SHRAVAN - BHADRAPAD 1945, AUGUST 2023
VOL 19 ISSUE 88

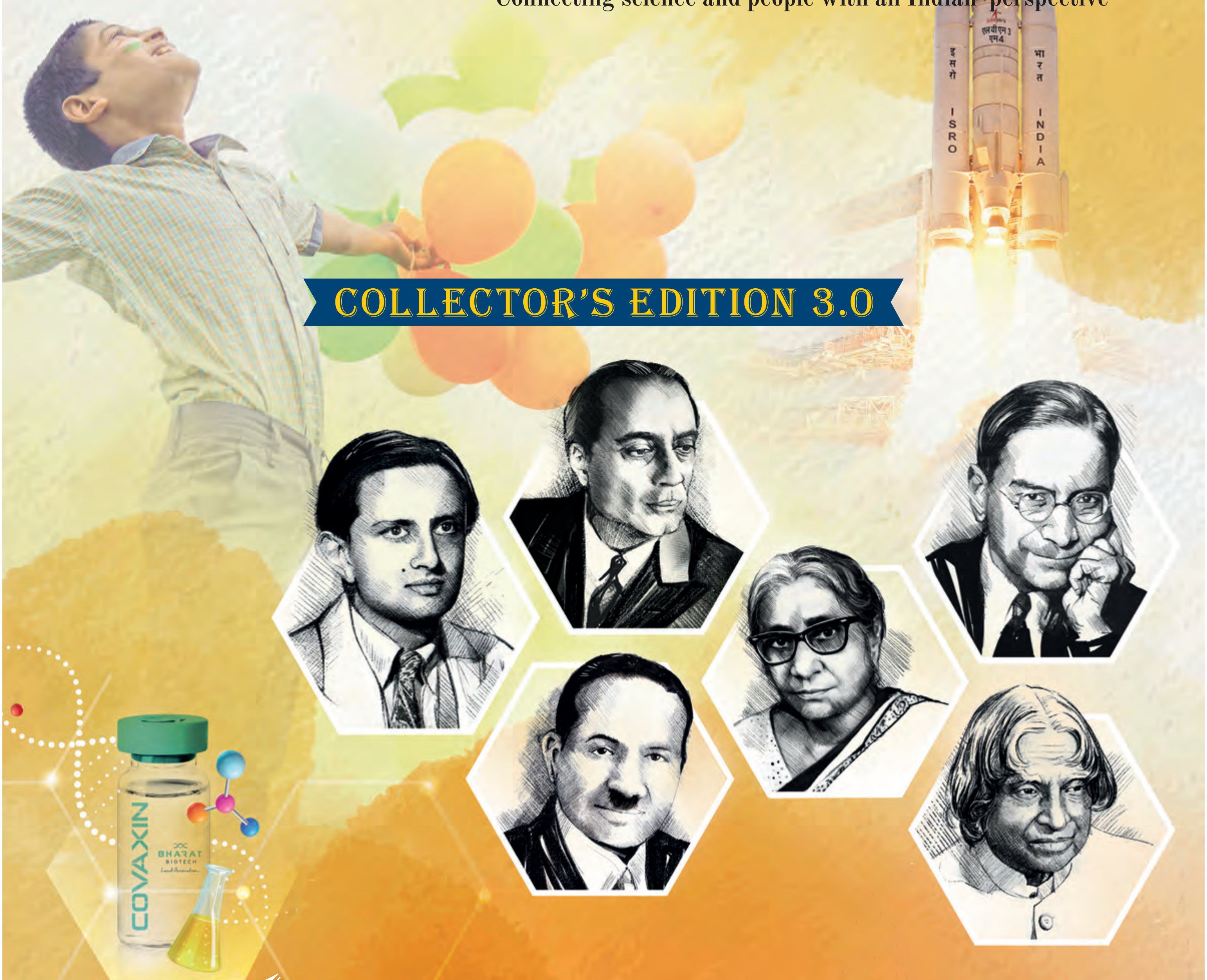
www.scienceindiamag.in

PUBLISHED BY VIJNANA BHARATI
₹ 100

Science INDIA

राष्ट्रहिताय विश्वमङ्गलाय

Connecting science and people with an Indian perspective



COLLECTOR'S EDITION 3.0

SWATANTRA BHARAT

MARCHING TO NEW FRONTIERS OF SCIENCE

CSIR-INSTITUTE OF MINERALS AND MATERIALS TECHNOLOGY

Council of Scientific and Industrial Research
Bhubaneswar-751013, INDIA

CORE AREA COMPETENCY

- Material characterization
- Mineral beneficiation, pelletisation and agglomeration
- Extraction of metals from ores, sludge and scraps
- Plasma processing of materials
- Nanomaterials, bio materials and energy materials
- Coatings, thin films, alloys, composites
- Green technology for industrial waste management
- Drinking water filtration and wastewater recycling
- Environmental impact assessment
- CFD/DEM modelling and simulation

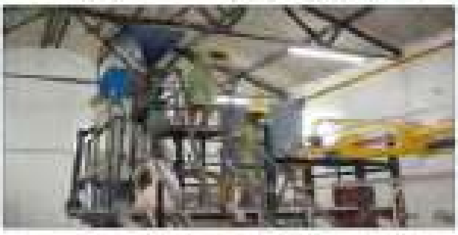
Constructed wetland for waste water treatment

XPS

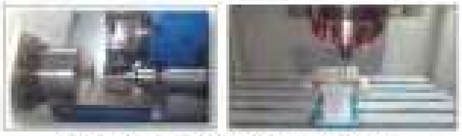
Particle Size Analyzer

INDUSTRY INTERFACE

- Technology development for mineral, material, metallurgical and chemical industries
- Contract research and consultancy for process optimization
- TEFR and Basic engineering packages in core area
- Testing of water quality and components in ores, rocks, soils, slags, and processed products
- Skill development



High Concentration Slurry Transportation



CNC Turning & Milling Machines

FACILITIES

- Mineral processing pilot plant
- SOPs for extraction of materials from industrial wastes
- Coal characterization
- Processing of natural gemstones for value addition
- State-of-the art analytical equipments for characterization of ores, minerals & materials
- Commercial scale production facility for fly ash and red mud building materials
- Mechanical workshop for design and fabrication
- Biomass operated cook stoves and testing lab
- Technology validation

Fly Ash & Red Mud Bricks

EPMA

XRD

Plasma Spray Coating

Column Flotation Unit

Hydrogen Plasma Reactor

TEM

X-ray Micro CT

Microwave Plasma Reactor

Scanning Electron Microscope

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Owned by Swadeshi Science Movement, Kerala (A unit of Vijnana Bharati) Sastra Bhawan, B 4, Fourth Floor, Mather Square, Town Railway Station Road, Kochi — 682 018, Kerala

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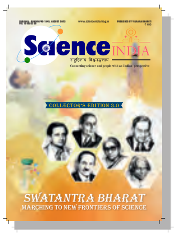
Published from New Delhi
Printed at Innovative Designers & Printers,
E-41, Sector 6, Gautam Budh Nagar, Noida-201301.
Tel No.: 020-4269987/ 9810145783

COLLECTOR'S EDITION 3.0

Swatantrata ka Amrut Mahotsava

What's Inside

BUILDING A NEW NARRATIVE



Cover Illustration: Bhaskar Deb

ISRO
Chandrayaan-3 Mission:

Smile, please!

Pragyan Rover clicked an image of Vikram Lander this morning.

The 'image of the mission' was taken by the Navigation Camera onboard the Rover (NavCam).

NavCams for the Chandrayaan-3 Mission are developed by the Laboratory for Electro-Optics Systems (LEOS)

DRDO
@DRDO_India

#DRDOUpdates | Achieving major milestone towards #atmanirbharbharat ASTRA-Beyond Visual Range (BVR) Missile in its maiden flight trial was successfully fired from LCA Tejas off the coast of Goa.
@DefenceMinIndia
@SpokespersonMoD

pib.gov.in/PressReleasePa...

ISRO
@isro

Chandrayaan-3 Mission:
'India,
I reached my destination
and you too!'
: Chandrayaan-3

Chandrayaan-3 has successfully soft-landed on the moon !.

Congratulations, India!

#Chandrayaan_3
#Ch3

Hearty Congratulations to ISRO and its team of scientists

India has reached the Moon after the successful landing of the Vikram Lander Module of Indian Space Research Organisation's (ISRO) third lunar mission Chandrayaan-3, on August 23.

With Vikram's successful landing near the moon's south pole, India became the first country to reach the rather difficult part of the lunar surface, and only the fourth country in the world after Russia, US and China to reach the moon.

Send your letters to editor@scienceindia.in

DISCLAIMER : The views, thoughts, opinions and content expressed in the articles in this magazine are solely that of the authors; and not necessarily of *Science India* or Vijnana Bharati.

Let's Connect

Dear Readers,
The month of August 2023 is going to be memorable for a long time to come. The biggest reason that the people of our generation — living in these glorious times for our nation — will remember it for, is the successful Chandrayaan-3 mission.

On August 23, the mission's Vikram lander successfully touched the surface of the moon, reaching the hitherto unexplored and rather difficult south pole of the celestial body, making it a double dose of sweetness for all Indians. The thrill, the elation, the pride and the feeling of absolute happiness that this event afforded to all Indians is going to be unsurpassed for a long time to come. We still can't get enough of reliving that outstanding moment — precisely 6.03 pm on August 23 — when Vikram touched down on the surface of the moon, sending ripples of unprecedented joy amongst Indians all over the world.

This truly world-class achievement, besides adding heft to our worthiness on the global stage, has far deeper meanings for Indians than is apparent on the surface. It is not just an acknowledgement of space science powerhouse that India has become, or of the huge pool of homegrown scientific talent that India is a repository of, or of our standing among the elite space faring nations of the world, and so on and so forth.

It is more profound; it is an affirmation of what our visionary scientists and politicians-statesmen had set out to achieve for this country post 1947. With the success of Chandrayaan-3, we have reaffirmed our faith in our abilities, in pushing our past as a subjugated nation into the bins of history, and in our belief that our abilities will push as a global leader in all fields in the bright future that we can see.

Science India dedicates this third Collector's Edition of the magazine to this belief, to this faith, to this optimism, to this confidence. While the two previous Collector's Editions (2021 & 2022) highlighted the oppression and subjugation of Indian science by the British using 'science as a tool' vis-à-vis the role of Indian scientists as warriors of freedom struggle, this third edition has showcased the contribution of our scientists in building of institutions — 'temples of modern India' — post-Independence.

As envisaged by our leaders at the time of Independence, progress in science is aimed at ameliorating the condition of the country's masses

In the past 76 years of our independence, we have crossed hurdles and scaled mountains not just in the field of space, but in other areas of scientific research as well, as the bouquet of special stories in this edition showcases. From space research to atomic energy, from defence capabilities to India's prowess in the field of Information Technology, from non-conventional energy sector to biotech and life sciences, from organic farming to applying next generation technology in agriculture sector, there is an entire gamut of well-researched and pithy articles in this edition, taking a look at the future of these respective fields and how India is poised to scale heights in all aspects of life.

Scientific achievement in India is not just to add feathers to our national cap. As envisaged by our leaders at the time of Independence, progress in science is aimed at ameliorating the condition of the country's masses. As we put our past firmly behind us and march into the future with our heads held high, we need to include every Indian in this scientific journey of bettering our lot. Our global success in the field of IT and space research has shown that we can do it.

Our great visionary scientists laid strong foundations for scientific research in the early years of Independence despite facing tremendous hurdles, most of which are unimaginable today. Yet, they persisted, and left us with institutions and an indomitable spirit that have now proved to be springboards for a new, resurgent India.

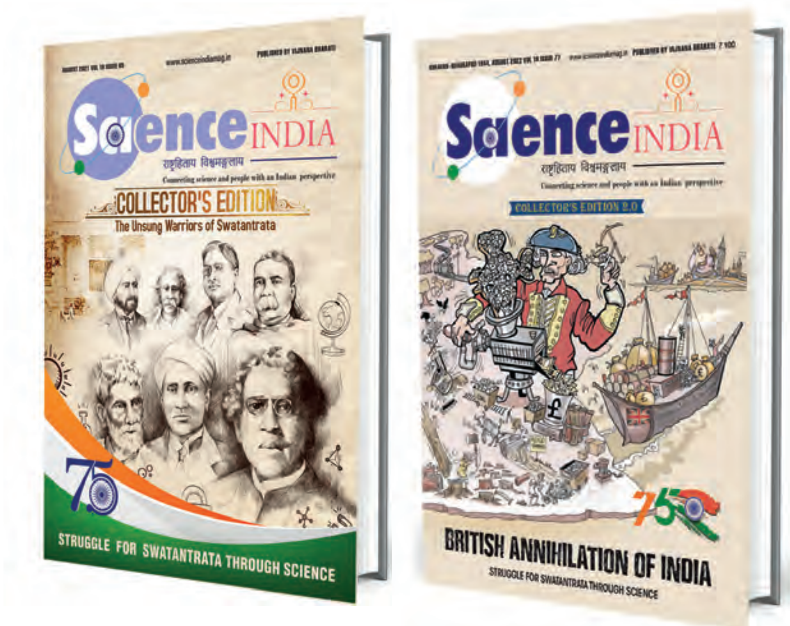
With this zeal in our hearts, we leave you to enjoy *Science India*'s Collector's Edition 3.0 based on the theme of 'Swatantrata ka Amrut Mahotsav' , with a compendium of untold and exclusive stories, and rare images put together with great effort by our esteemed writers and Team Science India.

May the success of Chandrayaan-3 fire the imagination and potential of our people for all times to come!

Building a New Narrative:
Repositioning Scientists as Freedom Fighters

The landmark of 75 years of Independence called for re-examining the history of our freedom struggle, to give due credit to scientists who excelled despite oppressive colonial rule

■ **Debobrat Ghose**



Who was Dr Mahendra Lal Sircar? Or Radhanath Sikdar? I have posed this question to several people — from students to academicians, from Bengali households to even a few scientists in the past three years. To my utter surprise, less than 25 percent of them were familiar with these two names; but there were hardly a few who knew about the achievements of Dr Sircar or Sikdar in the domain of Indian science.

The works of Dr Sircar, Sikdar, and many more of their ilk are not unknown to science historians, science academicians or to the readers of *Science India*, as this magazine has regularly published exclusive articles related to them and their works. But it's largely missing amongst general masses.

Despite being the pioneer in establishing India's first indigenous research laboratory — Indian Association for the Cultivation of Science (IACS) in Calcutta for the Indian scientists during the British colonial rule, Dr Sircar has remained almost in oblivion. It was at this very IACS, where Dr CV Raman carried out his pathbreaking research on Raman Scattering and won Asia's first ever Nobel Prize in science (Physics) in 1930.

Similarly, Sikdar, a 'chief computer' at the Great Trigonometrical Survey of India, computed the height of Peak XV as the highest mountain peak in the world, which we today know as Mt. Everest. While the peak was named after Sikdar's former boss, George Everest, who served as the Surveyor General of India 1830-43 and had nothing to do with the calculation of the height, Sikdar vanished into the pages of history.

How many people know about the scientific vision and work of Lokmanya Bal Gangadhar Tilak, who is known as a nationalist freedom fighter and for giving the clarion call — 'Swaraj is my birth right and I shall have it'?

Reams of newsprint have been used till date for writing and chronicling the contributions of people, masses, organisations and the society in India's freedom struggle.

Textbooks on history and political science have mentioned at length about the political struggle by our leaders or the armed struggle by Indian revolutionaries — be it the Non-Cooperation, or Civil Disobedience or Quit India movement, the Tribal uprising or the armed struggle by the Indian National Army.

But despite having evidences in the forms of books and detailed information available in the pages of history about the British colonisers using 'science' as a potent tool to subjugate and exploit India, vis-a-vis the significant role being played by Indian scientists during the colonial era not only through their meticulous works in the domain of science and technology, but through their vision, resistance and struggle in countering the onslaught — the students and the general public in Swatantra Bharat are hardly aware about these facets of the 'untold history'.

In spite of this reality, is it not surprising that we as a society, are yet to acknowledge and perceive our scientists as warriors of the struggle for *swatantrata*? As a result, our scientists — who scaled heights during the oppressive colonial rule — have remained the 'unsung warriors of *swatantrata*'. This necessitated Vijnana Bharati (VIBHA) to deep dive into the colonial history and bring before the world the 'untold truth' that has unfortunately remained missing from our textbooks.

BUILDING OF A UNIQUE NARRATIVE

Vijnana Bharati (VIBHA) through its Swadeshi Science Movement has been reaching out to the masses across the country to create awareness related to India's indigenous science, work of scientists from ancient times and inculcate a scientific temper.

During my first meeting with the late Jayant Sahasrabudhe*ji*, who was then the national organising secretary of Vibha, in mid-July 2020 — ahead of formally joining *Science India* magazine as the editor — Jayant*ji* narrated to me a story on how the British colonisers suppressed the high quality work of Indian scientists, used science as a tool to show India and its rich scientific and cultural heritage in bad light, and how the scientists faced discrimination, humiliation and their works — many of which were superior to their western counterparts — were looked down upon, efforts were made to obliterate them and the Indian identity, how it was instilled in the minds of Indians that theirs was a

Dr Mahendra Lal Sircar (1833-1904) established the Indian Association for the Cultivation of Science in 1876

civilisation without any science, and they did not have what it took to pursue serious science.

During our subsequent meetings, ahead of the relaunch of *Science India* in its new avatar on 21 October 2020, Jayant*ji*, who by now was the chief editorial advisor of the magazine, made it clear that that this magazine must come up with a special edition focussing on the history of struggle, sacrifices and work of Indian scientists — 'the unsung warriors of *swatantrata*' — when the nation would be celebrating its 75th Independence Day on 15 August 2021.

"This neglect, discrimination, suppression and systematic decimation of our scientists and their scientific work by the British in 190 years of colonial rule that completely destroyed the 'Swa' — the very identity of the Indian nation, always troubled my mind. The British used science as a tool to achieve their expansionist goal in India and to obliterate our identity. Though India made a great contribution in science from ancient period, they succeeded in making the Indians believe that they were much inferior to the West in its culture, education and scientific knowledge. There is an immediate need to make our people and the world know the truth of this British annihilation of India, the way the colonial rulers looted India and siphoned off $45 trillion from this country in 190 years," Jayant*ji* had asserted in several of his meetings and addresses.

This effort of building a discourse, a narrative under the tutelage of Vijnana Bharati began in full-swing during the second half of 2020, with a series of lectures by science historians, scientists, academicians, etc; various programmes highlighting the role and contribution of Indian science and scientists were conducted in national laboratories and institutes, and academic institutions across the country.

Coinciding with the government's 'Azadi ka Amrit Mahotsav'— an initiative to celebrate and commemorate 75 years of Independence and the glorious history of its people, culture and achievements which was commenced in 2021 — Vibha along with the Ministry of Culture jointly organised various programmes to make public aware about this discourse through talks, exhibitions, celebrations, films, etc.

The CSIR-NIScPR (National Institute of Science Communication & Policy Research) played a pivotal role in dissemination of information based on this discourse, through various channels.

THE OUTCOME

Vibha organised internal sessions and formed a group — Sahitya Nirman Samuh. Brainstorming sessions were held every week that eventually brought out many unknown facets.

To make the narrative everlasting, *Science India* published two Collector's Editions in 2021 and 2022, and a Coffee Table book, showcasing the strength of Indian science and invaluable contributions of our stalwart scientists during the British Raj in India. Through untold stories and rare photographs, these two editions narrated how our legendary scientists like Acharya Jagadish Chandra Bose, Acharya Prafulla Chandra Ray, Dr Mahendra Lal Sircar, Dr Ruchi Ram Sahni, Dr CV Raman and many others not only made invaluable contributions to Indian science, but also played the role of freedom fighters in the domain of science. A rare feat indeed.

**The writer is Editor, Science India.*

Organic Farming: *India's Pathway to Achieve SDGs & Climate Pledges*

With the largest number of organic producers in the world, India is well-placed to utilise this method of agriculture to address its multifarious challenges


Raj Seelam and
Ambica Vankamamidi

India is the second largest producer of wheat, rice, cotton, farmed fish, sheep & goat, meat, vegetables, fruits, and tea, and a leading producer of pulses, milk, and spices. Our food grain production in 1950-51 was just 51 million tonnes, which increased six times to a record 315.7 million tonnes in 2021-22. We have come a long way from a food-deficit country to a food-surplus and net-exporter nation. Yet, Indian agriculture has several challenges to address. Increasing population, climate change, depleting natural resources, average farm size, productivity, soil fertility, and profitability are weighing down the sector. Organic farming has answers to several of these challenges.

Organic farming can mitigate concerns of small and marginal farmers, enhance farmer income, reduce fertilizer use and water use, decrease fossil fuel usage, bring about carbon sequestration, encourage the use of renewable energy, reduce greenhouse emissions, and help farmers adapt to climate change.

SOIL CARBON CONTENT

A Centre for Science and Environment report on the *State of Biofertilizers and Organic Fertilizers in India* stated that testing about 5.27 crore soil samples as part of the Soil Health Card (SHC) scheme revealed the deteriorating health of Indian soils. 'About 85 percent of samples are deficient in organic carbon. Of these samples, about 15 per cent contain very low levels of organic carbon, 49 per cent contain low levels of organic carbon and 21 per cent contain medium levels of organic carbon,' the report stated. This observation is significant for tropical ecosystems as most carbon is stored in vegetation and soil. Organic matter plays a role in retaining the carbon in the soil. The chemical, biological and physical conditions of soil declined over a period of time in the country.

In the Vedic period, farmers followed a sequence of cropping and fallowing. Cow dung was used as fertilizer. The ash mound tradition, dating back to 2800 BC, was developed in the Deccan plateau region. *Brhatsamhita* of Varahamihira, *Sarngadharapaddhati* of Sarngadhara, and *Vrikshayurveda* of Surpala are Indian texts that contain details on botanical and agricultural practices such as procuring, preserving, and treating of seeds, selection of soil, pits for planting saplings, groundwater resources, diseases of plants and its causes, veneration of trees, ideas for a pleasure garden, natural vegetation, animal husbandry, soil classification, fertility and physical characteristics of soils. Accordingly, crops were recommended for the soils.

Indian agriculture was dominated by subsistence farming in the pre-colonial era. Excess food grains cultivated were stored so that they could be used against any natural calamity. Indian farmers practiced crop rotation and mixed cropping. For instance, millets such as Jowar were sown mixed with leguminous crops like Arhar. Under imperial rule, India witnessed changes in land ownership, crop failures, famines, and a shift from domestic farm production to commercial production. Food

Image Courtesy: Wikimedia Commons

crops such as rice and paddy were also channelised for distant markets. Commercial crops such as indigo, opium, silk, sugarcane, cotton, wheat and jute were largely grown by small farmers who depended on merchants for their working capital.

Studies indicate that the food grain output between 1891 and 1946 was stagnant. One reason was the World Wars. The other was that food output could not accelerate in the same proportion as the population increase. The per capita availability of food declined. This situation was acute in Bengal where the population grew at an annual rate of about one percent, and the food output declined at a rate of about 0.7 per cent in the 1921-1946 period.

Recurrent famines forced the British to study soil and agricultural conditions in India. The appointment of JA Voelcker and JW Leather was the first step towards a policy on agricultural research. The work of JW Leather on characterising Indian soil paved the way for a soil map of India. In 1932, Madam Scholasky prepared the first soil map of India. However, the first Soil Map of India with soil properties, was prepared in 1943 by B Viswanath and AC Ukil at the Indian Agricultural Research Institute (IARI), New Delhi.

