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India

September 1973

Science

NATIONAL INTELLIGENCE SURVEY

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INDIA

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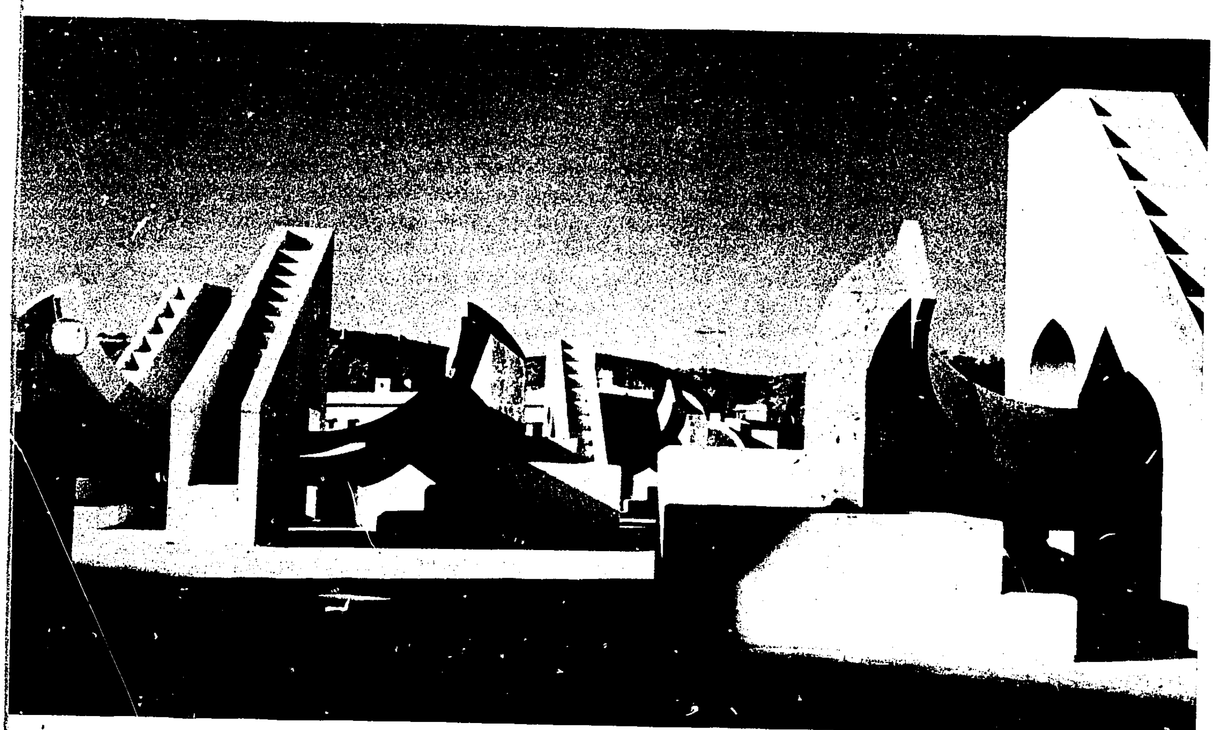
Science



Eighteenth century open-air observatory, Jaipur (U/OU)

A. General (S)

In the years since independence India has developed a substantial and varied scientific research and development establishment. Its present research and development capability is in no way comparable with that of the larger developed countries of the West or the Soviet Union, but India has developed what is probably the strongest overall capability among the less developed countries, excluding China. In Asia, its capability is exceeded only by Japan and, in most fields, by China. Over the past few years India has developed a greatly enhanced indigenous military production capability. Development of a scientific establishment, nevertheless, has been uneven and is still grossly inadequate to support India's projected

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program of economic and scientific development. The facilities have been built, and effective research is being done in government laboratories in nuclear energy, defense, space, and public health, as well as in the development of industrial processes. Nevertheless, judged against the number of laboratories, the manpower involved, and the research budgets expended, India has not yet realized substantial returns on its scientific investment. Rather, the investment has only laid the groundwork for a capability which, if properly managed, could make India an important scientific and technological power in the future.

Indian science has benefited from the strong encouragement given to it by the central government, which adopted an impressive national science policy in 1958, known as the Scientific Policy Resolution. The resolution is aimed at promoting basic and applied research and scientific education. Scientists take an active role in the formation of the government's scientific policy and programs, primarily through the National Committee on Science and Technology (NCST), numerous committees of the Council of Scientific and Industrial Research (CSIR), the Indian Council of Medical Research (ICMR), and the Indian Council of Agricultural Research (ICAR). A major new policy paper, *An Approach to the Science and Technology Plan,* was released in January 1973. It is to be refined, made more specific, and embodied in the Fifth Five Year Plan by March 1974.

Among the many problems that hinder the national development of science is the absence of an established scientific tradition. Compared with the developed countries, India has produced few internationally prominent scientists. Notable is the work in spectroscopy by C. V. Raman before 1930 and the work in statistics by S. N. Bose. A serious and continuing hindrance to scientific growth is the depressed state of the economy. Indian leaders have been unable to provide adequate financial support for scientific and technical research. In addition, the government through excessive regulation of private industry has discouraged the development of new products. The administration of research has become enmeshed in politics, and the lack of coordination among various national agencies set up by the government has resulted in the fragmentation and duplication of research activities. Governmental encouragement of education and science has led to a large increase in the number of colleges and universities, but with a sacrifice in the quality of education generally and of scientific education specifically. Part of the university quality problem has to do with reservation of space for those from the Scheduled Castes and Tribes, perhaps as much as one-fourth of the slots at the Indian Institutes of Technology. Efforts have been made to slow down the expansion of facilities so that quality can be improved by establishing special schools, institutes, and centers for advanced studies.

Traditionally, Indian scientists have tended to emphasize theoretical rather than applied research. This emphasis has been due in large measure to the limited funds available for undertaking applied research and to a lack of adequate experimental facilities. As a result, the government has found it more economical and more dependable to import foreign technology than to encourage its development in India. Both government and industry have been reluctant to rely on domestic technology and industrial processes developed within the country. In an effort to reverse this trend and to channel research into more applied areas, the government has set up numerous applied research laboratories. Unfortunately, in many cases the laboratories have attracted scientists away from the universities and have taken over some of the fundamental research which could have been done more effectively in the universities if they had received adequate financial support.

India probably has received a greater amount of assistance from private and public foreign sources for science and education than any other country in the world. It has received teachers, apparatus, and equipment through bilateral agreements with foreign countries and through agreements between Indian universities and foreign universities, as well as from the United Nations specialized agencies, such as the U.N. Special Fund, U.N. Expanded Program for Technical Assistance, and U.N. Educational, Scientific, and Cultural Organization (UNESCO). Dr. Nag Chaudhuri, scientific adviser to the Minister of Defense,[1] stated recently that the United States has been the strongest influence in the teaching of science in India, and the United Kingdom is the strongest military influence. India and the U.S.S.R. have cooperative programs for the exchange of information. A series of cultural agreements between the two countries has provided for an exchange of Indian and Soviet scientists.

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[1]For a current listing of key government officials consult *Chiefs of State and Cabinet Members of Foreign Governments,* published monthly by the Directorate of Intelligence, Central Intelligence Agency.

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

Most of the scientific and technical research conducted in India is under the jurisdiction of the central government, which provides the financing for about 90% of the research done in the country. Numerous ministries, research councils, committees, departments, national laboratories, and government-sponsored universities are involved (Figure 1). There is virtually no research or development sponsored solely by private organizations with the exception of that carried out by a few independent research institutes which support fundamental research. Industrial research is in the early stages of development, and only a few production establishments conduct research in units of their own, although there are several small industrial research associations.

Governmental planning and financing of research are carried out through agencies which operate in conjunction with appropriate ministries. The most important are the NCST, the CSIR, the ICMR, the ICAR, the Defense Research and Development Organization (DRDO), and the University Grants Commission.

The NCST was established in November 1971 under the Department of Science and Technology of the then Ministry of Planning, Science, and Technology. Subsequently, NCST was placed under the newer Ministry of Industrial Development. As the government's adviser on scientific matters and on the formulation and implementation of science policy, the NCST works closely with the Planning Commission, which has been placed under the Ministry of Planning. The NCST replaced the Committee on Science and Technology (COST) and absorbed its functions. In addition to its advisory duties, the NCST determines the development and utilization of research resources; allocates funds for research received from the government and from foreign sources; promotes better cooperation between government and nongovernment scientific and technical institutes and professional societies; and makes recommendations on scientific and technical cooperation with other countries and international organizations. The NCST has been charged with setting priorities for future research. Although five full-time members were to have been appointed to the NCST, the appointments never occurred. The 10 part-time members are under a chairman, C. Subramaniam, who now is the Minister of Industrial Development.

