-2	900	1977	*Do.*
Lemoniz-2	900	1978	*Do.*
Asco-2	900	1979	Contracted
Cofrentes	975	1978	*Do.*
Zorita-2/Bolarque	1000	1978	Planned
Zorita-3/Bolarque	1000	1981	*Do.*
Trillo-1	1200	1981	*Do.*
Trillo-2	1200	1985	*Do.*
San Vicente de Barquera	900	*na*	*Do.*

na Data not available.

project would be principally a state venture. In late 1971 *Empresa Nacional del Uranio, S.A.* (ENUSA) was established. ENUSA is interested in producing enriched uranium and is the Spanish member of EURODIF and ACE, which study the possibility of building uranium isotope separation plants in Europe. The uranium thus far has been provided by other countries. A considerable amount of plutonium will be produced in the Spanish nuclear power reactors, but all will be subject to safeguards limiting its use to peaceful purposes.

4. Electronics (C)

Spain has a limited capability for electronics research and development. Most of the research is directed toward improving the production capability of Spanish industry. The CSIC National Institute of Electronics (INE) at Madrid has engaged in a variety of minor research programs. One of the primary objectives has been to reduce the dependence on foreign technology, but only slight progress is being made, and Spain still ranks low compared with other European countries. The institute has developed components for infrared and visible light applications as well as communication and radar equipment. Under a 4-year economic development plan initiated in 1972, the Spanish Government earmarked electronics and telecommunications for priority consideration. The planned production growth of just under 25% predicates an annual increase of 23% in Spain's electronics markets. This would provide 2% for export and/or inventory development. Two other Spanish organizations that have engaged in electronic-related research are the observatory at Ebro, which has done ionospheric studies, and the Institute of Physics, Madrid, which has done some theoretical work related to semiconductor junctions.

Spain has no domestic computer industry, and it offers a rapidly growing market for U.S.- and West European-produced computing systems. However, the local manufacture of peripheral equipment is being accomplished, and the government is encouraging industry to expand its facilities for further development and manufacture of such equipment.

5. Medical sciences (S)

Spain is limited by its modest financial resources to a minor role in medical research. While the quality of its senior medical research workers is excellent, the country suffers from a shortage of scientific and professional manpower and facilities for training. The medical schools emphasize teaching more than research. The country, nevertheless, is presently making a strong effort to expand research; judicious planning is exercised in the use of government subsidies to utilize wisely the very limited funds available. Laboratory work is efficiently and sensibly organized for its practical return. Pooling of research equipment is practiced to make it available to personnel with related interests. Support for medical-biological research is obtained from the U.S. National Institutes of Health, the U.S. Department of Agriculture, the World Health Organization, the National Fund for the Development of Scientific Research, and the Juan March Foundation.

Administration of fundamental research in medicine and biology is assigned to the Santiago Ramon y Cajal Foundation, which is an element of the Science Division of the Higher Council for Scientific Research. The Center for Biological Research of this foundation has an Institute of Histology; the Jaime Ferran Institute of Microbiology, the Gregorio Maranon Institute of Metabolism and Enzymology, and an Institute of Cell Biology. The Institute of Histology also bears the name Santiago Ramon y Cajal and has a department of biophysics, sections for cytology and comparative histology, electron microscopy, comparative neuroanatomy, neurobiology, and pathological anatomy of the nervous system, and laboratories of developmental genetics and histochemistry.

Competent microbiological research ranges in scope from studies of plant and animal viruses to bacterial genetics and the efficacy of bacterial and viral vaccines. A new Center for Virology has been constructed at the outskirts of Madrid. The Jaime Ferran Institute emphasizes the study of plant and animal pathogens. Substantial contributions are made in food hygiene and in the viral etiology of cancer. Key research personnel have spent time abroad in the United States or the United Kingdom to acquire an understanding of the approaches taken to microbiological research in other countries. World Health Organization support is given to epidemiological studies of virus disease of public health importance, to study of methods of control and prevention of enteric, respiratory, and other viral diseases, and to provision for training facilities.

