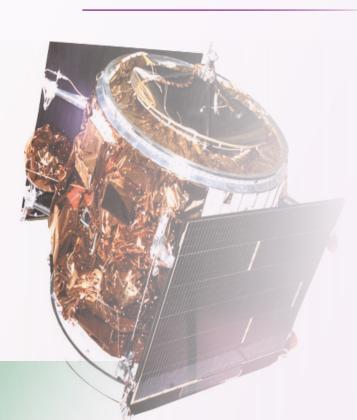




CONTENTS



Message from Union S&T Minister Dr Jitendra Singh



SPECIAL CONTRIBUTIONS

Some Leaders Who Helped Shape Science in India

And Who Left Us Recently

K. VijayRaghavan

9

Celebrating 75 Years of India's S&T Journey

Major Recent Contributions of DST

Ashutosh Sharma, Akhilesh Gupta & Jenice Jean Goveas

16

From Sounding Rocket to Launch Vehicles

Achievements of Department of Space

K. Sivan

24

Changing the Tide in Public Health Systems in 75 Years Role of ICMR

Balram Bhargava & Rajni Kant

32

75 Years of India's Independence and 80 Years of CSIR

Shekhar C. Mande, Geetha Vani Rayasam & G. Mahesh

38

Department of Atomic Energy

A Proud Symbol of AatmaNirbhar Bharat

K.N. Vyas & M. Ramanamurthi

45

Ministry of Earth Sciences

Contributing Towards a Weatherready & Climate-smart India

M. Rajeevan, Gopal Iyengar & Bhavya Khanna





G. Satheesh Reddy

57

Indian Agriculture

Journey from Begging Bowl to Sustainable Food Security

Trilochan Mohapatra & P.K. Rout

63

DBT

Building a Strong Biotechnology Research & Translation Ecosystem

Renu Swarup & A. Vamsi Krishna

70

Reforms & Action Points to Strengthen STI Ecosystem in India

Ashok A. Sonkusare, Seepana Mohit Rao & Neeraj Sinha

77





Science

DIRECTOR DR RANJANA AGGARWAL

EDITOR HASAN JAWAID KHAN

ASSISTANT FDITOR **SONALI NAGAR** MEHER WAN

LAYOUT & DESIGN **NEERU VIJAN** MANENDER SINGH

PRODUCTION **ASHWANI KUMAR BRAHMI** ARUN UNIYAL ANIL KUMAR

BUSINESS DEVELOPMENT DR MOHAMMAD RAIS



COVER DESIGN MANENDER SINGH

INDIA'S 75 YEARS S&T JOURNEY

EVERY time an Indian spacecraft soars into the skies or a long-range indigenous missile hits its target several kilometres away with pinpoint accuracy, our hearts fill with pride. India-made spacecraft and missiles have become symbols of the grand success of science and technology in a country that gained independence just about seven decades back. But, beyond spacecraft and missiles, there is much more to the success in science and technology that India has achieved despite battling several odds.

And so, it is with the intention of showcasing just a snapshot of the achievements of the Indian scientific community and scientific institutions during the past seven decades that this special issue is being brought out. The issue has been planned on the occasion of the initiation of the year-long programme by the Government of India - Azadi ka Amrit Mahotsav – to commemorate 75 years of India's Independence.

At the time of Independence, India inherited a shattered economy, no worthwhile infrastructure for the development of science and technology, no sound industrial base, abysmally low agricultural production and almost non-existent health services. Imported foodgrains fed the people. Famines were chronic. The country led a "ship to mouth" existence.

However, today as we initiate the celebrations of 75 years of the country's independence, we look back with pride at the innumerable occasions when India's scientists innovated, devised ingenious processes, and came up with practical solutions for the industry on one side of the spectrum and the country's rural and remote areas on the other end of the spectrum. Most of us have heard these success stories...these are stories that cannot be forgotten... these are stories that swell our chests with pride every time we hear them.

For instance, when multinationals tried to make us believe that powdered milk food could not be made from buffalo milk, Indian scientists came up with the technology of spray-drying fat-rich buffalo milk which could then be converted to powdered milk food. Similarly, when denied the services of a top-end supercomputer for research and meteorological purposes, India developed its own supercomputers that today compete with the global best at a fraction of the cost. The space story is not much different. Despite technology denials at various points of time, the Indian space programme has notched up enviable successes placing it among the top space programmes in the world.

This special issue of Science Reporter centred round the theme "75 Years of S&T in India - Retrospect and Prospects" is not an exhaustive account of the successes and achievements of the Indian scientific community and scientific institutions, but strives to provide a glimpse into some of the innumerable S&T developments in the country after independence.

We are indeed grateful to the Hon'ble Union Minister for S&T Dr Jitendra Singh for graciously agreeing to write a message for the special issue. We are also grateful to the Principal Scientific Adviser to the Government of India and nine science Secretaries to the Government of India - DST, DBT, Earth Sciences, Space, Health, DSIR, Atomic Energy, Defence, and Agriculture - for honouring our request and supporting our endeavour to come out with a publication to showcase India's S&T prowess.

Hasan Jawaid Khan

Science Reporter is published monthly by the National Institute of Science Communication and Policy Research (NIScPR), CSIR, Dr K S Krishnan Marg, New Delhi-110 012. NIScPR assumes no responsibility for statements and opinions advanced by the authors or for any claims made in the advertisements published in Science Reporter.

For Editorial Queries: Ph.: 91-011-25848702: Email: sr@niscair.res.in: Fax: 91-011-25847062

For Sales & Subscription Related Queries: Ph.: 91-011-25841647, 25846301 Extn. 289; Email: sales@niscair.res.in; rs@niscair.res.in

For Advertisement Related Queries: Ph.: 91-011-25843359,291; Email: sales@niscair.res.in; Website: http://www.niscair.res.in

Subscription: Inland: 1 yr: Rs 300/-; 2 yrs: Rs 570/-; 3 yrs: Rs 810/-Foreign: 1 yr (Air Mail): US \$ 90 (Annual)

© National Institute of Science Communication and Policy Research (NIScPR)

MESSAGE



Dr Jitendra Singh

Minister of State (Independent Charge) Science & Technology

Minister of State (Independent Charge) Earth Sciences

Minister of State PMO, Personnel, Public Grievances, Pensions, Atomic Energy and Space

INDIA has had an ancient scientific legacy spanning fields such as astronomy, medicine, surgery, mathematics, metallurgy — some of it documented, much of it undocumented. After years of being under foreign rule, it was this embedded scientific spirit and technological acumen of India's scientists, technologists, science administrators and policymakers that helped the country catapult itself to becoming a world scientific power to reckon with so soon after it gained independence in 1947.

Today, as we enter into the 75th year of India's Independence, it is appropriate that we appreciate, assess and evaluate our scientific prowess and achievements. Some recent global indicators are especially noteworthy. India today has attained the 3rd global ranking in terms of research publications and is globally at number 9 in the quality of research publications in the world's reputed and recognised SCI Journals. The country has featured within the top 50 innovative economies globally (at 48th rank) as per Global Innovation Index (GII). India has also been consistently making its presence felt as a member of leading international scientific coalitions - in fields such as Artificial Intelligence, Astronomy, Solar Energy, Climate Research, and as amply demonstrated recently, in global vaccine research, development and supply. India was even elected as Chair of the World Health Organization's (WHO) Executive Board recently.

While these developments are indeed praiseworthy and make us feel proud, there is still much that awaits for the country to be achieved. The role of the Indian scientific community and its scientific institutions is precisely cut out — to make the country truly "AatmaNirbhar" and come up with scientific and technological solutions to problems that not only Indians face but also ones that plague the global citizens. The time is opportune for this to happen — the present government has given a special filip to S&T in keeping with Prime Minister Shri Narendra Modi's special focus on Science and Technology.

However, for this to happen, the Indian scientific establishment will have to reorient its functioning. I have said this at many fora and would like to reiterate once again that the scientists of different Ministries and Departments should further enhance collaboration in the field of Research & Development so that our dependence on imports can be reduced considerably. Science Ministries and Departments should stop working in isolation and enter into active collaborations to make the scientific endeavour more citizen-centric. And today, with several industries and corporate houses engaging in excellent R&D, the scientific institutions should actively look for and further streamline and strengthen collaborations and networking with them.

The celebration of the 75th year of India's Independence should be an occasion for the scientific enterprise in the country to resolve to come together to work for the country's progress. It is, however, also an occasion to celebrate what science and scientists have contributed to India all these years. And so, I congratulate Science Reporter and the CSIR-National Institute of Science Communication and Policy Research (CSIR-NIScPR) for putting together this special issue that seeks to showcase the growth of India's scientific institutions during the past 75 years and the excellent contribution of the Indian scientific community to the country's progress.

I take this opportunity to wish India's scientists and scientific establishments more strength in the days and years to come.

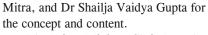
Dr Jitendra Singh



SOME LEADERS WHO HELPED SHAPE SCIENCE IN INDIA **AND WHO LEFT US RECENTLY**



Prof. K. VijayRaghavan Principal Scientific Adviser to the Government of India



The Prime Minister Shri Narendra Modi, when he addressed the nation during Mann Ki Baat on National Science Day 2021 said:

> "The way we know of other scientists of the world, in the same way, we should also know about the scientists of India... I definitely would want that our youth know, understand and read a lot about the history of science of India; about our scientists as well."

Here are a few who left us but not before they gave us lessons, we will live by and not without leaving an impact on the global scientific community.



(7 May 1936-11 January 2021)

Shashikumar Madhusudan Prof. Chitre, known as Kumar Chitre to his friends, was born in Bandra, Mumbai (then Bombay) in 1936. He did his schooling in Mumbai itself and went to obtain a B.A. in Mathematics from the Elphinstone College, Mumbai, in 1956. He then won the Duke of Edinburgh Scholarship to study at Cambridge, St. Peter's College (Peterhouse) where he obtained the Mathematical Tripos in 1959. While at Peterhouse, he wrote an essay on "Why are sunspots dark?" for his final Tripos. Reading this, Fred Hoyle suggested he develop this into a PhD thesis and this earmarked a lifelong affair with the Sun. For his PhD, he moved to Churchill College and was neighbours with Stephen Hawking.

HE COVID-19 pandemic has wreaked havoc in India and all over the world. Many scientists passed away in 2020 and 2021; some due to COVID-19 complications and some due to other causes. When we lose people in our communities, we always meet to share memories and to grieve. This pandemic has not only killed many but has also disrupted our grieving and mourning and made these a remote exercise. We should not let this de-humanising of interactions a compulsion of the times - become the new normal. It is important that we remember each of these lives and celebrate them while mourning their departure and being supportive of family and friends. It is in that spirit that this collection — not comprehensive, not complete — is to be viewed.

I would like to acknowledge the support and efforts of my colleagues Dr H.S. Sudhira, Gubbilabs, Dr Siuli

'Kumar' Chitre was a scholar, scientist, and a thoughtful colleague. There was, and still is, collegiality, and only a modest level of hierarchy at the [Tata Institute of Fundamental Research] and, much interaction over tea, across disciplines. Kumar nucleated these with his understated wit and insights.

At a personal level, I owe him a lot. My Molecular Biology Unit PhD interview, which had him on the panel, focused on fluid mechanics, of which I had a very modest understanding; and not on biology, of which I had no training, poor knowledge, and no understanding.

My fortuitous entry into TIFR, a scientific paradise, a biology questioner would not have permitted, was facilitated by this gentle and understanding interviewer... A big loss.

Prof. K. VijayRaghavan tweeted

His PhD thesis was on the structure of Sunspots with Fred Hoyle.