Governmental planning and financing of research are carried out through agencies and departments which operate in conjunction with appropriate ministries. In addition to the NCST, one of the most important agencies is the CSIR, which is the largest and most influential organization concerned with the direction and financing of scientific research and development. It was constituted originally in 1942 and has been placed under various ministries. It was moved from the Ministry of Education to the Ministry of Planning, Science, and Technology and, most recently, has been placed under the newer Ministry of Industrial Development. The CSIR is a semiautonomous body; the Prime Minister serves as its chairman, and the Minister of Planning serves as vice president. The CSIR operates 35 national laboratories, institutes, and museums, and in 1970 employed 16,000 people, including 4,000 scientists, 5,100 technicians, 2,400 administrative personnel, and several thousand supporting personnel. Its research facilities are intended to be concerned mainly with applied research, and much of the effort is defense oriented. Some of the facilities are ill fitted to translate the findings of their research programs into pilot-plant and semicommercial production because they lack qualified staff members with specific industrial experience. Industry tends to favor proven foreign technology and is reluctant to take the risk of going ahead on a commercial basis with the relatively unproven products and processes of the CSIR laboratories and institutes. The CSIR also supports basic research in the universities and independent research institutes, provides research grants and fellowships to research associations, and disseminates scientific knowledge and information. Other functions include maintenance of a National Register of Scientific and Technical Personnel and of documentation and information services, and the responsibility for temporary placement of well-qualified Indian scientists and technologists returning from abroad.

Similar to the CSIR but much more restricted in scope are the ICMR, which has the major responsibility for the promotion and coordination of medical research, and the ICAR, which promotes agricultural research. The ICMR is a private organization financed mostly by the Ministry of Health and Family Planning. It maintains research facilities of its own and supports and coordinates medical research in other research institutes, medical colleges, universities, and hospitals. The ICAR, under the Ministry of Agriculture, has no institutes of its own but supports agricultural research projects in the research laboratories of various colleges and institutes.

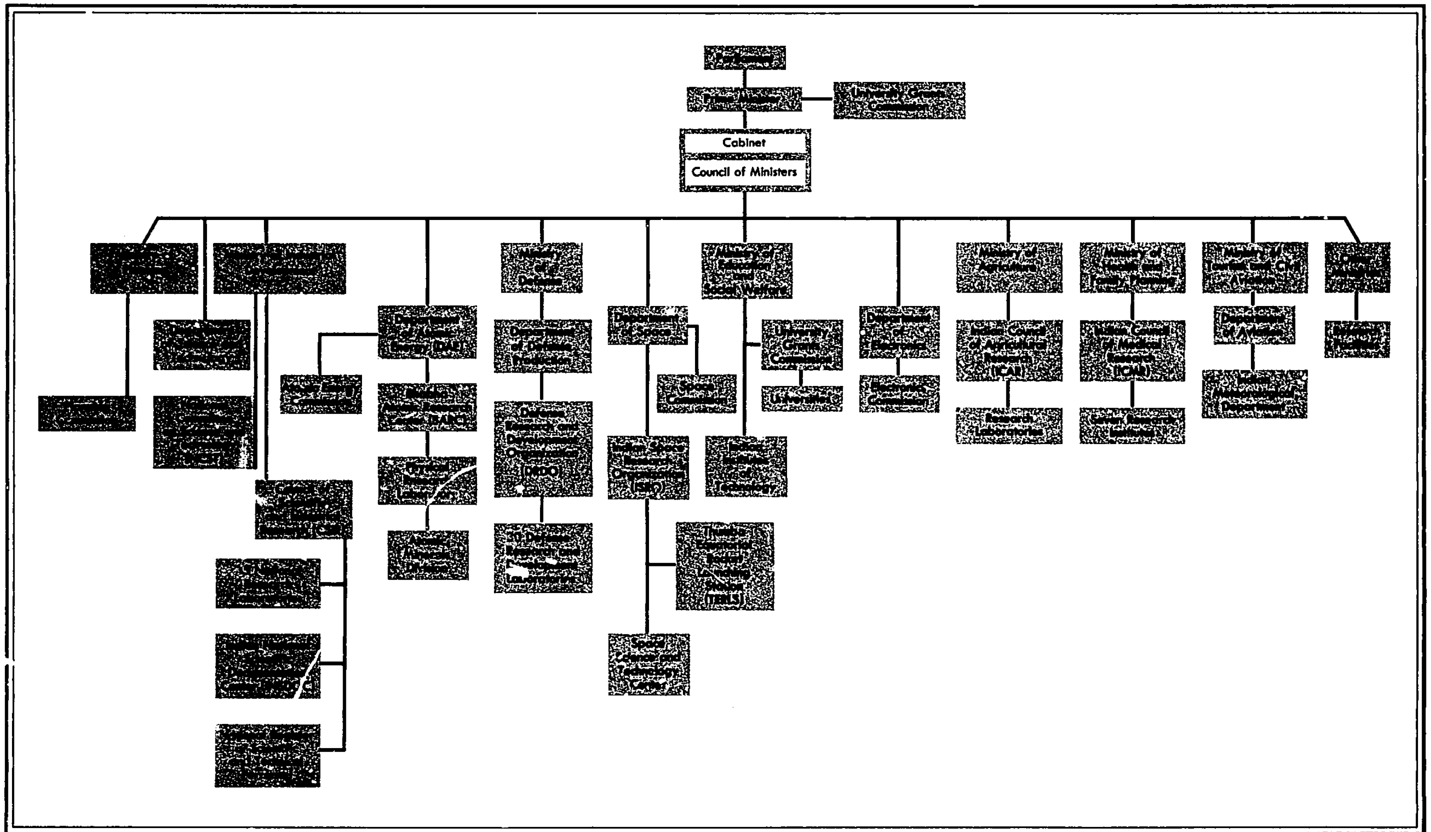

FIGURE 1. Government organization for scientific and technical activities, 1972 (S)

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It maintains a research and reference library and acts as a clearing house of information for research and other agricultural and veterinary matters.

Defense research activities are carried out in about 30 research and development establishments functioning under the Defense Research and Development Organization, under the Department of Defense Production of the Ministry of Defense. The DRDO is responsible for coordinating and directing scientific research relating to defense problems. It also controls several research laboratories and testing installations, including the Gas Turbine Research Center at Bangalore and the Aeronautical Testing Laboratory at Kanpur.[2] Recently, Departments of Space and Electronics have been established as well as a Space Commission and an Electronics Commission. The Prime Minister serves as Minister for the Department of Space, and Dr. S. Dhawan is secretary for the Department of Space.

The University Grants Commission, a statutory body set up in 1953 and responsible directly to Parliament, supports scientific research and promotes education in the universities. It is an influential organ of the government and has the authority to take the necessary measures to promote and coordinate university education and to determine and maintain standards of teaching, examination, and research. The commission disburses grants to national and state universities for higher education in arts, sciences, and commerce; sets up committees to review teaching and research in various fields; and has set up and financed 20 Centers of Advanced Studies, mostly in science.

The Department of Atomic Energy is probably the most effective of the various governmental departments concerned with scientific research. It has better facilities and scientists than the other departments and is in a favorable position because the Prime Minister also serves as the Minister of Atomic Energy (there is no ministry, but rather a Department of Atomic Energy). The Department of Atomic Energy and its subordinate Atomic Energy Commission are headed by Dr. Homi Sethna, who is a secretary of the Government of India. The DRDO and Atomic Energy Commission are responsible for formulating and implementing policies in all matters bearing on nuclear energy research in agriculture, biology, industry, and medicine, and for the development of nuclear power. The department and commission are also responsible for preparing the budget for the program. The Bhabha Atomic Research Center (BARC), Trombay, about 15 miles from Bombay, and the Atomic Minerals Division (which is subordinate to the Physical Research Laboratory) at New Delhi conduct scientific and technical research for the department. The BARC is the national center for research and development in atomic energy and is the largest single research facility in the country. The work of the BARC is done by five groups: Physics Group, Electronics Group, Engineering Group, Metallurgy Group, and Biology Group. The Atomic Minerals Division is responsible for the survey, development, and acquisition of atomic minerals. Other facilities under the department which are concerned with nuclear research are the Tata Institute of Fundamental Research in Bombay and the Saha Institute of Nuclear Physics in Calcutta. The Tata institute works also with the Department of Space.

Although industrial research is very limited, some industrial organizations have established research associations as the result of encouragement and partial financing extended by the CSIR. The increasing research activities of the associations are due to exemptions offered by the government under the Indian Income Tax Act, which exempts the contributions made by industry to approved research organizations from the computation of their total income.

Some of the Indian research establishments were organized originally as private foundations. Most of them are almost wholly supported by governmental grants, although they still have independent boards of directors. Among the most effective of these institutions are the Indian Statistical Institute, Calcutta; the Tata Institute of Fundamental Research, Bombay; the Raman Research Institute, Bangalore; the Bose Research Institute, Calcutta; the Indian Association for the Cultivation of Science, Calcutta; the Shri Ram Institute for Industrial Research, Delhi; the Birbal Sahani Institute of Paleobotany, Lucknow; and the Indian Institute of Science, Bangalore.

