

Science and Technology in India

Introduction:

India is still considered to be a developing country. However, India has had a rich history in scientific innovations, and in its past used to be many years ahead of the Europeans when it comes to science. Some of the brightest scientists have taken birth in the Indian subcontinent. Post independence, India has once again become a global leader in scientific research.

Scientific Research in Ancient and pre-Colonial India:

Albert Einstein famously stated, "We owe a lot to the ancient Indians, teaching us how to count. Without which most modern scientific discoveries would have been impossible."

The people of the subcontinent had made advancements in mathematics and physics which were at par with research done in ancient Greece and Egypt. Baudhayana was the first one to observe Pythagorean triplets, and made a similar statement in his book BaudhayanaSulba Sutra. Indians were also among the first to think about a spherical Earth; the Hindi term for Geography is Bhugol, which contains the words "Bhu" and "Gol (round)".

Later on, the Vedic Age marked a new era of intellectual inquiry and technological endeavour. Ancient mathematical works such as the *Sulva-Sutras* utilized geometry for designing and constructing altars. Mathematics was an important field of knowledge and Ancient India made important contributions to it.

Unfortunately, the concept of documentation was not very strong in India, and coupled with the middle ages when it was dominated by foreign cultures, our achievements have not always received the credit they should have received.

Hindu Numerals

As early as 500 BC, Indians had devised a system of different symbols for every number from one to nine. This notation system was adopted by the Arabs who called it the *hind* numerals. Centuries later, the system was adopted by the western world who called them Arabic numerals as it reached them through Arab traders.

Zero

The concept of zero is one of the most important discoveries of all time. The famous mathematician Aryabhata was the first person to create a symbol for zero and it was through his efforts that mathematical operations like addition and subtraction started using the digit zero.

Decimal system

India gave the ingenious method of expressing all numbers by means of ten symbols – the decimal system. In this system, each symbol received a value of position as well as an absolute value. Thanks to the simplicity of decimal notation, which facilitated calculation, this system made the uses of arithmetic in practical inventions much faster and easier. The concept of zero and its integration into the place-value system also enabled one to write numbers, no matter how large, by using only ten symbols.

Fibonacci Series

Fibonacci numbers and their sequence first appear in Indian mathematics *asmatrameru*, mentioned by Pingala in connection with the Sanskrit tradition of prosody. Although not a mathematician, Pingala stumbled upon the binomial theorem and Pascal's Triangle during his research on mathematics. Later on, the methods for the formation of Fibonacci numbers were given by mathematicians Virahanka, Gopala and Hemachandra, much before the Italian mathematician Fibonacci introduced this fascinating sequence to Western European mathematics.

Quadratic Equations

The *chakravala* method is a cyclic algorithm to solve indeterminate quadratic equations, including the Pell's equation. This method for obtaining integer solutions was developed by Brahmagupta, one of the well-known mathematicians of the 7th century CE. Another mathematician, Jayadeva later generalized this method for a wider range of equations, which was further refined by Bhaskara II in his *Bijaganita* treatise.

Ayurveda & Medicine

Charaka, who is known as the Father of Indian Medicine, did extensive research on Ayurveda, long before the Europeans. His manual, the *Charaka Samhita*, has detailed descriptions of digestion and immunity in humans, and has been translated into many different languages.

Medical & Surgical discoveries

As far as medicine is concerned, Indians have also been pioneers in surgeries, notably the sage Sushruta. He had devised a way to perform cataract operations, which eventually made its way to the Europeans via the Arabs.

Written by Sushruta in 6th Century BC, *Sushruta Samhita* is considered to be one of the most comprehensive textbooks on ancient surgery. The text mentions various illnesses, plants, preparations and cures along with complex techniques of plastic surgery.

The *Sushruta Samhita* 's best-known contribution to plastic surgery is the reconstruction of the nose, now known as rhinoplasty.