Spain does not have a tradition of research in pharmaceuticals. Conducting research is a problem, since Spain lacks experience, maturity, and qualified indigenous personnel in the drug field. The government encourages and fosters research and development by Spanish companies and by the domestic subsidiaries of foreign-owned firms. This is,

however, a long-term policy, and returns are slow. The Spanish Nuclear Energy Board is producing radiopharmaceuticals for research and therapy. The Juan de la Cierva Foundation of Scientific Research has established a Department of Applied Pharmacology in Barcelona to investigate new drugs. Attention is being given to atmospheric contaminants, synthesis and trial of glycosides, isolation of natural plant products, and synthesis of enzyme inhibitors. The Max Planck Society of West Germany assists in this work through exchange of professional personnel. Biochemical investigations have been of a practical nature, emphasizing studies of enzyme chemistry, metabolism, preservation of fish and meat products, and lyophilization of foods. The U.N. Educational, Scientific, and Cultural Organization has supported the study of physical, chemical, and biological characteristics of the sea. Spain has become interested in the exploitation of yeast for the production of edible protein, especially fodder.

Some effort is devoted to protection from environmental hazards. The Higher Council on Occupational Health and Safety is promoting studies on industrial health protection. Private research is encouraged on environmental control. Good work is done on radioecology, especially contamination by plutonium and uranium.

Military medical research is limited by lack of funds and qualified research personnel. The army's Military Medical School of application and its subordinate Captain Ramon y Cajal Army Institute of Preventive Medicine are the major medical research facilities in the armed forces. The school coordinates technical research for the army, conducts surgical research, and studies the application of medical research to the military medical services. The institute carries out research biochemistry, epidemiology, hematology, nutrition, radiation and radiation protection, and toxicology. In the air force, the Institute of Clinical and Aerospace Medicine is responsible for aerospace medicine. The Spanish Navy has almost no capability for medical research, but it has done work in underwater physiology at the Submarine School Training Center in Cartagena.

6. Other sciences (S)

a. Chemistry and metallurgy

Spain is making progress in chemical research but is not considered among the leading European countries in chemistry. The volume of published research has increased, but it still is small compared with that published by France or Italy. Research in all of the important branches of chemistry is conducted in the research institutes of the CSIC and in several universities. Research in analytical and organic chemistry and in biochemistry is strongest. Francisco Bermejo Martinez and associates at the University of Santiago do extensive research on the analytical use of chelating agents, particularly for spectrophotometric determinations. The Juan Vigon National Center of Nuclear Energy is concerned with the development of analytical methods useful in connection with its nuclear research. This center is active in various aspects of nuclear technology involving organic and physical chemistry, including production of uranium, purification of uranium hexafluoride by distillation, separation of stable isotopes by ion exchange techniques, and processing of reactor fuels.

A moderate amount of organic chemical research is done at several universities, including an increasing amount of synthetic work. The strongest activity in organic chemistry is at the CSIC National Center of Organic Chemistry, Madrid. The Institute of General Organic Chemistry, a part of this center, does research on alkaloids, terpenes, and pharmacologically active synthetic compounds, including antihistamines, and psychotropic agents. The Institute of Plastics and Rubber, also part of this center, is the leading laboratory for high-polymer research, and research is in progress on vinyl polymerizations, polymerization of isocyanates, poly (phenylene oxide), and polyimides. The University of La Laguna in the Canary Islands specializes in the organic chemistry of marine and other natural products. The CSIC Antonio Gregorio Rocasolano Institute of Physical Chemistry, Madrid, is prominent in physical organic chemistry in the study of organic reaction mechanisms, molecular orbital calculations, and conformational analysis.

Spain has relatively little capability in metallurgical research and development. Although the metallurgical research effort has increased during the past few years, the emphasis has been directed toward developing a research capability in solving production problems in the small steel and nonferrous metals industries. The principal facility for metallurgical research is the National Center for Metallurgical Investigations, Madrid, under the *Patronato Juan de la Cierva.* Research there has been concerned with ore enrichment, steelmaking operations, foundry technology, corrosion studies and welding, with particular emphasis upon the development of optimum casting conditions for the elimination of defects in aluminum and copper alloy castings. The only higher educational facility that does significant metallurgical research is the Department of Metal Physics at the

Higher Technical School of Industrial Engineering in San Sebastian. Work here has included the continuous casting of steel, nondestructive testing of steel products, and the cyclic torsion testing of stainless steels at elevated temperatures.