GREEN REVOLUTION

At the time of Independence, agricultural productivity was very low and almost stagnated. After Independence, the Indian government initiated immediate programmes aimed at food security. Dr MS Swaminathan pioneered India's Green Revolution. He introduced a programme encouraging the cultivation of high-yield varieties of wheat and rice. The green revolution helped in ramping up food security. The success was due to a combination of research, infrastructure, policy support, the introduction of new varieties, use of pesticides and fertilisers. There was a greater acceptance of modern farming methods in the country.

Mono cropping, indiscriminate and

The first Soil Map of India with soil properties was prepared in 1943 by B Viswanath and AC Ukil at the Indian Agricultural Research Institute (IARI), New Delhi

unbalanced use of chemical fertilisers and pesticides, high-yielding hybrid seeds response to high doses of chemical fertilisers to get high yields, absence of policy guidelines regulating farm inputs and techniques caused pest resistance, a decrease in soil fertility, soil health, and a decline in the health of farming communities.

Traditional farming systems can help restore soil organic carbon and fertility in Indian soils. The biological methods to control pests, native sustainable crop protection practices, double cropping, inter cropping, agroforestry, crop rotation, use of local varieties, and other methods of traditional farming techniques improve soil fertility and create a sustainable environment.

ORGANIC MOVEMENT

The work of Sir Albert Howard, Rao Bahadur B Vishwanath, Acharya Vinoba Bhave, Robert McCarrison, and others was responsible for creating a movement on organic farming. In 1937, Rao Bahadur B Vishwanath stressed organic manure is the life of the soil. Acharya Vinoba Bhave experimented with "Rishi Krishi" at his Paunar Ashram. McCarrison defined the 'wheel of health' to explain that composted organic residues improved soil fertility, and the health of crops/plants, and provided a healthy diet for animals and humans. Robert McCarrison and Vishwanath in their work stated that mineral nitrogen fertilizer decreases the food quality.

Sir Albert Howard, imperial economic botanist and director of the Institute of Plant Industry, Indore, from 1924 to 1931, chronicled traditional farming practices of our country in his work *An Agricultural Testament*. He realised that Indian traditional farming practices improved the health of the soil, villagers, livestock, and crops. He believed that unhealthy soil caused the

Image Courtesy: Wikimedia Commons

Organic agriculture can improve the livelihood of small and marginal farmers

disease of a plant or animal. Howard championed his theory by highlighting the health of the Hunza people who followed a primitive organic agriculture practice in the Himalayas.

Howard advocated composting in India, which was termed the Indore Process. He demonstrated to the farmers that composting organic wastes is a good source of plant nutrients and improves soil properties. Howard published details of the Indore method in 1931 in *The Waste Products of Agriculture: Their Utilization as Humus*. Several Indian scientists since ancient, medieval and British periods have made formidable contributions towards natural resource management. In 1940, CN Acharya said organic manures enrich soil fertility, and agricultural wastes aid in the production of biogas and compost.

SYMBIOTIC RELATIONSHIP

Modern agriculture looks at maximising agricultural profits rather than sustainability. The focus is more on soil chemistry rather than soil's biological and physical properties.

In the soil, there is a symbiotic relationship between soil microbes. These soil microbes play an important role similar to gut microbes in humans. In soil, the higher the carbon content, the higher the microbes, which increases soil fertility. Soil microbes can increase through crop rotations, inter-cropping, symbiotic associations, cover crops, organic fertilizers, and minimum tillage. Soil fertility can increase the water-holding capacity, improve nutrient-holding of the soil, suppress crop diseases, and mitigate groundwater pollution.

Green manuring aids in atmospheric nitrogen fixation in the soil. Traditional seeds, breeds, and the absence of chemical inputs create a conducive ecosystem creating natural areas within and around organic fields. This activity promotes natural pollination and reduces pest infestation.

The Indian Council of Agricultural Research (ICAR) launched a project to promote Indigenous Technical Knowledge for the benefit of farmers. A few of the experiments conducted to validate traditional methods include intercropping, green manuring, mixing paddy seeds with cow dung before sowing, and growing trees along the field to prevent soil erosion. Another notable experiment was on Rolu, (a granite stone block with a hole 7.4" depth, 9" diameter hole) in rainwater management. The quantity of rainwater in the Rolu decides the time of sowing seeds for crops such as sorghum and castor.

Millets have often been sown with other crops by Indian farmers practising crop rotation

Image Courtesy: Shutterstock

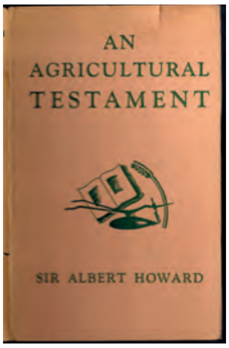


Image Courtesy: Internet

Left: Sir Albert Howard, director of Institute of Plant Industry, Indore, from 1924 to 1931, chronicled traditional farming practises of India in his book

IMPROVED LIVELIHOOD

Organic agriculture can improve the livelihood of small and marginal farmers in terms of health and income, as exposure to product and market risks is limited. In India, about 85% of farmers cultivate less than five acres of land and depend on non-institutional lenders for credit. The formation of organic Farmer Producing Organisations limits farmers' exposure to risks and gives a better platform to market their produce. It also creates rural employment opportunities as organic farming is labour-intensive.

In 2001, the National Programme for Organic Production (NPOP) under the Agricultural and Processed Foods Products Export Development Authority (APEDA) was implemented. This programme contains norms for organic production, promotion, and accreditation for certification agencies. Sikkim became the first state in the country to be completely organic. Other states such as Uttarakhand, Karnataka, Andhra Pradesh, Telangana, Uttaranchal, Madhya Pradesh, Gujarat, Rajasthan, Tamil Nadu, Kerala, Maharashtra, Nagaland, and Mizoram are promoting organic cultivation. In 2002 about 85% of the 14,000 tonnes of harvested organic produce was exported.

According to the Base Paper on Organic Farming, ICAR conducted experiments on organic farming practices during the 10th Five-Year Plan. The purpose was to understand the agronomic aspects of arable crops at 13 centers, and later under the Twelfth Plan, seven more centres to cover additional crops such as spices and tuber, and include hilly and rain-fed regions were approved. The analysis revealed an increase in

Image Courtesy: Pixabay

Organic farming has a positive impact on UN Sustainable Development Goals

soil organic carbon, and soil microbes, and a slight improvement in nutritional quality in crops such as soybean, turmeric, and ginger and offered a higher net return.

SCHEMES

To boost organic farming, the government in 2016 initiated various schemes such as the Paramparagat Krishi Vikas Yojana (PKVY) and Mission Organic Value Chain Development for North Eastern Region (MOVCDNER). Under these schemes, financial assistance for procurement of organic inputs, support through Farmers Producers Organisation (FPOs), training, value addition, certification and marketing of organic produce, residue analysis, and cluster formation are provided. The Bhartiya Prakritik Krishi Padhati (BPKP), introduced as a sub-scheme of the PKVY is to promote traditional indigenous practices like Natural Farming (NF). The Participatory Guarantee System (PGS) encourages organic certification through Regional Council or NPOP. At the global level, IFOAM - Organics International supports the Participatory Guarantee Systems (PGS) worldwide.

According to the Research Institute of Organic Agriculture FiBL on The World of Organic Agriculture Statistics and Emerging Trends 2023, "India leads with almost 1.6 million organic producers worldwide." The minimum requirements for farms to be certified organic in India are: conversion; cropping pattern; planting; manurial policy; location; pest, weed, and disease management; soil and water conservation; contamination control; processing; labeling; packaging; documentation, and certification. It takes three years for a farm to be certified organic.

The Department of Agriculture, Cooperation and Farmers Welfare (DAC&FW) has begun mapping Traditional Organic Areas that can be converted into certified organic production through the 'Large Area Certification' (LAC) Regulations and Policies.

TRACEABILITY

Traceability, a blockchain technology, is a step toward food safety. Verified information on seeds, location, and inputs used can go a long way in building trust in organic produce in the country. Traceability is mandatory for organic products to be certified 100% organic by the APEDA. The concept of traceability enhances transparency in the organic food sector. The 100% organic certification commands better prices in the market and benefits farming communities with higher returns.

Additionally, the policymakers must ensure all the laboratories and certification agencies are a part of the blockchain system, as this can eliminate fake certifications. Such support from the government will aid in plugging loopholes in the certification processes and lend credibility to organic exports from the country that are on the threshold of a 10-fold increase in the next five years.

IMPACT ON SDGS

The World of Organic Agriculture Statistics and Emerging Trends 2023 figures state the Indian organic market can grow at a CAGR of about 20.5 percent in the forecast period of 2021 and 2026. For this to happen a robust policy promoting organic farming and encouraging marginal farmers to join organic FPOs or supporting them through the conversion process and create appropriate linkages to encourage them to cultivate organic produce is essential. To create a market, awareness on consumption of organic food is necessary.

Another reason for promoting organic farming is it has a positive impact on the UN Sustainable Development Goals. Organic agriculture is climate-smart (SDG 2), organic produce has higher levels of nutrients (SDG 3), improve water holding capacity (SDG 6), reduce the impact of chemicals on workers' life (SDG 8), organic produce is certified and recognisable for customers (SDG 12), carbon sequestration and reduction of agrochemicals (SDG 13), limit dead zones (SDG 14), and improve 30-50% biodiversity on organic farms (SDG 15).

Organic farming can be one of the pathways for India to achieve her commitments of SDGs, five climate pledges (Panchamrit), carbon neutrality, and bio-diversity conservation.

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Agriculture: The Way Forward

With the Green Revolution, India turned from a food-deficit to a food-surplus, export-oriented country. Now is the time to apply technology for second-generation challenges

■ **Dr Sudeshna Chakraborty, Dr Kalyanrao Patil, Dr Vidyadhar B Vaidya**

Agriculture plays a significant role in India's growing economy. With around 54.6% of the total workforce involved in agriculture and allied sector activities, the sector contributes to 17.8% of the country's gross value added (GVA). During 2021-22, the country recorded US$ 50.2 billion in total agriculture exports with a 20% increase from US$ 41.3 billion in 2020-21. It is projected that the Indian agriculture sector will grow by 3.5% in FY23.

HISTORY OF INDIAN AGRICULTURE

Indian agriculture post-Independence is typically identified with the 'Green Revolution' that started in the 1960s, enabling the nation to make great strides in domestic food production and significantly contributing to progress in agriculture and allied sectors. It transformed India from a food-deficit nation to a food-surplus, export-oriented country. Although the agriculture sector plays a crucial role in the Indian economy, there is a constant drop in this sector while the service sector is comparatively improving. Now the country is facing second-generation problems, especially related to sustainability, nutrition, adoption of new agricultural technologies and, perhaps most importantly, income levels of the population dependent on farming.

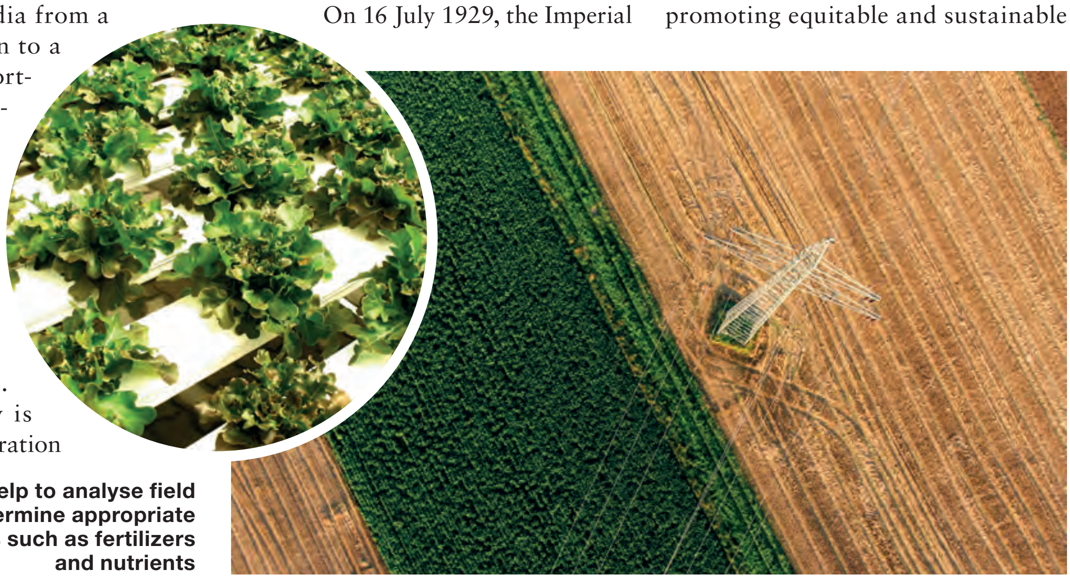
The cultivation of crops started during 7500 B.C. and thus agricultural science came into existence. To produce the crops, human beings tilled the soil. Tilling of soil or in another word, cultivation of soil is called 'Agriculture'. Thus, agriculture is an art and science both in which we study all the human activities related to use of soil. In India, scientific cultivation has been started with the commercialisation of sugarcane, cotton and tobacco. On 27 April 1871, a joint department of agriculture, revenue and commerce was established by Lord Mayo on the request of AO Hume. Due to directions issued by the Famine Commission 1880, a separate central department of agriculture was established in 1881. In 1905, Agricultural Research Institute was established at Pusa (Bihar) under the viceroyalty of Lord Curzon. It was renamed Imperial Agricultural Research Institute in 1919. After Independence, the word 'Imperial' was substituted by 'Indian' and now it is called Indian Agricultural Research Institute (IARI). In 1958, IARI was given the status of deemed university by the University Grants Commission.

On 16 July 1929, the Imperial Council of Agricultural Research was established, which was later renamed to Indian Council of Agricultural Research (ICAR) in March 1946 under the presidentship of Jogendra Singh.

In 1966, ICAR was reconstituted into a full autonomous body and its first Director General was Dr BP Pal. The benefits of new technology or technical knowhow of agricultural production were being utilised by the big and rich farmers. Therefore, it was felt that for a holistic development approach of the agricultural sector, the evolved technology in the laboratory should be stretched out to the lands of small and marginal farmers. In this context, the lab to land programme was launched in India on the occasion of ICAR golden jubilee celebration year in July 1979. Under the programme, the problems related to agriculture were brought to the laboratory where the particular solution was to be found out or searched out and later on was communicated to the farmer.

PROSPECTS OF INDIAN AGRICULTURE

The continuous technological innovation in the Indian agriculture sector plays a critical role in the growth and development of the Indian agriculture system. It will be crucial for ensuring agricultural production, generating employment, and reducing poverty to promoting equitable and sustainable



Drones help to analyse field conditions and determine appropriate interventions such as fertilizers and nutrients

Image Courtesy: Unsplash

Futuristic technologies such as aerial imaging have helped farms become more productive, efficient, safe, and environmentally sustainable

growth. Constraints include diminishing and degraded land and water resources, drought, flooding, and global warming generating unpredictable weather patterns that present a significant barrier for India's agriculture to grow sustainably and profitably. The future of agriculture seems to involve much-developed technologies like robotics, temperature and moisture sensors, aerial images, and GPS technology. Farms will be able to become more productive, efficient, safe, and environmentally sustainable owing to this cutting-edge equipment, robotic systems, and precision agriculture. Various factors such as data analysis matrix and technological advancement in the existing agricultural machinery contribute to the production of food grains for consumption and commercial needs. The production of commercial food grain supports the economy and improves the GDP. Hence, the future growth of Indian agriculture appears to be growing with an upward graph which is backed by technological advancements and government initiatives.

RECENT DEVELOPMENTS IN AGRICULTURE

India's agriculture mainly depends on nature. However, changing climate and global warming are making farming unpredictable. There have been significant changes in India in the context of agriculture over the decades and many new technologies have been developed. Several new-age farmers are using soil mapping software as well to determine the optimum level of fertilizers used in the farms. These emerging technologies in farming and agriculture pave the way for more opportunities. The aggrotech start-ups and traditional farmers are also using the latest solutions and trends to improve production in the food value chain.

It includes the adoption of new technologies such as cloud-based solutions and other relevant advanced agricultural management techniques to increase farmer efficiency and produce more crops. Emerging trends in the agricultural sector that are quite prominent in the post-liberalisation era include increased production, increased investment, diversification of the sector, use of modern techniques, development of horticulture and floriculture, increasing volume of exports and development of the food processing industry.

RECENT TRENDS IN AGRICULTURAL TECHNOLOGY

Agricultural Drone Technology

Drones are used widely for medical delivery to protection assistance and are used in agriculture to improve the growth of crops, maintenance, and cultivation methods. For example, these aerial carriers are used to access crop conditions and execute better fertilization strategies for more yields. Even the accessibility of hovering robots helps farmers through a survey of large areas and data collection to generate better insights about their farms. Using drones in agriculture has provided more frequent, cost-effective remote monitoring of crops and livestock. It also helps to analyse field conditions and determine appropriate interventions such as fertilizers, nutrients, and pesticides.

Diversification of Agriculture

The agricultural sector produces generic consumption needs as well as crops like fruits, vegetables, spices, cashews, areca nuts, coconuts, and floral products such as flowers, orchids, etc. With the increasing demand for these products, there's a huge potential in terms of production and trade of these products. This shows how the agricultural sector is being transformed into a dynamic and commercial sector by shifting the mix of traditional agricultural products towards higher quality products, with a high potential to accelerate production rates. The diversification in agriculture is being supported by changes in technology or consumer demand, trade or government policy, transportation, irrigation, and other infrastructure developments.

Increasing Trend in Horticulture Production

The availability of diverse physiographic, climatic, and soil characteristics enables India to grow various horticulture crops. It includes fruits, vegetables, spices, cashew, coconut, cocoa, areca, etc.

Development of Agriculture in Backward Areas

In the post-Green Revolution era, the introduction of new agricultural strategies, research, and technology was mostly limited to producing specific food grains, i.e., wheat and rice. However, under the wave of liberalisation, with the growing demand for agricultural exports, many new sectors of agricultural activities have become favourable and profitable. In some agriculturally backward areas with no irrigation system and access to fewer resources, dryland farming has been introduced. Other activities were also encouraged such as horticulture, floriculture, animal husbandry, fisheries, etc. To support the development in those areas, various modern techniques have been installed in the backward areas.

Above: Plants grown hydroponically do not need extensive root systems, mature quickly and possess better immunity; Left: Dr BP Pal was the first Director General of the Indian Council of Agricultural Research

Aerial Imaging

Aerial imaging involves the use of Geographic Information System (GIS) technology to analyse the potential of irrigation projects and their impact on land degradation, erosion, and drainage. The visuals of this technology allow assessment of an individual plant's foliage. These visuals are actively used to detect pests and diseases to protect crops from environmental threats. It mostly helps farmers to monitor the soil conditions of farms and is useful in the summer season when there is the least availability of water.

Hydroponics and Vertical Farming

The concept of hydroponics farming focuses towards better yields, texture, and taste of the final product with less water consumption. Plants which are grown hydroponically do not need extensive root systems and it allows them to contribute more energy towards the production of leaves and fruits. Because of indoor cultivation, these plants mature quickly and possess better immunity against pests and other diseases. In the context of sustainability, vertical farming allows farms to be located near or within areas of high population density which reduces the need for transportation and any harmful emissions. Vertical farming provides the ability to grow crops in urban environments and contributes to the availability of fresh foods conveniently. This farming significantly reduces the amount of land space required to grow crops compared to conventional farming methods.

IoT in Agriculture

IoT (Internet of Things) supports agriculture through the installation of various sensors in agricultural farms. These sensors are used to monitor light, humidity, soil moisture, temperature, crop health, etc. Some of the major uses of IoT in agriculture are as follows:

- Various farm sensors such as autonomous vehicles, wearables, button cameras, robotics, control systems, etc. help in the collection of data to analyse the performance of the farm.
- Use of aerial and ground-based drones for crop health assessment, irrigation, monitoring and field analysis.
- Use of tools to predict rainfall, temperature, soil, humidity, and other forecasted natural calamities.

GOVERNMENT INITIATIVES

The government has taken various initiatives to enable the potential digitalisation of the agricultural sector in India. It focuses on promoting Agri-tech businesses which are working towards boosting productivity.

- The government has finalised an India Digital Ecosystem of Agriculture (IDEA) framework that will establish the architecture for the federated database of farmers. This database is being built by taking the publicly available data as existing in various schemes and linking them with the digitalised land records. The IDEA would serve as a foundation to build innovative Agri-focused solutions leveraging emerging technologies to contribute effectively to creating a better ecosystem for agriculture in India. This ecosystem shall help the government in effective planning towards increasing the income of farmers and improving the efficiency of the agriculture sector.
- To facilitate agricultural engineering research, operations, and technology diffusion, the Central Institute of Agricultural Engineering, Bhopal (ICAR-CIAE) of the Indian Council of Agricultural Research (ICAR) has created the Krishi Yantra App. A web portal has been made available by ICAR-CIAE on their website to guarantee that businesses choose the proper mechanisation technology. This aids current and potential business owners in choosing machines and purchasing options. The portal also offers the option of user and specialist engagement.
- Farm Safety app was developed by ICAR-CIAE which provides information about safety guidelines and gadgets to avoid accidents while using different types of agricultural machinery.
- A smartphone app called Water Balance Simulation Model for Roof Water Harvesting assists decision-makers in recommending design criteria. It provides that the implementation of a roof water harvesting system may result in water savings and water security.

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Image Courtesy: Wikimedia Commons

India's Energy Odyssey: Pioneering a Sustainable Revolution

India's non-fossil fuel narrative, deriving from its vast resources of solar-wind-tidal energy and green hydrogen production, has the strength to power the country towards total energy independence well before the 100th anniversary of political independence

■ Uduay Kumar Varma

Over three-quarters of a century ago, at one of history's most momentous moments, a new nation was born. In 1947, the first flag of independent India was unfurled over Princess Park near the iconic India Gate and later flew aloft the historic Red Fort, symbolising a young country's aspirations. At that juncture, India's population stood at 340 million, and a mere 1,362 MW of electricity generation capacity illuminated the nation. The per capita power consumption barely touched 16.3 kWh, a faint glimmer compared to the glare of the energy-intensive world we inhabit today.

Fast-forward 75 years, and the landscape has metamorphosed into one of dynamic growth and transformation. With a soaring population that has quadrupled, India now boasts an astounding installed power capacity of 403,760 MW—almost 300 times what it had back then. And the energy consumption per capita has soared to a vibrant 1208 kWh. As India enters her 'Amrit Kaal' on her relentless and buoyant march to become a developed nation and the third strongest economy of the world, her soaring journey is aglow with milestones of progress, propelled by an unwavering spirit and commitment to explore and chart new energy horizons.

SUN – THE SOURCE OF ENERGY AND WISDOM

Embedded in the rich tapestry of Indian tradition, the sun holds a revered position, radiating its brilliance not only across the physical realm but also within the realms of culture, spirituality, and literature. For ages, the sun has been revered as the ultimate source of vitality and life, showering its radiant blessings upon the land and its inhabitants. This celestial luminary has illuminated the verses of ancient Indian literature, its brilliance intricately woven into the cultural fabric. As eloquently penned in the *Suryashtakam*:

तं सूर्यं जगतां नाथं ज्ञानप्रकाशमोक्षदम् !
महापापहरं देवं तं सूर्यं प्रणमाम्यहम् !!

This declaration not only venerates the sun as the fount of vitality but also as the source of wisdom, knowledge, and ultimate liberation.