Coinage

Indians were minting money before it was even a term – coins made of silver and copper were used in the kingdoms of the subcontinent since 500 BCE. Iron work along the subcontinent took place more than 3000 years ago, and on a large scale, which is evident by the weapons discovered in various excavations along the country.

Yoga

Around 200 BC, the sage Patanjali, after whom a company is named today, did extensive research on natural cures of meditation and yoga. Yoga, along with breathing techniques such as *Pranayama*, is effective in curing stress and heart diseases as well – diseases which were not even known at the time.

Astronomy

Indians had done extensive research in astronomy too, with records stating that Indian scientists had figured out the distance between the Sun and the Earth hundreds of years before it was scientifically calculated by the Europeans. Ancient Indian mathematicians often applied their mathematical knowledge to make accurate astronomical predictions. The most significant among them was Aryabhatta whose book *Aryabhatiya* represented the pinnacle of astronomical knowledge at the time. He correctly propounded that the Earth is round, rotates on its own axis and revolves around the Sun, preceding the heliocentric theory by several centuries. He also made predictions about solar and lunar eclipses, duration of the day as well as the distance between the earth and the moon.

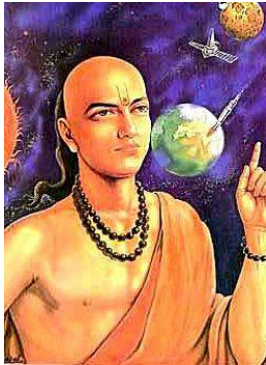
Atoms and Molecules

In the first century BC, the Vaisheshika school of thought believed in fundamental constituents of matter, which were called *Anu*. Later, they hypothesised that these particles too, would have smaller pieces – called *Parmanu* – a theory strikingly similar to the atomic theory Dalton proposed almost 2000 years later. The scientist, Kanad, also stated that *anu* can have two states – absolute rest and a state of motion. He further held that atoms of same substance combined with each other in a specific and synchronized manner to produce *dvyanuka* (diatomic molecules) and *tryanuka* (triatomic molecules).

Negative Numbers

Negative numbers had become common along the subcontinent as a way of measuring debt. Aryabhata and Bhaskara – II, two of the most prominent Indian scientists, did

extensive research on trigonometric equations and geometry of shapes, as well as integral and differential equations.



Aryabhatta

Navigation

The Indian concept of *Sapekshavad* was formed in this era, which is the same as Galilean Relativity. Indian shipbuilders and navigators had access to compass like devices way back in the 5th century, which were used for navigation. They also understood the concept of the Pole Star, which remains fixed in the North, and its use for navigating along the ocean. The Buddhist school on atomism favoured the statement made by the *Vaisheshika* school of thought regarding atoms.

Metallurgy

The Iron Pillar in Delhi – believed to be about one thousand five hundred years old- is an example of the excellence of Indian metallurgy. It has not rusted despite its exposure to the environment and pollution for hundreds of years.



The Iron Pillar's resistance to rust continues to perplex scientists.

Wootz Steel

A pioneering steel alloy matrix developed in India, Wootz steel is a crucible steel characterised by a pattern of bands that was known in the ancient world by many different names such as *Ukku*, *Hindwani* and *Seric* Iron. This steel was used to make the famed Damascus swords of yore that could cleave a free-falling silk scarf or a block of wood with the same ease. Produced by the Tamils of the Chera Dynasty, the finest steel of the ancient world was made by heating black magnetite ore in the presence of carbon in a sealed clay crucible kept inside a charcoal furnace.

Planetary Motion

In Kerala, Nilakantha Somayaji built upon the works of Aryabhatta and his other predecessors regarding the motion of planets. He derived the equations of motion of planets across the sky with astounding accuracy, years before Kepler and Newton came up with their laws of planetary motion and gravitation, respectively.

Seamless Metal Globes

Indian technological innovations took place during the Islamic era as well, as there was an influx of scientific ideas from all over the world.

