also be determined from the celestial observations, the VLBA may also be used to locate the instantaneous position of the Earth's rotation axis and the wandering of the poles. Accurate determination of the rate of the earth's rotation (time) and a better evaluation of the rate of its slowing down will also be possible.

The VLBA can also be used to measure with great accuracy the relativistic bending of radio signals as they pass close to the sun. Classical optical measurements of stars near the limb of the sun made during times of solar eclipses provided one of the first experimental demonstrations of general relativity. But even now, it is difficult to measure the bending of starlight with an accuracy better than 10 percent. Radio measurements made with connected element interferometers have already given an order of magnitude improvement in accuracy, and the much greater resolution of the VLBA will lead to further improvements. Indeed, the sensitivity to relativistic effects will be so great that even position measurements made 90° away from the sun will need to be routinely corrected for relativistic bending.

References and Notes

1. The response of a radio interferometer is described in detail by G. W. Swenson, Jr., and N. C. Mathur, *Proc. IEEE* **56**, 2114 (1968).
2. M. Ryle, *Science* **188**, 1071 (1975). Ryle was awarded the Nobel Prize for the development of synthesis mapping.
3. D. S. Heeschen, *Telescopes for the 1980's*, G. Burbidge and A. Hewitt, Eds. (Annual Reviews, Palo Alto, 1981), p. 1.
4. The principles of operation and early results from the VLA have been described by R. M. Hjellming and R. C. Bignell, *Science* **216**, 1279 (1982). For detailed technical descriptions see P. J. Napier, A. R. Thompson, and R. D. Ekers [*Proc. IEEE* **71**, 1295 (1983)] and A. R. Thompson, B. G. Clark, C. M. Wade, P. J. Napier, [*Astrophys. J. Suppl.* **44**, 151 (1980)].
5. D. S. De Young, *Science* **225**, 677 (1984).
6. R. C. Walker, J. Benson, S. Unwin, unpublished observations.
7. J. G. Davies, B. Anderson, I. Morison, *Nature (London)* **288**, 64 (1980).
8. J. L. Yen *et al.*, *Science* **198**, 289 (1977).
9. C. Bare, B. G. Clark, K. I. Kellerman, M. H. Cohen, D. L. Jauncey, *ibid.* **157**, 189 (1967); N. W. Broten *et al.*, *ibid.* **156**, 1592 (1967); J. M. Moran *et al.*, *ibid.* **157**, 676 (1967).
10. G. W. Swenson, Jr., and K. I. Kellermann, *ibid.* **188**, 1263 (1975).
11. Preliminary design studies were issued by the National Radio Astronomy Observatory in 1977 and 1981 and by the California Institute of Technology in 1980.
12. M. H. Cohen *et al.*, *Science* **162**, 88 (1968).
13. The data-acquisition system is being developed at the MIT Haystack Observatory under contract to the National Radio Astronomy Observatory.
14. The playback system is being developed at the California Institute of Technology under contract to the National Radio Astronomy Observatory.
15. T. J. Pearson and A. C. S. Readhead, *Annu. Rev. Astron. Astrophys.* **22**, 97 (1984). Pearson and Readhead describe the use of self-calibration techniques to remove instrumental as well as atmospheric errors in the measured interferometer amplitudes and phases.
16. M. H. Cohen and S. C. Unwin, *Int. Astron. Union Symp.* **110**, 95 (1985).
17. J. Baretta, thesis, California Institute of Technology, Pasadena (1985).
18. From M. J. Reid *et al.*, *Astrophys. J.* **239**, 89 (1980).
19. R. Genzel *et al.*, *ibid.* **247**, 1039.
20. On 8 and 9 April 1983, the National Research Council organized a 2-day workshop to discuss these nonastronomical uses of the VLBA [*Proceedings of the Workshop on Multidisciplinary Uses of the VLB Array* (National Academy Press, Washington, D.C., 1983)].
21. A. E. E. Rogers *et al.*, *Science* **219**, 51 (1983).
22. The VLBA has been selected by the National Academy of Science, Astronomy Survey Committee (Field Committee) as the next major ground-based facility for astronomy [*Report of the Astronomy Survey Committee* (National Academy Press, Washington, D.C., 1982)]. Preliminary funding for detailed engineering and design was made available to the National Radio Astronomy Laboratory in 1984, and Congress approved a construction start in 1985. The VLBA will be constructed by the National Radio Astronomy Laboratory and will be operated as a national facility open to all qualified scientists. Allocation of observing time will be based solely on the scientific merit of the proposed observing program. Many individuals throughout the radio astronomy community have contributed to the design and development of the VLBA. We thank especially M. H. Cohen, M. S. Ewing, J. M. Moran, M. J. Reid, A. C. S. Readhead, J. D. Romney, A. E. E. Rogers, G. W. Swenson, Jr., and R. C. Walker for many useful discussions and comments on the manuscript. The National Radio Astronomy Laboratory is operated by Associated Universities, Inc. under contract with NSF.