Chitre then worked as a Lecturer at the University of Leeds and then went to Caltech for his post-doctoral research. While at Caltech, a meeting with S.K. Bhattacharjee, a nuclear physicist from TIFR, resulted in him applying to TIFR for a position in 1966, the year when Homi Bhabha had passed away in an accident. However, Prof. MGK Menon, the Director of TIFR then, offered him a position and Chitre came back to Mumbai in 1967 to spend the rest of his life.

During his career at TIFR, primarily worked on the he magnetohydrodynamics of the Sun. One of the major contributions from his group was in the mapping of differential rotation of the solar interior and the measurement of heavy element abundances in the solar interior. He was also interested in gravitational lensing and carried out studies through his students. During his research career, he collaborated with his colleagues at TIFR and abroad as well.

After his retirement at TIFR as a Senior Professor in 2001, he shifted his focus to science communication and outreach. He was instrumental in setting up the Centre for Excellence in Basic Sciences, for which he was the Academic Chairperson, until his demise. Chitre received numerous honours during his vast career. He was a Fellow of the Third World Academy of Sciences, Royal Astronomical Society, and all three Indian science academies. He also served as the President of the Astronomical Society of India. He was also awarded the Padma Bhushan in 2012. Chitre also served on the board of Trustees of JN Tata Trust and worked as an Honorary Executive Director of Homi Bhabha Fellowship Council. Chitre died on 11 January 2021, aged 84.



(20 July 1933-14 December 2020)

Prof. Roddam Narasimha was an eminent scientist who worked on aerospace and particularly on fluid dynamics. He was also referred to as Roddam in professional circles and Simha in family circles. He was the

eldest son of RL Narasimhaiah and Leelavati. His father was a professor in Physics at Bengaluru's Central College and among one of the early science communicators in Kannada. His father had a significant influence on Roddam. His younger brother, Prof. RR Simha was a mathematician and a faculty at TIFR, Mumbai. He is also known for his work on Simha - Narasimhan measures on Riemann surfaces.

Narasimha studied in Acharya Pathashala, Bengaluru, the same school where Prof. CNR Rao also studied as batchmates. He later went on to obtain a Bachelor of Engineering degree in Mechanical Engineering from the University Visvesvaraya College of Engineering in Bengaluru. After his graduation, he was initially unsure and one visit to IISc (then, Tata Institute) changed the course of his life. When he visited for the first time, he was mesmerized with the Spitfire aircraft that was on display in front of the Department of Aerospace at IISc, which



helped him to resolve his decision to pursue studies at IISc. He obtained a Master's (then, Diploma) in 1955 and worked under Prof. Satish Dhawan. On Prof. Dhawan's insistence, he went to Caltech to pursue his doctoral research under Hans Liepmann, which he obtained in 1961. He returned to IISc



"Deeply pained by the demise of noted aerospace scientist Prof. Roddam Narasimha today who contributed immensely to space technology. His research in parallel processing, aerospace electronics, surface technologies, and computational fluid dynamics, leadership at National Aerospace Laboratories, and policy contributions to aerospace technology proved to be the stepping-stones to make India self-reliant in civil aviation. Indian science is indebted for his remarkable contributions to many of India's major scientific programs from issues of climate change, the design and development of civilian aircraft programs, and of the Light Combat Aircraft, Tejas. His passing away creates a void in the scientific community globally and in India."

Prof. K. VijayRaghavan wrote in his obituary for Prof. Narasimha

in 1962 as a faculty that he remained until his retirement in 1999. While at IISc, he was instrumental in setting up the Centre for Atmospheric Sciences (now, Centre for Atmospheric and Oceanic Sciences) in the early 1980s. His interest in the atmosphere, and more particularly the monsoon and clouds, continued to drive his research interests till his final years.

While being the Professor at IISc, he served as the Director of CSIR-National Aerospace Laboratories (NAL) on deputation from 1984-1993. Post his retirement from IISc, he served as the Director of the National Institute of Advanced Studies until 2004. He was then affiliated with the Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR), where he continued his research. During all these years, he published extensively. He also served as a visiting faculty and held various positions during his career.

While at the CSIR-National Aerospace Laboratories, he instrumental in setting up of a parallel computing system, which was not conceived hitherto, to solve several computational problems. He offered critical support to ISRO, particularly in investigating failures of certain launch vehicles, which greatly helped in their rectification later. He was also a member of the Indian Space Commission.

He was awarded the Padma Vibhushan, India's second-highest civilian award, in 2013.

He passed away on 14 December 2020, after a brief illness.

Dr V. Shanta

(11 March 1927-19 January 2021)

Dr V. Shanta was an Indian oncologist well known for her efforts in making cancer treatment affordable. She was the chairperson of Adyar Cancer Institute, Chennai. She has been associated with the Adyar Cancer Institute since 1955,



holding several positions including that of the Director during 1980-1997. She has also contributed her efforts as a member of many national and international committees.

Dr Shanta was born on 11 March 1927, in Chennai in an illustrious family that boasted of two Nobel Laureates, C.V. Raman (grand uncle) and S. Chandrasekar (uncle). She studied at the National Girls High School, Chennai. Completing her preuniversity course at Presidency College in Madras, India, Dr Shanta went on to pursue her ambition to become a doctor. She then graduated in MBBS in 1949, and MD in obstetrics and gynaecology in 1955. A chance meeting during her last year of MBBS drew her towards cancer. But the key moment was when Dr Muthulakshmi Reddy, the first woman house surgeon in India, set up the cancer centre in Chennai. She was looking for a medical officer

> and Dr Shanta jumped in. And the rest is history. Dr Shanta dedicated all her life at the Cancer Institute to support cancer patients, studying the disease, its detection, and its treatment.

> Dr Shanta was elected as a fellow of the National Academy Medical Sciences. She has received several accolades in recognition for her work including Magsaysay Award the (2005)and Padma Vibhushan (2016).

> Dr Shanta died on 19 January 2021, aged 93 vears.

"Dr V. Shanta, Chairperson of the Adyar Cancer Institute, Chennai passed away early this morning. She will be greatly missed by the cancer care and research community all over the world and the many tens of thousands of lives she has impacted. At 93, Dr Shanta was active to the end. A month ago, she wrote to a science agency on a matter related to the cancer institute and was pleased that it was resolved. Her attention to detail, and caring were legendary. The great institution she has built will live and grow."

Prof. K. VijayRaghavan tweeted

Prof. Khadg Singh Valdiya

(20 March 1937-29 September 2020)

Prof. Khadg Singh Valdiya or KS Valdiya as he was popularly referred to, was a leading Indian geologist, educationist, and science communicator. He was popular for his contribution to an understanding of Indian geodynamics.

Valdiya was born to Dev Singh Valdiya and Nanda Valdiya on 20 March 1937 in Kalaw, now in Myanmar. His



family moved back to Pithoragarh in Uttarakhand where he did his schooling. He obtained his BSc, MSc, and PhD from Lucknow University. He then joined there as a faculty in 1957. He was a Fulbright Scholar during 1965-66, during which he was at Johns Hopkins University. During his career,

he taught and researched various institutions including Wadia Institute of Himalayan Geology, Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR), and Kumaon University. He also served as the Vice-Chancellor of Kumaon University.

Valdiya was instrumental in the establishment of several key geological institutions in India, notably, Wadia Institute of Himalayan Geology, Central Himalayan Environmental Association. Nainital, G.B. Pant Institute of Himalayan Environment and Development, Almora, and the Geology Department at Kumaon University. He was elected as a Fellow of the Third World Academy of Sciences. Geological Society of India, Geological Society of America, Geological Society of Nepal, and all three Indian science academies. During his scientific career, he extensively published many journal articles and authored many books. He was conferred with Padma Bhushan by the Government of India.

Valdiya's key contribution was on understanding Himalayan geology. His studies have greatly contributed to the understanding of the paleogeography of the region and shed light on geodynamics. This resulted in providing a more detailed account of the evolutionary history of the Himalayas. A synthesis of his work on geodynamics has led him to author a very popular book called, The Making of India: Geodynamic Evolution.

During the latter part of his life, he had dedicated himself to science communication. He was actively involved in science outreach activities to popularize science among young students, particularly in his home state of Uttarakhand.

He passed away on 29 September 2020.

Prof. M.S. Narasimhan

(7 June 1932-15 May 2021)

Dr Narasimhan was a renowned mathematician who carved a niche for himself through some of his seminal contributions in the field of algebraic and differential geometry.



Narasimhan was born into a family hailing from the North Arcot district in Tamil Nadu. He was the eldest of five siblings. He completed his schooling and joined Loyola College in Chennai for his Bachelor's degree. He then joined the Tata Institute of Fundamental Research (TIFR), Mumbai for his doctoral studies in 1953. He obtained his doctorate from the University of Mumbai in 1960 under the guidance of K. S. Chandrasekharan, a well-known mathematician working on number theory. He then joined as a faculty at the TIFR in 1960.

Narasimhan's major contributions are in the field of algebraic and differential geometry, more specifically in the field of vector bundles. His

"With the passing of Khadg Singh Valdiya, we have lost a Himalayan scholar and a scholar of Himalayan proportions. Born in Myanmar he returned to his native Pithoragarh and then studied at Lucknow University where he completed his Ph.D.

Valdiya was a geologist focusing on sediments and tectonics. His research interests were wide. He helped establish and grow the best geology institutions in the country and found a welcoming research abode after retirement [from JNCASR], where he continued to be productive.

An abiding interest of his research was the origin of the Himalayas and the origin of the Himalayan rivers in general and the Ganga in particular."

Prof. K. VijayRaghavan tweeted

work with C.S. Seshadri, an Indian mathematician, on unitary and stable the Narasimhan-Seshadri bundles, theorem, is considered a pioneering work and has significant applications in gauge theory and conformal field theory used in mathematical physics.

Narasimhan also characterised real analytical functions, these are functions with derivatives of all orders that obey Taylor's series--via Cauchy type inequalities. With S. Ramanan, another Indian mathematician, he worked on the proof of the existence of universal connections, generalization of well-known results on the existence of universal bundles in topology. He also collaborated with mathematician Prof. R. R. Simha, another TIFR faculty (younger brother of Professor Roddam Narasimha) to prove the existence of moduli of general type complex structures on a real analytic manifold. These measures were called Simha-Narasimhan measures on Riemann surfaces.

Narasimhan played a key role in the development of mathematics in India. He was the first Chairman of the National Board for Higher Mathematics. He was elected as a Fellow of the Royal Society. He was also a Fellow of all the three science academies in India. He was a recipient of the French National Order of Merit (1989) and the Padma Bhushan award in 1990. To date, he is the only Indian to win the King Faisal International Prize for Science from Saudi Arabia, which he received jointly with Simon Donaldson of Imperial College.

Narasimhan passed away on 15 May 2021 in Bangalore, aged 88 years.

Prof. Munirathna Anandakrishnan

(12 July 1928-29 May 2021)

Prof. Munirathna Anandakrishnan was an engineer, educationist, and science administrator. He was the chairperson of the Indian Institute of Technology, Kanpur, and a former Vice-Chancellor of Anna University. He also served as an Advisor to the Government of Tamil

"Prof. M. Anandakrishnan's passing is a loss for engineering. Felled by COVID at age 92, his brisk stride, sharp mind, infectious cheerfulness, all shook others from sluggishness. Son of a brick-layer, Head of Civil Eng, [IIT Kanpur], VC of [Anna University], a caring teacher is gone."

Prof. K. VijayRaghavan tweeted

Nadu on Information Technology and e-Governance.

Anandakrishnan was born in Tamil Nadu. He obtained his Bachelor of Engineering in Civil Engineering from the College of Engineering, Guindy, Madras University, Chennai in 1952. He went on to obtain a Master's degree in 1957 and a PhD in Civil Engineering in 1960 from the University of Minnesota.