In ancient Sanskrit texts, such as the *Rigveda*, the sun is poetically hailed as the radiant eye of the universe, witnessing all terrestrial activities. Its life-affirming rays are likened to the emergence of truth and enlightenment within human consciousness, underscoring its spiritual significance that transcends its physical brilliance.

The worship of the sun, known as Surya or Aditya, has been an integral part of Indian spiritual practices for millennia. With roots tracing back to the Vedic period, hymns dedicated to the sun extol its divine attributes. The revered *Gayatri Mantra*, extracted from the *Rigveda*, pays homage to the sun as the wellspring of enlightenment, seeking its guidance in dispelling ignorance. The dance of sunrise and sunset takes on cosmic symbolism, inviting contemplation on the cyclical nature of life and mortality.

Beyond its material representation, the sun's symbolism in Indian literature delves into philosophical inquiries. The *Upanishads*, ancient philosophical

Muppandal Wind Farm, India's largest operational onshore wind farm at Aralvaimozhi in Kanyakumari treatises, explore the metaphorical role of the sun as the illuminator of consciousness, dispelling the darkness of ignorance. The sun's celestial voyage across the heavens metamorphoses into an allegory for the soul's expedition towards enlightenment.

The Sun's prominence in ancient Indian literature testifies to its dual role as an energiser and bestower of sagacity. Its brilliance not only nurtures the earth's abundance but also illuminates the spiritual landscape of the nation. Through verses and hymns, the sun's radiance is extolled, creating a profound bridge between the physical and metaphysical realms. As the sun continues to grace India's horizon, its legacy as a symbol of vitality and spirituality endures, an inspiration to harness its boundless bounty.

A SYMPHONY OF SUNBEAMS: INDIA'S SOLAR ODYSSEY

As dawn bathes the earth in its soft glow, humanity has long marvelled at the sun's brilliance. Yet, it was during the industrial age that we tapped into sunlight's potential as an energy source. India, blessed with abundant sunshine, stands poised to harness this extraordinary gift. With an astonishing 5,000 trillion kWh annually gracing its expanse, most regions bask in 4-7 kWh per sq. m per day. Here lies the grand promise of solar photovoltaic power—a realm of infinite scalability.

Solar energy transcends power generation; it orchestrates a symphony of sustainability. Its decentralised nature allows rapid capacity expansion, adapting with unparalleled agility to local needs. In remote corners, off-grid installations become lifelines for rural communities. Solar's gift of energy security is unparalleled—it's a perpetual offering, where even a fraction of its abundance can illuminate a nation.

India embarked on its solar journey nearly a decade ago with the launch of the National Solar Mission (NSM) in 2010, aimed at achieving 20 GW of solar capacity by 2022. However, the momentum truly accelerated when this ambitious goal was not just achieved but surpassed, setting the stage for success stories built on policy support, incentives, and ground-breaking research. The 'Make in India' initiative nurtured domestic solar manufacturing, reducing dependence on imports. Solar parks emerged as fertile grounds for large-scale installations, creating economies of scale that drove down costs and attracted investments.

Today, India stands as the world's fourth-largest solar PV deployer, boasting an impressive installed capacity of approximately 61.97 GW as of November 2022. The concept of grid parity, where solar tariffs rival those of conventional sources, has been realised, propelling solar to a prominent position in the energy landscape.

Image Courtesy: Shutterstock

A GLOBAL SYMPHONY: THE INTERNATIONAL SOLAR ALLIANCE

India's solar narrative transcends borders, harmonising with the International Solar Alliance (ISA). Born of Indian-French collaboration, the alliance represents more than technology—it embodies collective aspiration. The ISA is a testament to India's global vision, a commitment to unite nations under the banner of solar energy.

Conceived during the 21st Conference of Parties (COP21), the ISA stands as a beacon of collaboration in the battle against climate change. With 116 member countries embracing its mission, the ISA's ambition knows no bounds. The 'Towards 1000' strategy envisions a solar-powered revolution, mobilising $1 trillion in investments, granting energy access to a billion individuals, and installing 1,000 GW of solar capacity by 2030. Beyond mere numbers, the ISA seeks to transform lives and mould a sustainable tomorrow.

RIDING THE WIND'S WHISPERS

Wind, nature's poetic breath, has emerged as a potent ally in India's pursuit of non-fossil energy. As an aspiring leader in wind energy, India's potential crosses the threshold of 300 GW. Through initiatives like the National Wind Energy Mission, the nation has set its sails to capture the kinetic magic of the wind.

Incentives, innovation, and a dash of competition shape India's wind energy landscape. Feed-in tariffs, generation-based incentives, and auction-based mechanisms have paved the way for a vibrant wind energy market. Yet, wind's intermittent nature presents challenges, demanding advanced storage solutions and sophisticated grid management.

As a renewable, clean energy source, India currently boasts an installed wind energy capacity of 42,633 MW, contributing over 34 percent of its total clean energy capacity.

Over the upcoming seven years, India aims to add 58 GW of wind energy capacity through an investment of over Rs 4 lakh crore, expanding the onshore wind energy capacity to 100 GW, in alignment with the government's goal to establish 500 GW of non-fossil fuel-based capacity by 2030. This includes a target of 140 GW of wind capacity, enough to power around 100 million homes.

SAILING UNCHARTED TIDES: INDIA'S TIDAL ENERGY EXPLORATION

Tidal energy, a newcomer in India's non-fossil narrative, draws inspiration from the rhythmic dance of the seas. India's extensive coastline holds untapped potential for tidal energy generation, estimated at around 12,455 MW. The Gulf of Khambat, Gulf of Kutch, Tamil Nadu's Palk Bay-Mannar Channel, and West Bengal's Hoogly River beckon as potential areas for tidal energy harnessing. With the Gulf of Kutch Tidal Energy Plant leading the way, India's venture into utilising tidal currents for electricity is a testament to its pioneering spirit.

However, this uncharted course is not without challenges. Refining the technology, assessing environmental impacts, and managing capital costs represent the turbulent waters that must be navigated to unlock the full potential of tidal energy. These challenges, though, pave the way to discovering another green treasure trove.

Wind, nature's poetic breath, has emerged as a potent ally in India's pursuit of non-fossil energy. As an aspiring leader in wind energy, India's potential crosses the threshold of 300 GW

DREAMING IN HYDROGEN HUES: NATIONAL HYDROGEN MISSION

As the world paints its energy dreams with diverse hues, and pursues the goal through diverse approaches, hydrogen emerges as a champion, capable of transforming sectors. The simplest element in the periodic table, its potential lies in its myriad pathways of production. Green, blue, and grey hydrogen each define their role in reshaping our energy landscape. The colours symbolise its origins: grey from methane, blue from carbon-capture, and green from renewable energy.

Green hydrogen is defined as hydrogen produced by splitting water into hydrogen and oxygen using renewable

Image Courtesy: Shutterstock

electricity. This is a very different pathway compared to both grey and blue.

Grey hydrogen is traditionally produced from methane (CH_4), split with steam into CO_2 — the main culprit for climate change — and H_2, hydrogen. Grey hydrogen has increasingly been produced from coal, with significantly higher CO_2 emissions per unit of hydrogen produced, so much that it is often called brown or black hydrogen instead of grey. It is produced at industrial scale today, with associated emissions comparable to the combined emissions of UK and Indonesia. It has no energy transition value, quite the opposite.

Blue hydrogen follows the same process as grey, with the additional technologies necessary to capture the CO_2 produced when hydrogen is split from methane (or from coal) and store it for long term. Not 100% of the CO_2 produced can be captured, and not all means of storing it are equally effective in the long term.

Green hydrogen has, thus, significantly lower carbon emissions than grey and blue hydrogen, which are derived from fossil fuels with or without carbon capture.

India's quest for green hydrogen emanates from Prime Minister Narendra Modi's resolve to achieve net zero by 2070, in addition to achieving aggressive near-term targets such as 500 GW of renewables capacity, 50 percent of requirements to be met with renewables, one billion tonne reduction in cumulative emissions by 2030, and 45 percent lower emissions intensity of gross domestic product (GDP) by 2030.

Announced on August 15, 2021, in the Prime Minister's 75th Independence Day address, the National Hydrogen Mission aims to make India a hub for the production and export of green hydrogen.

Among its ambitions, the National Hydrogen Mission envisions creating the world's largest electrolysis (green hydrogen generation) capacity of over 60 GW/5 million tonnes by 2030 for domestic consumption. It aims to produce the world's largest quantity of green steel, 15-20 million tonnes by 2030, fostering a pioneering effort in green steel production. The mission also seeks to establish the world's largest annual electrolyser manufacturing capacity of 25 GW by 2028, making affordable options available to India and the world. Furthermore, the goal is to lead the world in exporting green ammonia by 2030, supporting India's allies in their decarbonisation journey. An investment of $1 billion into hydrogen research and development is poised to pave the way for breakthrough technologies on a global scale and at the necessary pace.

With proactive collaboration among innovators, entrepreneurs and government, green hydrogen has the potential to drastically reduce CO_2 emissions, fight climate change, and put India on a path towards net-zero energy imports. It will enable India export high-value green products, making it one of the first major economies to industrialise without the need to 'carbonise'. It will also substantially reduce the burden of energy imports, to the tune of $160 billion, likely to double in next 15 years, if not mitigated.

INDIA'S SYMPHONY OF SUSTAINABILITY: A GRAND FINALE

As India pioneers its sustainable energy odyssey, it concurrently navigates its path to becoming the world's third-largest economy. These two narratives converge, weaving a future where economic advancement and environmental stewardship harmonise seamlessly. The synergy of renewables and hydrogen as cornerstones of India's energy matrix propels the nation towards its audacious ambitions.

India's energy transition is more than a pivot; it's a reimagining of India's global status. The mission's ripples extend far beyond energy, resonating through industries, innovation, and international relations.

India's march towards non-fossil energy isn't just a story—it's a resounding anthem where solar rays, wind whispers, tidal rhythms, and hydrogen dreams converge to create a world of clean, secure, and shared energy. This symphony of innovation, collaboration, determination, and economic aspirations is India's contribution to the global stage. It's the resounding echo of India's energetic odyssey—a journey that illuminates lives while igniting a revolutionary change.

And as this harmonious odyssey continues, India is poised to achieve energy independence before celebrating its 100th year of Independence in 2047.

**The writer, a Harvard educated civil servant, is a former Secretary to the Government of India. He also served on the Central Administrative Tribunal and as Secretary General of ASSOCHAM. He commands extensive expertise in the fields including Media and Information, Industrial and Labour Reforms, and Public Policy.*

Image Courtesy: Shutterstock

Biotechnology: *Amrit for Humanity*

Biotechnology touches every sphere of human life, from food to fuel, health to wealth, and with the industry poised to reach a value of $150 billion by 2025, it indeed is an elixir for the country

Prof Neel Sarovar Bhavesh

Biotechnology has been a buzzword for academia and industry alike and has always been seen as a sector of the future with unlimited promises. Though it had made huge imprints on different sectors, the world realised its true potential to serve humanity during the COVID-19 pandemic. Riding on the progress made during the last decades, modern biotechnology delivered numerous kinds of vaccines, drugs, and other technologies at an unimaginable pace. The leadership shown by the biotechnology industry and institutions in India gained praise from all because it not only served its own population in coming out of the pandemic but helped other countries too to tide over the pandemic. This overwhelmed everyone, and the jargons of biotechnology were on everybody's lips; all seemed to have started understanding the nuance of biotechnology. In a nutshell, modern biotechnology saved humanity from one of the worst crises it had faced.

BIOTECHNOLOGY IN HISTORY

According to one definition of biotechnology, it is an 'application of the principles of engineering and biological science to create new products from raw materials of biological origin.' Though not in a structured manner, during their course of evolution, humans always used contemporary knowledge and tools to exploit biological matter to improve the quality of life. Development of traditional medicinal systems like Ayurveda, animal cross-breeding, domestication of plants, improvisation of agricultural techniques, milk products, use of microbes, and fermentation products were the earliest 'biotechnological' pursuits by humans in ancient times.

Though the term Biotechnology was coined by Karl Erkey, a Hungarian engineer, in 1919, the true development of modern biotechnology took decades. In the initial years, fundamental discoveries in biological sciences like Mendelian genetics, nucleic acids and the laws of inheritance, and the discovery of antibiotics laid the foundation for the development of biotechnology. The discovery of double-helical DNA structure using X-ray crystallography, which explained the transfer of genetic information from one generation to another, provided the impetus for modern biotechnology. The real boost came after Hargobind Khorana succeeded in the chemical synthesis of DNA, and later, Karl Mullis designed the Polymerase Chain Reaction (PCR) method to rapidly amplify a target DNA stretch by a thousand times more than the original amount of DNA. Discoveries like hybridoma technology, stem-cell technology, precision gene editing techniques, omics platforms, imaging technology, mRNA technology, structural biology methods, machine learning, and artificial intelligence continue to expand the reach and horizon of biotechnology.

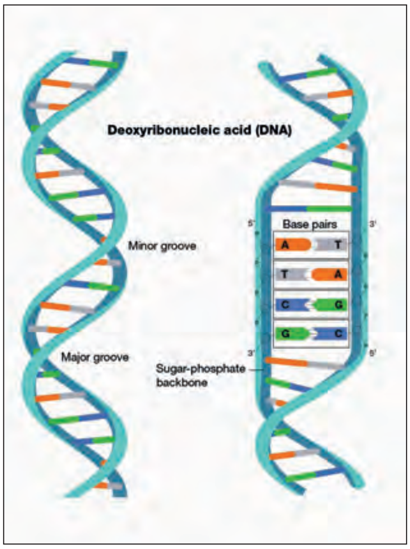

Image Courtesy: Wikipedia

The discovery of double-helical DNA structure using X-ray crystallography provided the impetus for modern biotechnology

BIOTECHNOLOGY IN INDIA

Like in other places around the world, biotechnology started in India with research in fundamental biological sciences by scientists like Jagadish Chandra Bose, GN Ramachandran, Subhash Mukhopadhyay, and others. To distinguish between biology and biotechnology projects and formulate an appropriate national policy and new funding mechanisms to build up the biotechnology, the Department of Science & Technology constituted a National Biotechnology Board (NBTB) in 1982. NBTB later evolved into a separate department, and the Department of Biotechnology (DBT) was set up under the Ministry of Science and Technology in February 1986, with an initial budget of around 40-60 million. In the same year, at the initiative of UNIDO, one component of the International Centre for Genetic Engineering & Biotechnology (ICGEB) was established in New Delhi. ICGEB was the first institute in India to have an exclusive focus on biotechnology. The National Institute of Immunology (NII), which was conceived to grow on the aegis of the ICMR–WHO Research & Training Centre in Immunology has been in operation since 1981. The All India Institute of Medical Sciences (AIIMS), New Delhi, was the first institute to be brought under the wings of DBT as an autonomous institute. In the next two decades, DBT established seventeen autonomous institutes, each focusing on different areas of biotechnology and four public sector undertakings.

To create a pool of qualified human resources required for highly specialised biotechnology research and industry, DBT provided financial assistance to several universities and scientific institutions to start MSc, MTech, PhD, and post-doctoral programmes with studentship and fellowship. Over the years, these programmes have matured, evolved, and provided a critical mass of trained human resources, powering the biotechnology industry.

KEY GOVERNMENT INITIATIVES TO PROMOTE BIOTECHNOLOGY

Considering biotechnology as a sunrise sector and a key part of India's vision of reaching a $5 trillion economy by 2024, the government, in the last decade, has paid special attention and initiated new funding mechanisms to bolster the biotechnology industry. The government has allotted 2,683.86 crore (~$325 million) to the Department of Biotechnology in the 2023-24 budget, almost double its budget outlay in 2013-14. In addition, recent initiatives like Atmanirbhar Bharat, Swasth Bharat, Startup India, and Make in India have fueled the biotechnology industry.

The Department of Biotechnology has created a unique not-for-profit section 8, Schedule B, Public Sector Undertaking called Biotechnology Industry Research Assistance Council (BIRAC), which works as an industry-academia interface to foster innovation, entrepreneurship, and commercialisation, promote affordable innovation in key social sectors and empower start-ups and small and medium enterprises. It has played a transformative and catalytic role in building a biotechnology start-up ecosystem by creating more than

75 incubators across the country and supporting more than 4000 start-ups with an investment of more than 6,000 crore, of which around 2,400 crore has come from the industry.

Funded at a total cost of 1500 crore, co-funded by the World Bank at 50% cost sharing with the Department of Biotechnology, the National Biopharma Mission (NBM), a government-industry-academia collaboration, was launched in 2017 for 'Accelerating Discovery Research to Early Development for Biopharmaceuticals.' The mission is supporting 197 grantees working in different verticals—medical devices and diagnostics, vaccines, and biotherapeutics to plug in the necessary gaps in the biopharmaceutical development pipeline.

In 2021, a new biotechnology center for the Northeast, in the remote area of Kimin (Arunachal Pradesh) was inaugurated, and a pan-India Star College Mentorship Programme for young innovators supported by the Department of Biotechnology was launched. The Department of Biotechnology has created 51 Biotech-KISAN (Biotech Krishi Innovation Science Application Network) hubs in different agro-climatic zones of the country to connect farmers with scientists and research institutions. The initiative is to enable innovation in agriculture, promote sustainable agricultural practices and empower farmers, especially women farmers, with scientific information on new agri-technologies. In 2022, it helped more than 160,000 farmers across India.

GOBARdhan (Galvanizing Organic Bio-Agro Resources Dhan), another scheme with a total investment of 10,000 crore, was launched in 2023 to promote a circular economy. Under the scheme, it is planned to commission 500 new 'waste to wealth' plants, including 200 compressed biogas (CBG) plants, 75 plants in urban areas, and 300 community or cluster-based plants. To foster collaboration among startups, industry, academia, and research organisations, 75 Amrit Grants worth 10-15 crore ($1.2-1.8 million) for biotech projects have been announced.

The Department of Biotechnology (DBT) launched a biomanufacturing initiative on 7 July 2023, a 'plug and play' manufacturing model for Industry 4.0, to promote biomanufacturing and bioeconomy in India with activities ranging from R&D to pilot scale. Advanced biotechnology tools, like synthetic biology, genome editing, metabolic engineering, robotics, artificial intelligence, etc., will likely form the backbone for this initiative. DBT has identified six thematic priority sectors with a tagline for each of the sectors:

1. Biobased catalysts and enzymes: Catalyzing greener reactions.
2. Functional foods and smart proteins: Tasty without cruelty.
3. Precision Biotherapeutics: Remedies that understand You.
4. Climate change resilient agriculture: Krishi that makes earth happy.
5. Carbon capture and biomass utilisation: Recover to prosper.
6. Futuristic maritime and space research: Diving into infinity.

Image Courtesy: HIMT.ac.in

Department of Biotechnology's assistance to universities and institutions over the years has resulted in a critical mass of trained human resources, powering the biotechnolgy industry in the country

BIOTECHNOLOGY AS A DRIVER OF THE ECONOMY

The biotechnology industry has benefited immensely from supportive government policies and enabling ecosystems. The Indian bio-economy for 2021 accounts for nearly 2.6% share of India's GDP. India's bio-economy has grown from $10 billion to $80 billion during 2014-2022. It is expected to reach $150 billion by 2025 and $300 billion by 2030. The growth is fueled by rising demand at both domestic and international levels. Investment in bio-economy has increased from 10 crore in 2014 to 4200 crore in the last eight years. This growth of over 400 times has generated more than 25,000 highly skilled employment opportunities. During the same period, biotechnology startups have increased to 5300 compared to a mere 52 startups in 2014. At this rate, the number of biotechnology startups is expected to grow to more than 10,000 by 2025. All these have brought India among the top 10 destinations for biotechnology worldwide, and it is expected that the contribution of the Indian biotechnology industry to global biotechnology will grow to 19%. The pace of growth of the biotechnology sector can be gauged from the fact that it crossed one-billion-dollar R&D spend, and it almost trebled within a year from $320 million in 2020 to $1.02 billion in 2022, and products have increased from 10 to more than 700 in 2022.

Among the different biotechnology sectors, the Bio-Pharmaceutical industry contributes about 62% to the bio-economy. In recent years, especially during the COVID-19 pandemic, the Indian Bio-Pharmaceutical industry has grown phenomenally and gained global trust

Image Courtesy: ICGEB

Left: International Centre for Genetic Engineering & Biotechnology (ICGEB) in New Delhi was the first institute in India to have an exclusive focus on biotechnology

Below: Hargobind Khorana, an Indian-born American biochemist who shared the 1968 Nobel Prize, revolutionised the world of biotechnology with his chemical synthesis of DNA

so much that now India is called the 'pharmacy of the world'. India already had strong vaccine programs like BCG, Rotavirus ($1 vaccine by Bharat Biotech), Recombinant Hepatitis B vaccine, Japanese encephalitis, polio, bi-valent oral vaccine for cholera, and Meningitis A, which are exported to more than 150 countries. Using the already built-up capacity and support from the current government, Indian companies produced different kinds of vaccines, like inactivated virus vaccine (Covaxin by Bharat Biotech), viral vector vaccine (Covishield by Serum Institute of India), subunit vaccine (Corbevax by Biological E., Covovax by Serum Institute of India), DNA vaccine (ZyCoV-D by Zydus Cadila), and mRNA vaccine (HGCO19 by Gennova Biopharmaceuticals), and using them, more than 2.2 billion COVID-19 doses were administered in India and around 300 million doses of COVID vaccines supplied to 101 countries under the Vaccine Maitri program. COVID vaccines alone accounted for $8.7 billion of the value of India's biotechnology sector, which was about 18% of the bio-economy. Vaccines and biotherapeutics are expected to generate $15 billion each by 2025. The therapeutics segment will likely create a bio-economy of $15 billion from recombinant and biosimilar products. Similarly, the Indian biologics market

Image Courtesy: Wikipedia

is forecasted to reach US$ 12 billion by 2025 at a CAGR of 22%.

BioAgriculture, comprising BtCotton, pesticides, marine biotech, and animal biotech, currently contributing to about 13% of the bio-economy, is likely to reach $20 billion in 2025, doubling its bio-economy contribution. The BioServices sector comprising CROs/CDMOs and the BioIT segment, which now accounts for about 7% of the bio-economy, is forecasted to quadruple and reach $26.6 billion. New segments like smart proteins, protein and peptide-based materials, contact lenses, speech restorers, smart pills, nerve regenerators, portable dialysis, prosthetic limbs, and a new wave of smart tele-diagnostics could add $10 billion to the bio-economy. As the push for green energy becomes stronger and the government has advanced its plan to bring 20% ethanol mixed fuel into the market, from the earlier timeline of 2030 to 2025, it is expected that the Biofuels segment will contribute about $50 billion, while enzymes will add another $20 billion. Inaugurating the Biotech Startup Expo-2022 at Pragati Maidan in New Delhi, Prime Minister Narendra Modi has said the Biotech sector is one of the most demand-driven sectors. The campaigns for ease of living in India over the years have opened up new possibilities for the biotech sector. He lauded the significant role of the biotech industry in the development of the country.

As we see today, Biotechnology touches every sphere of human life, from food to fuel, from health to wealth, and it is the technology of choice for fulfilling human's perennial desires for everlasting well-being and to make its existence better. In that sense, Biotechnology is Amrit for humans in this Amrit Kaal.