Science and Technology in India

J. S. Rao

India has, throughout history, had a fair share of discoveries in medicine, mathematics, astronomy, metallurgy, and other scientific fields. A great surgeon who lived more than 2000 years ago is said to have used 500 different instruments and accomplished miracles in plastic surgery. The zero was first used in Indian mathematics. The earliest mention and description of various planets and other phenomena in the sky are found in Vedic texts, where the sun, worshipped as the source of energy to our planet, was given the central position in our solar system. Great observatories were built, making possible the tabulation of lunar and solar calendars. On the outskirts of New Delhi is an iron pillar that has stood for more than 1500 years without rust or blemish.

India, once a rich and prosperous country, fell prey to incessant invasions, and its people, weighed down by the opulence of their rulers, were impeded in their quest for innovation. During the period of industrial revolution, when the Western countries flourished with discoveries of science, India was struggling to gain independence. Railways and textile mills were brought to India in 1850's, yet not a single locomotive or textile mill was built there until independence was won in late 1940's.

Independent India's first Prime Minister, Pundit Jawaharlal Nehru, realized the importance of science, particularly its end application to society. He once said (*1*): "What is planning if not the application of science to our problems?" Science and technology have received major emphasis in all 5-year plans in India during the last three decades. Despite the problems that exist in a developing democratic country of large population, there has been considerable progress. For example, (i) the Indian farmer, through a green revolution, made the country self-sufficient in food and even produced exports in small quantities; (ii) the average life-span of an Indian has more than doubled since India's independence; (iii) development of basic heavy industry has placed India today among the ten largest industrialized nations in the world; (iv) India has designed and built nuclear power plants; (v) space programs have been undertaken with emphasis on applications such as long distance telecommunications, community television, and remote sensing of Earth resources and meteorological parameters; (vi) a permanent manned station has been established in Antarctica for scientific studies; and (vii) in the last decade, India has nearly tripled its oil production.

The infrastructure for R&D has had to be totally developed by the government, and a scientific policy resolution was made as early as in 1958. A chain of 42 national laboratories was established under the Council of Scientific Industrial

J. S. Rao is the science counsellor at the Embassy of India, Washington, D.C. 20008.

Research (CSIR) and research institutes like Tata Institute of Fundamental Research and the Indian Institutes of Technology were created. Since Nehru's time the building of the scientific and technological infrastructure has continued with more emphasis on self-reliance. For the late Indira Gandhi, there was a special position for science in her thinking: "It has to be part of the life of every Indian, the soldier, the farmer, the worker, the housewife and the student" (*2*).

Summary. This assessment of the current status of science and technology in India focuses on developments in the areas of agriculture, energy, medicine, space, basic sciences, and engineering sciences. India has benefited in many fields from international collaboration during the last 30 years, but the country's leaders have also placed particularly strong emphasis on self-reliance.

Science plays a special role in almost all the government departments, some of which are exclusively devoted to science, such as those involving atomic energy, space, electronics, ocean development, coal, and petroleum. The Department of Science and Technology (DST) identifies strategic areas and makes substantive grants to research organizations and educational institutions. A chain of 40 laboratories is run by the Defence Ministry to cater to its specific applications. Besides CSIR, there are two other major scientifically oriented councils—the Indian Council of Medical Research and the Indian Council of Agricultural Research. There are 140 universities funded by the University Grants Commission, and they also receive specific project funds from different departments.