Anandakrishnan returned India in 1962 and worked briefly at the Central Road Research Institute, New Delhi. After working for a year, he joined as a member of the faculty of civil engineering at the Indian Institute of Technology, Kanpur (IIT Kanpur) where he worked till 1974. He held various positions at IIT Kanpur including the Chairman of the Department of Civil Engineering, Dean, and Acting Director.

Anandakrishnan moved to the USA in 1974 to work as a Science Counsellor at the Indian Embassy in Washington DC, on deputation from the Department of Science and



Technology. He then joined the United Nations Commission on Science and Technology for Development (CSTD) as the Chief of New Technologies at the Office of Science and Technology (OST), where he served until his retirement in 1989. While at UN, he was also the Deputy Director of CSTD and served as the secretary of the UN Advisory Committee on Science and Technology for Development. Anandakrishnan returned to India in 1990 to become the Vice-Chancellor of Anna University, which he served until 1996.

Anandakrishnan has received several awards and honours for his services. Notable among them is Padma Shri in 2002 and the Distinguished Leader Award by the University of Minnesota in 2003. He was also conferred the Commander of the National Order of Scientific Merit by the Government of Brazil in 1996. Anandakrishnan was also elected as a Fellow of the National Academy of Sciences, India, Institution of Engineers (India), and the Indian Society of Technical Education.

He passed away on 29 May 2021, aged 92 years.

Dr Srikumar Banerjee

(25 April 1946-23 May 2021)

Dr Srikumar Banerjee was the former Chairperson of the Atomic Energy Commission of India and the former Secretary of the Department of Atomic Energy, Government of India. He was well-known as a metallurgical engineer by training.

Banerjee obtained his B. Tech. with honours in Metallurgical Engineering from the Indian Institute of Technology, Kharagpur in 1967. He then went to attend the Training School at Bhabha



Atomic Research Centre (BARC). Soon after, in 1968 he formally started his career there with the Metallurgy Division at BARC and went on to become its Director during 2004-2010.

Earlier in 1974, for the work he carried out at BARC, he was awarded the PhD in Metallurgical Engineering from IIT Kharagpur. In the latter part of his career, he also served as DAE Homi Bhabha Chair Professor at BARC. Banerjee held various visiting positions abroad at the University of Sussex, Brighton, England, Max-Planck-Institut für Metallforschung, the University of Cincinnati, and the Ohio State University, USA.

He also served as the Chairman, the Board of Governors of IIT Kharagpur during 2014-2017. He was elected as a fellow of the Indian Academy Sciences. National Academy of Sciences, India, and the Indian National Academy of Engineering. He received numerous recognitions for his work and contribution to services. Dr Banerjee was awarded the Shanti Swarup Bhatnagar Prize for Science and Technology in Engineering Science (1989) and Padma Shri in 2005.

Banerjee passed away during the early hours of 23 May 2021 due to a heart attack.

"Dr Srikumar Banerjee's passing is too sudden, too soon. Former Chairman of the Atomic Energy Commission [DAE, India], his interests straddled the most fundamental to the most applied. In every discussion, his astute leadership ensured that there was more light and no heat."

Prof. K. VijayRaghavan tweeted

Dr Nandivada Rathnashree

(26 November 1963-9 May 2021)

Dr Rathnashree was an avid astronomer and science communicator. She was the Director of Nehru Planetarium where she started her career as a senior educator. Earlier she was trained in theoretical astrophysics.

Rathnashree was born Hyderabad on 26 November 1963. After her schooling in Kendriya Vidyalaya (1981), she studied at the University College for Women in Hyderabad. She obtained her Master's in 1986 from Hyderabad Central University. She then joined for her doctoral research at the Tata Institute of Fundamental Research with the theoretical astrophysicist Prof.

Alak Ray. She received her PhD in 1992 for the work on binary stars. She was a postdoctoral fellow at the University Vermont, USA 1992-1994. during where she worked on observations pulsar the Arecibo using radio-telescope. During 1994-1996, she was a postdoctoral fellow at the Raman Research Institute in Bengaluru.

Rathnashree moved to New Delhi in 1996 as a Senior Planetarium Educator at the Nehru Planetarium.

Soon, in 1999, she also became its Director. Since then, she was a force to reckon with for numerous activities on astronomy outreach, that not only impacted within the National Capital Region, but across the country.

Rathnashree's key contribution has been towards the preservation of the Jantar Mantar observatories of Raja Sawai Jai Singh. She and her team have been instrumental in enabling these accessible to the general public. She firmly believed that astronomy outreach carried out at archeo-astronomy heritage sites and through archeo-astronomy instruments, had immense potential for wider communication and appreciation. Rathnashree and her students have extensively worked in the cleaning and



"Rathnashree's key contribution has been towards the preservation of the Jantar Mantar observatories of Raja Sawai Jai Singh. She and her team have been instrumental in enabling these accessible to the general public."

restoring of some of the Jantar Mantar instruments, apart from creating a host of outreach collaterals to train tour guides in both Jaipur and New Delhi. She has also written extensively on the mathematics behind these instruments.

Acknowledging her role these, the Archaeological Survey of India appointed her to the committee overseeing the restoration of Jantar Mantar in New Delhi. Rathnashree also worked with the National Council of Science Museums advising them on astronomy-related exhibits and activities at various science centres.

Rathnashree passed away on 9 May 2021.

Prof. Govind Swarup

(23 March 1929–7 September 2020)

Govind Swarup, astronomer, discovered the 'type-U' solar bursts. He also developed the

"Professor Govind Swarup was an exceptional scientist. His pioneering works in radio astronomy have attained global commendation. Anguished by his passing away. My thoughts are with his near and dear ones."

Shri Narendra Modi, Prime Minister of India tweeted

gyro-radiation model, a model that considers radiation from electrons whose speeds are much smaller than the speed of light, to explain microwave solar emissions. Several observations made by him and his students provide independent support for the Big Bang model of the Universe.

Swarup was born in 1929 at Thakurdwara, Uttar Pradesh. He came from a relatively wealthy family. He had an early education in English and many other subjects.

Swarup went on to obtain a Bachelor's (1948) and Master's degree (1950) in Physics from the Allahabad University. After his Master's, he

joined the CSIR-National Physical Laboratory in New Delhi (1950-53). A fellowship he chanced upon led him to work at CSIRO in Australia during 1953-1955. He returned to India in 1955 and was back at NPL till 1956. He then proceeded to pursue doctoral research at Stanford University which he obtained in 1960. He was an Assistant Professor at Stanford University from 1961-1963.

His notable contribution has been to initiate and start the radio astronomy program and activities in India. With his brief stints at CSIRO, Australia, and while at Stanford University, USA, he had the urge to establish something similar back home. He and a few of his colleagues wrote to about five key organisations in India about this. And the most encouraging one was from Dr Homi Bhabha who was the Director of TIFR, Mumbai. This prompted Prof. Swarup to return to India in 1963 while joining as a Reader at TIFR in 1965.

Swarup is known for building the Ooty Radio Telescope (ORT) on the hillslopes of Ooty and the Giant Metrewave Radio Telescope (GMRT) near Pune. These ingenious, economical, and powerful observational facilities are used not just by Indian scientists, but also by scientists from 31 countries the world over.

A recipient of the Padma Shri, and a Lifetime Achievement Award from the Department of Atomic Energy, Prof. Swarup was a promoter of an allinclusive approach to teaching science. The proposal that he made along with Prof. V. G. Bhide for a 5-year integrated program for an intensive education in science led to the establishment of the Indian Institutes of Science Education and Research (IISERs).

Prof. Govind Swarup passed away on 7 September 2020.



With Professor Govind Swarup's demise, the world of astronomy has lost a great scientist, institution-, and telescope-builder. Ever-smiling, not one to take a no for anything he wanted to be done, he took on many impossible tasks, inspired colleagues to accomplish them.

Prof. K. VijayRaghavan tweeted



CELEBRATING 75 YEARS OF INDIA'S S&T JOURNEY

Major Recent Contributions of Department of Science & Technology



Ashutosh Sharma
Secretary to Government
of India, Department of
Science & Technology



Akhilesh Gupta
Senior Advisor
Department of Science &
Technology



Jenice Jean GoveasDST Post Doctoral Policy
Fellow

The Prologue

ESSESSE.

India being the cradle of one of the oldest civilisations in the world. has a tradition that is embedded in science and technology. Ancient Indian land well balanced the wisdom and knowledge of sages and seers, of rishis and researchers, of scholars and scientists whose scientific knowledge is preserved in the Vedas, Ayurveda and our other ancient granthas. Today many centuries later, and 75 years after achieving independence, India has come a long way as she gears up to provide and deploy high-tech solutions in several key areas including education. healthcare, etc. to all citizens, reaching even the marginalised communities.

S&T in India Post-independence

Travelling back in time along the eventful lane of India's S&T ecosystem, flashes in to the mind's eye several milestones that directed our nation to

the significant global position that we are in today. The stalwarts who stand out include Pandit Jawaharlal Nehru, the first PM of India, who initiated several reforms in higher education and science and technology and was particularly instrumental in setting up the Indian Institutes of Technology. The first one was inaugurated on 18 August 1951 at Kharagpur by India's then Minister of Education, Maulana Abul Kalam Azad.

India propelled herself into the domain of space right from the 1960s and through diplomatic ties with the Soviet Union planted the seed of the Indian Space Research Organisation, simultaneously advancing nuclear capability which was jubilantly demonstrated through the first nuclear test explosion on 18 May 1974 at Pokhran.

All along the past 75 years, India held on to S&T as the magic wand that transformed an economically

beleaguered country, handed over to Indians from the shackles of the British, to a world leader that we are today. India's S&T journey has been no less than a rollercoaster ride, and the real drivers of India's S&T ecosystem have been the well-paced National Science Policies.

Science Policies Propelling India's S&T Growth

The Science Policy Resolution 1958 captured the vision of India as a welfare state and largely emphasised basic research in almost every field of science. It was instrumental in building and nourishing the science ecosystem in India through science education and research. It provided the required directions to set up organisations like Defence Research and Development Organization (DRDO-1958), Department of Electronics (DOE-1971), the Department of Science Technology (DST-1971),

Department of Space (DOS-1972), and the Department of Environment (DOE-1980). It fostered the creation of basic infrastructure needed to build the foundation of India's scientific research, critical human capital and R&D capacities.

By the 1980s, India could boast of some strong science and agriculturebased qualified professionals and technological strategic platforms. India's agronomy got a major thrust during the green revolution of the sixties, the white revolution of the seventies, the yellow revolution of the eighties, the golden revolution of the nineties when India started becoming self-sufficient in agricultural produce, particularly food grains.

The Technology Policy Statement of 1983 majorly focused on achieving technological competence and selfreliance by nurturing indigenous technologies and reducing dependence on imports in critical areas. The policy also aimed at strengthening the technology base especially in trending sectors of that time including information technology, electronics, and biotechnology. investments and Increased R&D collaboration among governmental organisations, educational institutions and industries were guided by this policy. Technology Development Fund (TDB) was established to provide financial assistance to Indian industries. Technology Information Forecasting and Assessment Council (TIFAC) was established for continuous and systematic forecasting and assessment studies of emerging technologies. In the following two decades, India took massive strides towards progress by opening the economy through liberalisation, privatisation and globalisation.