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Atomic Energy in Independent India: A Story of Self-reliance

Led by a great visionary, Dr Homi Jehangir Bhabha, India made foray into nuclear energy soon after Independence, and despite western sanctions later on, the country has become a successful player in the field with truly indigenous efforts

Image Courtesy: Wikimedia Commons

India's first indigenously developed 700 MWe Pressurised Heavy Water Reactor has started working at its full capacity at Kakrapar, Gujarat

■ Abhijit Mulye

September 1, 2023 will be remembered in the history of the nuclear programme of India. The first indigenously developed 700 MWe Pressurised Heavy Water Reactor (PHWR) started working at its full capacity at Kakrapar in Gujarat on this day. This made India 'the only developing country to have indigenously developed, demonstrated and deployed nuclear reactors for electricity generation.' The spectacular success of Chandrayan-3 followed by this achievement underlined the beginning of 'Amrit Kaal' for Indian Science.

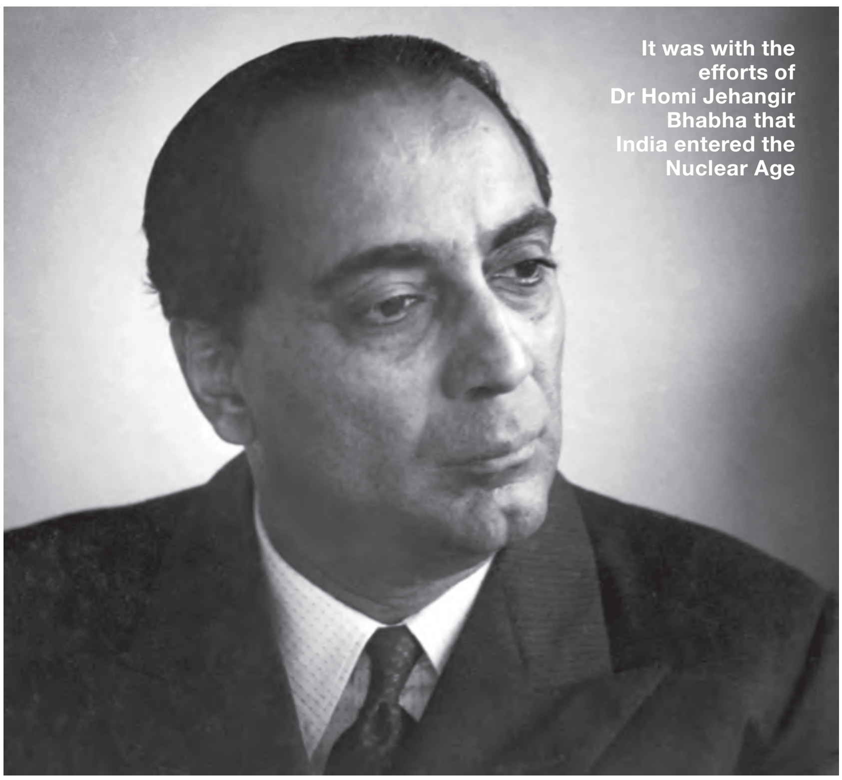
Dr Homi Bhabha was a great visionary. He foresaw the importance of fundamental research. It was due to his efforts that India entered the Nuclear Age within a decade of a major breakthrough in the field in 1939 (when the scientists could get the first experimental confirmation of Albert Einstein's 1905 postulates regarding equivalence between mass and energy.) Within a year of its Independence, India's Atomic Energy Commission (AEC) was established in 1948. Developments on the scientific as well as the administrative fronts began under the able guidance of Dr Bhabha.

GENESIS OF INDIA'S NUCLEAR PROGRAMME

Tata Institute of Fundamental Research (TIFR), which was founded by Dr Bhabha with the help of the Tata group, was the centre of research and development in the field those days. Later, Atomic Energy Establishment, Trombay (AEET), was established where an open tank light water reactor — Apsara — was built. The entire reactor system including control instrumentation was indigenously designed, fabricated and commissioned. Only the fuel rods came in from the UK. India's nuclear programme took a great leap when this first nuclear reactor attained 'criticality' (a state where each fission releases a sufficient number of neutrons to sustain an ongoing series of nuclear reactions) on August 4, 1956. Eventually, after the tragic accidental death of Dr Bhabha, the AEET was renamed as the Bhabha Atomic Research Centre (BARC).

India's nuclear programme began at a time when the industrial infrastructure in the country was in its infancy. The thrust was on maximising the use of indigenous technologies and raw materials in driving the programme. Geological surveys showed that uranium reserves in the country were quite limited, but thorium was abundant in the monazite bearing areas on the long Indian coastline. It led to the adoption of the three stage nuclear programme. In the first stage PHWRs (pressurised heavy-water reactors), which use natural uranium dioxide as the fuel and heavy water as both moderator and coolant, were developed. PHWRs suited the Indian conditions, as they did not require enriched fuel. In order to be self-sufficient, development of technologies related to the manufacturing of PHWR-fuel and the heavy water production was taken up. Today, India is among the largest producers and exporters of heavy water.

Exploration of atomic minerals too was started in 1949 with the setting up of the Raw Materials Division (RMD) under the Atomic Energy Commission. In the initial days, information on the materials and minerals useful for nuclear programme was not easily available. Several technologies from spectrometry to remote sensing and hand-held GPS were developed indigenously in every aspect of the nuclear programme. After formation of the Atomic Mineral Division, exploratory mining began at Jaduguda of Singbhum area (now in Jharkhand) in 1957. It led to the forma-



It was with the efforts of Dr Homi Jehangir Bhabha that India entered the Nuclear Age

Image Courtesy: Wikimedia Commons

Image Courtesy: Wikimedia Commons

tion of Uranium Corporation of India Ltd. (UCIL) in 1967. Simultaneously the Nuclear Fuels Complex (NFC) started functioning at BARC in 1968. Later it was shifted to its own campus at Hyderabad. While UCIL mined the nuclear ores, and purified them, for them to be used into the nuclear reactors requires many more processes. These processes involve several aspects, like finding out the best-suited chemical form of the fuels for them to be most effective as per the purpose for which they are to be used, finding out the best suited shape and size of the materials for them to be most effective, etc. Accordingly, pellets of different shapes, sizes and materials are formed. Doing all this while taking care of the radiation and decay makes the tasks more complex.

DIFFERENT STAGES OF INDIA'S NUCLEAR PROGRAMME

India has nuclear ores from which a total of about 78,000 tonnes of uranium metal and about 518,000 tonnes of thorium metal can be extracted. If the entire uranium resources are first used in natural uranium-fueled PHWRs, it is estimated that about 420 GWe-yrs of electricity can be produced. The resulting depleted uranium and separated plutonium from these PHWRs, if used in fast breeder reactors (FBRs), could generate an additional 54,000 GWe-yrs of electricity. In these FBRs, production of uranium-233 (U233) can also be achieved by loading thorium assemblies in their blanket and low-power zones. With installation of the Fast Breeder Test Reactor (FBTR) in 1985, India entered this second stage of the nuclear programme. With the experience gained in operating FBTR and in handling molten sodium, the Prototype Fast Breeder Reactor (PFBR) of a capacity 500 MWe was designed and developed by Indira Gandhi Centre for Atomic Research (IGCAR) at Kalpakkam in Tamil Nadu.

The third stage of India's nuclear programme envisages transitioning to generations of Th-U233 fuelled breeder reactors, to be able to produce an additional 358,000 GWe-yrs of electricity. Thus, even at an installed nuclear power capacity of 500–600 GWe, the country's nuclear resources will be able to sustain its electricity generation needs far beyond the extinction of its coal deposits.

The first nuclear power reactors built in India were two Boiling Water Reactors (BWRs) at Tarapur, constructed by GE as turnkey projects through Indo-US cooperation. Construction of these reactors began in 1962 and the plant went operational in 1969. Meanwhile, the Power Projects Engineering Division (PPED) was formed in 1967 in order to channelise all the necessary research and administrative pursuits required for setting up of nuclear power plants. It was renamed as the Nuclear Power Board in 1984 and as Nuclear Power Corporation of India Ltd. (NPCIL) in 1987. Several initiatives were being taken on various fronts simultaneously during this period, like the Electronics Corporation of India Ltd (ECIL) too was set up in 1967, in order to develop electronic systems necessary for the nuclear programme.

India was gathering whatever it could get from the global nuclear powers and building upon that. A group of scientists was sent to France in the late 1960s for research related to reactors. When they returned, the Reactor Research Centre (RRC) was formed at Kalpakkam near Chennai in 1971. The centre was later renamed as Indira Gandhi Centre for Atomic Research (IGCAR) in 1985.

NUCLEAR TESTS AND INDIA'S SOLO JOURNEY

India conducted first peaceful nuclear tests in 1974. This led to the withdrawal of Canadian support. BARC then took the responsibility of components development and testing such as nuclear grade pumps, fuelling machine, fuel, clad, etc. and other major R&D support for design and safety of PHWRs from normal operations to design extension conditions.

In the following years, the accidents at Three Mile Island in USA in the year 1979 followed by Chernobyl in 1986, there was radical change in the philosophy of design of new nuclear reactors. Passive safety systems became an integral part of the reactors. This philosophy gave birth to the concept of Advanced Heavy Water Reactor (AHWR) being designed by BARC. The AHWR retained the pressure tube concept of PHWRs but adopted several passive systems in design, making the reactor safe enough to deploy close to the population centres. Apart from this, AHWR targeted to produce significant power (more than 60%) from thorium as a demonstration reactor for power from thorium.

In 1998 India conducted nuclear weapon tests at Pokhran. "India is now a Nuclear Weapon State. This is a reality that cannot be denied. It is not a conferment that we seek; nor is it a status for others to grant," Prime Minister Atal Bihari Vajpeyee said in his speech in the Parliament a couple of weeks later. This reflects how the Pokhran II nuclear tests saw India re-imagining itself in the emerging global strategic landscape and the domestic establishment of a new political template for an aspirational India. These tests expectedly resulted in a round of global condemnations and multi-layered sanctions led by the United States (US). However, they triggered a transformational moment as India made clear strategic choices, which, thereafter, successfully culminated in the Indo-US nuclear deal in 2008 and its entry into the global nuclear non-proliferation regime in the following decade.

Image Courtesy: IGCAR

The Indira Gandhi Centre for Atomic Research, Kalapakkam, designed and developed the Prototype Fast Breeder Reactor (PFBR) of capacity 500 MWe

NUCLEAR POWER FOR DEVELOPMENT

After entering into the International Civil Nuclear Cooperation agreement in 2008, India was bestowed with the opportunity of setting up nuclear reactors with international cooperation. This treaty also ensured continuous supply of fuel for Indian NPPs. It led to BARC's plans to develop PWRs indigenously for accelerated capacity building.

The Indian molten salt breeder reactor (IMSBR) is the platform to burn thorium as part of the third stage of the Indian nuclear power programme. The fuel in IMSBR is in the form of a continuously circulating molten fluoride salt which flows through heat exchangers for ultimately transferring heat for power production to Super-critical CO_2 based Brayton cycle (SCBC) so as to have a larger energy conversion ratio as compared to existing power conversion cycle. Because of the fluid fuel, online reprocessing is possible, extracting the 233Pa (formed in conversion chain of 232Th to 233U) and allowing it to decay to 233U outside the core, thus making it possible to breed even in thermal neutron spectrum.

Hence, IMSBR can operate in self-sustaining 233U-Th fuel cycle. Additionally, being a thermal reactor, the 233U requirement is lower, thus allowing higher deployment potential. These reactors require several new technology developments which are being undertaken by BARC.

In addition, BARC is also developing the Innovative High Temperature Reactor (IHTR) with an aim to provide high temperature process heat for hydrogen production by thermochemical water splitting. This reactor is a molten salt cooled pebble bed type reactor where coolant temperatures up to 665°C can be reached which allows for efficient interface with the hydrogen plant. Currently, a 20 MWth IHTR is being designed as a demonstration reactor.

One of the recent feathers in the cap of India's nuclear programme is that India became the first country in the region to complete its nuclear triad i.e. it possesses the capacity to launch nuclear weapons from land, air and sea. In November 2018, Prime Minister Narendra Modi made a formal announcement in this regard. India is the sixth country in the world to possess a nuclear triad.

Nuclear power is generally linked only to electricity generation and weapons. However, in the Indian nuclear establishment, a massive amount of research is conducted on the applications of radiation for the development of humanity.

Applications of nuclear technologies in the field of health, food and agriculture is one of the prime areas of research at BARC. The premier research institute of India has also led to several spin off technologies. A separate technology transfer division has been set up for development of societal applications and handing over the technologies developed at BARC. From sterilization of medical kits and food preservation to advanced technologies like lasers and supercomputers is the vast range of such applications which assures the citizens of India of safety, security and prosperity.

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From Operation Shakti to Shiv Shakti: Rise of Space-faring India

The world is entering an era of lunar geopolitics and economy, and Chandrayaan-3's success must be leveraged to make the Moon the destination of India's strategic scientific and economic goals

Image Courtesy: Shutterstock

■ Dr Chaitanya Giri

In 1998, a year before Bharat began seriously contemplating going to the Moon, NASA's orbiter, the Lunar Prospector and its payload, the Gamma Ray Spectrometer, found an unusual geological feature on the dark side of the Moon. The high reflectance feature, almost 15 x 30 km in area, was due to a high concentration of the trans-uranic element — Thorium. The feature now known as the Compton-Belkovich Anomaly is said to have spiked thorium concentration ranging between 40 to 55 parts per million. The same thorium is critical to the three-stage nuclear programme conceived by the visionary Dr Homi Bhabha, and we never talk about thorium and Moon in one breath. Perhaps a brief history of it should help here.

THE SIGNIFICANT NINETIES

During the 1990s, the Bharatiya space programme faced tremendous hurdles yet made astonishing achievements. The decade began with the US State Department, fresh after the dissolution of the Soviet Union, deciding to impose penalising sanctions on ISRO under the pretext of the Missile Technology Control Regime. This was concurrent with the machinated and false spy case. A fledgling and recently liberalised Bharatiya economy was asking for global investments. The Bharatiya government, too, was weakened by two back-to-back assassinations of our prime ministers. Apart from Prime Minister PV Narasimha Rao's government, which ran its full term, the 1990s was a period of vulnerable 'coalition governments'.

As K Subrahmanyam, ace geostrategist and the former director of Manohar Parrikar Institute of Defence Studies and Analyses (then IDSA) acknowledges in his article 'Narasimha Rao and the Bomb', that Rao, since his time as defence minister in the Rajiv Gandhi government, was in the 'decision-making' loop on nuclear weapons. The nuclear test could have happened in December 1995 but did not happen due to a lack of consensus among administrators, economists and scientists. Fortunately, the delay gave time for designing the asset to be tested on 11 May 1998. Despite two PMs in between — HD Deve Gowda and Inder Kumar Gujral — the messaging on the high secret was passed only from PM Rao to PM Atal Bihari Vajpayee, who assured his stable coalition government would hold the bull by the horns.

PM Vajpayee addressed the world that summer evening. Operation Shakti — a joint creation of the Ministry of Defence and the Department of Atomic Energy — created a tsunami across global strategic circles. The test ensured that our neighbour to the west, Pakistan, got its hidden weapons out of the catacombs of Balochistan's Chagai Hills in the next few days. The US imposed too strong sanctions on both the countries, which it always loved to hyphenate. The sanctions could not last two months, as the US Senate voted to exempt food exports from the sanctions. Later, the Brownback Amendment of October 1998 and the India-Pakistan Relief Act ensured

The Launch Vehicle Mark III (LVM3-M4) with Chandrayaan 3 at the launch pad at Sriharikota in Andhra Pradesh

Image Courtesy: ISRO

that economic aid and export-import banking resumed normalcy. Fourteen countries that followed the US sanctions with their own, too, pulled back their economic sanctions. These were the first signs of a confident India rising, but none acknowledged it.

INNOVATION THROUGH SANCTIONS

While all these developments were happening, ISRO, under the sanctions raised in the early 1990s, demonstrated a multi-satellite launch of nearly 1-tonne payload mass with international customers. The PSLV-C2 launch culminated on 26 May 1999 successfully with two small satellites contributed by the Korea Advanced Institute of Science and Technology (KITSAT-3) and the German Aerospace Center and Technical University of Berlin (DLR-TUBSAT). These were ISRO's first international launch customers. Crippling sanctions on ISRO and the nuclear sanctions in 1998 were indeed not working. India faced two back-to-back challenges: The Kargil War and, later, the hijacking of the IC-814 flight to Kandahar. Eventually, in early 2000, US President Bill Clinton made that famous state visit to India, visiting the cities of New Delhi, Mumbai and Hyderabad. A thaw in India-US relations was becoming visible, not to forget the big leaps taken by the emergent IT and pharmaceutical sectors.

Returning to the Compton-Belkovich Anamoly, the first research papers on this anomaly came out in 1999. The same year, Dr Krishnaswamy Kasturirangan, ISRO's then chairman, twice publicly announced the capabilities of the PSLV, space-proven by then, to take a spacecraft to the Moon. The first announcement was on the National Technology Day celebrations — 11 May 1999 — when we commemorate Operation Shakti. The second announcement happened in a well-curated 'lunar science' seminar organised by the Indian Academy of Sciences in October 1999. Intense, well-curated deliberations within India's scientific community between 1999 and 2003 gave PM Vajpayee the following bold announcement of his tenure — that of the launch of India's first-ever lunar spacecraft, Chandrayaan-1.

Images Courtesy: ISRO and Wikipedia

Above: India's second nuclear test of May 11, 1998, named Operation Shakti, created a tsunami across global strategic circles

Left: The landing site of Chandrayaan-3, ISRO's third lunar mission, has been named Shiv Shakti Sthal

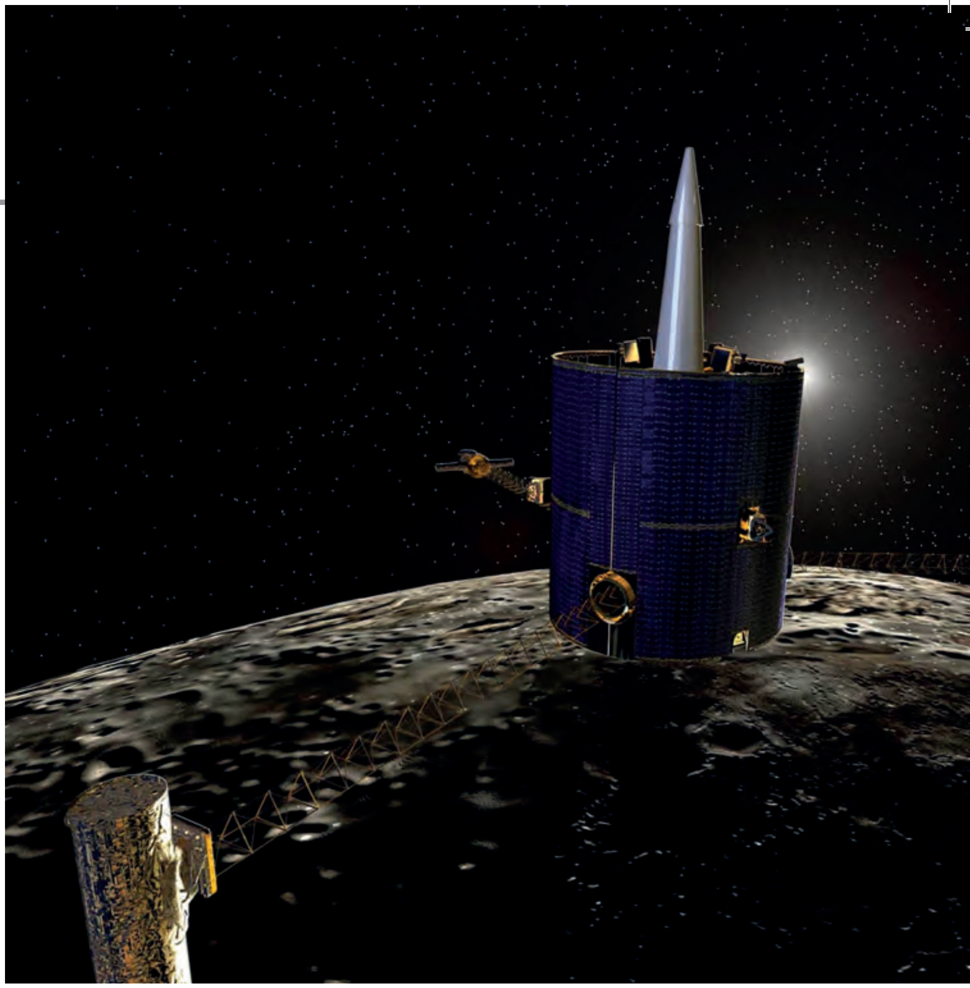
With the formation of the new government led by PM Manmohan Singh in 2004, the subsequent international recognition over the horizon was the India-US Civil Nuclear Cooperation and India-US Civil Space Cooperation, both commencing in 2005. Where Chandrayaan-1 benefited from the latter, the prior opened doors for Bharat to join the International Thermonuclear Energy Reactor (ITER) programme with members including the European Union, the US, Russia, Japan, South Korea and China. This was a momentous next step for Bharat's Department of Atomic Energy (DAE), which had a functional tokamak 'Aditya' since 1989, and ITER is a tokamak-based nuclear-fusion reactor. The thoughts on going to the moon and realising nuclear fusion began converging in Bharat, and it first happened during the visit of G Madhavan Nair — then ISRO chairman — in September 2006 to the Bhabha Atomic Research Centre (BARC) in Mumbai.

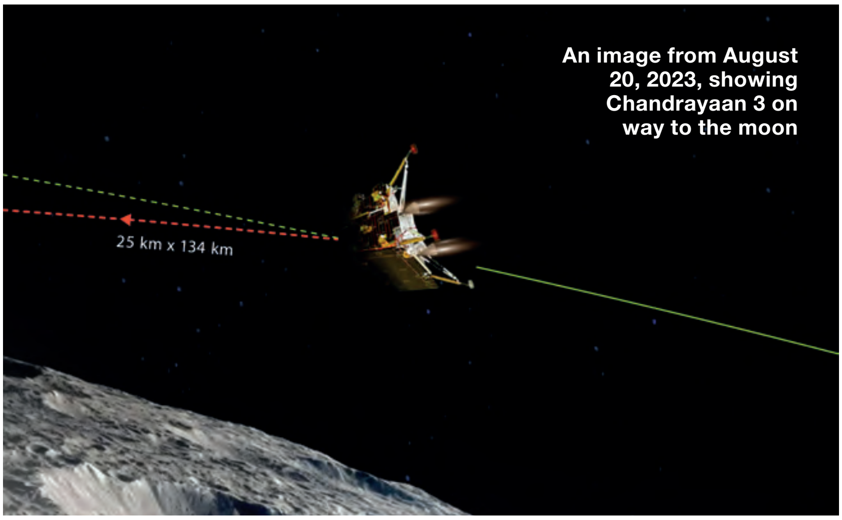
RETURN TO THE MOON

Prof Gerald Kulchinski had run the Fusion Technology Institute at the University of Wisconsin Madison since the 1970s. The institute was a global hub of thermonuclear fusion reactor engineering and was heavily funded by the US government. In the early 1980s, famous Apollo astronaut and senator Harrison Schmitt joined the institute as a faculty with a keen interest in lunar 'helium-3' as the reason to set up a human presence on the Moon. After nearly twenty-five years of advocacy and consultancy on this topic, Schmitt wrote a book in 2006 titled 'Return to the Moon: Exploration, Enterprise, and Energy in the Human Settlement of Space.' Around the same time, scientists from Bharat's DAE, while visiting a nuclear fusion conference in Wisconsin in 2004, came across the idea of lunar helium-3. It was not serendipitous that ISRO Chairman Nair and Dr Anil Kakodkar, then Atomic Energy Commission Chairman, converged their thoughts on lunar helium-3 in that BARC meeting.