The most influential group in science and technology nationally, however, is the Planning Commission, which is responsible for systematic planning of the Indian economy. At least one senior scientist has always been a member of this commission. The major policy directions in science and technology and investment are recommended by this commission to the cabinet. India spent about $1 million on science and technology activity in 1947–1948; this has gradually increased, through the 5-year plans, to about $1450 million in 1983–1984.

Agriculture

Modern agricultural research in India began with the establishment of the Imperial Council of Agricultural Research [subsequently renamed Indian Council of Agricultural Research (ICAR)] during British rule in 1929. At the time of its independence in 1947, India had to depend heavily on imported food grains. In the middle of 1950's, India produced less than 50 million metric tons of food grains, whereas in 1983–1984 it produced more than 150 million tons. This increased food production is perhaps the greatest achievement of independent India; it is the result mainly of the efforts of 22 agricultural universities, which were established in all major states of the country on the pattern of U.S. land grant colleges, and 36 other research institutes. Besides ICAR, major projects in agriculture are supported by DST, CSIR, IIT Khargpur, and other universities.

Progress in agriculture has been achieved through sustained efforts to expand irrigation, increase consumption of fertilizers, and develop new high-yielding crops, particularly wheat and rice. Today the net irrigated land makes up a little more than 25 percent of the net sown area in the country, and India is adding 2 million hectares to the area under irrigation each year. Fertilizer production has increased from 18,000 metric tons in 1951 to 3 million tons in 1981. The production of nitrogen fertilizers alone is expected to increase from about 2 million to 10 million tons by the end of this decade.

Another major factor of India's agricultural production is the development of hybrid seed varieties, plant protection, and other scientific methods of farming. Research efforts are concentrated on developing plant types to suit various agro-ecological and management conditions; in arid zones, for instance, dryland farming is used. The development of triple gene dwarfs in wheat, composite varieties of maize, varieties with high lysine content, and others has helped increase the total productivity of crops. Among pulses, the development of early maturing varieties in arhar and mung was a major breakthrough for multiple cropping. Among oil-seed crops, considerable improvement in production in groundnut has been achieved through improved high-yielding varieties. In recent years, India has become a significant producer of potatoes and apples, both introduced from outside. India is also one of the world's largest exporters of cotton textiles, producing 8 million bales of cotton today compared with 3 million bales three decades ago. Breakthroughs in crop production were also made possible by systematic plant protection research.

Traditionally Indian farmers depended on bullock power. Since the 1950's, farming has been increasingly mechanized with tractors manufactured from imported designs. A significant development in mechanized farming is the design of a tractor to match the specific requirement of the Indian market. One of the CSIR laboratories designed the tractor "swaraj," which is rugged, relatively inexpensive, and yet capable of basic farm operations like soil preparation, pumping, seed and fertilizer placement, and threshing.

Energy

India has large reserves of coal, which is the main energy source today. Coal production has increased from 30 to 144 million metric tons in the last three decades. In addition to the use of coal for generating power, India has hydraulic and nuclear power stations. The total installed power generating capacity has increased from around 2,000 megawatts in 1950 to about 40,000 today. This has been brought about through considerable efforts to manufacture the power plant equipment initially under license from foreign manufacturers. India's first 500-MW plant will be installed soon; plans to manufacture 1000-MW capacity machines are under way in order to achieve a capacity of 100,000 MW by mid-1990's. A major effort has been directed at developing within the country the know-how to build and maintain plants.

India's reaction to the oil crisis in early 1970's has been a quick exploitation of the Bombay High offshore oil. Through the ambitious plans of Oil and Natural Gas Commission, 30 million tons of oil a year and 14.5 million cubic meters of gas a day were produced during the current year, meeting almost 75 percent of the country's needs. At the same time refining capacity has been increased to meet all indigenous needs of 40 million tons of oil a year. Three advanced research institutes have been established to develop capabilities in seismic surveying, reservoir engineering, design and fabrication of offshore platforms and communication systems, and ocean engineering for piping oil and natural gas from offshore wells.

The prime objective of India's atomic energy program is the development, control, and use of atomic energy for power generation. The leading research institution directing these programs is Bhabha Atomic Research Centre (BARC) in Bombay. The long-term fuel-cycle strategy has several phases: (i) to produce power and plutonium from natural uranium-fueled reactors, (ii) to use plutonium-fueled fast breeder reactors to produce power and more plutonium, as well as uranium-233 from thorium; and (iii) to use uranium-233–thorium breeder reactors to produce power. The atomic power plant in Madras, designed and engineered indigenously is generating power and another one in Narora is nearing completion. Two heavy water plants at Baroda and Tuticorin are operating continuously. A nuclear fuel complex in Hyderabad manufactures fuel and zircaloy structural materials for the reactors.