India was also the only place where “seamless” globes were manufactured. Since a globe is essentially spherical, it would often take longer to make one, and the end product would always have slight deformities, since a sphere is one of the hardest 3 dimensional figures to build perfectly. However, there have been evidences of perfectly spherical globes in India during the Mughal era. Considered one of the most remarkable feats in metallurgy, the first seamless celestial globe was made in Kashmir by Ali Kashmiri-ibn-Luqmanduring the reign of Emperor Akbar. In a major feat in metallurgy, Mughal metallurgists pioneered the method of lost-wax casting to make twenty other globe masterpieces. Before these globes were rediscovered in the 1980s, modern metallurgists believed that it was technically impossible to produce metal globes without seams, even with modern technology.

Rocketry

The first iron-cased rockets were developed in the 1780s by Tipu Sultan of Mysore who successfully used these rockets against the larger forces of the British East India Company during the Anglo-Mysore Wars. His engineers crafted long iron tubes, filled them with gunpowder and fastened them to bamboo poles to create the predecessor of the modern rocket. With a range of about 2 km, these rockets were the best in the world at that time and caused as much fear and confusion as damage.

Science and technology in Colonial times

Talk of modern day science and technology is essentially since British colonisation of India and the post-independence era. During the British conquest of India, indigenous scientific and technological advancements almost came to a standstill, since Indians had naturally become more preoccupied with fighting for the Independence.

While India did undergo modernisation under the British – the advent of railways is but one example of British technology applied in India – it also lost many of its traditional values, and gradually the Indian education system was completely replaced by the British one. The upside is that it exposed many Indians to international practices. India produced many scientists and mathematicians, such as CV Raman, Homi Bhabha and Srinivasa Ramanujan, to name a few, who gained international exposure because of the British.

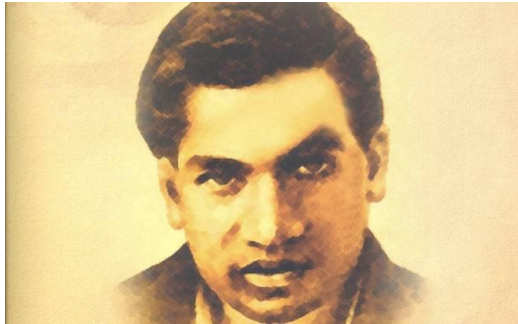
Sir CV Raman is known for his work on scattering of light. The Raman Effect was discovered by him during his research at IACS. His discovery further established the quantum nature of light. During his time in India, he was associated with the Indian Institute of Science in Bangalore and Banaras Hindu University.



Raman's theory was one of many that led to the development of quantum mechanics.

Homi Jehangir Bhabha was formerly known as the father of India's nuclear programme, as he is credited with bringing nuclear power to India. He completed his basic education in India and then joined Cambridge University in 1927. He worked with some of the greatest pioneers of the day in the field of physics, such as Niels Bohr and Paul Dirac. It was Bhabha who persuaded Jawaharlal Nehru to think about India's nuclear programme. He established the Tata Institute of Fundamental Research (TIFR) in Mumbai, which is one of India's leading institutes for science education today. Electron positron scattering is known as the Bhabha effect after him.

Srinivasa Ramanujan is considered to be one of the smartest minds to have ever come out of India. Even though he had no formal education in mathematics, during his short life, he compiled more than 4000 mathematical results, which perplexed some of the brightest minds of his time. Ramanujan worked closely with the British mathematician Hardy. Even though he died at the young age of 32, he made invaluable contributions to the field of mathematics, and is counted as one of the greatest mathematicians to have ever lived.



The man who knew Infinity – Ramanujan

Modern Day India

Today, India is considered to be one of the most technologically advanced nations. Science and engineering graduates of the country have made immense contributions in various fields throughout the world. The Indian government has plans to turn India into one of the top five global scientific powers by 2020.