By 2007, an armada of lunar-bound missions of various space agencies — China's Chang'e-1 (2007), Japan's Kaguya (2007), Bharat's Chandrayaan-1 (2008), and Lunar Reconnaissance Orbiter (2009) were preparing to go to the Moon. Helium-3 was on every mission's agenda. China's State Key Laboratory of Wave Scattering and Remote Sensing Information used the Lunar Prospector datasets to estimate lunar helium-3 to be around 6.5 x 108 kg on the moon, globally, with the near side considerably more abundant than the far side.

While helium-3 continued to dominate the narrative on lunar extraction, the case for thorium went on the back burner or perhaps was kept so. One of Chandrayaan-1's scientific goals was to detect emissions of thorium, but this may have happened with no or bare minimum collaboration with the Department of Atomic Energy. It carried a High Energy X-ray Spectrometer (HEX) designed to detect natural low energy (30-270 keV) gamma rays emitted from the decay of uranium and thorium from the lunar surface. HEX was aiming to detect radioactive lead (210 Pb) and decay-product of volatile radon (222 Rn), both being part of the uranium (238 U) decay series. Besides that, HEX was also aiming to detect gamma emission lines of thorium (234 Th), radon (226 Ra), and uranium (235 U), and thereby map the uranium-thorium rich 'KREEP' regions on the Moon. Despite HEX's impactful first scientific results, Bharat would need a more profound lunar mineralogical prospection exercise, especially in search of helium-3 and thorium.





An image from August 20, 2023, showing Chandrayaan 3 on way to the moon

Image Courtesy: ISRO

LINK BETWEEN SPACE AND ATOMIC PROGRAMME

There is an old English-language saying: what's good for the goose is good for the gander. In the context of the thought, this article presents — what is good for the space programme is also good for the atomic programme of Bharat. This atomic-space programme duality might be supported in some scientific quarters but is certainly not coming across vividly as a solid collaboration between the two. There is immense scope for the Department of Space and Atomic Energy to cooperate. But the cooperation could only work if a dogged insistence and strategic decision-making come from the top — the Prime Minister's Office.

It is imperative to erase the unsaid notion that only ISRO has to go to the moon. The US scientific apparatus does not adhere to such psychological silos. Let's take the example of the Gamma-Ray Spectrometer on the Lunar Prospector spacecraft. It is easy to attribute the spacecraft to a NASA mission. But not many would realise that the US Department of Energy's Los Alamos National

Image Courtesy: NASA

Observatory led the scientific investigation of this instrument. Another thorium mapping mission to the moon, where NASA played a secondary role, was Clementine. The mission was led by the Department of Defense's Ballistic Missile Development Organization (BMDO), which today is named Missile Defence Agency.

We have to plan for Bharat's Ministry of Defence or Department of Atomic Energy to participate as crucial or even leading stakeholders in missions to the Moon. The 1990s was an exciting time in the US too. In 1992, the US National Research Council created COMPLEX (Committee on Planetary and Lunar Exploration) that sought to develop an integrated approach towards why the US should explore planets and the Moon. In the coming years, it would be crucial for Bharat to source well-designed, robustly-built payloads that would carry out highly impactful lunar science, which has economic value to generate. These payloads could come from the Ministry of Defence, Department of Atomic Energy, Council on Scientific and Industrial Research, or many central and state universities. Who has stopped these agencies and institutions from going to the Moon?

In 1998, NASA's Lunar Prospector found an unusual geological feature on the dark side of the moon, which was due to a high concentration of the transuranic element, thorium

POLITICISATION OF LUNAR TERRITORY

Most of us are too consumed with the euphoria around every Chandrayaan mission, which is justified. However, what is more justified is the strategising that is required about Bharat's larger goals on the Moon, what we are trying to achieve, and what is the end goal. Are we going there as an obedient nation of the world order in place, or are we prepared for any surprise — even that of a lunar takeover? In an interview with a political magazine, Bill Nelson, the current chief of NASA, expressed deep suspicion about Chinese activities on the Moon. He said, "It is a fact: we're in a space race.....It is true that we better watch out that they don't get to a place on the moon under the guise of scientific research. And it is not beyond the realm of possibility that they say, 'Keep out, we're here, this is our territory'."

The establishment of the Artemis Accords and the International Lunar Research Station are testimony to the US and China's ability to create astropolitical blocs that abide by the lunar economy and military strategy they make. The rest of the junior partners, signatories to the Accords or partners on the research station would only follow the strategy these two countries set.

Only pragmatic and realist leaders of countries can attain leadership positions in polycentric global geopolitics. There is no room for the ideological and unrealistic romanticism that crept up after the Second World War. Bharat may not be interested in a war, but certainly, the world is moving in pre-war times. The Artemis, the ILRS, and Bill Nelson's statements precisely convey the same.

NUCLEAR REACTORS ON MOON

Finally, about helium-3 and thorium, it is clear that the thorium-abundant regions — particularly the Compton-Belkovich anomaly region — are sites of immense interest for companies like Rolls Royce or X-energy. Let us not assume that the helium on the moon will only be used when thermonuclear fusion reactors are ready. Helium-cooled, thorium-powered, miniature nuclear fission reactors generating up to 100 MW and with an operational life cycle of around 50 years could come up on the Moon by the middle of this century.

For such avant-garde technologies to come up from Bharat's *bhumi*, it would become imperative for our scientific agencies — DoS, DAE, and DRDO — to collaborate. The early leaders of these agencies, Vikram Sarabhai, Homi Bhabha and Daulat Singh Kothari, made sure that their agencies fulfilled each other's technology needs even in times when India was carrying rocket nozzles on bicycles and satellites on bullock carts. Today, India is an industrialised superpower. The world is entering an era of a lunar economy, and Chandrayaan-3's success must be leveraged to make the moon the destination of our strategic scientific and economic goals. The lunar landing on Shiv Shakti Sthal is no less than the Operation Shakti moment or perhaps is even bigger.

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Science Building Blocks of a New India

- **November 11, 1947:** Physical Research Laboratory was established in Ahmedabad by Dr Vikram Sarabhai. The initial focus of this institute was to do research on cosmic rays and the properties of the upper atmosphere.
- **December 13, 1947:** Ahmedabad Textile Industry Research Association was established. It is the largest association for textile research & allied industries in India and it started functioning in 1949.
- **April 24, 1948:** The Central Leather Research Institute was established in Chennai. It is the world's largest leather research institute in terms of research papers and patents.
- **July 25, 1948:** Central Electro Chemical Research Institute (CECRI) was established in Karaikudi, Tamil Nadu, and started functioning from January 1953.
- **April 6, 1949:** Sardar Vallabhbhai Patel, then Deputy Prime Minister of India, laid the foundation stone of the Vallabhbhai Patel Chest Institute, New Delhi.
- **August 26, 1950:** The Central Glass and Ceramic Research Institute (CGCRI) was established in Calcutta, to focus on the area of glass, ceramics, mica, refractories, etc.
- **October 21, 1950:** CSIR-Central Food Technological Research Institute (CSIR-CFTRI), one of the constituent laboratories under the aegis of the CSIR, opened in Mysore.
- **January 7, 1951:** The Indian National Science Academy (INSA), earlier called The National Institute of Sciences of India, was shifted to New Delhi and got its present name in 1970.
- **February 17, 1951:** Central Drug Research Institute was established in Lucknow. It is a multidisciplinary research laboratory employing scientific personnel from various areas of biomedical sciences.
- **February 1, 1953:** The National Library of India, India's largest library, was established in Calcutta and opened to the public.
- **January 3, 1954:** The Atomic Energy Establishment, Trombay (AEET), was established by Dr Homi Jehangir Bhabha, the Father of Nuclear Programme of India. He was the first director of AEET, which was renamed Bhabha Atomic Research Centre (BARC) after his untimely death in 1966.
- **June 2, 1956:** The first AIIMS — All India Institute of Medical Sciences — was established in New Delhi, under the All India Institute of Medical Sciences Act, 1956.
- **February 26, 1958:** Central Mechanical Engineering Research Institute was established in Durgapur, West Bengal. It is a public engineering research and development institution and the only national level research institute in the field of mechanical engineering in India.
- **June 1, 1959:** National Aerospace Laboratory (NAL), India's largest aerospace firm, was established by CSIR in New Delhi. Its headquarters were shifted to Bangalore in 1960.
- **November 2, 1959:** Indian Institute of Technology Kanpur was founded.
- **April 21, 1961:** The National Academy of Medical Sciences was registered as the 'Indian Academy of Medical Sciences' under the Societies Registration Act XXI of 1860.
- **April 1, 1962:** Postgraduate Institute of Medical Education and Research (PGIMER), Chandigarh, was established; it was declared an Institute of National Importance in 1967.
- **November 17, 1962:** Institute of Tropical Meteorology (ITM), New Delhi, was founded.
- **April 22, 1969:** Jawaharlal Nehru University, popularly known as JNU, was established.
- **August 15, 1969:** ISRO or Indian Space Research Organisation was founded, to harness space technology for national development.
- **May 12, 1972:** The Indian Academy of Forensic Medicine (IAFM) was founded and registered as society. It is located in Bambolim, Goa.
- **May 18, 1974:** Operation Smiling Buddha, or India's first nuclear test, was conducted at Pokhran Test Range, Rajasthan.
- **April 19, 1975:** India's first satellite, Aryabhata, was launched on 19 April 1975 onboard a

Ever since Independence, Indian science has taken the fast road to achieve success for the benefit of the society. **Science India** lists out some landmarks in India's journey to become a country with scientific acumen to reckon with on the global stage

■ **Sonam Singh Subhedar**

Soviet Kosmos-3M rocket from Kapustin Yar. The Aryabhata spacecraft was named after the famous Indian astronomer and mathematician who lived in Pataliputra (now Patna) in the 5th – 6th century AD.

April 1, 1977: Centre for Molecular and Cellular Biology, Hyderabad, was established.

June 7, 1979: Bhaskara-I, the first experimental Remote Sensing Satellite built in India, was launched by C-1 Intercosmos from Volgograd Launch Station (in present-day Russia).

February 26, 1986: The Department of Biotechnology (DBT), an Indian government department under the Ministry of Science and Technology, was founded.

April 30, 1986: INS Sindhughosh, the first submarine of the Indian Navy, was commissioned in Riga, in present-day Latvia, under the command of Commander KC Varghese.

May 11-13, 1998: India's second set of nuclear tests were conducted at the Indian Army's Pokhran Test Range in Rajasthan, code named Operation Shakti. It marked India's entry into the elite nuclear group.

September 20, 2004: The first dedicated 'Educational Satellite', GSAT-3, also known as EDUSAT, was launched by GSLV-F01. It provided the country with satellite-based two-way communication to class room for delivering educational materials.

October 22, 2008: Chandrayaan-1, India's first mission to the Moon, was launched successfully from SDSC-SHAR (Satish Dhawan Space Centre-Sriharikota Range), Sriharikota, by PSLV-C11.

May 5, 2009: The CARTOSAT-1 satellite — first Indian Remote Sensing Satellite capable of providing in-orbit stereo images — was launched, atop PSLV-C6 rocket launcher from SDSC-SHAR, Sriharikota.

September 14, 2012: Jagadish Chandra Bose's experimental work in millimetre-band radio and Raman Scattering discovered by Sir CV Raman were recognised as IEEE Milestones (by US-based Institute of Electrical and Electronics Engineers), becoming the first two Indian entities to be bestowed this honour.

November 5, 2013: India's first interplanetary mission to Mars, the Mars Orbiter Mission (MOM) Spacecraft, was launched by PSLV-C25 from SDSC-SHAR Centre, Sriharikota.

January 20, 2016: The fifth navigation satellite of the seven satellites constituting the IRNSS space segment IRNSS-1E, was launched.

March 10, 2016: IRNSS-1F was launched by PSLV-C32 into a sub-Geosynchronous Transfer Orbit.

February 15, 2017: India scripted a new chapter in the history of space exploration with the successful launch of a record 104 satellites by ISRO's Polar Satellite Launch Vehicle (PSLV) in a single mission.

February 6, 2019: India's telecommunication satellite, GSAT-31 was launched in 2019 from Kourou launch base, French Guiana.

July 22, 2019: Chandrayaan-2 was launched by GSLV-Mk III - M1. It reached lunar orbit in August 2019.

June 2020: Covaxin, created by Bharat Biotech, became India's first indigenously created vaccine against COVID-19.

November 2020: The Giant Metrewave Radio Telescope (GMRT) in Pune became the third Indian entity to be awarded the IEEE milestone.

April 2021: After several trials, Covaxin was declared to have an estimated efficacy of 78 per cent.

July 2023: Government approved use of Ceravac, India's indigenously developed vaccine against cervical cancer. It has been developed by Pune-based Serum Institute of India.

14 July, 2023: Chandrayaan-3, the third mission in the Chandrayaan programme, was successfully launched from SDSC-SHAR, Sriharikota.

23 August, 2023: Chandrayaan-3's Vikram lander, carrying the rover Pragyan, successfully landed on the moon's south pole, making India the first country in the world to land on the difficult south pole, and only the fourth in the world to reach the moon.

Cyber Towers in Hyderabad, widely considered as a heritage building for India's IT industry

Our IT Story Shows How A Truly World-class Industry can be Made in India

The nation's first computer was introduced in 1955 but it would be a while before the country's techpreneurs would start pushing the envelope to make India one of the top software countries in the world. Now is the time to forge further ahead

Image Courtesy: Shutterstock

■ Dr Ajai Chowdhry

The start of India's Information Technology (IT) journey can be traced to Prof PC Mahalanobis, who introduced the nation's first computer at ISI (Indian Statistical Institute), Kolkata. Mahalanobis employed sophisticated models in 1955 with the HEC-2M Computer to allocate investments in different sectors of the economy. However, the then public sector-driven growth stifled private enterprise. This was later followed by an era of over-regulation, licensing and other controls, which diminished competition further.

In 1956, the pilot of the first computer developed in India was made at the Tata Institute of Fundamental Research (TIFR) in Mumbai. The project was overseen by the visionary Dr Homi Bhabha, as well as the scientific geniuses R Narasimhan and PVS Rao. In 1963, IIT Kanpur offered the first course in computer science. An anecdote in the book *Against All Odds: The Story of India's IT Revolution*, co-written by Infosys co-founder Kris Gopalakrishnan, describes how an IBM 1620 computer arrived at IIT Kanpur in a bullock cart!

MISSED OPPORTUNITIES AND BABY STEPS

The IT revolution had to wait till the 1980s. While prime minister Jawaharlal Nehru was a socialist, later prime minister Indira Gandhi too missed the opportunity to encourage private businesses, even as Asian counterparts like Japan and Korea were making headways. During the Emergency, customs duties rose to 140%, income tax rate went up to 97.5% plus wealth tax above it. There was little hope for accumulating capital for investment in this scenario.

Foreign companies were forced to divest their equity to 40%. This led IBM, the market leader, to quit India. However, IBM's departure made space for Indian companies to enter the market of small computers. HCL launched a computer which even came around the same time as Apple's personal computer (PC).

By the 1980s, with hardware becoming a challenging domain due to different regulation controls, IT enterprises explored the realms of software. Rajiv Gandhi's leadership marked a new chapter, and computers became increasingly accessible. People at that time made fun of Rajiv Gandhi's childish "obsession with high-tech toys". He was progressive, and had provided a personal computer to every district office in the country. His untimely death prevented him from seeing the IT revolution.

By that time, following the lead of IIT Kanpur, students at all IITs had embraced computer education. Devang Mehta, co-founder of India's IT support body, NASSCOM (National Association of Software and Service Companies), lobbied with N Vittal, secretary of the Department of Electronics, to remove obstacles. Vittal understood the needs of the industry, helped in cutting the red tape, and introduced the revolutionary software technology parks of India (STPI) in 1991. Winds of change were brought in by the economic liberalisation of 1991. Sam Pitroda, US-based entrepreneur, created the STD booth revolution, giving urban India universal access to long distance calling. Later offshoring started, when engineers in India would use the latest computers and telecommunication links to develop software for the global markets. Companies like GE wanted the software done here. After the successful sail through of the Y2K challenge (also known as the 'millennium bug'), many international tech giants like IBM returned to India, tapping into the nation's vast pool of talent.

FACING CHALLENGES WITH AUDACITY AND BRAVURA

For growth to be inclusive and sustaining, each small player needs to grow. There were a large number of SMEs in electronics before WTO destroyed all that. As duty dropped to zero, many local brands struggled to match the prices offered by China, leading to their decline.

Indian IT stalwarts displayed resilience when faced with challenges. Behind the success of India's IT sector are myriad tales of persistence and ambition. Like, the TCS's audacious acquisition of an IBM mainframe, or the tenacity of Infosys founders. When I embarked on my exciting entrepreneurial journey in the 1970s, I was 25 years old. I left the stability of my comfortable job at DCM, the fifth largest company in India at the time, to create HCL with five other hungry tech-preneurs. We were armed with nothing but a great idea and a massive drive to succeed.

Leading software companies started out as hardware companies. For instance, the origins of Infosys can be linked to the Mumbai-based Patni Computers, which was once a distribution company for Data General. Its founder, Narendra Patni, was among the pioneers in software exports. In 1977, he appointed NR Narayana Murthy to lead their software division. By 1980, Murthy and six of his peers departed from Patni Computers to establish Infosys. Kris Gopalakrishnan and Nanadan Nilekani, Infosys co-founders, thus started their career at Patni Computers. Hinditron too started with selling digital hardware and PCs. Harish S Mehta, co-founder of Nasscom, was in hardware earlier. Similarly, Tata Burroughs was formed after a collaboration venture signed between the Tata Group and Burroughs, in 1977. Burroughs was among the largest computer manufacturers in the world, and through the joint venture, TCS got global opportunities.

HCL too has origins in hardware. At HCL, we had set up a hardware manufacturing plant in the US in Silicon Valley. However, due to a specification by the US government, we couldn't distribute that hardware. As a result, we were burdened with a significant loan from ICICI bank. The product we wanted to market in America was a Unix-based mini-computer with multi-processor capabilities. The operating system developed for this advanced hardware was a distinctive, fine-grained Unix — first of its kind globally. Unable to sustain the hardware venture in America, we pivoted to software, bolstering our R&D. It was our expertise in Unix that steered us towards software. Wipro too moved to software because of its hardware capability. And that's how our local enterprises began to rival major corporations.

Back in the days, we would do the system analysis of the requirements of the customers in Singapore, and send back the findings to our software export division in Madras, that created very special tools. Those were early days to automate the whole process of programming, to export the software faster.

Image Courtesy: Shutterstock

India's breakthrough digital products such as UPI (for seamless movement of money, seen at a grocery store in Katni, Madhya Pradesh, above) are proof of our ability as a nation to create world class innovation

Even though automation discussions are common today, we pioneered it back in 1980, when communication links left much to be desired. Instead of digital transfers, we would send the software on floppy disks. However, these disks would sometimes get damaged by X-ray machines during customs inspections. Then we would be constrained to repeat the process, and send it again.

At HCL, we had a Singapore subsidiary in 1980 to manufacture computers. But the market there also wanted solutions. So, we broadened our appeal by not just giving the hardware, but also the application software to run businesses, to sort out customized workflows, finance and accounting applications, sales order processing, inventories, HR, and so on. To support the hardware business, we started a software export division in Madras in 1980. HCL became the largest IT company in India in 1986, ten years after its start, and was among the earliest to do software in India, for global companies.

> ***We created our own word processing software, our own relational database, and so on, much before Oracle did!***

ECOSYSTEM FOR GROWTH OF ELECTRONICS

Foreign companies started banking upon the low-cost Indian talent, and the arbitrage advantage, though now with the Global Capability Centres, it's no longer about cost arbitrage but about quality work that India is known for. So a lot of capability got built and honed over time, as a result of designing and making our own software and hardware. We created our own word processing software, our own relational database, and so on, much before Oracle did! We realised early on that building our own skill capital would bring us sustainability. Given the growing demand of electronics now — which has seeped all verticals and sectors — all these skills will help us in becoming the product capital of the world, backed by favourable geo-politics.

Now all the top IT companies do engineering and R&D exports where hardware expertise is used to create products for global markets. In addition to hardware, there is also the push for chip designing. The revised semiconductor policy announced this year enables 50% contribution from the government for all types of plants. The Production Linked Incentive (PLI) scheme and a string of reforms in the last decade, including the Nasscom policies, ISPIRT, the Electropreneur Parks, the MEITY proposed fund-of-funds, the recent changes in the semiconductor policy, and so on, have provided an enabling ecosystem for electronics growth in the country. Now we need to build Make in India products that are safe, fully repairable, upgradable, and recyclable, and support the vision of a robust growing nation, supplying to the global market as well.

We need to ensure our products have India inside and out, and we are not dependent on foreign components. For that, we need to deepen R&D and make our engineers turn their gaze on hardware too. We certainly know how to integrate software into hardware. There should be no need for Indian companies to go to China to design their products in future.

Introduced in 1971, floppy disks became popular as a device to store and share data

Image Courtesy: Wikimedia Commons

Image Courtesy: Infosys

Left: NR Narayana Murthy (extreme left) was appointed head of Patni Computers' software division in 1977, which he would leave with six of his peers to form Infosys in 1980. Seen here with the IT giant's co-founders

By building our own agritech, medtech or drone facilities, for example, we reduce the import bill, and also make products that no outside agency can spy on. That's the aim of Atmanirbarta, Make in India, Digital India, Startup India and so on.

As per MEITY, electronics consumption in India will rise to $400 billion in 2025 from $100 billion at present. We need to rapidly transform India into a manufacturing hub for new generation electronics products. There are 92 angel networks in India that have CEOs and entrepreneurs investing in diverse industries, from agriculture to spacetech. The angel networks provide the highest quality mentorship for startups with great potential.

MADE IN INDIA WITH PRIDE

In welfare access, in climate resilience, in EVs, in security and defence, in the consumer durables market, there's a big zone of opportunity that awaits Indian engineering and manufacturing capabilities.

Our breakthrough digital public goods are enabling a wave of innovation in delivery of public services as well as seamless movement of money (UPI), people (DigiYatra), and Data (DEPA). UPI and RuPay are making forays in UAE, Japan, the US, Singapore, Bhutan, Nepal, and recently in France. This showcases our abilities to build world class innovations and products.

I recall when we first made the HCL computer and took it to the LIC office, they refused to take it, fearing job loss. Decades later, we know that technology has helped to streamline processes and cumbersome tasks, leaving humans to focus on the creative tasks, and has spawned new kinds of jobs. Going forward, I see a blended workforce where humans and AI work together. We need to encourage new tech and allow it to usher in new growth.

The scope is immense. The domestic revenue of the IT industry is estimated at $51 billion, and export revenue is at $194 billion in FY23. The share of the IT-BPM sector in the GDP of India was 7.4% in FY 2022.

We need to have pride to truly design exceptional products. I mention in my book, *Just Aspire*, about HCL's Mindia campaign launch in 2004. We created Mindia badges in glorious tricolour and made them mandatory for everyone including me. We would attend client meetings, proudly, supporting badges and that would invariably pique their interest. We need that kind of pride in our own Made in India products. India's IT story shows how a truly world-class industry can be made in India.