India has now achieved a position among the most advanced nuclear nations and plans to produce 10,000 MW of atomic power by the turn of the century. In preparation for the second phase of India's fuel-cycle strategy, a 20-MW plutonium-fueled fast breeder test reactor is being designed for the Kalpakkam Reactor Research Centre. This center will prepare the ground for India to embark on the design and construction of commercial-sized liquid metal cooled fast breeder reactors, the first of which is scheduled for commissioning in 1990.

A significant effort relating to R&D in renewable sources has been made—for example, building and industrial production of solar thermal units for supply of hot water for domestic and industrial purposes, solar driers in the agricultural sector, water pumps that use wind and photovoltaic devices, solar cold storages, individual and community biogas plants, and biomass production and conversion to alcohol. A large solar heating system, with a capacity of 0.18 million liters a day, is being commissioned in central India. Recently some villages have been lit by solar-powered streetlights, and photovoltaic systems have been successfully used in wireless sets, beacon lights, and offshore platforms among other places.

Recently scientists at BARC have made a major breakthrough in fabricating superconducting wire for experiments in fusion research. An R&D program in the field of coal-based magnetohydrodynamic power generation was taken up, and a 5-MW unit has been commissioned in Tiruchirapalli.

Health

The Haffkine Institute established in Bombay in 1896 developed a vaccine that was the first to be used on a large scale against plague, and a modified version still remains as an effective weapon for prevention of plague today. A string of Pasteur institutes was established from 1900, and the transmission of malaria by mosquitoes was discovered in Secunderabad more than 80 years ago. The Indian Research Fund, established in 1911, later became the Indian Council of Medical Research.

Medical research in India addresses the most important health problems; initially this was communicable diseases and later nutrition, maternal and child health, and indigenous drugs and recently contraceptive technology, noncommunicable diseases, occupational and environmental health hazards, and health care delivery systems. Life expectancy has been increasing at the rate of 1 year per year and is now a little over 54 years. Smallpox has been eradicated and plague is no longer a problem. Cases of malaria dropped from 75 million in 1947 to 100,000 in 1967 (although the number increased again in the early 1980's), while the mortality from malaria dropped from 800,000 to almost zero during this period. In an effort to aid the nearly 3 million leprosy patients in India, two new vaccines have been developed at the Indian Cancer Research Centre and All India Institute of Medical Sciences, and both are ready for field trials.

Space

India made a modest beginning in space research by establishing the Thumba Equatorial Rocket Launching Station near Trivandrum in 1963 to conduct sounding rocket experiments. The Department of Space, created in 1972, is responsible for space activities through the Indian Space Research Organisation (ISRO), which oversees research in launch vehicles, satellites, satellite applications, launch services, and tracking.

The launching of Aryabhata (1975), Bhaskara I and II (1979 and 1981, with Soviet Intercosmos rockets), APPLE (1981, with the European space agency Ariane) and Rohini Satellites RS 1, RSD 1, and RSD 2 (1980, 1981, and 1983, with the indigenous Satellite Launch Vehicle 3) were some of ISRO's accomplishments during an eventful decade. Two important large-scale experiments in satellite applications, the Satellite Instruction Television Experiment (SITE 1975–1976, carried out with the use of the ATS-6 satellite provided by NASA) and the Satellite Telecommunications Experiments Project (STEP 1977–1979, with the Franco-German Symphony Satellite) were also successfully conducted during this period.

In April 1982, INSAT-I, a multipurpose operational satellite system for domestic long-distance communication, meteorological earth observation and data relay, and nationwide direct television broadcasting was launched but failed after 147 days in orbit. In August 1983, INSAT-1B was launched by the space shuttle and has been operational from 15 October 1983. The launching of INSAT-1C, expected in mid-1986, will give the program an active in-orbit spare. These INSAT-1 spacecraft, which are built by Ford Aerospace and Communication will eventually be replaced by indigenously built second-generation (INSAT-II) satellites that are under development.