Major national achievements include a significant increase in food production, eradication or control of several diseases and increased life expectancy of our citizens. Science is becoming increasingly inter- and multi-disciplinary, and calls for multi-institutional and, in several cases, multi-country participation. Major experimental facilities, even in several areas of basic research, require large amounts of materials, human and intellectual resources. Science and technology have become so closely intertwined, and so reinforce each other to the extent that, to be effective, any policy needs to view them together.

Research in different areas of science, such as agriculture, health care and astronomy are widely known today. The Atomic Research Commission, set up in 1948, is engaged in valuable nuclear research for peaceful purposes. The executive agency for implementing atomic energy programmes is the Department of Atomic Energy. The Bhabha Atomic Research Centre, Trombay, near Mumbai is the biggest single scientific establishment in the country, directing nuclear research. Today, India has five research reactors, including *Apsara*, *Cirus*, *Dhruva*, *Zerlina* and *Purnima*.

India has many interests in the field of ocean development, such as, exploration of offshore oil, fishery resources to increase food supplies, etc. A department of Ocean Development was established in 1981, under the charge of the Prime Minister, to coordinate and direct India's activities in the field of ocean research. This department has two vessels ORV *SagarKanya* and FORV *SagarSampada*, which have advanced facilities for working in the field of physical, chemical, biological, geological and geophysical oceanography and meteorology. India's achievements during the past few years include sea-bed mining using the research ship *Gaveshna* and setting up of a research station named DakshinGangotri in Antarctica.

Even though India has always been an economy centred around agriculture, advancements in science and technology have significantly boosted India's agricultural output. Today, India ranks first in the world in the production of tea and groundnuts. It ranks second in the world in the production of rice, sugarcane, jute and oil seeds. Before independence, Indian agriculture mostly depended on the rains, and as a result, the yield was modest.

Agricultural colleges and universities have been set up throughout the country, such as the Indian Council of Agricultural Research. Students learn about the basics of agriculture and implementation of technology in various processes. These colleges and universities also organise orientation courses for farmers, training them in modern farming techniques and methods. Doordarshan and Aakashvani (the state-run television and radio networks) also educate farmers regarding new farming techniques.

Advancement in modern day medicine means that many life-threatening or fatal diseases of yore have now been eradicated from the country. Diseases like polio, maternal tetanus and smallpox have now become a thing of the past. Today, only 35% of deaths caused are due to communicable diseases such as malaria and dengue, which shows how efficiently India has prevented outbreak of diseases. Life expectancy, as a result, has increased rapidly – it stands at about 70 years today. Research in biotechnology has created modern vaccines, therapeutic bioactive molecules, hybrid high yielding seeds, artificial seeds, tissue cultured propagules of agricultural, horticultural and forest plants, bio-fertilisers and bio-pesticides.

For generation of technology leading to self-reliance in the electronics sector, the Department of Electronics constituted the Technology Development Council (TDC), which has promoted several technology development programmes. The Department of Electronics has also undertaken the development of high technology linear accelerator machine for cancer therapy (LINAC) and has developed a workable prototype, the technology transfer of which is in progress.

Programmes of the Department of Ocean Development have resulted in the generation and absorption of new technologies related to the fields of Antarctic research, polymetallic nodules, and survey of living and non-living resources, development of coastal zones and islands, and marine instrumentation.

Department of Science & Technology

The Department of Science and Technology (DST), Government of India, was established on 3rd May 1971 following the success of the Green Revolution, that signified innovative deployment of scientific methodologies. Since then DST has developed several streams that later established themselves as departments or even ministries with focussed goals. Some of these include the Department of Biotechnology (DBT), Department of Scientific and Industrial Research (DSIR), Ministry of Environment & Forests (MoEF), Ministry of New & Renewable Energy (MNRE), Department of Electronics (DoE) and Ministry of Earth Sciences (MoES). The DST serves as a nodal agency connecting the science sector to the Government verticals. The roles played by DST are varied and these evolved with time. DST accordingly

- (a) develops S&T policies
- (b) strengthens human resources and institutional capacities
- (c) enables development & deployment of technologies
- (d) creates opportunities for societal interventions through S&T &
- (e) establishes and engages in mechanisms of cooperation, partnerships & alliances.