Very little research is done by industry. The small metallurgical industry is dependent on foreign technology, which is supplied by U.S. and West German firms that have financial interests in Spanish industry. For example, U.S. Steel Corporation has just entered into an agreement to build a large steel plant, and U.S. Steel is to have a 25% interest in the planned mill, which by 1980 is to have an annual capacity of about 6 million tons.

b. Physics and mathematics

Although physics research in Spain is limited in breadth, certain areas are stressed because of their importance to economic development of the country. Major emphasis is placed on the nuclear sciences, and capabilities are growing rapidly in nuclear technology. Some progress has been made in solid-state physics. Fundamental research is pursued primarily in the universities, and a major portion of this research deals with high energies, because it is felt that high-energy research provides an element of scientific prestige. Approximately 12% of all research efforts devoted to the natural sciences is related to physics, and approximately one-half of this deals with nuclear physics. In the category of high-energy nuclear physics, the subjects studied include inelastic processes and scattering amplitudes, muon capture, hyperon decays, and hadron interactions. The high-energy research at most of the Spanish universities is approximately 5 years behind research done by physicists in more advanced European countries. Other nuclear physics research is of an applied nature which supports reactor development or contributes to the production and application of radioactive isotopes for industry, medicine, and agriculture. Also, some studies are made of spectroscopic factors of nickel isotopes.

Solid-state physics absorbs approximately one-fourth of the physics research effort. During the past few years significant progress has been made in improving capabilities for growing thin films, particularly silver on graphite, at the Leonardo Torres Quevedo Physics Research Center. JEN and the Universities of Madrid and Valladolid study thermoluminescence, interlayer forces of graphite crystals, and ferromagnetic materials. Some modest programs for studying lasers and masers are underway at the Complutensian University, Madrid, where physicists are investigating power levels of optically pumped sodium atoms for their laser action. Other limited research programs are underway in magnetohydrodynamics (MHD), plasma, and acoustics. The plasma and MHD programs are pursued at the Science Faculty of the University of Madrid, whereas the acoustics work is done at the Leonardo Torres Quevedo Center.

Only a small amount of mathematical research is performed in Spain, despite an apparent abundance of trained mathematicians. Mathematical publications typically treat subjects of primarily academic interest and are often largely expository. Recent publications touched several major branches of mathematics, but only quite selectively: publications in algebra stressed category theory, and those in analysis stressed measure theory. Other branches touched upon included geometry, probability, operations research, and mechanics of particles. There seems to be little activity in numerical analysis and relatively little with differential equations. Thus, applied mathematics is weak, indicating a gap between science and industry.

Little recent information is found concerning computers, probably because computing is still at a low level. The University of Madrid and the University of Bilbao have been reported to have fairly modern electronic computers, but there is little evidence of their use.

c. Astrogeophysical sciences

(1) *Astronomy and meteorology*—Astronomical observatories and organizations associated with astronomical activity are relatively numerous, but observing equipment is poor, and the research performed is not of international significance. The leading city in astronomy is Barcelona. Installations include the Fabra Astronomical, Meteorological, and Seismic Observatory, the observatory at the University of Barcelona, the principal activity of which is solar observing, and the Comas Sola Observatory. An observatory at madrid makes routine solar observations and collects and publishes summaries of the solar data acquired throughout Spain. It also makes determinations of the positions and orbits of asteroids and comets and conducts research on double stars and in stellar spectroscopy.

The Naval Institute and Observatory, San Fernando, works in positional astronomy, but it is known principally for the annual publication of *Astronomical Ephemerides*, which is on a par with the *American Ephemeris* and *Nautical Almanac*.

Other observatories at which astronomical, principally solar, observations are made include the Seminary of Astronomy and Geodesy of the University

of Madrid and several observatories associated with the *Patronato Alfonso el Sabio*.