The first in a series of Indian remote-sensing satellites (IRS-1A), which will provide images in visible and infrared bands, is scheduled to be launched into a polar orbit by a Russian launch vehicle in 1986. To coordinate the space segment, the ground system, and the use of the data products a National Natural Resources Management System (NNRMS) will be initiated. The existing Earth station established near Hyderabad has been acquiring data from LANDSAT. It can also receive data in the future from the French SPOT satellite (Satellite Probatoire de l'Observation de la Terre) and IRS.

The successful conclusion of SLV-3 development with the launching of SLV-3-D2 in April 1983 has given India the confidence to build larger launch vehicles for orbiting heavier payloads. Work is already under way on two projects: the Augmented Satellite Launch Vehicle (ASLV) is designed to place 150-kilogram class satellites in low Earth orbit; the Polar Satellite Launch Vehicle is designed to launch 1000-kilogram class remote-sensing satellites into polar orbit.

In April 1984, the first Indian cosmonaut conducted experiments in biomedical, materials science, and remote-sensing areas as a part of a joint Indo-Soviet team during a Salyut mission. An Indian payload specialist who is to fly aboard the U.S. space shuttle in connection with the flight of INSAT-1C in 1986 will also be involved with joint experiments in the areas of Earth observations and life sciences.

Basic Sciences

Sir C. V. Raman, Nobel Prize winner for his discovery of the Raman effect in 1920's, set the pace for the renaissance of basic science in India. He founded the

Indian Institute of Science in Bangalore, and later the Raman Research Institute in the same city. The main fields of research are liquid crystals, astronomy, and astrophysics. Studies of liquid crystals have led to a number of new discoveries, and the latest liquid crystal display technique is being used in the manufacture of watches. The Raman Institute has two radiotelescopes, one at Ootacumund for observing pulsating stars and the other at Gauribidanur, one of the largest of its kind in the world. The Institute is planning to build a millimeter wave telescope.

The Bose Institute Calcutta, founded in 1917 by the eminent physicist Acharya Jagadish Chandra Bose, is conducting studies in nuclear physics and biology. Calcutta has another premier science center, The Indian Association for the Cultivation of Science, founded in 1876. In the area of energy research, this organization has contributed extensive studies, particularly related to amorphous silicon in improving its photoelectric yield.

Tata Institute for Fundamental Research (TIFR) was set up in Bombay in 1945 by Homi Bhabha on lines similar to the Institute for Advanced Studies at Princeton University. Mathematics is very strong in this Institute, continued in the tradition of the Srinivasa Ramanujan. A digital electronic computer was built there in early 1950's, and the institute is well known for its contributions in theoretical physics, cosmic ray physics, astrophysics, and nuclear physics. Today the high energy cosmic ray group of TIFR is conducting a proton decay experiment at Kolar Gold Fields, and TIFR physicists are commissioning India's first charged particle accelerator called "Pelletron." Bhabha Atomic Research Center has developed a microprocessor-based scanning Auger microprober for its nuclear material development program, and it is being commissioned at the Reactor Research Centre in Kalpakkam.

The main programs of the Physical Research Laboratory in Ahmedabad are in solar planetary physics, infrared astronomy, geocosmophysics, theoretical physics, plasma physics, archeology, and hydrology. A compact torus plasma ring has been designed and built here. For carrying out advanced studies in nuclear fusion, plasma physics, lasers, and accelerators, a Centre for Advanced Technology is being set up in Indore.

A systematic study of the Indian Ocean was started with India's participation in the International Ocean Expedition in the early 1960's. The National Institute of Oceanography (NIO) in Goa has two research vessels, *Gaveshavi* (1900 metric tons) and *Sagar Kanya* (1555 metric tons). India is the only developing country to acquire the status of a "pioneer investor" in seabed mining as a result of scooping polymetallic nodules from the floor of the central Indian Ocean at depths of 3 to 4.5 kilometers. India also has a permanently manned station on the Antarctica continent.

The National Geophysical Research Institute in Hyderabad has undertaken a major seismic sounding program to study the origin of the Deccan Traps in southern India. The outcome of this program has shown that this massive lava field, the largest accumulation of lava now known, consists of a lense-shaped structure about 1.5 kilometers thick on the west coast, thinning progressively inland. A huge sedimentary basin discovered beneath the igenous layer is thought to have formed when India was still a part of Gondwanaland.