The Science and Technology Policy of 2003 aimed at upgrading the research and academic infrastructures, building a connection with the economy and society at large. It focused on the investment required for research and development (a target of 2% of GDP), collaboration between industry and research institutions, and the

"There is commendable improvement in the participation of women in extramural R&D projects from 13% in 2000-01 to 24% in 2016-17. India is ranked 3rd in terms of the number of PhDs awarded in Science and Engineering (S&E) after the USA and China and also 3rd in global scientific publication as per NSF, USA. According to the World Intellectual Property Organisation (WIPO), India's Patent Office stands 7th among the top 10 Patent Filing Offices in the world and 9th for Resident Patent Filing."

establishment of intellectual rights regimes to protect and incentivise inventors. The rapid advancement of communication technologies, new issues related to cybersecurity and ethics, such as privacy consideration and inequity came to light. Mechanisms to address such unforeseen issues were also considered in this policy. This helped India grow her S&T investments. R&D spending touched a significant percentage of GDP (0.7%), though way behind the targeted 2%. Research outputs such as publications, numbers of PhD students, and patent filing from the research and innovation also increased significantly. Sixteen new IITs (2004 onwards) were established taking their total number to 23. In addition, new institutes like IISERs (2006 onwards) came into being. Thus, Science, Technology and Innovation (STI) became the major drivers of national development and the socio-economic benefits of S&T were firmly established.

The Science Technology & Innovation Policy 2013 laid emphasis on creating a robust environment for enhanced private sector participation in R&D and enthused new vigour to establish a PPP framework. It encouraged participation in S&T based high-risk innovations due to which India increased her participation in global mega-science projects, including the Laser Interferometer Gravitational-Wave Observatory (LIGO), the Large Collider (LHC-CERN), Hadron International Thermonuclear the Experimental Reactor (ITER) and the Square Kilometre Array (SKA).

The Indian decade of innovation. launched in 2010 made 'Innovation' a buzzword. Post 2014, the Government of India streamlined its efforts with new vigour by launching several flagship initiatives to support and stimulate R&D culture among students and young researchers including Make in India, Atal Innovation Mission (AIM), Start-Up India, Stand-Up India, Fund of Funds for Start-ups (FFS), Pradhan Mantri MUDRA Yojana (PMMY), E-Business portal, introduction of the Patent Box Regime, Regulatory Sandbox and tax sops including removal of Angel tax, etc. Such proactive steps and innovation strategies have enabled India to develop a fairly robust manufacturing and service sector while simultaneously ensuring a sound R&D ecosystem with skilled manpower giving rich dividends in terms of global rankings particularly in the Global Innovation Index where India stands 48th and is the third most innovative lower-middle-income economy in the world.

Recent Major Developments in STI

During the past 6-7 years, India has added several feathers to her cap. Particular note may be made of India's Gross Expenditure on R&D (GERD) that nearly tripled between 2007-08 to 2017-18 and per capita R&D expenditure increased 1.5 times. Another commendable improvement is in the participation of women in extramural R&D projects that increased from 13% in 2000-01 to 24% in 2016-17. India is ranked 3rd in terms of the number of PhDs awarded in Science and Engineering (S&E) after the USA and China and also 3rd in global scientific publication as per NSF, USA. According to the World Intellectual Property Organisation (WIPO), India's Patent Office stands 7th among the top 10 Patent Filing Offices in the world and 9th for Resident Patent Filing.

Some of India's biggest milestones have been in space exploration. India's achievements have skyrocketed from the successful launch of India's first satellite Aryabhatta in 1975 to the Mars Orbiter Mission (MOM) or Mangalyaan in 2013 followed by the Chandrayaan programme and the most awaited manned Gaganyaan mission. These achievements speak volumes of the exceptional scientists of the likes of Dr APJ Abdul Kalam who have left an indelible mark in the sands of time.

In the nuclear arena, exploded the country's first nuclear test Operation Smiling Buddha in 1974 and there has been no looking back ever since in exploring nuclear energy for peaceful purposes. India has made her presence felt from pole to pole, with the Indian Antarctic Programme launched in 1981 and several subsequent missions to Dakshin Gangotri. India's Arctic observation station IndARC was set up in 2015, halfway between Norway and the North Pole.

Today, India is actively engaged in emerging technologies such as Nanotechnology, Artificial Intelligence, Robotics, Augmented and Virtual Reality, Internet of Things and so on. In drug manufacturing, India through her generic lifesaving drugs has become the pharmacy of the world in supplying affordable medicines. As the COVID-19 pandemic forces the world to realign in terms of various sectors, the Indian scientific ecosystem is gearing up to receive yet another pathbreaking national Science, Technology and Innovation Policy (STIP-2021) shortly.

The clarion call by our Hon'ble PM Shri Narendra Modi to build an Atma Nirbhar Bharat further emphasises how essential technology indigenisation is

5th National Science, Technology and Innovation Policy (STIP) draft released for public consultation Image credit: DST

for us to truly be free and independent. Self-reliance in S&T is the way forward for India to ensure a hassle-free journey ahead.

Major Recent Initiatives and Missions of DST

The Department of Science and Technology (DST) established in the year 1971, has the mandate to diversify and strengthen S&T activities in the country. Since its inception, DST has played a pivotal role in coordinating and integrating S&T areas across the ministries and associated departments, S&T institutions, academia, industry, regionally and globally.

DST has made great efforts in taking science to society, ensuring lastmile connectivity, and has successfully catered to the application of S&T for the weaker sections, women, and other disadvantaged sections of the society. DST is striding ahead with an extensive network of programmes and facilitating schemes to promote research and development in areas of national importance.

The Department of Science & Technology is one of the key government departments contributing significantly to scientific research in the country. As the largest extra-mural STI funding agency in the country, DST is boosting India's entire innovation value chain comprising researchers, entrepreneurs, academic and research institutes, startups, industry, and so on. The last seven years witnessed the impactful initiatives undertaken by DST to steer the innovative culture in the country.

Today, DST has a portfolio of exhilarating programmes and schemes which are significantly elevating the STI ecosystem. DST's investment in the S&T system more than doubled in the last seven years from about Rs 2900 Cr in 2014-15 to Rs 6072 Cr in 2021-22.

Major Initiatives Impacting STI Ecosystem

Some of the milestone initiatives of DST during the last seven years are the following:

"As the largest extra-mural STI funding agencies in the DST is boosting country, India's entire innovation value chain comprising researchers, entrepreneurs, academic and research institutes, startups, industry, and so on."

Attracting and promoting innovation pursuits: Innovation in Science Pursuit for Inspired Research (INSPIRE), a flagship programme of DST, has been successfully implemented to attract and promote a scientific talent base in the country. INSPIRE-MANAK (Million Minds Augmenting National Aspirations and Knowledge) awards were launched in 2018 to further facilitate young school children to take up science and innovative projects.



Boosting innovation and startup activity: A national programme titled NIDHI (National Initiative for Developing & Harnessing Innovations), which addresses the entire value chain of Innovations, has been launched. **NIDHI** significantly impacted India's innovation ecosystem by nurturing 3,681 startups through a network of 153 incubators created by DST, which generated 65,864 jobs as cumulative direct employment, creating a wealth of Rs 27,262 crores and generated 1,992 intellectual properties. NIDHI's collective strength and power, its incubator network, and its startups were tested successfully during the COVID-19 pandemic through the 'Centre for Augmenting WAR with COVID-19 Health Crisis (CAWACH)' programme by supporting various solutions to resolve the COVID crisis.



Image credit: http://www.nidhieir.in/about.php

Cyber-Physical Systems: DST has launched 'A National Mission Interdisciplinary Cyber-Physical Systems' at a total outlay of Rs 3660 Cr for five years to create a strong foundation and a seamless ecosystem for cyberphysical systems and technologies [like Artificial Intelligence (AI), Robotics, Internet Things (IoT) encompassing knowledge generation, human resource development, research, technology, product and development, innovation, and commercialisation.

Aligning with national agenda:

- DST has enrolled new initiatives such as Super Computing Mission; Advanced Manufacturing: Waste Management, Science and Technology Yoga and Meditation (SATYAM) to boost the country's prowess through STI.
- DST also initiated a Mission Innovation Programme with smart grid and off-grid to develop domain-specific leadership of India.
- DST support through thematic programmes on Clean Energy and Water, Nano Science and Technology, Climate Change Research, and outreach has led to excellent progress in these thematic areas.

- Three Centres of Excellence (CoE) for 'Climate Research' were established in Himalayan Universities in Kashmir and the North Eastern States of Sikkim and Assam to lead climate change research.
- The Survey of India (SoI), a subordinate Department under DST, has embarked on a pan-India geospatial mapping of the country and launched web portals to facilitate the access of the digital map or data to every citizen of the country and help centre and state organisations in decision making, planning, monitoring, and governance.
- **Providing** state-of-the-art facilities researchers: to Sophisticated Analytical Technical Help Institutes (SATHI) centres to house major analytical instruments have been established to provide standard services of high-end analytical testing, thus reducing dependency on foreign sources. The DST has set up three such centres at IIT Kharagpur, IIT Delhi, and BHU under the SATHI programme.
- Reversing brain drain to brain gain: Several overseas doctoral and post-doctoral fellowships have been introduced to reverse the culture of brain drain to brain gain. Additionally, through its milestone initiative 'VAJRA', DST brings the best of global science and scientists to India, including NRIs.



Image credit: https://vajra-india.in/

Empowering women scientists: To address gender imbalance, a new scheme viz. KIRAN was launched, and a pilot scheme Vigyan Jyoti was tested on a limited scale and duration to attract and encourage young women to take up

"To address gender imbalance, a new scheme viz. KIRAN was launched, and a pilot scheme Vigyan Jyoti was tested on a limited scale and duration to attract and encourage young women to take up science."



Courtesy: DST

science. DST has also undertaken an implementation plan for Gender Advancement for Transforming Institutions (GATI), urging higher education and research institutions to support diversity, inclusion, and equity. In addition, the Science and Engineering Research Board (SERB), a Statutory body of the DST, launched SERB-POWER (Promoting Opportunities Women in Exploratory Research) in 2020 to mitigate gender disparity in science and engineering research funding in Indian academic institutions and R&D laboratories.

Communicating science: internet-based dedicated Science Channel and an hourly daily programme on Doordarshan (DD Science) were launched in early 2019. In addition, schemes such as 'AWSAR' empower the young to take up science by encouraging young scientists to



Launch of the DST DD Science and India Science channels by Former Hon'ble Minister Dr Harsh Vardhan (Courtesy: The Hindu)

write popular science articles their research pursuits. on

- **Inter-ministerial collaborations:** is actively collaborating with different ministries promote national STI. It has partnered with the Ministry of Education (MoE) under a 50:50 partnership to implement the IMPRINT (Impacting Research Innovation and Technology) programme to address and provide solutions to the most relevant engineering challenges faced by the nation. In association with the Ministry of Railways, DST has rolled out the Railway Innovation Mission to support the first phase of cyber-physical 4.0 implementation industry for the modern coach factory.
- **Building international networks:** New international S&T collaboration to connect with the



DST initiated international S&T collaboration including participation in 'Thirty Meter Telescope Project' (Courtesy: PIB)

best global science was initiated that includes participation in 'Thirty Meter Telescope Project' and 'India-Israel Industrial R&D Technological Innovation fund' established by DST in recent years.

Major Success Stories During

The significant challenges that 2020 put before the world helped India emerge as a forerunner in underscoring the critical role of science and technology in bringing positive transformations for a safe, secure and better society well prepared for the future. DST has played a facilitative role in pushing S&T to become the core of decision making, claiming increased media space and gaining public trust.

India's ranking in publications, R&D & innovations has risen exponentially: India is placed 3rd among countries in scientific publication as per the NSF database. The country has featured within the top 50 innovative economies globally (at 48th rank), as per Global Innovation Index (GII). It has also reached 3rd position in term of the number of PhDs, in size of Higher Education System, as well as in terms of the number of Startups.

4 S&T related policies formulated

5th Science, Technology, and Innovation Policy (STIP) creating India's vision for STI led economic growth.

- Liberalised Geospatial Policy for Guidelines and acquiring and producing Geospatial Data and Geospatial Data Services and mapping.
- Guidelines on Scientific Social Responsibility empowering the society.
- Policy on Scientific Research Infrastructure Sharing Maintenance and Networks (SRIMAN) for facilitating creation, use, access, maintenance and disposal of R&D infrastructure.