The National Meteorological Service under the Ministry of Air includes the National Institute of Meteorology, the National Center for Weather Forecasting and Analysis, and the Central Office of the Spanish Meteorological Service. Meteorological Research, both pure (such as theoretical dynamic meteorology and physics of the air) and applied (such as climatological studies, aeronautical, and maritime meteorology) is the primary responsibility of the research section of the Institute. It also conducts intensive research in agrometeorology. The Center for Weather Forecasting and Analysis includes a communications facility and sections for aerology, aeronautical meteorology, climatology, and maritime meteorology. Spain is making progress in developing methods of automating meteorological observations and techniques for automatic coding transmission and decoding of data. Processing of data, error checking statistical analysis, and graphical presentation of weather information is done routinely by computer.

(2) *Terrestrial geophysics and geology—The Patronato Alfonso el Sabio* sponsors a National Institute of Geophysics in Madrid. The Observatory of Cosmic Physics, Ebro, conducts geomagnetic and telluric current research and does some work in seismology. The Malaga and Toledo seismic stations are units in the Worldwide Network of Standard Seismograph Stations of the U.S. Coast and Geodetic Survey.

The National Commission of Geology in Madrid studies the international aspects of geology. The Geological and Mining Institute of Spain, also in Madrid, is responsible for geological and mineral resource mapping. The Lucas Mallada Institute of Geological Research in Madrid conducts research in geochemistry, paleontology, and petrology, and it also has a Section of Stratigraphy at the University of Granada.

The JEN is active in geological research related to uranium prospecting. In addition to conducting extensive ground-based geological and mineralogical research, in 1969 it began an airborne radiometric survey of northern Spain. While technical capabilities are good, they lag behind those of countries most advanced in these aspects of nuclear technology.

(3) *Space science and aeronomy*—While Spain takes some part in the activities of the European Space Research Organization (ESRO), it is of significance to international space research principally in that it provides sites for several key space tracking facilities. As part of the NASA manned spaceflight network, INTA and NASA have since 1960 jointly operated a space tracking and communications station located on the Maspalomas Coast of Grand Canary Island. INTA and NASA have also operated jointly three stations of the NASA deep space network, which are equipped with 85-foot parabolic antennas. In June 1972 construction by NASA and INTA of a 210-foot deep space tracking antenna was begun at a site about 40 miles west of Madrid; this was to become operational in 1973.

Spain's only research rocket launch facility is located on the Atlantic coast. Its first use was in late 1966 for the NASA-aided Spanish launching of a series of British Skua and U.S. Judi-Dart meteorological rockets. Rocket launchings have been made to study upper atmospheric winds and temperature and to study the ionospheric absorption of radio waves in cooperation with the Max Planck Institute of West Germany. INTA has under development a single-stage, solid-propellant sounding rocket, the INTA-255, having a ceiling of 150 km. Initial test flights occurred in 1969. A project to develop a two-stage rocket to reach 300 km was to have begun in 1971.

(4) *Geodesy*—Geodetic capabilities in Spain are less than those of other European countries. Research has been routine, and practically no effort has been made to improve geodetic methods and instruments. The stress placed on the improvement of the basic geodetic nets has hindered research. The country has been fairly active in triangulation and leveling, but only a small part of this activity is actual research. Current studies are related to instrumental observations and methods of computing and of adjustment.

The Spanish are active in the preparation of programs for the electronic processing of geodetic data as a replacement for conventional computing methods. Recent work has included the development of a computer program for the free geometric adjustment of the first-order nets in Spain and Portugal. Projects have been carried out on triangulation, baseline, and precise leveling measurements, first-order ties with Portugal, and completion of the Spanish portion of the United European Leveling Net by computing adjusted elevations. A revision of the geodetic tie between the French and Spanish fundamental nets has also been accomplished. Studies have been made in the fields of geomagnetism, aeronomy, and for the absolute determination of the deflection of the vertical by gravimetric methods. Activity in geodetic astronomy has been devoted to the determination of astronomic

positions to establish the proper orientation of the first-order triangulation network.