These approaches reflecting its mission ensure a holistic systemic influence for immediate, medium and long-term relevance/ gains. It enables cross cutting impacts across sectors to sustain growth, development and synergies to optimize on time as well as human, institutional and financial resources.

The DST has consistently enabled transformational changes through appropriate responses and often non-participative roles. DST accordingly played the role of an extra mural research funding agency wherein competitive grants for research were provided to investigators based on technical merit. This system was in vogue for nearly three decades. DST also took cognizance of several changes in approaches around the world, over the years and evolved its own systems adapted to India's needs. This resulted in some directional changes that evolved into proactive functions and participative actions. These are evident in DST's robust facets including proactive identification of gap areas and development of new programmes and schemes, evidence based approaches to define gaps / needs balancing competitive and development models, championing for larger resource allocations for science, expansion of stakeholder variety and base, interactions centered on value of stakeholder engagement, internal connectivity of various programmes, effective planning and coordination to optimize use and delivery of resources, gain a deeper understanding of local needs and establish a dynamic balance among three basic priorities of an integrated vision to synthesise equity, expansion and excellence in the science sector.

DST ensures a synthesis of the outcome of policies, plans, programmes and projects through appropriate forward and backward linkages. International S&T cooperation with friendly

countries had become a national priority and DST was assigned the task. Thus, DST establishes strategically important systems / mechanisms to stimulate and foster excellence and leadership in scientific research and development. These are aligned with India's developmental aspirations and will further help consolidate the niche it has established in several frontiers at the national, regional and global levels.

The Indian Space Programme and Indian Space Research Organisation (ISRO)



Today India is one of the biggest aeronautical superpowers

A space programme that is much younger than NASA or the European Space Agency, ISRO holds the record for launching 104 satellites in one attempt. Other than this, ISRO is also the first space programme to successfully send a probe to Mars in their first attempt. ISRO is also widely credited with finding water on the Moon.

India's space programme rocketed to greater heights with the successful launch of the second Geosynchronous Satellite Launch Vehicle Mark – 3 in 2017. As has been rightly observed, the challenge before Indian Space Research Organisation (ISRO) is to maintain the momentum of the programme by integrating it with other missions. The most obvious ones are related to military communication and reconnaissance.

ISRO was formed on August 15, 1969. Dr Vikram Sarabhai is considered as the founding father of space programmes in India. Department of Space and the Space Commission were set up in 1972. ISRO was brought under the Department of Space on June 1, 1972. The prime objective of ISRO is to develop space technology and its application to various national needs. Aryabhata was the first Indian satellite, launched from the former Soviet

Union on April 19, 1975. The Satellite Launch Vehicle-3 (SLV-3) was India's first launch vehicle.

ISRO has established two major space systems, INSAT for communication, television broadcasting and meteorological services, and Indian Remote Sensing Satellites (IRS) system for resources monitoring and management. ISRO has developed two satellite launch vehicles, PSLV and GSLV, to place INSAT and IRS satellites in the required orbits.

The Indian Space Programme began at Thumba Equatorial Rocket Launching Station (TERLS) located at Thumba near Thiruvananthapuram, because the geomagnetic equator of the earth passes over Thumba.

The Space Science and Technology Centre (SSTC) was renamed as Vikram Sarabhai Space Centre (VSSC) in 1972 in honour of Dr. Vikram Sarabhai, after his untimely demise on December 30, 1971.

ISRO has helped India form diplomatic ties with various nations, by helping them launch payloads into space. With space programmes costing less than a Hollywood sci-fi movie, ISRO has put Indian eyes in space. Along with the development of rockets, the agency also works to monitor the geography of India. Mapping of forest reserves, lakes, oceans, and other areas unsuitable for human intervention is done via remote satellite sensing by ISRO.