Other research areas in which India has made significant progress include: cloning of genes for penicillin acylase in *Escherichia coli*, plant tissue culture including experimental control of growth and differentiation of fruit trees and cereals, enzyme engineering, immunology, and fermentation technology.

Engineering Sciences

During the last three decades India has completed some of the world's largest dams and hydroelectric projects. One result is that about 25 percent of the area that is under cultivation is now irrigated. Major flood control measures have been undertaken to tame some of India's mighty rivers. The Idukki dam built across the Periyar River in southern India is the first double curvature-arch dam in the country. India has built many power stations of 500-MW and more: Bhakra Nangal in the north, Koyna in the west, Sharavati in the south, for instance. More than 50 major hydropower and thermal power stations with capacities of 2000 MW are under construction at Singrauli, Korba, Ramagundam, Rihand, and elsewhere.

In other areas, India has built a large network of roads requiring many impressive bridges such as the recently completed bridge on the river Ganges in Bihar. Besides 32,000 kilometers of national highways, 100,000 kilometers of state highways, and 150,000 kilometers of district roads, India has built 8,000 kilometers of border roads at high altitudes in the Himalayan belt. The skyline of major cities like Bombay and Delhi now includes multistory buildings built with the latest construction technology. Such activity is supported by several R&D organizations like the Central Building Research Institute, the Structural Engineering Research Centre, and the Cement Research Institute.

Advances made in science and technology have been contributing to a rapid growth in major industries like textiles, jute, sugar, cement, paper, iron and steel, petrochemicals, fertilizers, and drugs. Steel production from six major steel plants of over 8 million metric tons per year has provided the basis for the manufacture of a range of engineering goods from fasteners to giant machinery.

The textile industry, which has been preeminent since 1947, now covers not only the traditional sector of cotton and jute but also different types of synthetic fibers. The power-loom industry produces nearly 4500 million meters of textiles, up from 250 million in 1955. This was achieved largely as a result of the work done by several regional textile research institutes. The machine building industry has also made rapid strides due largely to the pioneering work of Hindustan Machine Tools Ltd., one of the largest manufacturers of machine tools in the world; this effort has been backed up by research activity of the Central Machine Tools Institute in Bangalore. Hindustan Machine Tools also has one of the largest and most sophisticated automatic watch-making production lines in the world and produces tractors, printing machines, and injection moulding material as well.

The engineering industry can supply virtually all requirements for power-generating equipment; steam turbines and diesel engines are used as basic power packs. The Gas Turbine Research Establishment has recently developed and successfully tested its first gas turbine for aviation purposes.

India has one of the largest railroad networks in the world, 114,000 kilometers of multigauge track, and now produces both diesel and diesel-electric locomotives within the country. Steam locomotion is being phased out gradually and at present about one-sixth of the total broad-gauge route is electrified. High speed trains (130 kilometers per hour) have been safely run between major cities with the help of mathematical stability studies for train handling and microprocessor based track recording systems for monitoring and maintenance. The engineering activities for the railways have reached high self-reliance through the R&D activity of the Railway Design & Standards Organisation in Lucknow.

To keep pace with modern developments, India has now adopted a liberal policy of importing computers as well as supporting indigenous manufacture. Two major computer networks, one for national information and the other for commercial work, are being established, and four other major networks are being planned for the railways, the oil sector, educational institutions, and for banking applications. The Press Trust is now in the final stage of computerizing India's news operations by adapting the latest technology to suit the conditions and growing needs of the media in the country.

Bharat Electronics, the Electronics Corporation of India, the Indian Telephone Industries, Central Electronics, and the Semiconductor Complex are engaged in R&D and manufacture of various electronics equipment like television tubes, large and very large scale integrated circuits, control systems, defense equipment, and computers. The country's first industrial robot, indigenously designed and built, is being used in the manufacture of television sets. An R&D center has been set up to develop digital electronic switching systems suitable to Indian conditions. The National Silicon Facility is being established in Baroda for the manufacture of polysilicon for LSI/VLSI circuits.