The annual budgets of the Indian space and atomic energy programs have increased rapidly in recent years, but large portions of the budgets have been allocated to capital expenditures for atomic power plants, a reac fuel reprocessing plant, and other items. The operating budget for the BARC scientific departments for FY1971/72 (1 April-31 March) was about US$15.6 million. The operating budget for space projects has been increasing at a much faster rate than the BARC budget and was about $8.6 million in FY1971/72.

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

The United States has supplied India with considerable material and financial assistance for the Indian atomic energy program, which has consumed a significantly large portion of research and development funds. The United States lent the Indian Government US$75 million to build a nuclear power station and supplied the fuel at a cost of $15 million. Financial assistance amounting to $3.3 million was received from the United Nations for the construction of a laboratory for the use of radioisotopes in agriculture.

The science and technology plans form an integral part of India's 5-year economic planning. During the period of the Fifth Plan (FY1974/75-1978/79), the government intends to reorient research and development activities and set new priorities. More than US$3.0 billion will be allocated to support the plan, compared to about $500 million under the Fourth Plan (FY1968/69-1973/74). Each plan generally has had such objectives as strengthening and expanding the existing research facilities and creating new ones, training research personnel, and providing research fellowships and scholarships.

Financial support for research and development is increasing somewhat both in terms of total expenditures and the percentage of the gross national product. Expenditures have risen from US$30 million (0..% of the GNP) in FY1958/59 to $223 million (0.43% of the GNP) in FY1970/71. The amount expended by all sources in FY1969/70 was $181 million; of the total, the central government supplied $158 million, the state government $11 million, and the private sector $11 million. Private industry spends only about .00% of total sales on research and development. The central government's research funds in FY1969/70 were allocated as follows:

	MILLIONS OF U.S. DOLLARS
Department of Atomic Energy (R&D only)	37.0
Council of Scientific and Industrial Research	27.3
Indian Council of Agricultural Research	22.1
Indian Council of Medical Research	2.3
Defense Research & Development Organization	20.3
Other Ministries*	48.8
Total	158.7

*Includes: Petroleum, Chemicals, Mines, and Metals; Tourism and Civil Aviation; Education and Social Welfare; Health and Family Planning; and others.

About one-third of the CSIR budget of $27.3 million was designated for capital expenditures. The CSIR provides about 80% of the financial support for nine industrial research associations.

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

In general, the level of science teaching in India is inadequate. Most of the college curriculums are rigidly planned and frozen. The educational practice is set by a university panel or board of studies, with some outside members. Undoubtedly a professor of science has a strong voice also in prescribing the curriculum. Because of a lack of vital laboratory equipment, the Indians tend to deemphasize experimental research and concentrate on theoretical studies, stressing rote taking and memorizing. Also, most students have traditionally concentrated on nonscientific subjects. Bachelor degrees in science and engineering are not comparable to those from Western institutions. The lower quality of scientific education in the Indian higher educational institutions stems in part from the inadequate preparation in the secondary schools, including poor preparation in English, the language used in science instruction.

Government and educational leaders have embarked on a comprehensive priority program for the improvement of science education, but progress has been slow. With U.S. cooperation, Summer Science Institutes on chemistry and other sciences have been held to define objectives and improve methods of teaching science on both the secondary and college levels. While facilities for training scientists and engineers have expanded considerably, the quality of education has suffered. The Indians have attempted to slow down the expansion of existing facilities and stress the establishment of new specialized schools, institutes, and centers for graduate studies. The University Grants Commission has established Centers of Advanced Studies in various subjects at universities, including the University of Bombay, University of Calcutta; University of Delhi; University of Madras; University of Sagar; Jadavpur University, Calcutta; Osmania University, Hyderabad; and Punjab University, Ludhiana.

India has made rapid strides in establishing facilities for higher technical education. From 1951 to 1961 the number of institutions granting degrees in engineering and technology increased from 53 to 111. By 1969, 138 institutions were offering courses in engineering and technology at the bachelor degree level. Five Indian Institutes of Technology have been established since 1951 at Bombay, Delhi, Kanpur, Kharagpur (Figure 2), and Madras. These schools are becoming major centers of scientific and technical education and research. They were established with financial assistance from either foreign countries or UNESCO

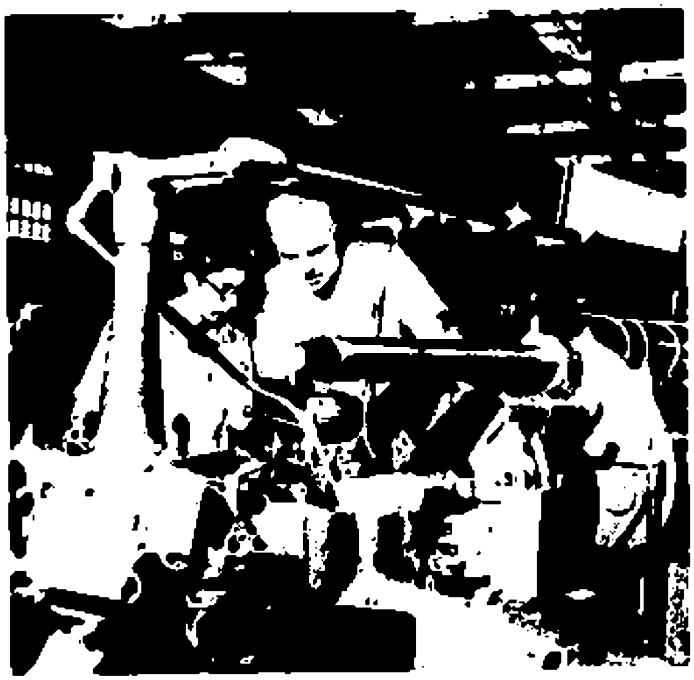


FIGURE 2. Machine shop in Institute of Technology, Kharagpur (U OU)

total AID contributions to the institute at Kanpur reached about $7 million by 1972. Each of the institutes accommodates about 1,500 students at the undergraduate level and about 400 at the postgraduate level.

About 50 Indian universities have science departments and half of these have active research programs. Faculty members at some of the older universities have produced outstanding research as part of their educational programs. In 1965 about 30% of the Indian college students were studying science while about 30% were studying engineering, medicine and agriculture. The number of students in postgraduate science courses in all fields is increasing substantially. In 1968, India graduated about 110,000 persons trained in science, engineering, and technology, including 15,000 postgraduates, 11,000 graduates in science, 11,000 engineers and technicians with degrees, 21,000 engineers and technicians with diplomas, 7,000 graduates in agriculture and veterinary medicine, and 7,000 medical school graduates.

India has a shortage of adequately trained scientific and technical personnel for research despite a growing supply of scientists and engineers. The number of researchers and the total number of scientific and technical personnel have increased 2½ times since 1961. In 1971 there were an estimated 1,187,300 scientists and technicians in the country, 71,750 of whom were engaged in research. The following tabulation provides a breakdown of the total number of scientific and technical personnel by specific fields of research:

Field of research	Total scientific personnel	Number in research	Percentage of total
Agriculture (Postgraduates, including doctors)	13,500	5,371	39.79
Agriculture (Graduates)	47,200	1,995	4.23
Engineering (Graduates)	185,400	13,440	7.20
Engineering (with diploma)	244,400	4,051	1.67
Medicine (Graduates)	97,800	9,399	9.60
Medicine (with diploma)	27,000	640	2.37
Science (Postgraduates and doctors)	139,200	20,762	14.92
Science (Graduates)	420,000	9,492	2.26
Veterinary medicine (Graduates)	13,000	1,602	12.32

The output of engineering institutes has expanded sufficiently to meet the demands for engineers, and in 1969, 40,000 engineers were reportedly unemployed. Highly specialized personnel in certain fields are not readily available, however, and many jobs in universities and research organizations remain vacant. The scientific manpower deficiency has been aggravated somewhat because many students, a large number of whom represent the outstanding young scientific talent of the country, have gone to foreign countries for advanced education in engineering and the sciences and have not returned. In 1967 the number of Indian scientists and technologists abroad was about 20,000 to 25,000, half of whom were in the United States. Since job opportunities for scientists and engineers especially have been somewhat restricted, the loss to other countries has not created serious problems except in a few specialized areas. The government is attempting, with some success, to persuade foreign-trained Indian scientists to return to their homeland. The CSIR maintains a pool which has been responsible for the temporary placement of a limited number of well-qualified Indian scientists and technologists returning from abroad. In recent years, the pool has been expanded greatly and has become a sanctuary for unemployed scientists. There is a deep-rooted dissatisfaction among scientists, both at home and abroad, about the commitment of India's political, administrative, industrial, and educational leadership to use science purposefully as a means of social transformation or government action. Probably the most dramatic indication of disillusionment is the significant overseas migration of high level professional talent in many fields.

Salary scales of Indian scientists have improved, although they are still low; a new Ph. D., who could be quite good, commands less than $100 a month salary. The social status of scientists is gradually being raised. Many scientists, however, still consider administrative positions in the government to be preferable to scientific positions. Educated Indians are becoming more aware of the role of scientists and technologists in the progress of the country, but most of the population has little understanding of the relationship of science to its welfare.