2 National Missions in new and emerging areas launched

- National Mission on Interdisciplinary Cyber-Physical Systems (ICPS) - technology development in the areas of Artificial Intelligence, Industry 4.0, Robotics, Sensors, IoT, etc. for rapid economic growth.
- National Mission on Quantum Technology and Applications (NM-OTA), for R&D to manufacture in **Ouantum** Technologies and related areas being launched.

Mission mode programmes initiated

- Sophisticated Analytical & Technical Help Institutes (SATHI) - to build a shared, professionally managed, S&T infrastructure for industry, MSMEs and Startups.
- Scientific and Useful Profound Research Advancement (SUPRA) - to encourage and develop projects that seek new scientific breakthroughs based on risk taking, profound thinking, long-term impact on our fundamental research.
- Technology Mission on Electric Mobility & Storage - R&D for tropical climate-







Courtesy: DST

proof battery and beyond the Li-ion battery chemistries, electric motors and power electronics.

- Supercritical Carbon Dioxide (S-CO₂) Power Plant and Material Acceleration Platform for Clean energy.
- Efficient Water Use and Purification - Technology demonstration for disruptive technology for desalination, renewable powered desalination systems, technology solutions for water conservation, water-energyfood nexus, agriculture & industrial water use efficiency.
- Mission Programme "Methanol Economy" - R&D for indigenous development process, technology, catalysts, chemical processes,

- for production and utilisation of Methanol/DME.
- National Hydrogen Energy Mission being initiated, led by MNRE but contributed by DST for enhancing the production and utilization of hydrogen, primarily green hydrogen.

3 Impactful schemes empowering women in science launched

- Vigyan Jyoti, for encouraging girl students to take up science as a career.
- Advancement Gender for Transforming Institutions (GATI), a charter for assessing gender equity in Science, Technology, Engineering and Mathematics (STEM).
- Power SERB fellowships research grants

empowering women researchers in STI.

National Missions - Significant impacts

- 5 Supercomputers assembled indigenously and installed under National Super Computing Mission, a dozen more likely to be set up shortly. Param Siddhi the Highperformance Computingartificial Intelligence (HPC-AI) achieved global ranking of 63 among the top 500 most powerful non-distributed computer systems.
- Three Sophisticated Analytical & Technical Help Institutes (SATHI) centres set up; five Centres every year likely.
- 25 Technology Innovation Hubs set up under National



Courtesy: DST

Mission on Interdisciplinary Cyber-Physical Systems (NM-ICPS) bringing about strong collaboration and coownership among industry, academia, and government, connecting them with full flexibility.

- **SVAMITVA** Scheme launched by Hon'ble Prime Minister of India on National Panchayat Day (24 April 2020) to provide an integrated property validation solution for rural India, using Drone Technology deployed by the Survey of India.
- Integrated geospatial platform SAHYOG launched to help area-specific strategies & decisions COVID-19 outbreak.
- DST's OTT "India Science Channel" launched, which also helped disseminate COVID-19 information.
- COVID Katha released a public awareness booklet in English, Hindi and a few regional languages.

Promoting S&T led Traditional Knowledge System

Inter-Ministerial funding "Scientific programme Utilisation through Research Augmentation-Prime Products from Indigenous Cows" (SUTRA-PIC India) undertake systematic scientific investigation of uniqueness of pure Indigenous Indian cows.

"Science and Technology of Yoga and Meditation" (SATYAM) aimed at fostering scientific research on the effects of yoga and meditation on physical & mental health was initiated.

Combatting COVID-19

- 'Centre for Augmenting WAR with COVID-19 Health Crisis (CAWACH)' launched to scout, evaluate and support innovations startups addressing COVID-19 challenges.
- startups Over 80 industries supported. More than two dozen products are already commercialised on scale including global quality or better ventilators, diagnostics, PPE and N95, based applications, biomedical waste disposal, thermal scanners, and other relevant innovations.
- Sree Chitra Tirunal Institute Medical for Sciences and Technology (SCTIMST) brought Out technologies several and products - diagnostic kit for COVID 19 which works better with mutations: UV-based Facemask Disposal Bin; superabsorbent material for liquid respiratory and other body fluid solidification and disinfection, etc.



SCTIMST, an Institute of the DST, developed a diagnostic test kit that can confirm COVID-19 in 2 hours at low cost

White paper on "Focused Interventions for 'Make in India': Post COVID 19" released by Technology Information, Forecasting and Assessment Council (TIFAC) giving immediate technology and policy impetus to make India Aatmanirbhar.

Vision 2025 and Beyond: Major **R&D** Missions & New Initiatives

DST has made concerted efforts in cultivating and promoting scientific temperament amongst the masses and is leading the innovation drive in the country. For the next five years, DST has laid down a vision to improvise novel and impactful programmes to bring technological and innovative based S&T growth in the country.

- Science, Technology and **Innovation Policy** (STIP): Decentralised, evidence-based, bottom-up draft 5th Science, Technology and Innovation Policy formulated with an eye on the future of S&T.
- National Mission on Interdisciplinary Cyber Physical

Systems (ICPS): Mission with a cost of Rs 3660 Cr, for technology development in areas Artificial Intelligence, Robotics, Sensors, Big Data Analytics, geographical information systems, advanced materials manufacturing via invention of new products and services, creation skilled young human resource at all levels, and development of start-ups.

- **National Mission on Quantum** Technology and Application (NM-QTA): To promote and foster R&D in Quantum Technologies and related areas like quantum computing, quantum cryptography, quantum communication, quantum metrology and sensing, quantum enhanced imaging, etc.
- Scientific Research Infrastructure Sharing Maintenance and Networks (SRIMAN): Policy on access and sharing of S&T infrastructure covering other issues like procurement, maintenance, disposal, capacity building for effective utilisation of public research infrastructure in all scientific departments and research organisations.
- Guidelines on Scientific Social **Responsibility:** To be implemented

- by the grantees of projects to reach out to stakeholders of science and society at large with all the tools. knowledge, manpower and infrastructure of S&T in the universities, R&D labs, IITs by choosing one or more activities such as scientific infrastructure sharing; mentoring/training of college/university faculty; training on high end scientific skills and research; student internships; fostering research culture and many more.
- **Positioning Sophisticated** Analytical & Technical Help Institutes: To build a shared, professionally managed, strong S&T infrastructure, readily accessible to academia, start-ups, manufacturing, industry and R&D labs.
- Vigyan Jyoti: To be implemented in 500 districts in the country, to sustain girls' career in science and technology with interventions at school to PhD/post doctoral level, targeting meritorious girls.
- **Technology Mission on Electric** Mobility & Storage: R&D for tropical climate-proof battery and beyond the Li-ion battery chemistries, electric motors and power electronics.



- Generation of High Resolution **Topographic National** Base (HRNTDB): To be prepared for the first time using Drone technology images being developed at 10 cm resolution. India to join select club of few nations to have Ultra/High resolution NTDB data as foundation data.
- Wikipedia in Indian Languages: Creation of Wikipedia in Hindi and other major Indian languages through a two-step process -Machine translation and vetting by experts before final posting.
- National Large Solar Telescope (NLST): Establishing a 2-metre National Large Solar Telescope (NLST) facility at Merak on the Indian side of Pangong Lake in Ladakh for observation of Sun and studies of various physical processes in the Sun.

The Wav Forward

Intending to build a technologically sound and self-reliant India, the Department of Science & Technology (DST) is aggressively marching ahead with novel approaches and initiatives to spur a research innovation culture across sectors and stakeholders. It aims to create a coordinated STI nexus of knowledge performers and knowledge consumers to address societal challenges and problems at large. DST would continue to work and contribute towards integrating science with society and science for society and will help S&T to find solutions to all societal problems.



Indian National Large Solar Telescope



FROM SOUNDING ROCKET TO LAUNCH VEHICLES ACHIEVEMENTS OF DEPARTMENT OF SPACE



K. Sivan Chairman, ISRO Secretary, Department of Space

HE Indian space programme has come a long way in the 58 years since its inception. From the modest beginning of its space programme nearly six decades back, India has persevered to pursue space research in earnest and to perfect many space technologies to facilitate that endeavour.

From a fledgling Sounding Rocket Launch Facility established in the early 1960s in Thumba near Trivandrum, it has matured into a giant world-class space power. Today, ISRO sprawls across the country with huge launch stations, tracking centres, R&D facilities and manufacturing and data processing units, all engaged in highly sophisticated and complex technological activities.

Notwithstanding its presence as one of the strong space-faring nations today, the Indian space programme began in a modest way in 1962 with the formation of the Indian National Committee on Space Research (INCOSPAR) under the Department of Atomic Energy (DAE), barely five years after the launch of the Earth's first artificial satellite Sputnik-1, that heralded the space age. This farsighted critical decision and the later perseverant philosophy of the people who steered the programme, facilitated India to master space technology.

Formal Beginning

The formal beginning of the Indian space programme can be traced to the launch of a Nike-Apache sounding rocket on 21 November 1963, from Thumba, then a fishing hamlet near Thiruvananthapuram, the capital of Kerala, with the establishment of the Thumba Equatorial Rocket Launching Station (TERLS). Later, TERLS became an international sounding rocket



Image credit: ISRO

launching facility and such rockets were launched for upper atmospheric, geomagnetic and space research by many countries.

It was at this time Dr Vikram Sarabhai, the architect of the Indian space programme, set up a Space Science and Technology Centre at Thumba for the development of technologies necessary for space research. In 1969, the Indian Space Research Organisation, better known by its ubiquitous acronym ISRO,



Dr Vikram Sarabhai - Architect of India's space programme

was formed. Government of India constituted the Space Commission and established the Department of Space (DOS) in 1972 and brought ISRO under DOS in the same year.

Today, with a total workforce of over 17,000, ISRO's establishments are functioning in many parts of the country with each concentrating on a specific area. The country's public as well as private sector industries are playing a crucial role in our space programme. Besides, academic institutions have also contributed to the Indian space endeavour.

The Learning Phase

The 70s were the learning phase during which many experimental satellites were built, including India's first satellite Aryabhata, which was launched on 19 April 1975 from a launch centre "Today. total with 17,000. workforce of over ISRO's establishments are functioning in many parts of the country with each concentrating on a specific area.



Apple Satellite

in the former Soviet Union. Aryabhata laid the firm foundation for the later immensely successful Indian satellite programme. Bhaskara 1 and 2, the two experimental earth observation satellites, provided the rich experience and the confidence to build complex operational remote sensing satellites. Today, India is a world leader in the satellite-based remote sensing area.

Additionally, APPLE, India's experimental communication satellite, though launched by the European Ariane rocket, reached its final geosynchronous orbital home in June 1981 with the help of a rocket motor developed in India. Aryabhata, the two Bhaskaras, as well as APPLE were launched free of cost, which reflects India's successful international space cooperation policy. In the recent past, India has not only flown foreign scientific instruments on-board Indian spacecraft but has also launched them.

Besides taking a leap into the domain of satellites, ISRO conducted two significant experiments in the 70s - Satellite Instructional Television Experiment (SITE) and Satellite Telecommunication Experimental Project (STEP) - to obtain handson experience on the utilisation of satellites for television broadcasting and telecommunication. The experiment became a tool for mass education through various programmes designed exclusively for the project.

SITE was conducted for a period of one year, covering more than 2400 villages in 20 districts of six Indian states and territories (Andhra Pradesh, Bihar, Karnataka, Madhya Pradesh, Orissa, and Rajasthan). SITE was followed by STEP and conceived as a sequel to SITE. STEP was for telecommunication experiments and was conducted for a period of 13 hours every day for a little over two years.