The Geographic and Cadastral Institute in Madrid is the official civilian geodetic and cartographic agency. It is under the general technical supervision of the Supreme Geographic Council. During the past decade, the institute modernized its facility and has been zealous in adopting modern techniques and methods for surveying and mapping programs. The Army Geographic Service in Madrid is the official agency for geodetic and cartographic work required by the Spanish Army.

(5) *Hydrology and hydraulics*—Hydrologic and hydraulic research programs continue to expand and improve. They are mostly of an applied nature and are managed by well-trained engineers. Hydrologic research is concerned primarily with the exploitation of water resources. Numerous comprehensive programs are conducted to locate ground water and areas suitable for irrigation and to record stream regime data. Hydraulic research is based primarily on model investigations to determine the best designs and locations for weirs and for gates and spillways of dams and to resolve problems concerning silting and scouring in riverbeds. These experiments are conducted primarily at the Hydraulic Laboratory in Madrid. Four outher hydraulic laboratories are in Bilbao, Zamora, Seville, and Madrid.

Spanish hydrologists and hydraulic engineers cooperate with foreign institutions and are active in international hydraulic organizations.

(6) *Coastal research and oceanography*—The level of activity in coastal research has remained lower in Spain than in most other countries in Western Europe. The greatest activity is concentrated in government agencies and officially sponsored institutes rather than in educational institutions. Coastal research activities are concerned primarily with coastal and harbor protection and port design, sedimentation, tides, seismic refraction, currents, eddies, shoreline and estuary changes, and fresh water for coastal communities. Research on control of beach erosion is embryonic at best as are investigations on coastal water pollution.

Oceanographic activity is at a lower level than in the majority of the other countries of Western Europe. Recent interest, however, indicates a possibility of some growth. Oceanographic capability is approximately at the same level as that of Portugal but far below that of France and the United Kingdom. The strongest field is biological oceanography. The Spanish hope to increase the development of fisheries, particularly in Spanish coastal waters and the waters surrounding the Canary Islands, but the lack of adequate equipment, funds, and marine science educational and training facilities precludes any significant expansion in research in the foreseeable future. The Spanish Government has shown little interest in oceanographic research. However, the acquisition of the new 50-meter multipurpose oceanographic ship *Jose Cornide de Saavedra* in 1970, at a cost of US$600 million, by the Merchant Marine office, Spanish Institute of Oceanography, and the Institute of Fisheries Investigations increases capability for oceanographic data collection and fisheries research. The vessel was outfitted with US$500 million worth of scientific equipment. Most Spanish oceanographers are young and have received their advanced education in other West European countries and the United States.

Most of the oceanographic research is carried out by the Spanish Institute of Oceanography, Madrid, and the Institute of Fishery Investigations, Barcelona, under the Juan de la Cierva Foundation for Scientific and Technical Investigation of the Spanish Ministry of Education and Science. The Institute of Oceanography has branch laboratories at Malaga, Palma, Santa Cruz de Tenerife, Santander, Vigo, and San Sebastian. Laboratories of the Institute of Fishery Investigations are at Blanes, Cadiz, Castellon de la Plana, and Vigo. The Navy Hydrographic Institute, Cadiz, has established an Oceanography Section. A Spanish Oceanographic Data Center has been established and has been combined with the facilities of the Spanish Institute of Oceanography.

Spain signed an agreement with Portugal in 1971 for oceanographic research in the Atlantic Ocean extending from the Bay of Biscay to the Canary Islands.

Glossary (u/ou)

ABBREVIATION	SPANISH	ENGLISH
CETME.....	*Centro de Estudios Tecnicos de Materiales Especiales*	The Center for Technical Studies of Special Material
CSIC.....	*Consejo Superior de Investigaciones Cientificas*	Higher Council for Scientific Research
INTA.....	*Instituto Nacional de Tecnica Aeroespacial*	Esteban Terradas National Institute for Aerospace Research
INIA.....	*Instituto Nacional de Investigaciones Agrarias*	National Institute for Agriculture Investigations
JEN.....	*Junta de Energia Nuclear*.....	Nuclear Energy Board