** The writer, a Padma Bhushan awardee, is the Chairman of Epic Foundation and Co-Founder, HCL. An author, he is recognised as the Father of Hardware in India.*

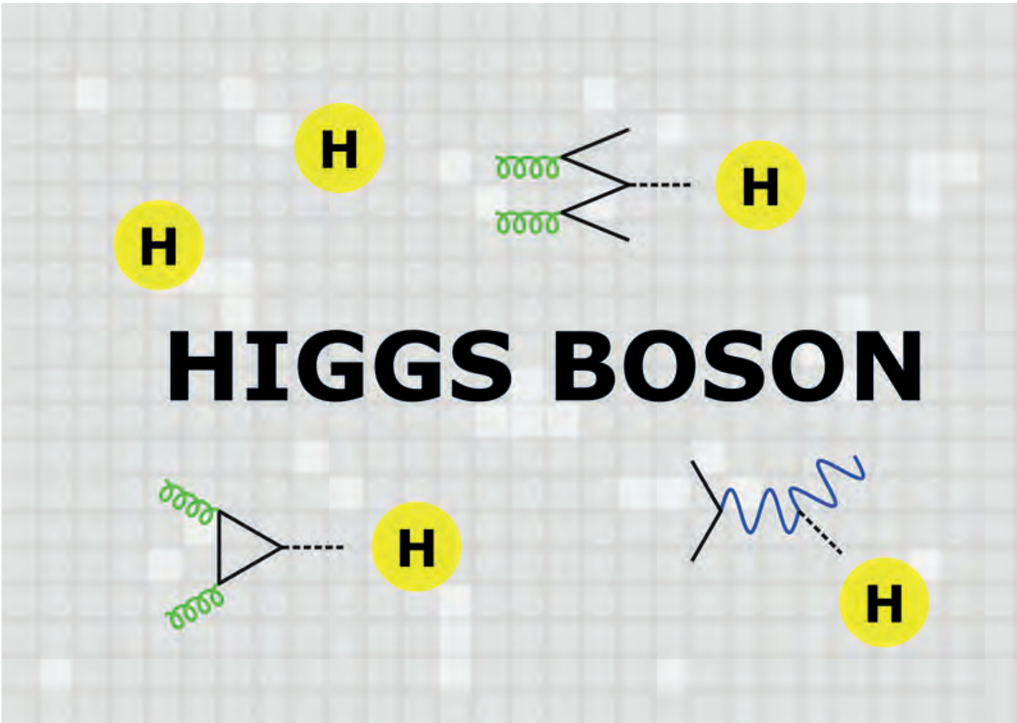


Image Courtesy: Shutterstock

Boson in Higgs boson, an elementary particle that imparts mass to other elementary particles like quarks and electrons, is perhaps one of the best known scientific terms of Indian origin. It is named after Indian physicist Satyendra Nath Bose

India Eponymous: Scientific Terms Bearing Indian Names

A browse through the life and works of scientists in the pre-Independence era reveals that Indian scientists, as citizens of a slave country, proved their mettle globally, despite hard times under colonial rule. Here's a brief analysis of some international scientific terms named after these scientists

■ Dr Jayanti Dutta

In my school days, I had a hobby to make a list of scientific terms which were named after the discoverer, inventor or researcher associated with that term. Secretly, I also cherished a dream that someday a scientific term will be named after me too, making my name famous and unforgettable. I came to know that the word, 'eponymous' is an adjective, meaning – (of a thing), named after a particular person. This list of phenomena, laws, equations, diseases, syndromes, body parts, devices, procedures which were named after the respective scientists was very long.

It struck me that almost all the names were of foreign-origin scientists, and I started looking for Indian names in the scientific terms list. I also became aware of the malpractice of not giving credit to Indians where it was due, during the British rule. Stories of how Radhanath Sikdar and Kishori Mohan Bandopadhyay were sidelined by the British officers, while naming Mount Everest and giving the credit for discovery of the malarial parasite, respectively, echoed in my heart. I am not ashamed to acknowledge that it gave me a lot of joy to spot an Indian name which symbolised to me my love for my country.

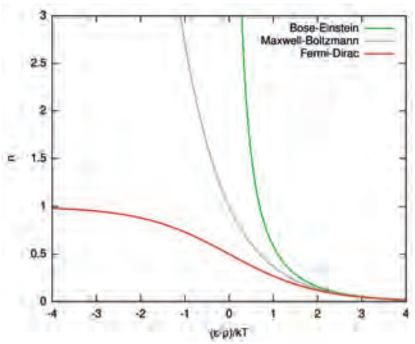
Today, when I ponder over this emotion with my mature world view, I think, it hardly matters if a scientific term is named after a scientist of the country of my birth or that of an alien country. But as a young student pursuing Science education, these names gave me inspiration and confidence. I could relate to these scientists and the study of science seemed home-grown, less alienated and hence less intimidating and more natural. It is because of this very reason that I am sharing a few of such eponymous terms in this article, more because of their anecdotal significance but also because this trivia might motivate our young researchers.

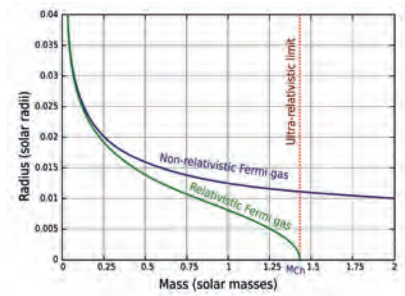
1. BOSON

Boson is, in my opinion, the most well-known Indian eponymous term. There are two fundamental classes of subatomic particles, Bosons and Fermions. The spin quantum number of Boson is an integer value (0,1,2…) and that of a Fermion has an odd half-integer value (1/2, 3/2, 5/2….). Both the subatomic particles are named after physicists who have discovered them. While Fermion is named after Enrico Fermi, Boson takes its name after the Indian physicist Satyendra Nath Bose (1894-1974) who worked on the behavior of photons in the 1920s.

2. BOSE-EINSTEIN STATISTICS

Satyendra Nath Bose in a short article





Nobel laureate Subramanyan Chandrashekhar (right) who discovered the Chandrashekhar Limit (above) depicting mass of white dwarf stars

'Planck's Law and the Hypothesis of Light Quanta' pointed out a discrepancy in the contemporary theory and presented his hypothesis based on the philosophical concept of the indistinguishability of the photons which would lead to different statistical results. Bose sent the article to Einstein requesting him to know his opinion on it and to make arrangements for publishing it in a German journal, *Zeitschrift fur Physik* if Einstein found it worthy of publication. Earlier, Bose had translated Einstein's paper on 'Generalised Relativity' and published it, but Bose had not known Einstein intimately. In his letter, Bose writes, 'Though a complete stranger to you, I do not feel any hesitation in making such a request. Because we are all your pupils profiting by your teachings through your writings'. Bose's letter hints at the globalised approach that the

Satyendra Nath Bose (above) after whom is named the Bose-Einstein Statistics (above, left)

scientists of pre-independent India possessed despite living under a suppressing imperial rule.

Einstein acceded to Bose's request and published the paper in 1924. Bose's paper laid the foundation of Quantum Statistics and its interpretations are now known as Bose-Einstein Statistics.

3. BOSE-EINSTEIN CONDENSATE

Another of Satyendra Nath Bose's articles, later followed by another paper by Einstein led to a prediction that in addition to the wave and particle, there existed another phenomenon — a dense collection of Bosons — a new phase of matter, which was named Bose-Einstein Condensate. This prediction was finally established experimentally in 1995.

4. RAMAN EFFECT OR RAMAN SCATTERING

This eponymous term after Chandrashekhar Venkata Raman is also very well known in India because this is the discovery for which CV Raman received the Nobel Prize in 1930.

When light photons get scattered by a material, most of them are elastically scattered, that is, they retain the same energy, frequency, wavelength and colour, but the direction gets changed. This is called Rayleigh scattering. However, a small fraction of the scattered photons, one in one million get scattered inelastically, wherein the scattered photon has different energy. This phenomenon was discovered by CV Raman and is called Raman Scattering or Raman Effect. CV Raman, Palit Professor in Presidency College, Calcutta, published an article titled, 'A New Radiation' in the *Indian Journal of Physics* on this discovery which he did on 28 February 1928. In India, 28 February is celebrated as Science Day to commemorate this discovery.

Another term, Raman Spectroscopy, also emanates from the phenomenon of Raman Effect. It is a spectroscopic technique used to determine vibrational modes of molecules and is used in Chemistry to identify structural fingerprint of molecules. Raman shift and Raman spectrum wavelength are terms which are used in further explanations of the phenomenon.

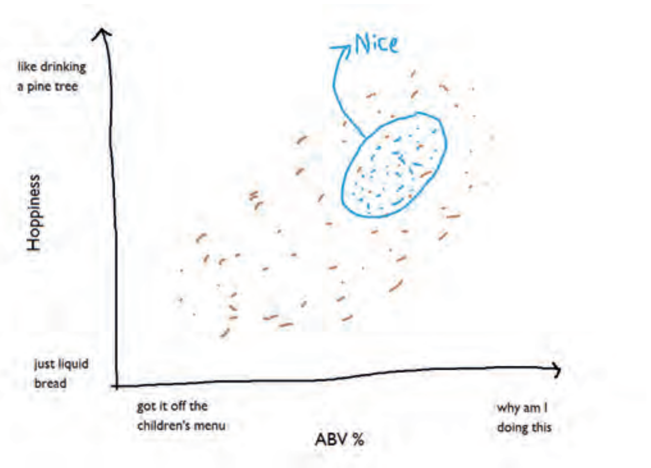
5.CHANDRASHEKHAR LIMIT

Subramanyan Chandrashekhar, a physicist who had his initial education in India and later worked in the United States, developed a theoretical model explaining the structure of white dwarf stars. He showed that the mass of a white dwarf cannot exceed 1.44 times that of the sun. This is called the Chandrashekhar Limit. Before his discovery, it was thought that all stars finally culminate into white dwarfs. His research added knowledge about supernovas, neutron stars and black holes.

6. MAHALANOBIS DISTANCE

PC Mahalanobis, founder of the Indian Statistical Institute, and member of the first planning commission whose birthday is celebrated in India as the National Statistics Day, is the statistician after whom the term is named. Mahanobis first described the concept of Mahalanobis Distance in 1936 while working with racial likeness of skulls.

Variables are usually two in number and are described in a Euclidean space through a coordinate of the x-axis and y-axis system. However, if there are more than two variables it is difficult to measure them along the planar coordinates. In such cases, the process of Mahalanobis Distance is used to find out how much a point diverges from distribution measurements in multiple dimensions.



PC Mahalanobis (above, right), founder of the Indian Statistical Institute, who first described the concept of Mahalanobis Distance (graph above) in 1936 while studying racial likeness of skulls

4. The Saha equation is:

$$\frac{N_{i+1}}{N_i} = \frac{2\,Z_{i+1}}{n_e\,Z_i}\left(\frac{2\pi m_e kT}{h^2}\right)^{3/2} e^{-\chi_i/kT}$$

where Z_i and Z_{i+1} are the *partition functions* representing the degeneracy of the electron states. For ionisation of Hydrogen from the ground state $Z_I = 2$ and $Z_{II} = 1$. Assuming most HI is in the ground state, calculate the fraction of HII at 8 000 K and 11 000 K in a stellar atmosphere where the electron *pressure* is roughly constant at $20\,\mathrm{N\,m^{-2}}$. Verify the assumption that most HI is in the ground state with a physical argument.

Image Courtesy: Internet

7. SAHA IONISATION EQUATION

Saha Ionisation Equation (stated above) is named after Meghnad Saha (left) who discovered it

Named after the renowned Indian physicist, Meghnad Saha, the discoverer of the equation, it relates to the ionization state of a gas in thermal equilibrium to the temperature and pressure. When a gas is at a high temperature or density, the thermal collisions of the atoms will ionize some of the atoms, creating an ionized gas. When several or more of the electrons that are normally bound to the atom in orbits around the atomic nucleus are freed, they form an independent electron gas cloud co-existing with the surrounding gas of atomic ions and neutral atoms. With sufficient ionization, the gas can become plasma. The Saha Ionisation equation describes the degree of ionization for any gas in thermal equilibrium as a function of the temperature, density, and ionization energies of the atoms. The equation is a result of combining ideas of quantum mechanics and statistical mechanics and its use has been found to explain the spectral classification of stars.

8. KAPREKAR CONSTANT

The number 6174 is known as Kaprekar's constant after the Indian mathematician DR Kaprekar from Maharashtra. Kaprekar has been a seeker of

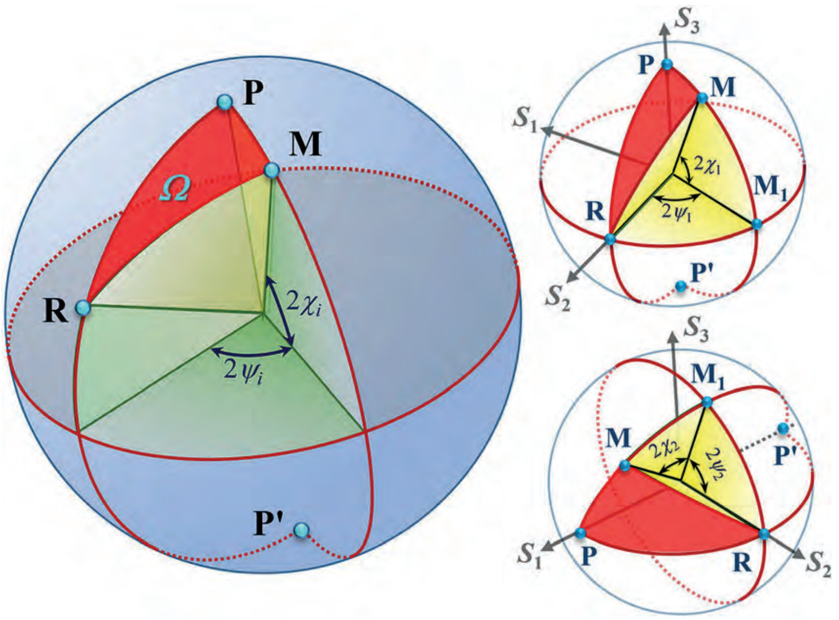


Image Courtesy: Internet

Pancharatnam Phase for polarised beams passing through crystals was discovered by Sivaramakrishnan Pancharatnam

mathematical aesthetics and rhythm. He observed that the number 6174 has a unique quality. It is a constant that arises when we take a four digit integer, form the largest and smallest numbers from its digits, and then subtract these two numbers. Continuing with this process of forming and subtracting, we always arrive at the number 6174.

Kaprekar number is another term named after him. In Mathematics, a natural number in a given number base is a p-Kaprekar number if the representation of its square in that base can be split into two parts, where the second part has p digits, that add up to the original number. Kaprekar also has the unique distinction of giving indigenous names to many mathematical numbers, such as Demlo number (after Dombivili station), Harshad number (after a Sanskrit word meaning a number which gives joy).

9. VAIDYA METRIC

Prahalad Chunnilal Vaidya was an Indian physicist and mathematician from Gujarat. He studied and worked as a teacher in different institutions in India and abroad. He worked in the field of General Theory of Relativity. He was a dedicated teacher and a Gandhian in his philosophy. It is said that the idea of spacetime geometry came to him when he used to wait for newspapers to arrive so that he could know about the developments about Gandhi's health status during the Quit India movement. He then developed this idea into the eponymous term Vaidya metric within a week. He was 24 years of age at that time.

Vaidya metric is a term used in general relativity which applies to a set of Einstein's equations of the gravitational field of a star which has a sizeable radiation. The idea implicit in it to use the light rays as a co-ordinate frame played a salient role in future research in gravitational theory. Vaidya metric is very frequently cited in studies on gravitation and general relativity.

10. PANCHARATNAM PHASE

Shivaramakrishnan Pancharatnam, an Indian physicist who did significant work in the field of optics, is noted for his discovery of a type of geometric phase also known as Pancharatnam phase for polarized beams passing through crystals. He was born in West Bengal in 1934 and taught Geometry as a reader at the Department of Studies in Physics, University of Mysore.

The Pancharatnam phase is a geometric phase associated with the polarization of light. When the polarization of a beam traverses a closed loop on the sphere, the final state differs from the initial state by a phase factor equal to half of the area encompassed by the loop upon the sphere. It is called Pancharatnam phase.

In addition, there are some more eponymous terms which are named after or in the honour of great mathematicians, for example, Ramanujan-Soldner constant (in honour of Ramanujan), Kapoor-Peierls Matrix theory (after PL Kapoor), the String Equation of Narasimha (after Roddam Narasimha), Parthasarathy Dirac Operators (after Rajagopalan Parthasarathy), Chowla-Selberg Formula/ Chowla-Mordell Theorem/ Mian-Chowla Sequence (after Sarvadaman Chowla).

There are some patterns that we can see in these eponymous trends. Most of these scientists and researchers who had eponymous terms worked in the pre-independence era, and most of them were in the field of Physics, Mathematics and Chemistry. Mostly the terms related to scientific phenomena, calculations or equations, areas where the researchers used their sharp intellects to leave their indelible stamps on the international science scenario. There were hardly any big experiments with costly resources that they conducted in their careers. In short, these Indian scientists proved their mettle at the global arena, in hard times, under foreign rule and while living in a slave country. In comparison, we do not have many Indian eponymous terms to show during post-independence era. How can this anomaly be explained?

PS: Readers, I am sure that in my academic journey, I have not come across all the eponymous terms related to Indian scientists. Through Science India, *we request all readers to send us any such eponymous terms that you might have come across, so that we can create an exhaustive list of all such scientific terms named after Indian researchers and scientists (editor@scienceindia.in).*

**The author teaches at Panjab University, Chandigarh.*

DRDO Bhawan, New Delhi

DRDO: Shoonya to Atmanirbharta and Beyond

India, the world's topmost importer of defence products till a few years ago, is on the path of becoming a top exporter, in a continued saga of self-reliance that traces its journey to baby steps taken soon after Independence

Image Courtesy: Wikimedia Commons

■ Ravi Kumar Gupta

We, the People of Bharat, globally the fifth largest economy and among the topmost military powers, living in the present time of Amrit Kaal are indeed fortunate. Today the nation has capacities, capabilities and resources including the most important resource — the young, hardworking, skilled and educated human beings. Our nation always had great potential, our capacities were deliberately destroyed by the colonial rulers, and the minds of most of the citizens were filled with a deep rooted sense of servitude during 1000 years of rule by foreign invaders.

Post-independence, rebuilding the nation from rubble and chaos left behind by the British colonial marauders was not an easy task. Capacities in the realms of science and technology were most difficult to rebuild, and it was more challenging in the realm of Defence Science Technology and Production. Thus, a beginning had to be made with a zero base in every aspect, be it knowledge, design expertise, R&D institutions, industry, infrastructure for testing and evaluation. Whatever little — ordnance factories, inspectorates, etc. were present with the Armed Forces / Defence Ministry — had been created by colonial rulers for their war efforts and were barely able to manufacture low-tech products under licence and supervision from parent companies abroad.

BIRTH OF DEFENCE SCIENCE ORGANISATION

At the time of Independence, our country had several brilliant scientists in various fields but none in the field of defence science. Prof Daulat Singh Kothari, an eminent physicist was handpicked by the then Prime Minister Jawaharlal Nehru to be the first Scientific Advisor to the Ministry of Defence and to set up Defence Science Organisation — DSO, a tiny organisation tasked with mainly an advisory role. Though decision to choose an academician teaching basic science (Physics) to lead a primarily engineering orientated organisation can be questionable, Prof Kothari proved himself to be a leader *par excellence* and from day one, he got down to business with his unique combination of devotion and zeal of a scientist and the insight of a great visionary architect, within the limits of his mandate and a legacy system of governance.

Perhaps, the worst impediments were a political leadership apparently still believing in supremacy of Britishers and a colonial era bureaucracy and bureaucratic tools that had been excellently designed to perpetuate slavery and servitude.

Low priority for self-reliance is reflected also in denial of Secretary rank to the Scientific Advisor for 30 years whereas all heads of leading scientific organisations had held that rank from the very inception of the organisation. This grave injustice, severely adverse service conditions, meagre financial resources and bureaucratic hurdles affected the morale of scientists and prevented them from achieving full potential.

Despite severe constraints, including financial ones, the DSO rendered valuable assistance to the armed forces. Nevertheless, a beginning had been made but the nation had lost a decade-long opportunity of building self-reliance. However, this decade was also a valuable learning phase for the DSO fraternity. Their knowledge in many fields of interest of defence science got enlarged and their skills got refined.

Under Prof Kothari's leadership, the DSO pursued a systematic, technology-oriented R&D approach by generating knowledge and technology-base for defence equipment. Success of this approach was evident in *ab initio* development during 1960s of Bharat's first Anti-Tank Guided Missile (ATGM) that was highly effective. More than 400 trials including ~100 by the user were held but finally import lobbies won, defeating efforts for self-reliance.

FROM DSO TO DRDO

Consequent to Prof Kothari's efforts and positive intervention by V Krishna Menon, the then Raksha Mantri, the

Image Courtesy: DRDO

Akash, a medium-range surface-to-air missile system, is developed by DRDO

Defence Research and Development Organisation (DRDO) was formed on 1st January 1958.

However, yet another mega blunder was made during the formation of DRDO and its 10 laboratories by merging a large number of defence units, which were not performing any R&D activities with the DSO. The assigned charter mandated DRDO to according highest priority (consequentially resources too) to the requirements specifically projected by the Armed Forces. The forces were largely interested in indigenizing existing imported equipment rather than seeking indigenously designed and developed equipment; not realising that developing components that exactly performed (no less, not more) like the component it sought to replace was far more difficult task than designing complete equipment (that would be even superior to previously held imported equipment). In spite of handicaps, DRDO continued its journey in pursuit of self-reliance making valuable contributions towards nation building. Many products were indigenously developed, some of them inducted by forces like 105 mm Indian Field Gun. DRDO also made a unique contribution to Bharat's first nuclear explosion — Pokhran I, in 1974 (as also later in Pokhran II in 1998).

The creation of the Department of Defence R&D (DDR&D) in 1978 with Dr Raja Ramanna, the then special advisor to Raksha Mantri as Secretary, was a major milestone. Till then, DRDO had been functioning under the department of Defence Production. Relatively more empowered, Dr Ramanna in his short tenure of five years initiated sweeping reforms in every domain and put the organisation on a fast track. His vision led to creation of Defence Research and Development Service (DRDS) and also the appointment of DRDO's first head (Dr VS Arunachalam) from within the organisation. With this began the era of initiation of mega R&D programmes of unprecedented scale such as Integrated Guided Missiles Development Program (IGMDP), Light Combat Aircraft LCA and more, as well as unique programme management framework capable of handling mega programmes.

Image Courtesy: Wikimedia Commons

DRDO made a unique contribution to India's first nuclear test, Pokhran I, on 18 May 1974. Then Prime Minister Indira Gandhi at the test site (above).

The organisation that made a humble beginning soon after independence in dilapidated colonial era barracks in the vicinity of South Block has over the time grown into strong well-knit network of about 50 laboratories and establishments each headed by an experienced scientist as its director, with each lab focusing on a group of specific, closely related areas of science and technology. The DRDO headquarters, now located in a magnificent green complex at Rajaji Marg in the national capital, functions as a hub for apex level planning and management of the nation's defence R&D efforts. DRDO is presently a family of about 20,000 strong workforce that includes about 7000 DRDS (Defence Research and Development Service) scientists and over 8000 Defence Research Technical Cadre (DRTC), each contributing to making DRDO the main driving force behind building Atmanirbharta in defence.

> ***Dr Raja Ramanna in his short tenure of five years initiated sweeping reforms in every domain and put the organisation on a fast track***

DRDO is part of the Department of Defence R&D under the Ministry of Defence. Besides DRDO, the department has under its umbrella several other Strategic Science organizations each focusing on a highly specialised area of defence R&D. Aeronautical Development Agency (ADA), for example, has its focus on indigenous development of Combat Aircrafts such as Tejas and its variants, AMCA and unmanned combat aircrafts. Secretary Department of Defence R&D is also the Chairman DRDO.