And, it was in this decade that ISRO developed its first Satellite Launch Vehicle SLV-3, which had its successful launch on 18 July 1980 thrusting India into the select league of six countries with the capability to launch satellites on their own.

The Experimentation Phase

The 1980s were times for experimentation for launch vehicle technologies to demonstrate country's ability to develop Augmented Satellite Launch Vehicle (ASLV) with a payload capability of 150 kg into Low Earth Orbit, a more capable launch vehicle compared to SLV-3 which was capable of putting a 40 kg satellite into a low earth orbit.

During the same period, ISRO acquired extensive experience in the design, development, building, launching and in-orbit maintenance of a variety of satellites including communication and remote sensing satellites. INSAT-1B, India's first multipurpose operational launched in 1983, demonstrated the country's ability to bring about a

"The world got an inkling of India's ability to design, build and maintain a complex remote sensing satellite in 1988 when IRS-1A, the first operational satellite built in India, started imaging the earth from orbit."

rapid and major revolution in India's telecommunications, television broadcasting and weather forecasting. Today, communication satellites are an integral part of our economic infrastructure.

The world got an inkling of India's ability to design, build and maintain a complex remote sensing satellite in 1988 when IRS-1A, the first operational satellite built in India, started imaging the earth from orbit. The images sent by satellite circling the Earth from its 900-km-high polar orbit were utilised in such diverse fields as agriculture, groundwater prospecting, mineral survey, forestry, etc.

The Growth Phase

During the 1990s, ISRO began building the INSAT-2 series of multipurpose satellites indigenously. At the same time, systematic usage of imagery from our remote sensing satellites for tasks like crop yield estimation, groundwater and mineral prospecting, forest survey, urban sprawl monitoring and wasteland classification and fisheries development, began.

Today, India has a fleet of advanced remote sensing satellites equipped with high resolution and multispectral cameras dedicated to cartography, resource survey and ocean and atmospheric applications. Apart from these, polar orbit based observation satellites, weather watching satellites INSAT-3D and INSAT-3DR circling the earth in the 36,000 km high geosynchronous orbit, are providing valuable inputs for weather forecasting.

Indian National Satellite (INSAT) system today is one of the largest domestic communication satellite systems in the Asia-Pacific region and has become an integral part of our telecommunications and TV broadcasting infrastructure including DTH services driving the country's communications revolution. Besides, our geostationary satellites are providing vital inputs to the task of nationwide weather forecasting, especially in the provision of advance warning of cyclones, saving lives and mitigating the loss of property. One of them carries a satellite-aided Searchand-Rescue transponder and has helped in speedy rescue of people in distress in the open seas.

High throughput satellites such as GSAT-11, GSAT-29 and GSAT-19 are supporting the Digital India campaign by boosting broadband connectivity to the rural and inaccessible Gram Panchayats in the country. The transponders on these satellites will also bridge the digital divide of users including those in Jammu & Kashmir and North-Eastern regions of India.

Perfecting the launch vehicle technology is an immensely difficult and challenging task, which only a few countries possess. Till now ISRO has developed five launch vehicles (SLV-3, ASLV, PSLV, GSLV and GSLV Mk III, which is also known as LVM3) and mastered the technology of rockets that use solid, liquid as well as cryogenic propellants.

Polar Satellite Launch Vehicle (PSLV) is the third generation launch

vehicle of India. It is the first Indian launch vehicle to be equipped with liquid stages. With 51 successful flights over the years, PSLV has emerged as the reliable and versatile workhorse launch vehicle of India. In fact, it has launched 342 foreign satellites as on 22 June 2021 and has carved out a niche in the commercial satellite launch arena.

On 15 February 2017, PSLV created a world record by successfully placing 104 satellites in orbit during a single launch. Well, as numbers go, it was undoubtedly a record, but the real significance is the immense confidence reposed by foreign countries, including the USA, in the capability of ISRO. This success was the result of meticulous planning and flawless execution of the mission by ISRO.

Expanding the Horizon

In the early 21st century, the Indian launch vehicle programme has ventured beyond the PSLV resulting in the development of the Geosynchronous Satellite Launch Vehicle (GSLV) with more payload capability, efficiency and sophistication. GSLV, with the capability to launch 2-ton satellites into Geosynchronous Transfer Orbit (GTO), employs cryogenic propulsion technology in its third stage.

Geosynchronous Satellite Launch Vehicle Mark II (GSLV Mk II) is the fourth generation launch vehicle having three stages (including the cryogenic upper stage) with four liquid strap-ons. Cryogenic technology involves storage of liquid hydrogen & liquid oxygen



Communication satellites (Image credit: ISRO)



at very low temperatures. Materials used to operate at these very low temperatures, chilling processes, and interplay of engine parameters make the development of cryogenic stage a very challenging and complex task.

With the successful qualification of the indigenously developed Cryogenic Upper Stage (CUS) in the GSLV-D5 flight on 5 January 2014, ISRO demonstrated its mastery of cryogenic rocket propulsion. Since January 2014, the vehicle has achieved six consecutive successes.

GSLV Mk III, India's fifthgeneration satellite launch vehicle has two solid strap-ons, a core liquid booster and a cryogenic upper stage. The vehicle is designed to carry 4-ton class of satellites into Geosynchronous Transfer Orbit (GTO) or about 10 tons to Low Earth Orbit (LEO). LVM3-X/ CARE Mission, the first experimental suborbital flight of GSLV Mk III on 18 December 2014 injected the Crew Module Atmospheric Re-entry Experiment (CARE) in December 2014. The CARE module began

"The space science missions of India - Chandrayaan-1, Mars Orbiter Mission, Astrosat and Chandrayaan-2 - have caught the attention of millions of Indians as well as the outside world."

its return journey and a little later, re-entered the earth's atmosphere. It was successfully recovered over the Bay of Bengal about 20 minutes after its launch.

Subsequently, after two successful developmental flights and with the successful injection of Chandrayaan-2 into the Earth Parking Orbit in July 2019, GSLV Mk III successfully entered into its operational phase.

Besides these, India's Reusable Launch Technology Vehicle Demonstrator (RLV TD) successfully flight tested in May 2016 and several critical technologies were successfully validated. The first experimental mission of ISRO's Supersonic Combustion Ramjet (SCRAMJET) engine towards the realisation of air breathing propulsion system was also successfully conducted in August 2016. With this, India became the fourth country to flight test the SCRAMJET engine.

The Indian space programme has always focused on the development and utilisation of space technologies to achieve overall development of the country. Despite its emphasis on applications, ISRO has pursued many space science projects in earnest to perform meaningful exploration of space. India's first satellite Aryabhata was a scientific satellite.

After Aryabhata, ISRO entered into the realm of science missions again with a unique mission that caught



SRE-1 (Image credit: commons.wikimedia.org)

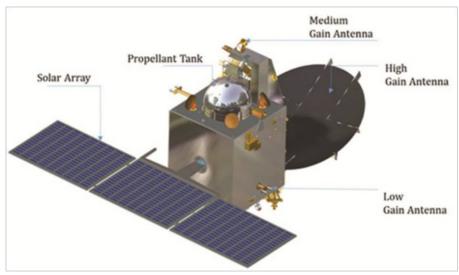
the attention of the world - the Space Recovery Experiment-1 Capsule (SRE-1). Launched by PSLV in January 2007, SRE-1 with its scientific experiments orbited the Earth for 12 days and was successfully de-orbited and recovered over the Bay of Bengal. This proved several technologies necessary for reusable launch vehicles and human spaceflight.

Venturing into Space

The space science missions of India -Chandrayaan-1, Mars Orbiter Mission, Astrosat and Chandrayaan-2 - have caught the attention of millions of Indians as well as the outside world.

Launched by **PSLV** on 22 October 2008, the 1380 kg Chandrayaan-1 spacecraft was successfully navigated to the Moon in three weeks and was put into an orbit around the moon. On 14 November 2008, when a TV set sized 'Moon Impact Probe' separated from Chandrayaan-1 spacecraft and successfully impacted on the surface of the Moon, India became the fourth country to send a probe to the lunar surface after the United States, the Soviet Union and Japan and the fifth individual country to put a spacecraft into an orbit around the Moon. Later, when Chandrayaan-1 conclusively discovered water molecules on the lunar surface, it was widely hailed as a pathbreaking discovery.

Encouraged by the success of Chandrayaan-1, ISRO endeavoured



Mars Orbiter Mission Spacecraft (Image Credit: isro.gov.in)

to realise the Mars Orbiter Mission for demonstrating India's capability to build, launch and navigate an unmanned spacecraft to Mars. Launched by PSLV on 5 November 2013, the 1340 kg Mars Orbiter Spacecraft encountered Mars on 24 September 2014. With this, ISRO became the fourth space agency to successfully send a spacecraft to Mars orbit. Achieving success in the first such mission itself is yet another accomplishment of ISRO.

AstroSat launched by PSLV in September 2015 is the first dedicated Indian astronomy mission aimed at studying celestial sources in X-ray, optical and UV spectral bands simultaneously. AstroSat recently made a major breakthrough by discovering one of the earliest galaxies in extreme-Ultraviolet light.

The Chandrayaan-2 mission, India's second mission to the moon, was successfully launched on 22 July 2019. Chandrayaan-2 Orbiter spacecraft was placed in its intended orbit. The eight instruments onboard the Orbiter are continuously providing useful



AstroSat (Image Credit: isro.gov.in)



Chandrayaan-2 (Image credit: Wikimedia Commons)

"The crew selection and basic space flight training of four astronaut trainees for the Gaganyaan project have been completed at the Gagarin **Cosmonaut Training Centre** (GCTC), Russia and ISRO are gearing up for the missionspecific training in India."

science data which will enrich our understanding of the Moon's evolution and mapping of the minerals and water molecules in the Polar regions.

Having successfully built many communications, meteorological (weather monitoring), remote sensing and scientific satellites, ISRO has successfully established operationalised the Navigation with Indian Constellation (NavIC), with eight satellites in orbit, which are providing accurate position, navigation and time information to users in India and its surroundings. Further, through GPS Aided GEO Augmented Navigation (GAGAN), ISRO is providing satellitebased navigation services with accuracy and integrity required for civil aviation applications and to provide better Air Traffic Management over Indian Airspace.

Apart from this, ISRO has also facilitated students in building and launching satellites for various applications. So far, 14 student satellites have been launched by ISRO.

Human Space Flight Endeavour

"Gaganyaan Programme" approved by the Government of India in 2018 is a point of inflexion in the growth profile of India's space endeavour. With the Gaganyaan Programme, a new vertical has been created within ISRO, and a new ISRO centre namely Human Spaceflight Centre (HSFC) was established on 10 January 2019 and started functioning.

Gaganyaan is a national programme wherein ISRO is leveraging the domain expertise of various national agencies like Indian Armed Forces, DRDO labs, CSIR labs, academic institutions, Indian maritime agencies, and industry



Inauguration of Human Space Flight Centre (Image credit: ISRO)

partners. MoUs/contracts are also in effect with concerned participating agencies. ISRO has organised various Industry meets and workshops to apprise the industries about the requirements of Gaganyaan.

The crew selection and basic space flight training of four astronaut trainees have been completed at the Gagarin Cosmonaut Training Centre (GCTC), Russia and ISRO are gearing up for the mission-specific training in India. The preliminary design of major subsystems has been completed and ISRO has entered into the realisation phase. The test plan for various systems is also finalised.

ISRO has initiated the process of encouraging micro-gravity research in academic institutes. Five microgravity experiment proposals have been shortlisted for flying in Gaganyaan unmanned flights. ISRO will be supporting the activities of payload design and qualification.

addition. to meet programmatic schedule targets, foreign collaboration is being planned in areas that require establishing large infrastructure and long lead research and development. The major areas of collaborations are astronaut training, life support systems, spacesuit, wind tunnel testing, flight surgeon training, etc. ISRO has entered into contracts and agreements with various international agencies like M/s Glavkosmos Russia; NRC Canada; INCAS Romania, and CNES France. In the framework

ISRO-CNES collaboration, three-week training programme for flight surgeons was conducted at ISRO.