Laboratory facilities for research are generally inadequate, although there are a few well-equipped laboratories. Many higher educational institutions and research institutes lack modern scientific equipment. Probably the largest and most important research facility is the BARC. It has well-equipped laboratories for research in physics, chemistry, electronics, metallurgy, and biology; the facilities include three nuclear reactors. The BARC has about 10,000 employees, about 2,000 of whom are scientists and 4,000 of whom are technicians. It has a training school in which more than 150 graduate scientists and engineers receive training for 1 year in various disciplines concerned with nuclear energy. The National Chemical Laboratory at Pune (Poona), under the CSIR, has excellent facilities for research in chemistry and chemical engineering. Many other CSIR laboratories are also equipped for their special types of work. The All-India Institute of Medical Sciences, New Delhi, founded in 1956, is housed in extensive, modern facilities.

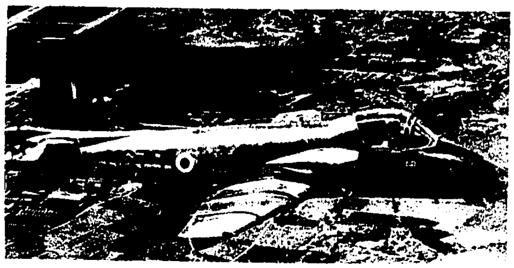
D. Major research fields

1. Air, ground, and naval weapons (S)

India's capability to manufacture foreign-designed weapons is advancing at a moderate pace. Although foreign-designed systems are produced, the industrial capacity is insufficient to meet military requirements. Defense research activities are carried out in about 30 research and development establishments functioning under the Defense Research and Development Council (DRDC), which is attached to the Department of Defense Production of the Ministry of Defense. The DRDC is responsible for coordinating and directing scientific research relating to defense problems. It also controls several research laboratories and testing installations, including the Gas Turbine Research Center at Bangalore and the Aeronautical Testing Laboratory at Kanpur. The Defense Research Laboratory (Materials), Kanpur, is devoted to research and development of plastics, polymers, POL, and chemicals. Desert research activities are conducted at the Defense Laboratory, Jodhpur, which also field tests equipment under desert operations. India is virtually self-sufficient in the production of small arms and quartermaster equipment and can produce most of the ammunition needed by the army. Considerable effort is being made to stimulate applied research in solid-propelled rocketry, propellants, ammunition, airframes and components, and avionics.

Aeronautical research related to the design, construction, and operation of aircraft is conducted by the National Aeronautical Laboratory (NAL) of the CSIR and the Indian Institute of Science, both at Bangalore. Limited basic research is conducted at these organizations and at academic institutions where excellent courses in aeronautical engineering are offered. The only aircraft company in India, Hindustan Aeronautics Ltd. (HAL), is under the

HF 24-Marut



HJT-16 Mk II Kiran

FIGURE 3. Experience with these two indigenous designs should aid future development efforts (S)

Department of Defense Production of the Ministry of Defense. HAL is a vast complex with manufacturing facilities for aircraft and helicopters in Bangalore, Kanpur, and Nasik; for aircraft engines in Bangalore and Koraput; and for electronics in Hyderabad.

India has developed two aircraft of indigenous design—the HF-24 Marut single-seat, twin-jet fighter and the HJT-16 Mk II Kiran two-seat basic jet trainer (Figure 3). Although both systems have been test flown and are being produced in limited numbers, they have design weaknesses that restrict their performance. Neither system is a state-of-the-art achievement nor competitive with many foreign systems. Nevertheless, the Indians have acquired design and engineering experience from these programs which can be applied to future development efforts. Attempts are underway to acquire similar capabilities in the technologies needed for aircraft engine development and production. The Bangalore Division of HAL is producing engines, based on foreign designs, for the Marut and Kiran, a transport, and the French Alouette III helicopter, being produced in India under license from the French. The HAL is fabricating MiG-21 (FISHBED) fighter airframes and engines from locally produced components, under a license agreement with the U.S.S.R. (Figure 4). HAL at Bangalore also produces indigenously designed agricultural aircraft, named Revathi, for crop spraying. This piston powered single engine plane is heavier and more expensive than similar Western aircraft.

Aerodynamics research is accomplished by the HAL, NAL, and the Indian Institute of Science in wind tunnels capable of continuous testing up to Mach 5.0. The facilities appear adequate to support the needs of the developing aircraft industry. The major facilities are located at the NAL's Wind Tunnel Center near Bangalore Airport. Although most of the work underway focuses on solving design-related problems, some basic research on boundary layer flow is being done.

Structures research is good but limited in scope. Both basic and applied structures research is conducted at the Bangalore Division of HAL, the aircraft structures and materials division of NAL, the Indian Institute of Science, and the Madras Institute of Technology. Full-scale aircraft strength and vibration test facilities, as well as smaller equipment for component testing, are available.

There is no concrete evidence that the Indians have a ballistic missile research and development program underway. India has the industrial capacity and know-how to fabricate surface-launched guided missiles and is gradually acquiring the capability to design and develop such weapons. The Indians are assembling the French SS-11 antitank missile from imported components and have concluded an agreement with the French firm, *Aerospatiale*, for the licensed production of the Harpon antitank missile and for options on obtaining production licenses for the Hot and Milan antitank weapons. Rocket components and propellants are manufactured at several facilities, the most important of which is the

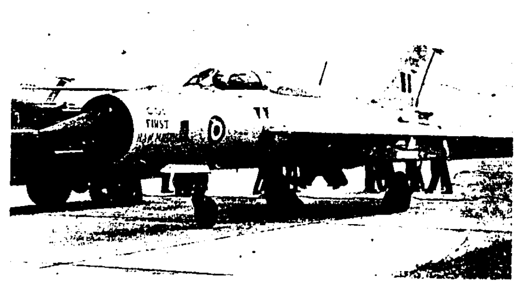


FIGURE 4. First MiG-21 with airframe built entirely from Indian raw materials at HAL's Nasik Division (S)

factory of Bharat Dynamics, Ltd. in Calcutta. This facility has design and development departments and produces the French antitank missiles. Capabilities in the rocket propulsion field have increased remarkably. The Indians have successfully developed solid propellants for their meteorological rockets and are working on a 1-meter diameter solid propellant rocket motor for a satellite launch vehicle under development. India has not demonstrated a capability to develop liquid rocket systems.

The Indian research and development capability for ground force weapons is limited; most of the efforts are devoted to the adaptation of foreign designs and development for domestic production. The most advanced project of this type is the modification of a main battle tank initiated in 1964 under an agreement with the British firm, Vickers-Armstrong, Ltd. The Indian version is a medium tank, designated Vijayanta, which mounts a 105-millimeter gun as its main armament and which, when fitted with a nylon screen for flotation, has an amphibious capability. The Indians have progressed from assembly of British-supplied parts to the manufacture of the main components for the tank at the Heavy Vehicle Factory at Avadi near Madras. The Vijayanta has been used as the basis for other developments, including an armored recovery vehicle and a self-propelled 130-mm gun artillery system.

India has developed and tested antipersonnel and antitank mines, and a mechanical mine planter of native design has been introduced into the army. Research is continuing on propellants for small arms and artillery, and some work is underway on explosives. Other research projects have included a canister ammunition for 57-mm and 106-mm recoilless rifles. The French have provided technical assistance on development of 120-mm mortar ammunition. An indigenous research effort has been underway on developing a 75-mm pack howitzer with supporting ammunition and a 105-mm howitzer. Reportedly, the 75-mm pack howitzer is in production.

A major effort is being expended in the development of clothing and individual equipment. Military research facilities have performed high-quality research, particularly on textiles. The trend in clothing design and development is characterized by emphasis on the environmental parameters, especially protection from cold-weather conditions. Considerable work also has been done on shelters, fuel, and rations for troops in the Himalayan area. Some work is underway applicable to troops in deserts. Research is continuing on biodeterioration of textiles, cellulosics, rubbers, leathers, polymers, paints, and metals. Much of the research is done under the supervision of the Defense Research Laboratory (Materials), Kanpur.

Limited work is being carried out on military transportation, airdrop, bridging, and topographic equipment. The Indian Institute of Technology in Madras has a materials conveying and handling laboratory with modern experimental and testing equipment. Only limited research and development have been performed on bridging equipment. Little effort is devoted to military motor-transport equipment.

India does not have a naval weapons research and development program, and efforts by the navy to initiate such a program have been unsuccessful. Until expansion of the naval base at Vishakhapatnam is completed in mid-1974, the only naval yard capable of handling the larger Soviet-supplied ships is the one at Bombay. Since 1962 the largest dockyard, Mazagaon Docks, Ltd., Bombay, has built British LEANDER-class destroyers, while two smaller dockyards in Calcutta have constructed smaller naval combatants.