DRDO has been working with a mission to design, develop and lead to production state-of-the-art sensors, weapon systems, platforms and allied equipment for our country's defence services; to provide technological solutions to the services for optimising their combat effectiveness; to promote well-being of troops; to develop infrastructure and quality manpower and to build strong indigenous technology base. The cumulative production value of DRDO developed systems approved under the capital head of expenditure alone stands at over 4,00,000 crore; the cost of acquisition of similar systems if imported would have been many times more. The figure does not include Strategic Systems like Agni and similar series of ballistic missiles, nor does it include the value of products procured by the services under the revenue head of expenditure from our country's own industries. The real output of DRDO's efforts towards nation building will come out to be many times more than all these added together if its contributions towards growth of R&D, industrial ecosystem and impact on employment generation are also accounted for.

Images Courtesy: Wikimedia Commons

The spectrum of DRDO developed products covers combat aircrafts (above), air defence tactical control radar (left), missile systems such as BrahMos (below), anti-satellite weapon system, field guns, combat vehicles, and so much more

THE WORKS AT DRDO

The spectrum of DRDO developed products covers Combat Aircrafts, Nuclear Powered Submarines such as Arihant, Strategic and Tactical Missiles such as Agni series, K15, Astra, Akash, Ballistic Missile Defence systems, Anti-Satellite weapon system (ASAT) Armoured Combat Vehicles, Field Guns, Mobility Systems such as Bridging Systems, Sensors such as Radars for the three services, Sonars for Battleships and Submarines, Torpedoes and anti-ship mines, Electro optical sensors, laser based instruments and sensors, Electronic Warfare systems, specialised circuits and Systems on Chip (SoC), Secure Communication Systems, Robotics and Artificial Intelligence, Cyber Defence Systems, Directed Energy Weapons (DEWs) and a wide range of Soldier Support Systems and Services including products and services for defence against Chemical Biological Radiation and Nuclear warfare.

The R&D activities of the DRDO cover nearly all the Science, Technology and Engineering subjects as well as Psychology as it has been mandated to cater to the complete spectrum of needs of our Armed Forces, including requirements of soldiers as human beings.

The DRDO laboratories, primary thrust generators behind drives for Atmanirbharta in defence, are grouped into seven technology clusters, each headed by a Director General. These are: Aeronautical Systems (Aero), Armament & Combat Engineering Systems (ACE), Computational Systems & Cyber

Systems (MED & CoS), Electronics and Communication Systems (ECS), Life Sciences (LS), Micro Electronic Devices, Missiles and Strategic Systems (MSS) and the Naval Systems and Materials (NS & M).

Academic institutions and industry have been key partners during DRDO's journey since inception, going well beyond their role of being quality human resource providers and engagements for carrying out basic science research. In many cases, deeper collaborations with academia were instrumental in the development of niche technologies that were denied to our nation. DRDO is working with more than 250 academic institutes on different defence R&D problems for basic, applied and targeted research. Presently, fifteen DRDO-Industry-Academia Centres of Excellence (DIA-CoE) exist for sustained collaborative R&D.

TOWARDS ATMANIRBHARTA

Defence industrial base in our country, as stated earlier, was nearly non-existent. Defence Public Sector Understandings functioning under the Department of Defence Production were engaged mainly in licensed manufacturing of imported products. Involvement of private sector industries as a matter of government policy in production of finished defence products/ complete systems was permitted since 2001 only. Until then, it remained the exclusive domain of defence public sector undertakings (DPSUs) and Ordnance Factories. Prolonged interactions of industries with DRDO for making DRDO developed components and subsystems as well as for key fabrication and testing equipment that were not available in the country and were denied by foreign suppliers led to significant expansion of our country's industrial base in both quantitative and qualitative terms. Numbers of such industries run into thousands and include private sector large industries, MSMEs as well as DPSUs and Ordnance Factories, and has been growing rapidly. Thus, each new product developed by

Images Courtesy: Internet

Above, left: Prof Daulat Singh Kothari was handpicked by then Prime Minister Jawaharlal Nehru to set up Defence Science Organisation (DSO); Above, right: Dr VS Arunachalam was the first DRDO head from within the organisation

DRDO when inducted by the Services has a multiplying effect on employment generation in the manufacturing partner industries.

In tune with its Atmanirbhar Bharat initiative, the present government has launched several game changer schemes that are also going to assist in fulfilling the aim of turning Bharat, till a few years back the world's topmost importer of defence products, into a major exporter of such products. Another game changer impact of such schemes is going to be the percolation of Defence R&D culture to our country's academia and industries on an unprecedented scale. TDF (Technology Development Fund) is one such scheme being implemented through DRDO that encourages our own MSMEs and start-ups to take up defence R&D projects aimed at fulfilling specific needs of the Ministry of Defence.

To further encourage the Indian industry, most of DRDO's patents and relevant intellectual publications are available for the domestic industry free of cost. Indian industry is utilising DRDO test facilities and proof & field firing ranges for ensuring quality defence products.

Innovations are key to development of cutting edge defence technologies. With a vision to promote innovations in defence technologies, DRDO has been launching Dare to Dream Contest every year since 2019. Aim has been to bring together innovators, entrepreneurs, individuals above 18 years and start-ups (recognised by DPIIT and with Indian founders) for innovative ideas in the field of Defence. The selected individuals/companies of Dare to Dream Contest are getting benefitted as DRDO supports them to realise awarded ideas into Prototype through TDF scheme.

According to a recent MoD press release, under the past three Dare to Dream contests, a total of 52 individuals and 34 start-ups have been awarded out of 5,637 applications received. A total of 07 projects had been sanctioned and awarded to start-ups of Dare to Dream contest winners.

Thus, DRDO has been driving innovations in the field of defence technologies. There has been a distinct and visible shift during the past several years in government policies whereby imports of defence products are being minimised, thus allowing indigenous systems to get inducted. Launching schemes promoting Atmanirbharta in the defence sector is leading to rapid growth of our own defence industries. Implications for our nation's youth are opening up of unprecedented opportunities for employment and career growth even as our country moves ahead with greater pace on the path of regaining its glory and immense prosperity.

**The writer is Former Scientist G & Director Public Interface, DRDO, Ministry of Defence, New Delhi. He has authored 'Institutions That Shaped Modern India – DRDO'.*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AUGUST 2021 VOL 19 ISSUE 65
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Image Courtesy: Tata Group

Jamsetji Tata: The Philanthropic Industrialist and His Legacy

The Tata group took the lead and buttressed the newly independent India's government in its efforts to set up scientific and research institutions in the country, the fruits of which are being enjoyed by its citizens today

■ Shivaprasad Khened

The genesis of the contributions of the Tatas in establishing scientific and research institutions in independent India takes us back to the founding father of the Tata Group, Jamsetji Nusserwanji Tata. 'What advances a nation or community is not so much to prop up its weakest and the most helpless, as to lift the best and most gifted, so as to make them of the greatest service to the country.' This thought, chronicled by his biographer, Frank Harris in his book, *Jamsetji Nusserwanji Tata: A Chronicle of his Life*, was central to the establishment of the Indian Institute of Science (IISc), a forerunner that paved the way for the establishment of many other such institutions.

IISc was the first scientific and research institution established by the Tatas in 1909. However, by then the Indian Association for the Cultivation of Sciences (IACS), was already founded by a genius medical doctor and social reformer, Mahendra Lal Sirkar in Calcutta (now Kolkata) in 1876. But unfortunately, IACS was not supported by the government and it had to rely on public contributions. It could not succeed during the lifetime of its founder and had to wait until the arrival of CV Raman to Calcutta to transform it into a world-class institute.

IISc was one of those three monumental projects of a veritably colossal character that Jamsetji dreamt of — Tata Steel, Tata Hydroelectric Power, and Indian Institute of Science — which proved to be a robust foundation for building, what Nehru termed, 'temples of modern India'. Beginning with the IISc, the Tatas have established other institutions — Tata Institute of Fundamental Research (TIFR), Tata Institute of Social Science (TISS), National Centre for Performing Arts (NCPA), Tata Memorial Hospital, National Institute of Advanced Studies, Computer Research Laboratory — that have served as a catalyst for the establishment of canonical institutions like the Bhabha Atomic Research Centre (BARC), Department of Atomic Energy (DAE), and Indian Space Research Organisation (ISRO).

CHANCE INTERACTION BETWEEN TWO CO-PASSENGERS

Legend has it that the seed for establishing a world-class science and research institution in India was sowed in the mind of Jamsetji Tata during a historic voyage of 1893, aboard the ocean liner *SS Empress of India*, on which two men destined to shape the future of India, were travelling. The other was Swami Vivekananda.

In his letter to Swami Vivekananda, dated 23 November 1898, Jamsetji recalls the discussion between the two that sparked an interest in his mind to build IISc. The letter reads, 'I trust you remember me as a fellow traveller on your voyage from Japan to Chicago. I very much recall at this moment your views on the growth of the ascetic spirit in India, and the duty, not of destroying, but of diverting it into useful channels. I recall these ideas in connection with my scheme of a Research Institute of Science for India, of which you have doubtless heard or read. It seems to me that no better use can be made of the ascetic spirit than the establishment of monasteries or residential halls for men dominated by this spirit, where they should live with ordinary decency, and devote their lives to the cultivation of sciences — natural and humanistic.' A long period of trials and tribulations was to elapse between the initial conception of the institution — perhaps on that 1893 voyage — to the birth of Indian Institute of Science in 1909.

TRIALS AND TRIBULATIONS IN BUILDING IISC

Jamsetji travelled the world to learn the best of science and technological practices for implementation in India. He chose one of his trusted aides, Burjorji Padshah, to pursue a study of the best scientific research institutions in the West and to submit a report for establishment of such an institute in India.

Padshah submitted a draft report to Jamsetji by highlighting that '...such a university might be the crown of the existing universities.' Jamsetji and Padshah met the newly appointed viceroy-designate Lord Curzon and submitted their report on December 31, 1898. Lord Curzon was in no hurry to act on the

An early image of the Indian Institute of Science, Bangalore

All images courtesy: IISc Archives

Jamsetji Tata (sitting, right) and his wife Hirabai (sitting, centre) with their sons and their wives — younger son Ratanji (sitting, left), his wife Navajbai (standing, left), elder son Dorabji (standing), his wife Meherbai (standing, right)

proposal, and he advised them to invite a European scientist to make suggestions on the venture. The committee chose British chemist Sir William Ramsay — who would win Nobel Prize in Chemistry in 1904 — for this task.

Ramsay submitted a detailed report to the government in early 1901 about the university (he called it the Indian Institute of Research), which he believed should be in Bangalore.

Jamsetji knew that the government would take its own time on the project, so he proactively met the Dewan of Mysore State, Seshadri Iyer, for help in acquiring a suitable plot of land in Bangalore. Iyer was also the advisor to the Regent Queen Vani Vilasa Sannidhana, who ruled on behalf of her minor son Krishna Rajendra Wadiyar IV. An extraordinary decision was made by the Mysore king to donate 371 acres of land in Bangalore for the institute. He also provided an additional Rs 5 lakh towards building the institution. To this, Jamsetji provided his own financial support of Rs 30 lakhs.

Unfortunately, Jamsetji Tata passed away in May 1904, before the official order creating IISc was passed on 27 May 1909.

Much before the official order of 1909, Sir Dorabji Tata, Jamsetji's son, decided to construct the main building. One of the students of Ramsay, Dr Morris Travers, was chosen as the founder-director of IISc, who appointed CF Stevens, an architect from Bombay, to build it. The main building, finally completed in 1919, was crowned by an imposing 150-foot tower.

During the first quarter century of IISc's formative years, from 1909-33, the institute embarked upon several scientific and technical investigations, which paved the way for the establishment of certain industries. What has been most remarkable is the balance in the various domains of its activity: education, research, development, international outreach, and societal development. With the establishment of the University Grants Commission (UGC) in 1956, IISc came under its purview. IISc has helped produce many scientists and science and technology leaders in India.

Although IISc remains the *crème de la crème* of the institutions that the Tatas established, some other institutions need to be mentioned.

TATA INSTITUTE OF FUNDAMENTAL RESEARCH (TIFR)

The idea of TIFR was seeded in the mind of its founder, Dr Homi Bhabha, while he was at IISc working with CV Raman. On 19 August 1943, Bhabha wrote to JRD Tata, the head of the Tata group, about his plan to establish a Fundamental Research Centre in Bombay, appealing for support. JRD Tata replied to Bhabha with great encouragement: 'If you and some of your colleagues in the scientific world will put up concrete proposals backed by a sound case, I think there is a very good chance that the Tata Trusts would respond.' Writing to the Dorabji Tata Trust (12 March 1944), Bhabha highlighted: 'Such an institute would ensure that India had its own expertise for the development of nuclear energy in the future, and would not have to look abroad for it'.

TIFR opened its doors in 1945, initially in Bangalore, but later shifted to Bombay; its first Bombay home was 'Kenilworth', the bungalow where Bhabha was born.

The first Indian-made digital computer, the TIFRAC, was commissioned at TIFR in 1960. When India began its atomic energy programme in the 1960s, TIFR had already trained scientists to steer this important national effort. In fact, 'Apsara', the first atomic reactor, built at BARC, and its control systems were made under TIFR's guidance.

Realising the importance of the institute in nation building, the Government of India decided to take responsibility for this institution in 1955, with the Tatas continuing to be present on its governing council.

TATA MEMORIAL CENTRE: THE FIGHT AGAINST CANCER

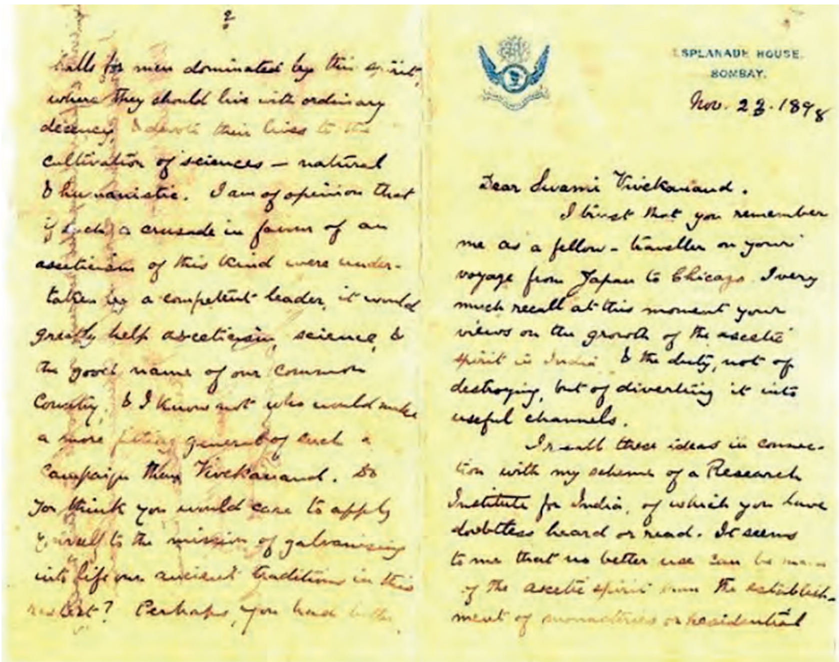
Tata Memorial Centre (TMC) is one of the institutes established by the Tatas that has touched the lives of millions in their fight against cancer. It was established as a tribute to Sir Dorabji Tata, whose dream was to establish a cancer hospital in India in memory of his wife, Lady Meherbai Tata, who had died of leukemia in 1932. Shortly thereafter, Sir Dorabji Tata also passed away. But such was his determination and commitment to the cause that the Tata group headed by Sir Nowroji Saklatvala and the trustees of the Sir Dorabji Tata Trust attached top priority to the project. They invited an American expert, Dr John Spies, to visit India and recommend the best-suited cancer research hospital for the country. The result was the establishment of the Tata Memorial Centre in 1941.

TATA INSTITUTE OF SOCIAL SCIENCES

Social science was another subject that was very close to the heart of Jamsetji Tata. Therefore, it was natural for the Tata group to support the establishment of a Dorabji Tata Graduate School of Social Work, which came up in 1936. In 1944, it was renamed as the Tata Institute of Social Sciences (TISS), a premier institution in the country for professional training in social work. Ever since, TISS has emerged as a pioneer of social work education in the Asia Pacific region, making significant contributions in the area of social policy, planning, intervention strategies, and human resource development.

EKA – TATA'S FORAY INTO INDIA'S FIRST SUPER COMPUTER

Tatas are known for taking up challenges to develop the best for the country and one such opportunity, which the Tata Consultancy Services (TCS) accepted was to build a Supercomputer for India. The result was the development of the EKA Supercomputer, which became the fourth fastest supercomputer in the world. A proposal to build this Super Computer in India was mooted by two IITians, Sherwalkar and Karmakar who presented their idea to S Ramadorai, the chief of TCS. The idea, which was capital intensive, was approved by Ratan Tata, and the project came through.



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halls for men dominated by this spirit where they should live with ordinary decency & devote their lives to the cultivation of sciences — natural & humanistic. I am of opinion that if such a crusade in favour of an asceticism of this kind were undertaken by a competent leader, it would greatly help asceticism, science & the good name of our common country; & I know not who would make a more fitting general of such a campaign than Vivekanand. Do you think you would care to apply yourself to the mission of galvanising into life our ancient traditions in this respect? Perhaps, you had better

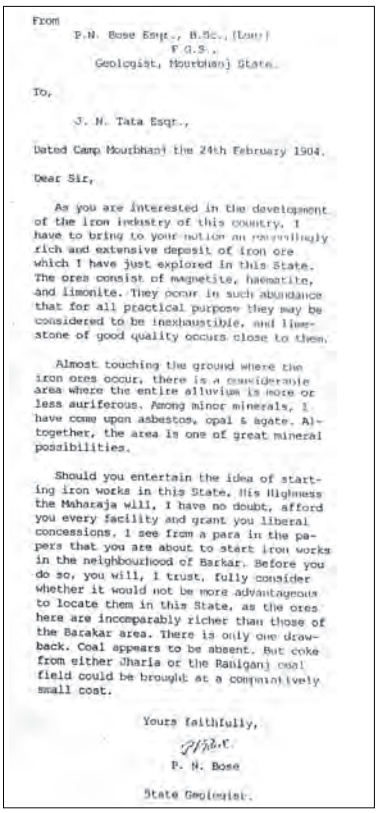
Esplanade House,
Bombay.
Nov. 23. 1898

Dear Swami Vivekanand.

I trust that you remember me as a fellow-traveller on your voyage from Japan to Chicago. I very much recall at this moment your views on the growth of the ascetic spirit in India & the duty, not of destroying, but of diverting it into useful channels.

I recall these ideas in connection with my scheme of a Research Institute for India, of which you have doubtless heard or read. It seems to me that no better use can be made of the ascetic spirit than the establishment of monasteries or residential

Above: The historic letter by Jamsetji Tata to Swami Vivekananda; Below: PN Bose's letter to Jamsetji Tata that eventually led to the setting up of Tata Steel in Jamsdhedpur



From
P.N. Bose Esqr., B.Sc., (Lon.)
F.G.S.,
Geologist, Mourbhanj State.

To,
J. N. Tata Esqr.,

Dated Camp Mourbhanj the 24th February 1904.

Dear Sir,

As you are interested in the development of the iron industry of this country, I have to bring to your notice an exceedingly rich and extensive deposit of iron ore which I have just explored in this State. The ores consist of magnetite, haematite, and limonite. They occur in such abundance that for all practical purpose they may be considered to be inexhaustible, and limestone of good quality occurs close to them.

Almost touching the ground where the iron ores occur, there is a considerable area where the entire alluvium is more or less auriferous. Among minor minerals, I have come upon asbestos, opal & agate. Altogether, the area is one of great mineral possibilities.

Should you entertain the idea of starting iron works in this State, His Highness the Maharaja will, I have no doubt, afford you every facility and grant you liberal concessions. I see from a para in the papers that you are about to start iron works in the neighbourhood of Barkar. Before you do so, you will, I trust, fully consider whether it would not be more advantageous to locate them in this State, as the ores here are incomparably richer than those of the Barakar area. There is only one drawback. Coal appears to be absent. But coke from either Jharia or the Raniganj coal field could be brought at a comparatively small cost.

Yours faithfully,
P. N. Bose
State Geologist.

The legacy of the Tata family in building institutions in India is a remarkable testament to their commitment to social welfare, education and industrial progress. Over the years, the Tatas have played a pivotal role in establishing a range of institutions that have had a profound impact on various sectors of Indian society. Their visionary approach and philanthropic endeavours have left an indelible mark on the country's development.

— The writer is advisor, Chhatrapati Shivaji Maharaj Vastu Sangrahalaya, Mumbai; former director, Nehru Science Centre, Mumbai, National Science Centre, Delhi and Visvesvaraya Industrial and Technological Museum, Bangalore; former director, National Gallery of Modern Art, Mumbai and NGMA Bangalore; member, Society, National Council of Science Museums, Ministry of Culture, Government of India. He is also a trustee of Gandhi Smarak, Nidhi, Mani Bhavan, Mumbai.

Present day entrance to the factory of Bengal Chemicals, founded by Acharya Prafulla Chandra Ray in 1892 in Calcutta

Image Courtesy: Wikimedia Commons

Emergence of Chemical Labs and Industries in Independent India

The British colonial rule severely compromised Indian industries, including its hitherto robust chemical industry, which had to begin from scratch post-Independence; but it has done an admirable job of catching up with the rest of the world since then

■ Prof Rajeev Singh

Chemistry is said to be one of the foundation pillars of a country's industrial and agricultural development. The role of chemical industries and research labs is recognised as a key factor of the economic growth of a country. The history of India's chemical industry is a tale of resilience, innovation, and transformation. In the years following its Independence from British colonial rule in 1947, India embarked on a remarkable journey to develop its chemical labs and industries. The post-Independence era in India witnessed a remarkable transformation in various sectors, with science and technology playing a pivotal role in the nation's development. One of the most significant strides was the emergence of chemical labs and industries, which not only propelled India's economic growth but also contributed to its self-reliance in critical areas. To achieve this, the Indian government recognised the pivotal role of industrialisation, particularly in sectors like chemicals. The establishment of chemical industries in post-Independence Bharat played a significant role in shaping the nation's economic landscape, reducing dependence on imports, and contributing to its overall development. In this article, we will delve into the journey of establishing chemical industries in post-Independence Bharat, highlighting their importance, challenges faced, and their impact on the nation's growth.

HISTORICAL CONTEXT

Before delving into the post-Independence developments, it is essential to understand the historical context. India's chemical industry had a rich heritage dating back to ancient times when it produced dyes, perfumes, and other chemical products. However, during British colonial rule, the focus shifted towards raw material extraction and export, leaving Bharat largely dependent on imported chemicals and technologies. This period marked a stark contrast to Bharat's historical contributions to chemistry and the chemical development techniques.

The establishment of Bengal Chemicals in Calcutta by Acharya Prafulla Chandra Ray in 1892 marked a significant milestone in the history of Bharat's chemical industry. Dr PC Ray's pioneering efforts not only laid the foundation for indigenous chemical manufacturing but also had a profound impact on the development of the chemical industry in India. This was a bold and visionary move at a time when Bharat was primarily a consumer of imported chemicals. The industry helped achieve multiple objectives like production of chemicals indigenously, promotion of chemical education by establishing the first in-house R&D facility (unknown in industries at that time) and establishing a legacy of self-reliance by building confidence in young generation.

Today, Bharat stands as a global player in the chemical sector, owing much of its success to the vision and determination of individuals like Dr PC Ray, who dared to dream of a self-reliant and scientifically advanced Bharat.