Several significant contributions to development have been made by scientific and industrial research laboratories: for example, a coal carbonization plant that uses low-temperature carbonization of coal was developed by Regional Research Laboratories in Hyderabad; a process for manufacturing 25 metric tons of cement per day in minicement plants was developed by the Regional Research Laboratory in Jorhat; and a process for producing 2000 tons of acetanilide for use in the manufacture of sulfa drugs was developed by the National Chemical Laboratory in Pune.

The engineering industry is today backed by science and technology efforts in national laboratories, by R&D groups in industry, and by organized consultancy services. Three decades ago, India exported raw materials and imported all manufactured goods, but today it is not only achieving self-sufficiency but also exporting engineering goods worth $1 billion.

International Collaboration

Although credit is due principally to Indian scientists for advancing the country from an almost preindustrial state to its present state in a short period of three decades, it is recognized that international collaboration has had a major role in this transformation process. As an example, the first Indian Institute of Technology was set up in early 1950's with scientists from the United States, the United Kingdom, West Germany, and the Soviet Union taking part in research and teaching. Major core industries like steel and power benefited from collaboration with several advanced countries. Such a direct contact with the international community helped India build scientific institutions of high caliber.

Indian scientists have maintained excellent relations with international groups by directly participating in their programs, attending international conferences and symposiums, organizing and hosting international meetings in India, and so on. Through these meetings and individual scientific collaborations and exchange of views, India has been able to sustain reasonably good international standards in scientific education and research.

India also has international collaborative programs with various countries, including Australia, Bangladesh, Brazil, China, Czechoslovakia, Cuba, East and West Germany, France, Greece, Hungary, Italy, Japan, the Netherlands, Poland, Saudi Arabia, Sweden, the United Kingdom, the United States, and the Soviet Union. For example, India and the United States have established major scientific collaboration programs in the areas of health, agriculture, monsoon research, and biomass. The National Science Foundation in the United States and the Council for Scientific and Industrial Research in India have regular exchange programs enabling scientists from both countries to participate in exchange conferences, symposiums, and lecture programs. NASA and ISRO have a long-standing program of cooperation in the field of peaceful use of outer space. Cooperation is enhanced by opportunities for individual scientists to take sabbaticals in different countries. Scientists of Indian origin are, for example, extending help in biotechnology programs by participating on an advisory committee on biotechnology for North America.

Some Reflections

Independent India has placed strong emphasis on self-reliance in science and technology since Nehru. Prime Minister Rajiv Gandhi (*3*) summarized the position most aptly: "Forty years ago, at the time of independence, India had very low levels of education, extreme poverty, no technological know-how, no industrial base and very low agricultural production. Now we have a major agricultural industry, we have a substantial industrial base, we have substantial technological and scientific manpower. It requires new thinking."

India today is both an ancient country and one where the silhouettes of the emerging world of tomorrow can be seen. One member of a recent delegation from U.S. agricultural institutions noted that India had developed the infrastructure in 25 years that one would expect to take 75 years elsewhere. Under the circumstances, India has been conducting a good democratic experiment with its self-reliant approach. At present, some of the promising indicators are: food grain stocks are over 22 million metric tons; inflation is about 6 percent, and industrial growth on average is running near 7 percent. With a basic infrastructure for science and technology established, India is now poised to achieve a further rapid industrialization by the turn of the century, but the transfer of technical know-how in certain specific areas is still desirable from advanced countries.

During the last two decades of development, India faced many problems, among them the migration of scientists and engineers trained in India to advanced countries. With more and more manpower trained in India, the problem became less acute, and in recent years it is being increasingly considered that the initial brain drain from India may even be becoming advantageous as a resource available from advanced countries.

India has shown the way to overcome many basic problems of developing countries by applying science, and the experience can be utilized by the other developing countries. India has also succeeded in developing major international collaborative programs, and a program like the Science and Technology Initiative between India and the United States might serve as a model to other nations.

References and Notes

1. Quotation from I. Gandhi, *On Peoples and Problems* (Hodder & Stoughton, London, 1982), p. 27.
2. I. Gandhi, quotation from "Science & Technology in India" (an advertisement), in *Scientific American* (August 1982), p. 12.
3. R. Gandhi, quotation from an interview with E. Behr, *Newsweek*, 14 January 1985.

4. The contributions made by D. N. Moorthi and R. Mathai of the Embassy of India in preparing this article are greatly appreciated.