An International Symposium on Human Spaceflight and Exploration was organised by ISRO in Association with the International Academy of Astronautics (IAA) to bring together national and international experts, scientists, professionals and academicians for the exchange of technical information and policy details on human space flights.

Space Technology

As a collaborator with industries, over the last five decades, ISRO has been successful in the development of indigenous end-to-end capability in space technology and space activities. This has also led to growth in Indian industries, with more than 500 MSMEs, PSUs and large private industries contributing significantly to the Indian space programme. The involvement of industries in space activities has created jobs for around 45,000 people in the country. Many sectors like defence production, telecom, materials, chemicals and precision engineering have benefitted from this exercise.

Space-based applications/services over the years have grown much more than originally envisaged. Many new applications are being developed worldwide to meet the growing user demands and requirements. activities are on a growth trajectory with huge commercial potential. In



Inauguration of NSIL by Dr K. Kasturirangan, former Chairman, ISRO (Image credit: ISRO)

India, many Non-Government-Private-Entities (NGPEs) have started engaging in space activities for commercial gains. Many start-ups and industries have started making launch vehicles and satellites and are eager to provide space-based services. Participation of NGPEs including academic institutions, start-ups and industries in end-to-end space activities is expected to expand the space economy.

In order to enhance the diffusion of space technology and boost the space economy within the country, the participation of private companies in space activities needs to be encouraged. The Government of India announced reforms for opening up the space sector to private entities by the creation of the Indian National Space Promotion and Authorization Centre (IN-SPACe) under the Department of Space (DOS). IN-SPACe will encourage, promote and hand-hold the private sector for their participation in the Space sector. IN-SPACe has already promoted and hand-held four student satellites, which were successfully launched by PSLV-C51.

To enable enhanced participation of Indian Industries in taking up high-tech space-related activities, the Government of India on 6 March 2019 incorporated NewSpace India Limited (NSIL), a wholly-owned Central Public Sector Enterprise (CPSE), under the administrative control of the Department of Space. NSIL is the commercial arm of ISRO with the primary responsibility



During UNNATI programme 2019

of enabling Indian industries to take up high technology space-related activities.

With the expansion of the space sector to private entities, Government of India enhanced the role and scope of NSIL to encompass more responsibilities in the primary business areas and widen the scope. The revised mandate broadly covers (i) Owning satellites for Earth observation and communication applications; (ii) Providing space-based Earth observation and communication services; (iii) Building and launching.

Building Human Resources

Towards capacity building in human resources and to meet the growing demands of the Indian Space Programme, the Indian Institute of Space Science and Technology (IIST), a deemed university, was established at Thiruvananthapuram in 2007. The institute offers Bachelor's Degree in Space Technology with specialisation Engineering Aerospace Electronics & Communication and Masters Programme in areas of space technology.

ISRO is also developing systematic capacity enhancement plans individual, organisational, institutional, industrial and user/community levels. Various training and development activities are envisaged through both centralised and decentralised systems. The scheme of Centralised Induction Training Programme for newly joined scientists/engineers, introduced during 2002, is aimed at introducing the newly recruited engineers to the ISRO systems by providing exposure to the ISRO programmes, achievements, regulations, systems, processes, etc. Similar Centralised Induction Training programmes are being provided to Office Assistants and Junior Personal Assistants in Administrative areas.

During the 50th anniversary of the United Nations Conference on the Exploration and Peaceful uses of Outer Space (UNISPACE+50), India announced a capacity building training programme UNNATI (UNispace Nanosatellite Assembly & Training by ISRO) on Nanosatellite development in three batches for international participants from countries around the world. The course comprises of a combination of theoretical coursework and hands-on training. As part of the theoretical coursework, the participants are taken through basics of satellite technology (Module 1) and nanosatellites (Module 2). The participants would be introduced to the design aspects of satellites, the various subsystems of a satellite and their functionality, configuration evolution and post-launch mission operations. As part of the hands-on training, all participants are introduced to Assembly, Integration and Testing (AIT) of Nanosatellites in the labs of URSC.

The first batch of UNNATI Programme was conducted from 15 January to 15 March 2019 with 29

participants from 17 countries and the second batch was conducted from 15 October to 15 December 2020 with 30 participants from 16 countries.

Geared for Future Challenges

The Indian space programme has many challenges ahead. There are plans to build heavier and more capable and efficient satellites. And, space science missions like Chandrayaan-3, Aditya-L1, Mission to Venus to further explore the solar system, are in progress. Pursuit of research and development activities pertaining to small satellite launch vehicle, air-breathing rocket propulsion and demonstration of reusable rocket technology, are also progressing.

The space programme in the country is poised for several major breakthroughs in the development of advanced technology needed for the realisation of the future launch vehicle and spacecraft missions in the coming years. Efforts are on to establish the necessary infrastructure for casting large boosters, liquidpropellant engines, heavy cryoboosters for advanced heavier launchers and missions in the area of remote sensing, communications and navigational satellites as well as space science systems. Necessary ground infrastructure for providing mission support during the launch phase and inorbit support for the planned missions is under realisation.

The continuing expansion of space applications programmes like Village Resources Centres, telemedicine, teleeducation, disaster management support and outreach through Direct-To-Home television, reiterates the increasing role played by the Indian space systems in providing direct benefits to society.

The Indian space programme continues to pursue successful goals on all fronts in meeting the objectives of achieving self-reliance in space technology and its applications for national development.





CHANGING THE TIDE IN PUBLIC HEALTH SYSTEMS IN 75 YEARS

Role of Indian Council of Medical Research (ICMR)



Dr Balram Bhargava

Secretary, Department of Health Research (DHR)
& Director General, Indian Council of Medical
Research (ICMR)



Dr Rajni Kant

Director, ICMR-Regional Medical Research Centre,
Gorakhpur

Scientist G & Head, Research Management, Policy, Planning and Coordination (RMPPC), ICMR Hqrs

achievements in population health improvement during the last seven decades. One of the key developments is the improvement in life expectancy at birth, which has increased from 32 years in 1947 to 69.4 years in 2021 – more than double increase in the last seven decades. The marked reduction in Maternal Mortality from 2000 per 100,000 live birth to 113 and Infant Mortality from 145 per 1000 live birth to 28.7 is again a testament to the tremendous progress in Indian medical research and health interventions.

The country has also been able to eliminate diseases like small pox, polio, Yaws, guinea-worm and neonatal tetanus through consistent research and ground level implementation. Diseases like cholera, leprosy, tuberculosis, malaria, kala-zar, lymphatic filariasis, which used to cause serious concern, have now been controlled

to a significant degree and are being targeted for elimination.

In recent years, the unfolding of Mission Indradhanush and schemes like Swachch Bharat, Ujjawala Yojna, Ayushman Bharat and Poshan Abhiyan are going to have tremendous impact on various health indicators.

Equitable Access to Healthcare

The public health landscape of a state, nation or country is ever evolving. There is always a need to balance the research efforts between various fields, with the existing availability of resources to achieve equitable access to healthcare and health services. The



Mission DELHI: Tackling heart attack within the first 30 minutes



Mobile Stroke Unit: Providing treatment at the doorstep

Indian Research Fund Association (IRFA) was established with this purpose before independence, in 1911. The primary objective of the IRFA was to carry out medical research in tropical diseases like malaria, tuberculosis and plague.

Post-independence, the Indian Research Fund Association was renamed as the Indian Council of Medical Research (ICMR), under the aegis of the Ministry of Health and Family Welfare. ICMR, in its new avatar, has grown into a pan-India organisation with 27 institutes, over a hundred field Stations/Units and a network of laboratories.

As the leading medical research institute in India, ICMR has become the apex body for planning, formulation, implementation coordination. promotion of biomedical research. ICMR today carries out pioneering work in areas of epidemic monitoring



Team working in COVID testing

control, maternal and child health, nutrition, lifestyle diseases and occupational health. The research carried out by the various ICMR institutes forms the basis of various government programmes and medical protocols.

ICMR is supporting Ayushman Bharat and ensuring a sustainable and cost-effective model through its ongoing programmes like health technology assessment, standard treatment workflows and national list of essential medicines and diagnostics. These programmes would serve as an important tool in prioritising national health spending and providing a uniform guideline to ensure quality healthcare services across the nation.

The health research infrastructure built by ICMR has been critical in turning around the country's health indicators, reduce the spread of infectious diseases, combat noncommunicable diseases, save lives and reduce the impact of health challenges. The lead taken by the Council in India's



ICMR team conducting COVID-19 Sero-survey

research response to the COVID-19 pandemic is an example of ICMR's commitment in the area. In addition to developing the nation's first indigenous vaccine against COVID-19, ICMR has made and approved testing kits, built a network of laboratories across the country with over 2600 labs, developed COVID-19 protocols, conducted serosurveys and essentially informed the policy response for the disease in India.

In addition to this, to achieve the goal of improving the healthcare system in the country through research programmes, **ICMR** encourages capacity building. Through its research grants and fellowships, the organisation supports innovative research in the field of medicine. The 27 institutes under the umbrella of ICMR cover medical research at a pan-India level and offer both region and disease-specific



Scientists working in High Containment Facility at NIV, Pune

expertise to state health ministries and departments.

ICMR also consistently collaborates with international partners to exchange ideas and work jointly on major research programmes thereby contributing to both extramural as well as intramural research in India. ICMR research programme are aligned with national health priorities and meant to serve the people of India.

Viral Outbreaks and Epidemics

Epidemics come at a great economic and social cost, not to mention loss of precious human lives. India has witnessed a multitude of epidemics ranging from water-borne diseases like cholera and vector-borne diseases like malaria. Epidemic containment and providing cure to the affected incurs great economic cost and loss of productivity. ICMR has led surveillance of critical diseases, conducted investigations and developed evidence to tackle numerous outbreaks and epidemics.

The organisation has contributed to the study of various virus-induced diseases like acute hemorrhagic conjunctivitis, rabies, polio, etc. ICMR also played a prominent role in India's biggest public health achievement of control and eventual elimination of polio. The country which was once the epicenter of polio in the world has now officially eliminated the disease.

Post H1N1 outbreak, ICMR recognised the gap and took lead to become self-sufficient in tackling the emerging and reemerging infectious diseases. It set up a network of Viral Diagnostic and Research laboratories (VRDL) across the country. ICMR also set up Asia's first BSL-4 laboratory to conduct research on the



Community based survey for epidemiological study in vector borne diseases

most infectious viruses in a contained environment. The combination of BSL-4 with a vast network of VRDL has resulted in successful investigation and containment of CCHF, Nipah & Zika. Not even one sample was sent outside the country.

During the COVID-19 pandemic too, these proved to be an asset in establishing the diagnosis of the novel Coronavirus as well as isolating and culturing it for developing a vaccine.

ICMR has also geared up to be future ready. An international platform 'RESEARCH - Regional Enabler for South East Asia Research Collaboration for Health' in collaboration with WHO and 10 other countries of South-Asian region has been set up to effectively combat emerging and re-emerging infectious diseases in South East Asia region as well as to tackle cross border infections. With increased interaction between humans and animals – domestic and wild, and influenced by climate change, human health can no longer be seen in isolation. To understand the complexities between animal health,



Asia's First BSL-4 laboratory at ICMR-NIV, Pune - played a pivotal role in tackling COVID-19, Nipah, Zika and other viral outbreaks

human health and the environment. a National Institute for One Health is being set up at Nagpur. The Institute will address the issue of zoonosis and anti-microbial resistance through intersectoral collaboration.