POST-INDEPENDENCE INITIATIVES

The period following Bharat's independence in 1947 was marked by a wave of optimism and a strong desire to transform the nation into a self-reliant and technologically advanced society. The immediate years saw the Indian government's renewed emphasis on building a self-reliant industrial base. This vision was encapsulated in the Industrial Policy Resolution of 1948, which recognised the importance of chemical industries in achieving self-sufficiency and overall economic growth. Several key initiatives were undertaken to lay the foundation for the growth of chemical labs and industries like the establishment of research laboratories, promotion of entrepreneurship, foreign collaborations and development of chemical parks.

SETTING UP OF RESEARCH LABORATORIES

To achieve the goals, the Indian government recognised the critical importance of scientific research and innovation. A crucial step in fostering indigenous research and development in chemistry was the establishment of various research laboratories across the country. These institutions played a pivotal role in fostering indigenous research and development, spurring innovation, and contributing to Bharat's growth in various sectors. The National Chemical Laboratory (NCL) in Pune, founded in

Image Courtesy: Wikimedia Commos

The National Chemical Laboratory (NCL), Pune, was founded in 1950

The Central Salt and Marine Chemicals Research Institute was founded in Bhavnagar, Gujarat, in 1954

1950, emerged as a prominent institution dedicated to advancing chemical science and technology. Other notable establishments included the Central Salt and Marine Chemicals Research Institute (CSMCRI) in Bhavnagar, founded in 1954. These laboratories played a pivotal role in nurturing innovation and developing novel processes.

The establishment of research laboratories in post-Independence Bharat was a strategic response to several pressing needs and challenges and assumed significance in completing the challenges faced by a new independent nation. On the one hand, where the developed world of Europe was achieving heights, Bharat faced the first challenge of catching up with the rapid scientific and technological advancements occurring globally. Research laboratories were seen as the engines of scientific progress, capable of conducting cutting-edge research and contributing to the global body of knowledge. Achieving self-reliance was considered a fundamental goal. Research laboratories like NPL, NCL were envisioned as hubs for developing indigenous technologies, reducing dependence on foreign imports, and fostering economic growth. These institutions were also tasked with human capital development by building the crucial skilled workforce. They not only promoted scientific research but also provided training and education opportunities for scientists, engineers, and technicians. Bharat at Independence was facing numerous challenges in agriculture, healthcare, energy, and other sectors and these research laboratories became the problem solvers as they were tasked to address these national challenges by conducting applied research and finding practical solutions in sectors like agricultural productivity, healthcare, renewable energy, and environmental conservation, leading to tangible improvements in these sectors.

Several of these research laboratories of post-Independence Bharat have earned international acclaim for their contributions. Some of the most prominent ones include Council of Scientific and Industrial Research (CSIR) with its network of laboratories that has made significant contributions in various scientific and industrial domains, including pharmaceuticals, materials science, and biotechnology, and the Indian Council of Agricultural Research (ICAR) and its research centres that have revolutionised agriculture by developing high-yielding crop varieties and innovative farming practices.

The establishment of research laboratories in post-Independence Bharat was a visionary step that has paid rich dividends over the decades. These institutions have contributed to scientific advancements, technological innovations, human capital development, and solving national challenges. They have not only played a critical role in Bharat's journey towards self-reliance but have also elevated the nation's status on the global scientific stage. As Bharat continues to evolve as a knowledge-driven society, research laboratories will remain indispensable in driving progress, fostering innovation, and shaping the nation's future.

SIGNIFICANCE OF CHEMICAL INDUSTRIES

Chemical industries are the backbone of modern economies, providing essential raw materials for various sectors such as agriculture, pharmaceuticals, textiles, and manufacturing. In post-Independence Bharat, chemical industries were seen as crucial for several reasons like helping promote economic growth by supporting self-reliance. Chemical industries contribute significantly to a nation's Gross Domestic Product (GDP) by generating revenue, providing employment opportunities, and fostering innovation. Reducing dependency on imported chemicals and achieving self-sufficiency was a key goal and the pivotal role of chemical industry in ensuring Bharat's autonomy in critical sectors. Indian chemical industries started producing a wide range of products, including fertilizers, pesticides, pharmaceuticals, petrochemicals, specialty chemicals and crop protection chemicals. This diversification became essential for meeting the needs of a growing population.

CHALLENGES FACED

The establishment of research labs and chemical industries in post-Independence Bharat was not without its challenges. The biggest challenge being the technological gaps — trying to bridge the vast technological gap with developed countries was a significant hurdle. The British colonial rule had sucked India completely of its wealth and natural resource treasure by the time they left, so newly established Bharat's institutions and industries had to invest heavily in research and development to catch up and innovate in various chemical domains. Another major limitation being the infrastructure constraints, which the industry faced including inadequate transportation networks and power supply, which hampered growth and operational efficiency.

International agencies and groups from developed countries had made a very unique stealth mechanism of limiting the growth of industrial development in upcoming and newly independent nations. These new nations were indeed in need of industrial growth, but they were restricted by putting up of Environmental and Safety Concerns. Indian chemical industries often faced criticism for environmental pollution and safety hazards. This led to the introduction of stricter regulations and the need for sustainable practices, which required substantial investments and compliance efforts from companies. Scarce resources, including raw materials and skilled labour, posed challenges to the industry's growth. Strategies had to be devised to maximise resource utilisation and train a skilled workforce.

IMPACT ON POST-INDEPENDENCE BHARAT

Over the decades, the chemical industry in Bharat has grown exponentially, making significant contributions to the nation's economy. The chemical industry has become one of the leading sectors contributing to Bharat's GDP, providing employment opportunities and generating revenue. Bharat has achieved self-sufficiency in the production of various critical chemicals, reducing its dependence on imports. This strategic shift had implications not only for economic stability but also for national security. Indian chemical companies diversified their product offerings, producing a wide range of chemicals, including pharmaceuticals, agrochemicals, and specialty chemicals. Bharat began exporting chemicals to various countries, contributing to its foreign exchange earnings. Several chemical companies expanded their presence globally, becoming competitive players in the international market. The growth of chemical labs and industries led to significant scientific advancements in Bharat. Researchers in these institutions made groundbreaking discoveries and contributed to the global body of scientific knowledge. The chemical industries demonstrated remarkable innovation by developing cost-effective and sustainable processes for chemical production. These innovations had ripple effects across various industries, promoting efficiency and resource conservation.

Images Courtesy: Wikimedia Commons

Far left: A 1943 advertisement of Eau De Cologne, manufactured by Bengal Chemicals

Left: Samples of some early products manufactured at Bengal Chemicals

CONCLUSION

The emergence of chemical laboratories and industries in post-Independent Bharat represents a testament to the nation's resilience, determination, and commitment to self-reliance. Through strategic policies, substantial investments in research and development, and collaborative efforts, Bharat's chemical sector has transformed into a vibrant and competitive industry. Its contributions to economic growth, self-sufficiency, and scientific advancement are undeniable, and its role in Bharat's ongoing development story remains pivotal.

As Bharat continues to evolve as a global player in the chemical industry, it must address new challenges related to sustainability, environmental stewardship, and global competition. The lessons learned from its post-Independence journey can serve as valuable guides for navigating these complex issues while furthering the sector's growth and contributions to Bharat's prosperity. The story of chemical labs and industries in post-independent Bharat is one of resilience, adaptability, and continuous progress, reflecting the nation's unwavering commitment to a brighter, self-reliant future.

**The writer is Professor of Chemistry, ARSD College, University of Delhi.*

Image Courtesy: IACS

IACS: The Pioneer of Fundamental Research in Science

Dr Mahendra Lal Sircar ignited mass interest in science with his Indian Association for the Cultivation of Science founded in 1876, which continues to remain true to its original ideals to this day

■ Prof Tapas Chakraborty

'I have only now to reiterate my conviction that if our country is to advance at all, and take rank and share her responsibilities with the civilized nations of the world, it can only be by means of Science or positive knowledge of God's works...'

— Dr Mahendra Lal Sircar

These prophetic words were uttered by Dr Mahendra Lal Sircar — the founder of the Indian Association for the Cultivation of Science (IACS), who is regarded as the apostle of modern scientific research in the country in the nineteenth century — in his last lecture in the Annual Meeting of the Association in the year 1903. The IACS was established in 1876 to cultivate science by original research in all its departments solely by the natives of India to help improve the 'art and comfort of life'. It is amazing to witness that the same conviction and appreciation towards science were echoed more than half a century later in the first Scientific Policy Resolution (SPR) by the government of independent India in 1958:

'The dominating feature of the contemporary world is the intense cultivation of science on a large scale, and its application to meet a country's requirements. It is this, which, for the first time in man's history, has given to the common man in countries advanced in science, a standard of living and social and cultural amenities, which were once confined to a very small privileged minority of the population. Science has led to the growth and diffusion of culture to an extent never possible before. It has not only radically altered man's material environment, but, what is of still deeper significance, it has provided new tools of thought and has extended man's mental horizon. It has thus influenced even the basic values of life, and given to civilization a new vitality and a new dynamism.'

The government of India decided in 1958 that the aims of its Scientific Policy will be: 'to foster, promote, and sustain by all appropriate means, the cultivation of science, and scientific research in all its aspects — pure, applied, and educational...'

The idea to cultivate modern science by original research by Indians was championed by Sircar in the late 1860s. Born on November 2, 1833, in an age of religious revivalism, Sircar's appearance was like a torch bearer of Raja Rammohan Roy (1772-1833), the great social reformer and founder of Brahmo Samaj in India. Rammohan Roy is aptly regarded as the herald of scientific education in colonial India. It was Roy who first emphasised that Sciences, as practiced in the west, were the *Desiderata* for the country's material development. In a historic letter on December 11, 1823, to Lord William Amherst, the then Governor General of colonial India, he made an appeal to promote a more liberal and enlightened system of instruction embracing mathematics, natural philosophy, chemistry and astronomy with other useful sciences, opposing the idea of establishing the Sanskrit College.

Dr Mahendra Lal Sircar (1833-1904) was way ahead of his times. He established the Indian Association for the Cultivation of Science in 1876 to encourage original research in science by the natives of India

However, as is well known, the colonial government ignored the appeal and rather introduced Macaulay's Minute on Education in India starting from 1835, and there was no natural science in the educational curriculum. The institutes of science or scientific research that the colonial government did create in India —Asiatic Society (1784), Botanical Garden (1787), Agri-Horticulture Society (1820) and Calcutta Medical College (1835) — were to serve colonial interests, which barred native Indians on the pretext of incompetence. Roy's ideals took a more concrete shape nearly five decades later when Sircar became the pathfinder of the Indian national science movement.

Sircar was a medical doctor by profession. In the August 1869 issue of the *Calcutta Journal of Medicine*, a monthly periodical that he started a year ago to propagate his ideas, he wrote an article, titled, 'On the desirability of a National Institution for the Cultivation of the Physical Science by the Natives of India.' Around that time a new interest in science in the city was generated by the great Jesuit teacher Reverend Father Eugene Lafont, the teacher and mentor of the first complete scientist of India and an active nationalist scientist, Acharya Jagadish Chandra Bose.

By 1880, the laboratory of the association was equipped with a large assortment of instruments — thermotic,

The Calcutta Medical College, founded in 1835, was meant to serve colonial interests like other colonial institutions that barred native Indians

acoustic, electrical and optical. As recounted by Sir CV Raman much before he received the Nobel Prize, "I have always felt that the Association is my proper home. Dr Sircar has sown the seed, and it has fallen to my lot to reap the harvest."

The Association shouldered the responsibility of making the countrymen believe that through its activities, India would be able to regenerate in scientific, material and spiritual terms. While Swami Vivekananda emphasised on spirituality and moral character, Sircar's realm was intellectual and he preached for the cultivation of science and building scientific attitude.

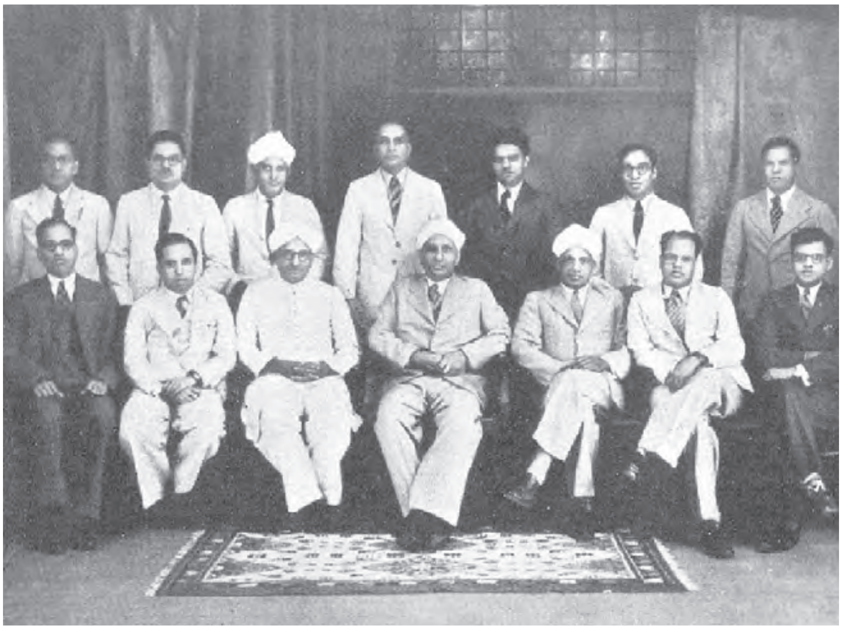
The original research activities, as envisioned at the inception, could not be started in the Association during the lifetime of its founder due to lack of funds. In every annual meeting he appealed to the countrymen to endow whole-time professors, but he was immensely disheartened as the response was poor.

By 1907, Raman had joined the association as an ordinary member and using available scientific facilities, and working on physical optics, he published a paper in *Nature*. Amritalal Sircar, the founder's successor, announced about the successful publication of Raman's paper and also mentioned that for his livelihood, he had been working in the finance department and what an amount of energy was being lost in doing so! He appealed to the countrymen that a lot could have been harvested from his intellect had the association provided him financial support. In the 31st annual meeting on 26 November 1908, Amritalal Sircar acknowledged the devotion of young Raman who wasted no time to utilise the scientific facilities for productive works. He said, we ought to wait and keep the sacred fire burning, and the country knows what Raman delivered in the next two decades.

A bust of Raja Ram Mohun Roy at his eponymous museum in Kolkata; the reformist was the earliest advocate of science education in India

An important object of the IACS, according to its 1870 prospectus, was to rescue from oblivion whatever was connected with India, ancient and modern, and to edit and publish the records. In 1879, Mahendra Lal Sircar had himself translated *Charaka Samhita*. He was delighted when the first volume of *A History of Hindu Chemistry*, by Acharya Prafulla Chandra Ray appeared in 1902.

During the first half of the 20th century, the scientific contributions made by IACS were synonymous to building the scientific base of the country. With respect to IACS, that period can be divided as the Raman-period and post-Raman period. Raman's stay at IACS for about thirty-five years is not only the most productive period of his own scientific career but also the dawn of a new era of vibrant scientific activities in the city of Calcutta. A galaxy of genius science enthusiasts from all over the country assembled at IACS, who in addition to making pioneering scientific contributions played a leading role in building scientific institutions across the country. Collective activities like scientific meetings to deliberate on original research conducted here covering all basic science subjects in multiple sessions were started as early as 1914, and for rapid dissemination of the scientific findings, publication of the *Proceedings of the Indian Association for the Cultivation of Science* was started in 1917. In fact, the first paper of the first issue of the first volume of the proceeding was contributed by Acharya Ray on his work on mercuric nitrite. Those publications



Right: Sir CV Raman (seated, centre) at the IACS in 1929 with other scientists; Below right: Prof KS Krishnan, co-discoverer of Raman Effect, became the first Mahendra Lal Sircar Research Professor at IACS

attracted the attention of the foreign societies, and in 1926, the publication transformed into the *Indian Journal of Physics*.

Raman left Calcutta to take the position of the director of the Indian Institute of Science in 1933, and Prof KS Krishnan, the co-discoverer of Raman Effect, took up the responsibility of IACS as the first Mahendra Lal Sircar (MLS) Research Professor. The seminal contribution of research led by Krishnan on crystal magnetism was recognised by the international community by offering him the Fellowship of the Royal Society of London in 1938. Krishnan left IACS in 1942 taking up the professorship of Allahabad University and MLS professorship was offered to Kedareswar Banerjee. Banerjee's research on crystallographic phase problem, which paved the way for direct methods in crystallography, attracted admiration of the international community. Prof Jerome Karle cited Banerjee's work in his Nobel lecture in 1985.

In the post-independence period, the research activities at IACS were reorganised in view of the realisation that scientific research has to be made an integral part of nation building. During this transition, Prof Meghnad Saha, who was a firm believer in the role of science in national development, and was an architect for the realisation of many institutions and initiatives, shouldered the responsibility of rebuilding IACS at a new campus and embarking on new areas of scientific research in the domains of basic and applied sciences. A review committee was set up under the chairmanship of the secretary of the Department of Scientific and Industrial Research, UK, Sir Harry Melville, and the committee recommended in 1959 that: 'The tradition of the Association is to continue, to undertake pure research. Therefore, the condition of work and an atmosphere must be developed to maintain this tradition.'

In the first decade of the 21st century, keeping in mind the opportunities created by economic liberalisation, the focus of STI (science, technology and innovation) policies was given on the conversion of knowledge into wealth, and to address the socio-economic problems through science and technology. During this period, there was a marked increase in R & D investment by the government, and policies were formulated to attract talents of Indian origin from across the globe, and to institute safeguards for intellectual properties.

The years 2010-20 were projected to be a decade for innovation to place India at the forefront of global competitiveness. It was aimed to instill a scientific temper amongst all sections of the society, developing trained S&T personnel hailing from all economic strata of life, use of S&T power for the inclusive growth, encouraging private sectors to join the S&T initiatives and through active PPP model, translating R&D knowledge into commercial products.

In this scenario of changing scientific landscape of the country, IACS has kept pace with changing times. From Raman's period till date, the research in the broader area of atomic and molecular sciences has remained the central attribute of the activities at IACS, and over many years, IACS has maintained its standard as one of the top research organisations of the country in the areas of basic sciences.

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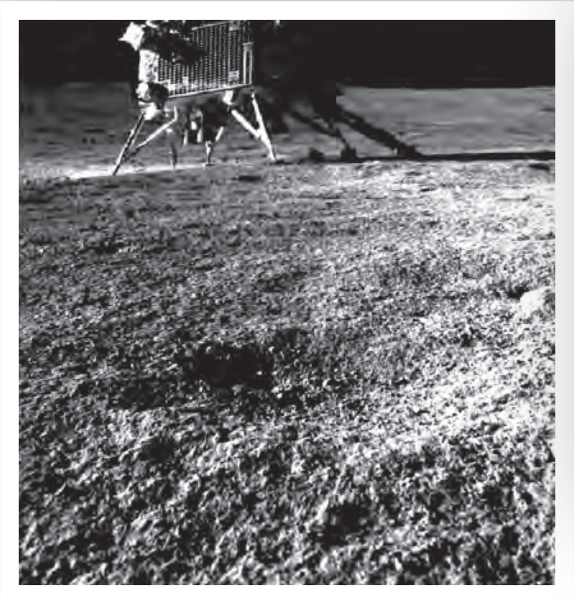
Picture Postcards from the Moon



On August 30, Chandrayaan-3 sent the first photo of Vikram lander (above) parked on the surface of the Moon, taken by the Pragyan rover. ISRO shared the pictures with the people of the country early in the morning. In the second picture, ISRO highlighted ChaSTE and ILSA payloads of Vikram, even as the historic lander stood on the Moon flying the country's flag high.

Images Courtesy: ISRO

Celebrating Science This Month

AUGUST 2
Acharya Prafulla Chandra Ray was born in 1861. Hailed as the Father of Modern Chemistry in India, Ray established the country's first pharmaceutical company, the Bengal Chemicals and Pharmaceuticals, in Calcutta in 1901.

AUGUST 3

The Indian Atomic Energy Commission was set up in 1948 under the late Department of Scientific Research. The Department of Atomic Energy (DAE) was set up in 1954.

AUGUST 7
Geneticist, M. S. Swaminathan was born in 1925 in Kumbakonam, Tamil Nadu. He is called the 'Father of Green Revolution in India' for pioneering the development of high-yielding varieties of wheat.

AUGUST 8
Indian biochemist, Yellapragada Subba Rao, passed away in 1948. He discovered the function of adenosine triphosphate (ATP) as an energy source in the cell, developed methotrexate for treating cancer and led the department at Lederle labs in which BM Duggar discovered chlortetracycline (Aureomycin).

AUGUST 9
The father of library science in India, S. R. Ranganathan, was born in 1892.

AUGUST 12
Since the year 2000, International Youth Day is being observed annually by the United Nations.

Indian physicist, Vikram Sarabhai, known as the Father of the Indian Space Programme, was born in 1919. After the launch of Sputnik, the world's first satellite, by then USSR in 1957, Sarabhai set up the Indian National Committee for Space Research (INCOSPAR) which later transformed into ISRO.

AUGUST 13
Sisir Kumar Mitra, an Indian physicist, known for establishing the first ionospheric field station at Haringhata and playing a pioneering role in radio broadcasting in India, passed away in 1963.

AUGUST 15
ISRO or Indian Space Research Organisation was formed in 1969.

BC Guha, 'Father of Modern Biochemistry in India', was born in 1894. He worked on the biochemistry of Vitamin C and B.

AUGUST 16
The Weather Woman of India, Anna Mani, physicist and meteorologist passed away in 2001.

AUGUST 20
Akshay Urja Day is observed annually in India to raise awareness about the development of renewable energy in the country.

World Mosquito Day is observed annually to commemorate British doctor Sir Ronald Ross's discovery in 1897 that female mosquitoes transmit malaria to humans. This won him Nobel Prize in 1902.

AUGUST 21
S Chandrasekhar, the Indian-American astrophysicist who was awarded the 1983 Nobel Prize in Physics with William A. Fowler for 'theoretical studies of the physical processes of importance to the structure and evolution of the stars', passed away in 1995.

Dr Brahm Prakash, first Director of Vikram Sarabhai Space Centre, was born in 1912. In 1951, he became the first Indian to head the Department of Metallurgy at IISc, Bangalore.

AUGUST 23
Anna Mani, Indian physicist and meteorologist, was born in 1918. She retired as the Deputy Director General of Indian Meteorological Department and served as a visiting professor at the Raman Research Institute.

AUGUST 26
Central Glass and Ceramic Research Institute (CGCRI) was established in Calcutta in 1950.

AUGUST 27
GSAT-6 was launched in 2015 by GSAT-D6. Its mission life is about nine years.

AUGUST 29
National Sports Day is celebrated every year to mark the birth anniversary of India's greatest hockey player ever, Major Dhyan Chand. Born in 1905 in Allahabad, Dhyan Chand was instrumental in India winning the gold medal at the 1928, 1932 and 1936 Olympics.

AUGUST 30
National Small Industry Day is observed annually.

GSAT-7 was launched in 2013 from Kourou, French Guiana by Ariane-5 VA-215 rocket.

Swami Kuvalayananda, a researcher and educator who is primarily known for his pioneering research into the scientific foundations of yoga, was born in 1883 in Gujarat. He published the first scientific journal dedicated to studying yoga, *Yoga Mimamsa*, in 1924.

AUGUST 31
Subbayya Sivasankaranarayana Pillai, an Indian mathematician specialising in number theory, passed away in 1950.

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