2. Biological and chemical warfare (C)

India is not known to have a biological warfare (BW) or chemical warfare (CW) research and development program, and it has signed the Biological Warfare Convention of 1972. The country adheres to the Geneva Protocol of 1925, which bans the offensive use of toxic chemicals or biological weapons. Several institutes engaged in microbiological research aimed at improving health standards of the Indian people could be employed in the support of BW research. Microbiological research is underway on drugs and vaccines to control endemic human and animal diseases, such as cholera, enteric fever, typhoid, foot-and-mouth disease, encephalitis, yellow fever, and anthrax. Research on plant diseases is directed against rice blast, bacterial blight of rice, wheat rust, and viral diseases of potatoes and sugarcane.

3. Atomic energy (S)

India has established a fairly advanced nuclear energy program, under the direction of the Atomic Energy Commission, encompassing basic research, the use of radioisotopes, and the development of nuclear power. The overall program is somewhat limited due to a shortage of trained personnel, lack of foreign exchange to purchase needed equipment abroad, and an insufficient industrial base to support a large scale program. Nevertheless, the nuclear program reached a stage of development several years ago which would permit India to embark on a small nuclear weapons program if it should decide to do so.

The principal efforts of the Atomic Energy Commission have been the establishment of the Bhabha Atomic Research Center (BARC) and the construction of nuclear power stations. The major research facilities of the BARC are ASPARA, a 1-megawatt (MW) swimming pool reactor, which went into operation in 1956; CIRUS, a 40-MW heavy water moderated, natural uranium fueled research reactor, which went critical in 1960; and ZERLINA, a zero energy critical assembly, which went into operation in 1961.

The enriched uranium fuel for the ASPARA reactor was supplied by the United Kingdom, but the natural uranium fuel for the CIRUS and ZERLINA reactors was produced by India except for one-half of the first fuel load of the CIRUS that was supplied by Canada. Heavy water for the CIRUS and ZERLINA was supplied by the United States. A small heavy water production plant at Nangal went into operation in 1962. This plant produces heavy water as a byproduct of a fertilizer plant and has a capacity of 14 tons per year. In addition, a 67.2-ton heavy water plant is under construction at Vadodara (formerly Baroda), due to go into operation in 1973. Three other heavy water plants are also under construction—a 100-ton plant at Kota, due to go into operation in 1974, a 71.3-ton per year plant at Tuticorin, due to go operational in 1974-75, and a 62.7 ton plant at Talcher, due to go into production in 1976.

India plans to establish, with French assistance, another nuclear research center near Madras at the future nuclear power station of Kalpakkam. The center is expected to take about 5 years to build and will include a 10-MW test reactor for work on fast reactor technology, which would be aimed at utilizing India's extensive thorium deposits for producing power.

The Indian Government has stated that it does not intend to develop nuclear weapons, but government officials have indicated that development of nuclear explosives for peaceful uses is receiving serious consideration. Such explosives would have an obvious military potential. India has all the facilities necessary for the production of small amounts of plutonium for use in nuclear explosives. BARC possesses facilities for uranium metal production, fuel fabrication, irradiated fuel reprocessing, and plutonium metal reduction.

India plans to have three nuclear power stations in operation by about 1975. The first nuclear power station located at Tarapur, about 60 miles north of Bombay, went into full operation in June 1969 with an installed electric power capacity of 380 megawatts electrical (MWe). This station consists of two U.S.-supplied boiling water reactors using slightly enriched uranium provided by the United States. The second nuclear power station is being constructed near Rana Pratap Sagar Dam in Rajasthan with Canadian assistance and will have two natural uranium fueled, heavy water moderated reactors, identical to the 200-MWe Canadian CANDU-type reactors. One of the two reactors began operation in August 1972, while the second reactor is expected to go into operation by 1975. These reactors are to be under safeguards intended to prevent diversion of plutonium to weapons use. India is constructing a third nuclear power station at Kalpakkam, in Tamil Nadu, which is identical to the Rajasthan station; work has started, but there is no firm project date for the station to go into operation.

Uranium and thorium mining have been underway since 1951 using monazite deposits of the southwest coast of India. The country possesses one of the world's largest deposits of monazite, the principal source of thorium, and also has large low grade reserves of uranium. Uranium is being mined in the State of Bihar at Jaduguda (near Jamshedpur) by the Uranium Corporation of India, Limited. A mill capable of processing 1,000 tons per day of low grade ore has been in operation since 1968. Plans are underway to develop a 2,500 tons per day mill at Narwapahar, near Jaduguda.

4. Electronics (S)

Electronics research and development continue to grow at ever-increasing rates, largely because of technical assistance from the United States, the United Kingdom, and the Soviet Union. The research is mostly applied and centers on the improvement of existing systems and components. The Telecommunications Research Center at New Delhi of the Ministry of Communications has the most active electronics research program in India. The center has designed or improved telephone exchange, converter, and ringing equipment. Industrial electronics research is carried out by four major producers of electronic equipment—Bharat Electronics, Bangalore; the electronics division of the HAL in Hyderabad; the Electronic Corporation of India, Hyderabad; and the Indian Telephone Industries. Each of these companies was established to assemble specific equipment under license and subsequently acquired an indigenous capability to develop the equipment. The Indians are doing good quality research in radio propagation, but the work is not extensive.

The Indians have made considerable progress in the design of converters for translating teleprinter codes to pulses that operate step-by-step switches. Radio relay equipment operating at 7 gigahertz and providing 300 telephone channels has been developed. The National Physical Laboratory of the CSIR at New Delhi has conducted extensive ionospheric research. Significant electromagnetic research in the field of surface wave phenomena has been carried out by the Indian Institute of Science. Some work has been done on the practical application of laser communications. Limited research has been conducted on transistorized devices such as telephone repeaters and carrier equipment.

5. Medical sciences, including veterinary medicine (S)

India is making substantial progress in its national program to improve the quality of biomedical research but is still far from achieving the research level of advanced countries, especially in fundamental studies. Research programs are coordinated by the CSIR and the Ministry of Health and Family Planning, with its associated Indian Council of Medical Research (ICMR). The council has seven permanent research institutes—the National Institute of Nutrition, Hyderabad; Virus Research Center, Pune (formerly Poona); Cholera Research Center, Calcutta; Tuberculosis Chemotherapy Center, Madras; Occupational Health Research Institute, Ahmadabad; Institute for Research in Reproduction, Bombay; and the Indian Registry of Pathology, New Delhi. The latter facility has five peripheral centers. Biomedical establishments of the CSIR include the Indian Institute of Experimental Medicine in Calcutta, and the Central Drug Research Institute, Central Indian Medicinal Plants Organization, and Industrial Toxicology Research Center, all in Lucknow.

Education in biomedicine is of poor quality. The government has embarked on a program, with U.S. assistance, to improve training in the discipline. The most important medical school is the All India Institute of Medical Sciences in New Delhi, which receives support from the United States and the World Health Organization (WHO) and through the Columbo Plan. The institute provides a good education in biomedicine; its professors are among the world's best.

Priority areas of research supported by the ICMR include reproductive biology, family planning, nutrition, and disease control. Microbiological research is not outstanding. The ICMR has created a division of clinical immunology and epidemiology which supports research to combat infectious diseases such as plague, cholera, and viral diseases, and noninfectious diseases such as diabetes, epilepsy, and diseases of the eye. Plague studies are undertaken by the All India Institute of Medical Sciences, the Haffkine Institute in Bombay, and National Institute of Communicable Diseases in Delhi. The Indian Institute of Experimental Medicine is investigating the epidemiology and prophylaxis of cholera and is developing phage-typing techniques for study of classical and El Tor strains of cholera infections and for differentiation of the types of cholerogenic vibrios. Research at the Central Research Institute at Kasauli is directed to the development of vaccines and serums, the preparation of national reference standards, and training of personnel.

Some impressive physiological research is done on neurophysiology, cardiovascular function, and sleep. Biochemical studies are practical and include the isolation of enzymes involved in microbial metabolism, the biochemistry of pneumoconiasis, the isolation from tissues of tumor growth inhibitors, and the biochemical and biophysical organization of intercellular tissues. Lyophilized snake venom, pure fatty acid esters, and papain have been isolated. Studies are underway to synthesize organic chemicals by fermentation. A promising area of research at the Assam Medical College in northeast India is the study of hemoglobinopathies and their relation to tribal groups. S. R. Mukherjee of the Department of Experimental Medical Sciences of the Institute of Postgraduate Medical Education and Research in Calcutta has discovered an antiepileptic drug and has contributed to research on the endocrinological, physiological, and pharmacological effects of indigenous plant drugs. He also has done research on cardiovascular homeostasis.

The Central Drug Research Institute of the CSIR is doing routine work on the development of new therapeutic agents, both synthetic and those derived from plants. Pharmacological screening of the drugs includes tests for hypotensive, anticonvulsant, central nervous system stimulant and depressant, spasmolytic, analgesic, diuretic, antihistaminic, and anti-inflammatory action. Biochemical and biophysical studies of drugs are aimed at blocking the metabolic pathways of pathogenic organisms and at attacking vulnerable enzyme systems of helminths and amoebas. Intensive biological screening of medicinal plants is an integral part of the drug development project of the institutes. Medicinal chemistry is given considerable attention in the survey and screening of medicinal plants to discover new drugs and alternative sources of drugs in use. The plants are screened for antifilarial, antihelminthic, antiviral, antifungal, antiamoebic, and antitumor acti ity. A national herbarium is maintained in Calcu ta which supports research on plants of medical and economic importance to India.