ISRO has various facilities across India, such as:

- Vikram Sarabhai Space Centre (VSSC), Thiruvananthapuram – where Launch Vehicles are built.
- ISRO Satellite Centre (ISAC), Bangalore – where satellites are designed and developed
- Satish Dhawan Space Centre (SDSC – SHAR) at Sriharikota – where integration and launching of satellites and launch vehicles are carried out
- Liquid Propulsion Systems Centre (LPSC) at Thiruvananthapuram, Bangalore and Mahendragiri – where development of liquid stages including cryogenic stage is carried out
- Space Application Centre (SAC), Ahmedabad – where sensors for communication and remote sensing satellites and application aspects of the space technology are taken up
- National Remote Sensing Centre (NRSC), Hyderabad – where remote sensing satellite data reception processing and dissemination is carried out.

Antrix is the commercial wing of ISRO, a single window agency for marketing Indian space capabilities, both products and services, to the world.

The role of CSIR

The Government of India constituted the Board of Scientific and Industrial Research in 1940. The Council of Scientific and Industrial Research was formed in 1942. Since independence there has been greater emphasis on the provision of additional facilities for the promotion of scientific and industrial research. The most significant development in this sphere has been the establishment of a chain of national laboratories and research institutes in different parts of the country.

CSIR is another major source of technology transfer for a wide spectrum of industries. It not only offers off-the-shelf technologies but also develops specific technologies on sponsorship from the user industry. Technology transfer from CSIR covers a wide gamut of application areas ranging from microelectronics to metallurgy, medicinal plants, industrial machinery, chemicals, microbiology, building materials, and food products. Newer areas of technology transfer encompass development of new drugs and catalysts for petro-refining and petrochemicals.

From allotment of stipends for doctoral programs to distribution of funds for scientific research, all major government involvement in scientific research comes under the umbrella of CSIR. CSIR also has many different laboratories throughout the country, which are premier labs for research and development in India. The increasing share for research in India's budget means that many programs are run by CSIR, for students as well as research scholars, and today many prominent Indian institutes collaborate with research institutions throughout the world with the funds distributed by the CSIR in its schemes.

The Indian IT Industry



Two of the world's largest technological giants are spearheaded by Indian-origin CEOs.

India is considered to be a superpower in Information Technology. Accredited as the country producing the largest number of engineering graduates per year, Indian engineers today form the backbone of not only Indian companies but also global powerhouses like Microsoft, Apple and Google. Cities like Bangalore, Pune and Indore have gone on to become IT hubs in India, which offer jobs to thousands of engineers and bring in millions of dollars in projects.

In the 1990s, the industry took off with an export of nearly \$100 million with around 5,000 employees. Now it is an industry that thrives globally and India's IT exports are now around \$70 billion with 2.8 million employees working in this sector. The IT sector is one of the top two industries in the country today. Tata Consultancy Services (TCS), Wipro and Infosys are some of the biggest players in the industry, and have garnered a worldwide reputation for IT solutions.

Research potential in India

India is home to some of the most prominent scientific research institutes in the world, such as the Indian Institutes of Technology (IITs), the Indian Institutes for Science and Education Research (IISERs), the Tata Institute of Fundamental Research (TIFR) and Indian Institute of Science (IISc). Modern day India has been at the forefront of major technological and scientific innovations.