The Industrial Toxicology Research Center is studying the mode of action of toxic substances encountered in industry, agriculture, and mines and is elucidating the mechanisms of tissue injury in order to suggest therapeutic and preventive measures. Psychopharmacological tests also are carried out to detect behavioral changes associated with intoxication by substances which affect the brain.

The Central Food Technology Research Institute of the CSIR in Mysore, in collaboration with FAO, is the International Food Technology Training Center for the countries of South and Southeast Asia. The institute is developing improved methods of processing, storing, and preserving food materials and has produced a protein-rich dairy product which includes buffalo milk, peanut meal, and skim milk powder. A feasibility study is underway on a field testing instrument for use in the assay of fortified and high protein staple and processed foods. Irradiation of foodstuffs is being carried out, and tests are underway on preservation, prevention of infestation, and pasteurization. The medical aspects of radiation are being studied in conjunction with the Indian nuclear energy program, and a training course in food irradiation is given at the BARC.

In the area of family planning, India is undertaking extensive demographic research and studies in reproductive biology and fertility control. Drug and mechanical contraceptive devices are being developed by the Central Drug Research Institute.

Military medical research for the three services is conducted by the Defense Institute of Physiology and Allied Sciences at New Delhi, the Defense Research Laboratory (Materials) at Kanpur, and the Institute of Nuclear Medicine and Allied Sciences at Delhi. The emphasis is on high-altitude and mountain-warfare operations, especially on food and water requirements, pulmonary edema, and injuries sustained under cold weather conditions. The Indian Air Force School of Aviation Medicine at Bangalore conducts research on aviation physiology, including light flash effect, particularly on night vision, factors affecting mental and psychomotor functions of aircrews, and the effect of tropical heat and humidity on personnel during preflight procedures. Research related to naval physiology concerns close living on submarines and ships, noise on aircraft carriers, arterial air embolism during ascent from shallow dives, and speed perception.

The Indian veterinary medical research capability is limited. Veterinary research is primarily applied and oriented to the animal diseases of major economic significance. The Indian Veterinary Research Institute, with laboratories at Izatnagar and Mukteswar, both in Uttar Pradesh, has an active program to develop methods for large-scale production of effective vaccines for hemorrhagic septicemia and rinderpest. Veterinary research also is carried out by the Institute of Veterinary Preventive Medicine at Ranippettai (formerly Ranipet) and the Central Leather Research Institute at Bangalore. In general, research emphasizes the development of improved vaccines and biologicals and of methods for quantity production. The animal diseases of major importance are foot-and-mouth disease, Newcastle disease, rinderpest, tuberculosis, salmonellosis, anaplasmosis, brucellosis, rabies, and glanders. Infectious infertility diseases, especially vibriosis and trichomoniasis, are a major cause of economic loss to the livestock industry. Significant financial support is provided by the U.S. Agency for International Development, the U.N. Food and Agriculture Organization, the United Kingdom, and private foundations.

6. Other sciences (S)

a. Chemistry and metallurgy

A substantial amount of research in chemistry and metallurgy is conducted. Although much of it is routine and lacks originality, the research has been of sufficiently high quality to offer satisfactory solutions to many of the problems associated with materials development. The universities devote a large part of their effort and personnel to basic chemical research. Most of the applied research is done in such facilities as the BARC, the National Chemical Laboratory, the Central Electrochemical Research Institute at Karaikkudi, and various central and regional laboratories set up for specific fields of chemical research. Chemical and metallurgical research by private industry is very weak.

India appears strongest in organic chemistry, and some of the best research has been done in this area. High-quality basic research has been done on the isolation, characterization, and synthesis of natural products derived from native plants. Probably the best work is done by researchers at the University of Delhi under the direction of T. R. Seshadri on chalcones,

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flavonoid compounds, coumarins, terpenes, plant pigments, and other natural products. The Punjab University has an active research program on terpenoids and on heterocyclic compounds containing both nitrogen and sulfur. The Institute of Science at the University of Bombay stresses research in organic chemistry, particularly the synthesis and reactions of heterocyclic compounds. The National Chemical Laboratory is strong in organic chemical research and is doing research on the synthesis of heterocyclic compounds, such as azulenes, thiophenes and related compounds, and epoxides. It recently has become interested in the synthesis and reactions of isocyanates. Considerable work is done on anthraquinone and violanthrone dyes and on the applications of nuclear magnetic resonance spectroscopy and mass spectrometry to problems concerning dyes. Only a small amount of research is devoted to polymers, synthetic fibers, and synthetic rubber, fields of chemistry that receive extensive study in the more industrially advanced countries. In general there is only limited activity in physical organic chemistry, partly because of a shortage of modern instruments at most laboratories.

Research in biochemistry is very weak. Some research is pursued at several facilities, including the biochemistry department of the All-India Institute of Medical Sciences in New Delhi. The department has done some research on estrogen binding, brain ribonucleic acid, and polypeptides.

A considerable amount of research is underway in inorganic and analytical chemistry. Much of the research in inorganic chemistry is concerned with the study of ferrocyanogen complexes in general, heavy metal soaps, interaction of metal ions with gelatin, and polarographic and spectrophotometric studies. The BARC has been actively working on neutron activation analysis, spectrographic determination of metals, and spectrophotometric analysis, particularly as related to the field of nuclear energy. Many problems in inorganic chemistry related to the preparation and processing of nuclear fuels are studied in the BARC laboratories. The Indian Institute of Science, the University of Allahabad, and the University of Delhi have active programs for the development of specialized analytical techniques. The institute has developed an extraction technique which is used in conjunction with neutron-activation analysis. Analytical techniques related to soil and fertilizer chemistry also are being studied by the Fertilizer Corporation of India at Sindi, several universities, and agricultural colleges.

Research in physical chemistry is fairly broad and includes studies on chemical kinetics, structural and quantum chemistry, surface phenomena and catalysis, thermodynamics, and electrochemistry. One of the important physical chemists in the country, Ram C. Paul of Punjab University, has worked extensively on Lewis acid complexes and on the properties and uses of polar solvents such as organic acid chlorides, dimethylformamide, nitro compounds, and ethyl acetate. The Central Electrochemical Research Institute is the major Indian facility for research in the theoretical and applied aspects of electrochemistry. It works on electroplating of metals and alloys, electrolytic and electrothermal processes for production of metals and chemicals, electrolytic oxidation and reduction of organic compounds, corrosion, and corrosion inhibition.

For an underdeveloped country, India conducts a surprisingly large amount of metallurgical research. Most of it is of a fundamental nature, however, and is of little benefit in improving the very low level of metallurgical technology in the country. The research is not well coordinated. The effort is supported by foreign funds, mainly from the United States, the U.S.S.R., and the United Nations. Most of the research is undertaken at the National Metallurgical Laboratory of the CSIR at Jamshedpur and at the BARC. Some research also is carried out by the Indian Institutes of Technology in Kharagpur, Kanpur, and Bombay; the Indian Institute of Science; the Defense Metallurgical Laboratory in Hyderabad; the National Aeronautical Laboratory in Bangalore; the University of Roorkee; and the Banaras Hindu University in Varanasi. The effort at the institutes of technology is directed primarily to producing engineers.

Research at the National Metallurgical Laboratory has concerned a wide variety of subjects including the benefication and reduction of ferrous and nonferrous ores, the physical metallurgy of steel, the development of special steels, oxidation and corrosion studies, and the conservation of critical metals. The laboratory operates several pilot plants, a corrosion research station at Dighwara in West Bengal, and a foundry station at Batala.

The Defense Research Laboratory, a well-equipped and staffed facility, conducts research on military metallurgical problems. Considerable research has been conducted on corrosion and stress corrosion cracking of military hardware. Studies have been done on roasting of copper ores, the powder metallurgy of copper, coatings for refractory metals, explosive welding, and stress corrosion cracking of low-alloy and stainless steels. The National Aeronautical Laboratory has done considerable high quality research on recrystallization, age hardening in aluminum alloys,

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and creep and rupture of heat-resistant alloys. The laboratory excels in crystallography and electron microscopy.

The BARC has carried out extensive research on materials for nuclear application. The work has concerned the production of nuclear metals, the fabrication of nuclear grade zirconium alloy mill products, the cladding of fuel elements, corrosion of nuclear metals, and the effects of radiation on the properties of structural materials.

Most of the university-conducted research is done at the University of Roorkee and the Banaras Hindu University. The main area of research is metal physics, especially the electronic structure of metals and alloys.

b. Physics and mathematics

Although India possesses the potential for conducting research in a number of subfields of physics, capabilities with few exceptions are low. In general, efforts underway are only attempts to refine research done by other countries 10 to 20 years ago. Almost half of the physics research is devoted to the broad areas of solid-state physics. Research in high- and low-energy nuclear physics also is stressed. The remaining subfields of physics receiving a significant amount of attention are optics, gravitation and relativity, atomic and molecular physics, acoustics and ultrasonics, magnetohydrodynamics (MHD) of fluids, and quantum electronics. A large amount of research is done in theoretical physics because of the lack of equipment needed to conduct experimental research. The best physics research is carried out by the BARC, the Tata Institute of Fundamental Research, the Saha Institute of Nuclear Physics, and the Indian Institutes of Technology at Bombay and Kanpur.

Solid-state physics research has concentrated on the study of properties of materials. Research in crystallography is done in the universities and supports the solid-state physics research effort. Physicists are studying crystal structures of many semiconductor elements and compounds. Some research has been done on the preparation, purification, and growth of single crystals of indium antimonide which can be utilized for further developments of photosensitive elements. The Solid-State Physics Laboratory in New Delhi is active and modern.

India is doing a limited amount of basic research in nuclear physics. Most of the universities and technical institutes conduct some research in the field, but most of it is of an academic nature related to advanced degrees. High-energy nuclear physicists are investigating many aspects associated with nuclear structures and energy levels and are highly competent in their theoretical studies dealing with hadron scattering and interactions. Some work has been done in cosmic ray research with the support of the United States, the United Kingdom, and Japan. Research in low-energy nuclear physics is devoted to the study of reactions and decay schemes associated with isotopes. The most impressive work, although conventional by world standards, is being done at the Saha Institute of Nuclear Physics, where investigators are studying neutron emission from prompt fragments in the fission of excited nuclei.

A modest amount of research is being carried out in physical and geometrical optics, with most of the work concentrated at the National Physical Laboratory and the Indian Institutes of Technology in Bombay and Delhi. Physical optical research is closely related to the study of dark field images under coherent illumination. A significant portion of optical physics research is related to spectroscopy and dark-ground microscopy. Some geometrical optics research is related to optical components associated with lasers. Among the many applications of lasers being investigated are uses for communications and holography. Most of the laser research occurs at the Institute of Technology in Bombay, where the effort is centered on holography.

Research in theoretical physics has stressed the study of gravitational fields and relativity. Most of such studies are underway at the Institute of Theoretical Physics and various larger universities. Some experimental work is underway on a limited scale on the effects of varying axial magnetic fields on the stability of gravitating cylinders.

Research in atomic and molecular physics is concerned with studies dealing with Raman, infrared, vibrational, and emission spectra of various chemical compounds associated with organic molecules. Ultrasonics and acoustics research is limited to the study of shock waves by researchers at the Defense Science Laboratory. The Indians are showing an increasing interest in MHD. Studies are theoretical and have concerned the general theory of hydromagnetic wave propagation in a magnetoactive plasma. The best research is centered at the Institute of Technology in Bombay where all aspects of MHD and magnetogasdynamics are being explored.

Contributions in mathematics have been insignificant. The quantity of research has increased since 1966 but is still meager and generally of low quality. The emphasis has been on applied statistics largely because of strong governmental support and encouragement, which is based on the need for accurate and practical statistical methods for population surveys and governmental planning operations. The Indian Statistical Institute in Calcutta conducts research in the field and acts as a consumer research organization. The Indians have begun research in analysis, especially in function theory and infinite series. Mathematicians at the universities are maintaining some interest in sets, logic, and number theory, but the research is superficial. There is some interest in differential geometry, but no activity in topology.

India has had modest computer research and development projects at the National Computing Center of the Tata Institute of Fundamental Research and at BARC; most of the Indian applications, however, have depended on imported computers. The BARC has developed a small computer, the TDC-12. India also has made some computer ancillary devices under license and has negotiated with the United States and West European countries for licenses to produce electronic components and circuits for both domestic use and export. Several Indian facilities have received technical advice and a few models of computers and related devices from the U.S.S.R. The government has established a National Computer Corporation with headquarters at New Delhi. India is a member of the International Federation of Operations Research Societies but has not made any contribution to this branch of mathematics.

c. *Astrogeophysical sciences*

Research in astronomy is increasing. The most important center of research is the Nizamiah Observatory of Osmania University of Hyderabad. The section of the observatory near Rangapuram, 40 miles southeast of Hyderabad, is equipped with a 48-inch reflector supplied by the United States. The Department of Astronomy at the university, together with the observatory, has been designated a Center of Advanced Study in Astronomy by the University Grants Commission. The observatory has participated in the international preparation of astrographic catalogs and during 1965 cooperated with Mount Wilson Observatory, California, for the measurement of star radials. It also has conducted studies of variable stars and theoretical studies on the dynamics of galaxies and of close binary systems. The observatory is the best equipped in southern Asia and is important to international astronomy because there is no other low-latitude observatory of comparable capability between Egypt and Japan. Other optical astronomical research, some of which is solar, is conducted at the Astrophysical Observatory, Kodaikanal, of the India Meteorological Department. Research in astrophysics also is carried out by the Uttar Pradesh State Observatory at Naini Tal and the Department of Physics and Astrophysics of the University of Delhi, designated a Center of Advanced Study in Theoretical Physics and Astrophysics by the University Grants Commission.

While a minor amount of research is done elsewhere, the principal facility for radio astronomical research is the radio telescope at Ootacamund, in southern India. It was designed and built under the direction of the Tata Institute of Fundamental Research and became operational in 1970. Located near the earth's geographical equator, it is unique in that its longitudinal axis is parallel to that of the earth, permitting it to follow radio sources continuously for up to 9 hours 30 minutes. The telescope will be used to study radio emissions from distant galaxies and from pulsars and quarsars.

India is active in ionospheric and radiophysical research, and individual scientists have done outstanding research in the fields. The Institute of Radio Physics and Electronics of the University of Calcutta has been designated a Center of Advanced Study for Radio Physics and Electronics. Ionospheric and radio propagation studies are conducted by a number of other organizations, notably the Radio Propagation Unit of the National Physical Laboratory, New Delhi, and the Physical Research Laboratory of the Ahmadabad Education Society, Ahmadabad. Research has included, in addition to making ionosonde observations, ionospheric absorption and drift studies, Faraday rotation measurements of satellite transmission, and very-low-frequency propagation investigations. Airglow and cosmic ray studies also are made, the latter mainly by the Tata Institute of Fundamental Research and the Physical Research Laboratory.

Meteorological research is largely of an applied nature. Emphasis has been placed on data collection and transmission and on designing and producing instruments. India has a well established weather service, the India Meteorological Department; it is headquartered in New Delhi and has an Institute of Tropical Meteorology in Poona. The department and institute have emphasized research on rainfall in India. Work in weather forecasting is not highly advanced, but good work is done in the study of monsoons and the general circulation of the atmosphere. A U.S. installed automatic picture transmission (APT) receiver is located at Bombay to receive transmission from U.S. meteorological satellites. Other receivers are located at Calcutta, New Delhi, and Madras. India is establishing a radar storm-warning network along its coasts and a cyclone warning and research center at Madras.

Since the early 1960s India has developed and subsequently maintained an active upper atmospheric research program. Through its participation in international programs and as a result of benefits derived from foreign technical assistance, the country has acquired a rudimentary capability in some space associated sciences, particularly those relating to communications. The Indians have conducted with the Soviets a sounding rocket program for meteorological purposes over the last 2 years; some 100, M-100 rockets were launched. The upper atmospheric research program received a boost in 1964 when India signed a licensing agreement with France to produce the *Centaure*. The first launch of an Indian-manufactured *Centaure* occurred in February 1969. The technical know-how acquired in the production of the *Centaure* has enabled India to develop its own sounding rocket program. The first of the single stage *Rohini* series was test fired in November 1967, and the first of the *Menaka* series, a two-stage sounding rocket, was test fired in late 1968. Fuel for these two rockets was produced in facilities at Khadki (formerly Kirkee). Later generation rockets of the *Rohini* and *Menaka* series are under development. India also is developing a four-stage solid propellant satellite launch vehicle with a liftoff weight of 17 metric tons.

Dr. U R. Rao of the Indian Physical Research Laboratory reported that prototype fabrication of India's first satellite is underway. The 250-kg *Rohini* satellite is scheduled to be launched in 1974 using a Soviet Cosmos launch vehicle from a launch pad in the Soviet Union. The spacecraft is to carry out three scientific experiments, including ionospheric and X-ray measurements.

Management of the space program appears to be divided between the Indian Space Research Organization (ISRO) of the Department of Atomic Energy and the Indian National Committee for Space Research (INCOSPAR) under the Indian National Science Academy. Apparently, ISRO is the principal governmental agency managing the more applied aspects of the country's space research program, such as those involved in the design, development, and production of space hardware; INCOSPAR is focusing greater attention on the thematic study of the space associated sciences. INCOSPAR continues to represent India at meetings of the International Committee on Space Research (COSPAR). Additional organizations concerned with the space program are the Physical Research Laboratory at Ahmadabad, the National Physical Laboratory at New Delhi, the Astrophysical Observatory at Kodaikanal, the Tata Institute of Fundamental Research, and the Meteorological Center at Colaba.