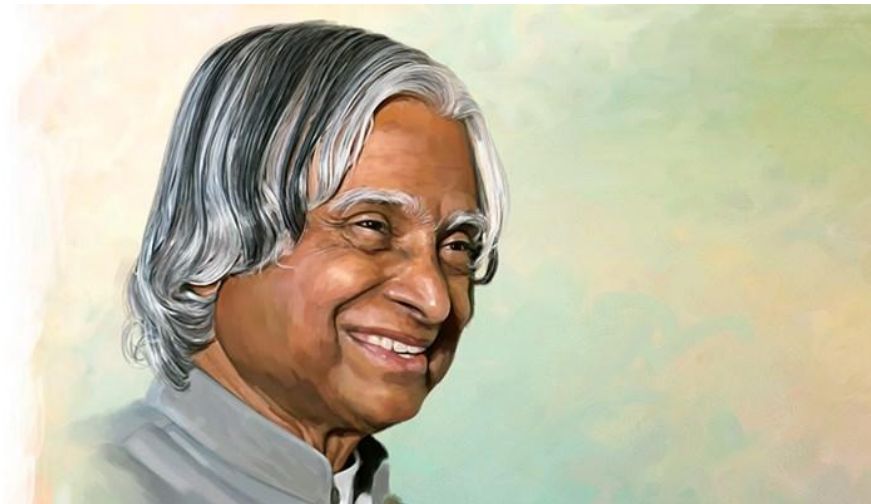
Even though almost every other modern superpower, such as France and Russia, had a headstart over India, India has quickly overtaken most of its competitors in terms of scientific publications. Prominent Indian institutes, such as University of Delhi, were a part of the collaborative project which found evidence for the Higgs Boson in 2012, while IISER-TVM was one of the many institutes involved in the discovery of the first gravitational waves in 2017. As a result, India is about to get its own gravitational wave observatory, LIGO India, by 2022, along with establishment of the Indian Neutrino Observatory (INO).

The government actively promotes research and development in fields of importance, and has recently launched the Prime Minister Fellowship Scheme for PhD scholars in IITs and IISc Bangalore, the finest institutes of research in the country. Facilities such as increased monthly stipend, and money grants to attend seminars and purchase of books, are provided to PhD students. The main aim of the program is to thwart brain drain, and instead help home-grown talent use their potential for the welfare of the country.

Institutes such as TIFR in Mumbai, IISER in Pune and RRIn Bangalore have collaborated with institutes all over the world for research, providing vast exposure to their students and faculty. TIFR and Punjab University in particular are centres of research in India, with a research output at par with the largest universities of the world.

The Indian Defence Programme

The Defence Research and Development Organization, or the DRDO, works exclusively in application of science and technology in the military, in order to stabilize Indian defence against intruders. Successful flight trials of indigenously developed first long range sub-sonic cruise missile *Nirbhay*, Quick Reaction Surface-to-Air Missile (QRSAM) and supersonic cruise missile BrahMos from fighter jet Sukhoi-30 MKI were done, and India has added submarines such as the *INS Kalvari* to the Navyarsenal. With the remarkable success of the 1000-km range *Nirbhay* trial, India demonstrated its capability to develop long range cruise weapon systems. DRDO has also conducted successful tests of a laser system mounted on a truck, and plans are now under way to create a more powerful laser with a longer range.



The innovative thinking and resurgence of DRDO can largely be credited to the Missile Man of India.

Since independence, India has acquired the capability to produce a wide variety of electronic goods such as radio and television sets, communication systems, broadcasting equipments, radars, nuclear reactors, power control systems and underwater systems. A very large part of the components required for these are produced indigenously. The production of electronic goods has been growing at the rate of 18 per cent per annum over the past decade. Today we are even exporting electronic goods to different parts of the world. Further, computers have been introduced to improve efficiency and enhance production. Major recently set up facilities, include the Semi-Conductor Limited (Chandigarh), National Computer Centre (Bombay), National Information Centre (New Delhi) and a number of regional computer centres.

India is set to become a science superpower in the coming years. With the increase in research output and technological patents in the country, we have surged ahead of many countries in science and technology. Indian scientists are now at the forefront of research and development in major industries. If India can deal with all shortcomings and invest more time and money in its science education program, Indian research students and engineers will no longer need to leave the country for better opportunities abroad.