In 1963 INCOSPAR, with the assistance of the United States, France, and the Soviet Union, established a modest sounding rocket launch facility, the Thumba Equatorial Rocket Launching Station (TERLS), near Trivandrum in southern India. Thumba is one of the few sites located near the geomagnetic equator and has been accorded U.N. sponsorship as an international rocket range. Comparison of data obtained at Brazil's *Barreira do Inferno* rocket range with those at TERLS will provide important information on many areas of space activity, including those of communications and atmospheric physics.

The Space Science and Technology Center is located near the Thumba range and has facilities for building, testing, and integrating rocket and satellite payloads. The center is responsible for the maintenance of ground observation stations, the conduct of ground based space experiments, and the development of space related sensors and instruments. Adjacent to both the center and Thumba range is a rocket propellant plant and rocket production facility. This facility is producing the Indian rockets, including the French-licensed *Centaure* rocket. It has been reported that 2,100 people are working at this complex, of which 500 are production workers.

A second launch-test rocket range has been established on Sriharikota Island in the Bay of Bengal north of Madras. This range was in limited operation as of October 1971, when at least three successful launches of a *Rohini* series rocket, the RH-125, were achieved. The area and location makes the site suitable for launching very large rockets. Construction is apparently underway on a launch pad for the small Indian satellite launch vehicle scheduled to become operational in 1975. An Intelsat communication satellite ground station has been constructed at Arvi and another is being constructed at Hardwar.

India has committed herself to the development of domestic communications satellites, communications ground equipment, and satellite launch equipment capable of attaining synchronous orbits. However, India lacks the industrial base to support such programs and will probably find it necessary to acquire a great deal of foreign material and technology to support these goals.

Terrestrial geophysical research is increasing. The Geophysics Research Board of the CSIR coordinates the research. The National Geophysical Research

Institute, Hyderabad, also under the CSIR, is the principal geophysical research center. It has a geomagnetic observatory, as well as a seismological observatory, at Hyderabad and a geoelectric observatory at Chutupalu, about 40 miles southeast of Hyderabad. The India Meteorological Department has four geomagnetic stations; the principal one, the Alibag Magnetic Observatory, about 18 miles from Bombay, is one of the world's primary magnetic facilities. The department also operates a network of about 16 seismic stations; the central Seismological Observatory at Shillong coordinates seismic data. The Indians are engaged in aeromagnetic and ground-based magnetic surveys and have undertaken studies of micropulsations. Some of the micropulsation data are shared with the Soviets. An investigation of the seismicity of the Himalayan foothills is underway. Other research is being done in paleomagnetism. A 5-year program to study deformations of the earth's crust is in effect. The Indians also are engaged in geophysical exploration and in collaboration with the U.S.S.R. have established a Center for Exploration Geophysics at Osmania University.

Basic research in geology is conducted in the universities in such subjects as geochemistry, geomorphology, Himalayan geology, mineralogy, paleontology, petrology, and structural geology. The geology departments of Punjab University and the University of Sagar sponsor centers of advanced study in the field. The Geological Survey of India, with headquarters in Calcutta, has eight regional areas and, in addition to geological mapping, has conducted geological and geophysical prospecting for minerals.

A moderate geodetic research program is underway, and geodetic triangulation, precise traverse, and gravity surveys are accomplished on a sporadic basis. The Geodetic and Research Branch of the Survey of India in New Delhi is the agency responsible for geodetic work; in times of national emergency, the Directorate of Military Survey would assume control of geodetic and mapping activities.

Since World War II the survey has reobserved some of the secondary triangulation nets and inserted new geodetic base lines and Laplace control where necessary to correct deficiencies and raise the accuracy to modern primary standards. The Indians have used in part the data acquired since 1945 to determine the boundary between India and Pakistan, to ascertain the amount of horizontal movement on the earth's crust caused by earthquakes, and to aid in the study of the local geoid as reflected by the changes of deflection of the vertical caused by seismic action. Although a readjustment of the primary triangulation net was made for scientific purposes in 1937, the 1880 adjustment still is used as the basis for all Indian triangulation and mapping. Research is underway currently on base line measurement, geodetic astronomy, tidal observations, precise leveling, deflection of the vertical, gravity, spheroid calculations, and terrestrial magnetism. India is active in international geodetic affairs and is a member of the International Association of Geodesy (IAG), its parent body, the International Union of Geodesy and Geophysics (IUGG), and the International Astronomic Union (IAU).

Capabilities in hydrologic and hydraulic research are very good. Efforts are mainly in the field of applied research and are directed toward the development and utilization of water resources for irrigation and power; flow, silting, and scouring in canals; dissipation of energy below dams, weirs, and canal falls; flooding, silting, and storage capacity of reservoirs; improvement of the navigability of rivers and harbors; and the effects of cavitation and vibration on hydraulic structures and equipment. Basic hydrologic and hydraulic research is conducted by the Central Water and Power Research Station near Pune. Each of 21 other research stations is concerned with projects in the state in which it is located. Research stations are adequately staffed by competent Indian scientists and engineers, some of whom have achieved international reputations in the fields of hydrology and hydraulics.

India shows a strong interest in coastal research and has active programs concerning harbor improvement and expansion, beach erosion control, and nearshore sediment studies. Testing grounds for practical research in coastal engineering have been provided by the development of a new harbor at Paradip Garh and the expansion of existing port facilities at Port Blair in the Andaman Islands, at Tuticorin in Tamil Nadu, and at Vishakhapatnam. Other research activities include the study of siltation processes, salinity intrusion, littoral transport along sandy shores, sediment movement off selected harbors through use of radioactive tracers, channel dredging, and beach profiles. The coast of Kerala, which is highly vulnerable to sea erosion, has been subjected to comparatively intensive technical study, and experimental seawalls and breakwaters have been constructed. Research and model studies are also conducted in coastal engineering, hydraulics, hydrology, water resources, construction materials, foundation engineering, and minor irrigation. In the future, India will be forced to deal with pollution of coastal waters near large cities or face recreational restrictions and decreases in fisheries production. Exploration of offshore areas for oil-bearing structures, investigation of heavy mineral sands, and wave hindcasting also will be considered for research. The most prominent organizations engaged in hydrologic, hydraulic, and coastal engineering research are the Central Board of Irrigation and Power near Pune and the Kerala Engineering Research Institute at Peechi.

India carries out research in all phases of oceanography. Although the emphasis is on biological oceanography in the Arabian and Laccadive Seas and the Bay of Bengal, considerable research also is done on the relationship of physical and dynamic oceanography to the formation of monsoons. The Indians also have been involved in studies on coastal pollution near port cities and disposal of nuclear reactor wastes. Military oceanographic research includes the development of a passive nondirectional sonobuoy for protection against submarines. Oceanographic progress is limited by the lack of research ships and funds for the maintenance of specialized equipment as well as the small number of senior research oceanographers with initiative and a real enthusiasm for the science. Only five universities offer instruction in oceanography, primarily in marine biology and marine geology, at the graduate and undergraduate level. In addition, the research effort is retarded by the rivalry between opposing groups seeking to control Indian oceanography.

Although some aspects of oceanography were developed in fisheries institutes and in universities, a comprehensive program of oceanographic research in India only started with its participation in the International Ocean Expedition (IIOE) of 1961 to 1965. The IIOE afforded Indian scientists an opportunity to work on foreign oceanographic ships and at advanced oceanographic institutes abroad. Some essential equipment was obtained during the expedition, and the laboratories set up to handle some of the expedition's work formed the basis for the creation in 1966 of the National Institute of Oceanography at Goa under the CSIR. This facility is doing considerable work on air-sea interaction and coastal erosion and accretion. The organizing and planning of oceanography at the national level is carried out by the National Committee on Oceanic Research.

India is a member of the Intergovernmental Oceanographic Commission (IOC) and the Indo-Pacific Fisheries Council (IPFC). Because of a lack of foreign exchange, the government generally does not allow most of its scientists to attend international meetings outside the country. India has separate agreements with the U.S.S.R. and Norway for data exchanges and for the development of marine resources in the Indian Ocean. The U.S.S.R. is seeking Indian Government cooperation for the establishment of submarine detection systems and underwater research areas in the Bay of Bengal. India hosted a symposium on the Indian Ocean in March 1967 at New Delhi, which was sponsored jointly by the National Institute of Sciences of India and the Indian National Committee on Oceanic Research.

Glossary (u/ou)

Name	English
BARC	Bhabha Atomic Research Center
COSPAR	International Committee on Space Research
CSIR	Council of Scientific and Industrial Research
DRDC	Defense Research and Development Council
DRDO	Defense Research and Development Organization
HAL	Hindustan Aeronautics, Ltd.
ICAR	Indian Council for Agricultural Research
ICMR	Indian Council for Medical Research
INCOSPAR	Indian National Committee for Space Research
ISRO	Indian Space Research Organization
NAL	National Aeronautical Laboratory
NCST	National Committee on Science and Technology
TERLS	Thumba Equatorial Rocket Launching Station

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