Communicable Diseases

Millions of lives in India have been lost due to communicable diseases like malaria, cholera, Kala azar and HIV in the past. Over the years, ICMR through its various research institutes has been working to tackle major communicable diseases in the country, with proven success.

ICMR pioneered the development of commercial diagnostic kits against dengue and chikungunya, direct antibody tests for early diagnosis of Kala-azar and timely development of vaccines against the Kyasanur Forest Disease (KFD) and Japanese Encephalitis. ICMR also demonstrated for the first time that home-based treatment is as successful as hospitalbased treatment for tuberculosis. The Council further simplified tuberculosis treatment by laying the foundation of the Directly Observed Treatment Short Course (DOTS) in 1964. Recently, ICMR has developed TruNAT, a cost effective, PHC friendly diagnostic for TB that has been recommended by WHO after successful multi-country trial. The same platform has also been deployed for Point-of-Care testing in Nipah, Leptospirosis & COVID-19.

Other communicable diseases like Malaria, Leprosy, Lymphatic filariasis and Cholera have also



Environmental surveillance for viral outbreak by NIV team

been under the purview of the organisation's research areas. Several malaria elimination demonstration projects (Konkan Railways, CCMP in Odisha, MEP in Mandla) have successfully shown 85-90% decrease in malaria cases. To combat death and illness caused due to diarrhea, ICMR demonstrated the efficacy of Oral Rehydration Therapy. It established that Home Available Fluids (HAF) such as sherbet or tender coconut water and pressed rice water were effective.

Following the successful elimination of polio in India, ICMR is now working towards eliminating diseases like Kala-azar, filariasis, leprosy, malaria and tuberculosis in mission mode by setting up multistakeholder platforms, India Research Consortium (ITRC) and Malaria Elimination Research Alliance (MERA) India. Over these years, ICMR has continued to perform research and develop strategies for treatment, prevention and control of enteric infections and HIV/AIDS that threaten the nation's health.

There has been continuous influx of evidence into national policy decisions, be it the malaria drug policy change in North-East (due to demonstration of rising resistance towards Chloroquine) or addition of triple drug therapy for accelerated elimination of lymphatic filariasis from the hotspot-areas of the country.

Non-Communicable Diseases

Non-communicable Diseases (NCDs) are not contagious, but they pose a



Field Station at Sagar (Shimoga) in Karnataka for study of KFD

great risk to the overall wellbeing of the society. In the recent past, such diseases have grown exponentially. The burden of non-communicable diseases weighs heavily, since they can go undiagnosed and lead to severe decline in individual productivity and even death. Early detection and prevention of non-communicable disease is one of the key focus areas of ICMR.

ICMR has dedicated institutes to carry out research on various noncommunicable diseases like cancer, environmental and occupational hazards, disease informatics and implementation research. **ICMR** also maintains national registries for cancer, stroke, cardiovascular diseases, diabetes, etc. Due to the efforts of the national cancer registry programme, cancer has been made a notifiable disease in 12 states.

ICMR's researches have often shape health policy mechanisms. For example, an India State-Level Disease Burden Initiative was launched in collaboration between ICMR, the Public Health Foundation of India (PHFI), Institute for Health Metrics and Evaluation (IHME), and senior experts and stakeholders from nearly a hundred institutions across India. The data estimates were based on the analysis of all identifiable epidemiological data from India over a quarter of a century, led by ICMR and the collateral aided in informing health planning to reduce health inequalities prevalent amongst states in India. This study led to the identification of the rising burden of NCDs thus guiding states to develop more nuanced policies.

another major initiative, ICMR along with the Cardiology and Emergency Medicine departments of All India Institute of Medical Sciences (AIIMS), launched a pilot project called Mission DELHI (Delhi Emergency Life Heart Attack Initiative) where people would be able to call prescribed tollfree numbers for a motorbike-borne emergency medical assistance unit in the eventuality of a heart attack or chest pain.

ICMR has also successfully initiated mechanisms to provide stroke treatment through state-of-the-art Mobile Stroke Unit (MSU) in Tezpur and Dibrugarh area of Assam, India. The MSU was a commendable piece of work in light of the ongoing pandemic.

Nutrition

made **ICMR** has salient also nutrition, contributions in like assessment of nutritive values commonly consumed Indian foods and studies of nutrient deficiency disorders. It has led intensive work in areas like deficiency, anaemia, blindness where it has addressed gaps in diagnostics and affordable treatment mechanisms to tackle the diseases paving the way for implementation of national programmes in these areas.

ICMR dispelled the myth that protein deficiency is the main reason malnutrition and highlighted calorie gap as the actual bottleneck Protein Energy Malnutrition (PEM). The organisation also laid the foundations for Recommended Dietary Allowances (RDA) which is used as guiding information for RDA values by government organisations and other statutory bodies till date.

ICMR has pioneered other inspiring work in the field of nutrition - from assessing dietary intake of individuals, households and nutritional profiles of different communities through periodic surveys to developing simple and sensitive biochemical indicators for assessment of vitamin nutritive and pathogenic mechanisms of various nutritional deficiency syndromes, to identifying and establishing growth norms for Indian children and even generating database on nutritive values of over 650 Indian foods, which is used by various national organisations, planners and academic research institutions. Now it is working in close partnership with the National Nutrition Mission to improve nutrition related deficiencies across India.

Reproductive, Maternal and Child Health

India has a high burden of morbidity and mortality in women, children and infants. ICMR has pioneered exemplary research in maternal and child health. In 1981, ICMR pioneered in vitro fertilization and successfully supported the delivery of the first Test Tube baby in India - Harsha - on 6 August 1986. This was a landmark step in the field of infertility treatment and placed India on



First scientifically documented Test Tube Baby Harsha – a contribution of ICMRNIIRH in collaboration with KEM Hospital, Mumbai

the world map in the arena of assisted reproductive technologies.

ICMR has also developed effective indigenous diagnostic kits for the detection of Chlamydia trachomatis, pregnancy detection, sperm quality assessment and fertility assessment tests to assist quick diagnosis and intervention. A quarter of India's population constitutes adolescents. Majority of young and growing children have poor or limited knowledge and lack of awareness on sexual and reproductive health. The ICMR-NIRRH, Mumbai, developed service delivery models for adolescent reproductive and sexual health and guidelines on sexually transmitted infections, to help build awareness among the youth of the country.

ICMR's contribution in last 75 years

S.No.	Activities	Relevance
1.	Network of 27 disease-specific institutes and more than 100 field Stations/Units	Evaluation of new drugs, insecticides, vaccines, devices, diagnostic kits & other interventions relevant for every corner of the country
2.	Clinical Trial Registry – India (CTRI)	 Registers clinical trials conducted in India to improve transparency and accountability, ensure conformation to accepted ethical standards and reporting of all relevant results of the trials. ICMR also provides ethical guidelines for clinical trials
3.	National Cancer Registry Programme	 Generate reliable data on the magnitude and pattern of cancer in India Undertake epidemiological studies based on results of registry data Help in designing, planning, monitoring and evaluation of cancer control activities under the National Cancer Control Programme (NCCP) Develop training programmes in cancer registration and epidemiology
4.	Surveillance networks (IDSP, rotavirus, polio, Antimicrobial resistance, etc.)	Generate timely and geographically representative data on the clinical, epidemiological, and pathological features of several diseases in Indian population
5.	Nutrition	 Identified priority areas, conducted research in a multicentre mode and found effective, practical, economically viable and sustainable solutions for nutrition related problems Nutritive value of Indian Foods and Food Fortification are landmark achievements of ICMR.
6.	Support in outbreak/epidemics/ pandemics/National Emergencies	 Leading the fight against COVID-19 Successful containment of Nipah and Zika Virus Surveillance of health impact due to Indian Ocean Tsunami in 2004 (NIE, NIRT, NICED, CRME, VCRC, RMRC-PB) Environment and health impact assessment for Bhopal Gas Tragedy, 1984 (NIOH, NIMS, BHRMC, NIP, NICPR) Earthquake in Gujarat, 2001 (NIMR, DMRC) Supercyclone in Odisha, 1999 (NIMR)
7.	Inputs for policy implementation	 Covaxin for COVID-19 DOTS for Tuberculosis UMDT for Leprosy Malaria Drug Policy in North-East ORS implementation in diarrhea
8.	Guidelines/Regulations	 National Guidelines for Accreditation, Supervision and Regulation of ART Clinics in India Ethical Guidelines for Biomedical Research on Human Participants Guidelines for Good Clinical Laboratory Practices Guidelines for Safety Assessment of Foods Derived from Genetically Engineered Plants Intellectual Property Rights Policy Guidelines for Stem Cell Research Dietary Guidelines for Indians
9.	Isolation/characterisation of new pathogens	 Asia's first BSL-4 laboratory developed Cholera strain O139 Kyasanur forest disease (KFD) Leptospirosis Paragonimiasis
10.	Research support to Medical Colleges	 Funds majority of research in medical colleges Short Term Studentship Program to promote interest and aptitude for research among medical undergraduates
11.	Capacity building	• Generate and nurture human resources for health research activities through fellowships (JRF, SRF, RA, STS) and trainings/workshops



Community study in nutrition during the 1960s

ICMR has also been a pioneer in the validation of contraceptive methods for incorporation in national programme. It has also led decisive work in contraception and family planning including research on efficacy of postpartum Intrauterine Devices (IUDs), evaluation of improved contraceptive implants, among others.

Promoting Health Research and **Ethical Practices**

Across all these years, ICMR has paid close attention to ensuring and promoting ethical practices in medical and health research by means of correct capacity biosafety infrastructure, building of doctors and scientists and much more. ICMR's guidelines related to ethical standards for human research are well recognizsed. The Central Ethics Committee on Human Research, a national level committee chaired by distinguished luminaries, has played a critical role in guiding ICMR policy and overcoming complex ethical



Demonstration by VCRC staff on the use of Insecticide treated Bed Nets for personal protection to the community in a tribal village in Koraput District, Odisha

It has now become mandatory to follow the National Ethical Guidelines for Biomedical & Health Research and to register ethics committees with the Department of Health Research under the New Drugs & Clinical Trial Rules, 2019. The ICMR Bioethics Unit at NCDIR. Bengaluru, has been recognized as the first centre in WHO South-East Asia Region to become a WHO Collaborating Centre for Strengthening Ethics in Biomedical Research. Recently, ICMR added another feather to its cap when in April 2020, India became one of the first countries in the world to release Guidelines for Ethics Committees reviewing research during the COVID-19 pandemic.

Regional Health Issues and Tribal Health

Habitat shapes our lives and the food we eat. Rural and urban habitats influence our diet and lifestyle, which



Laboratory facility at RMRC, Port Blair, Andaman & Nicobar

susceptibility to particular illness or disease. In India, apart from rural and urban habitats, some communities also live in isolated remote with varying terrains and ecosystems. Such tribal people have different health care needs.

ICMR conducts research on health issues of the tribal populations of the country, including nutritional disorders, common communicable and noncommunicable diseases, environmental health problems, etc. ICMR played a pivotal role in addressing the problem of fluorosis in the tribal hinterland of Madhya Pradesh leading to a drastic decrease from 51% prevalence of disease to 2.6% post-intervention.

ICMR also has four Regional Medical Research Centres (RMRC) at Gorakhpur, Port Blair, Dibrugarh and Bhubaneshwar. These regional centres work towards regional health challenges in these areas. For instance, the JE/AES disease, which was claiming the lives of thousands of children in the Gorakhpur area, now with a combination of ICMR research and state-led initiatives has been drastically reduced. In the Andamans, ICMR helped in diagnosis and control of leptospirosis (earlier known as Andaman Haemorrhagic Fever), a zoonotic infection that was haunting the island. Similarly, lymphatic filariasis is on the verge of elimination from Nancowry Islands due to the implementation of DEC-fortified salts.

Committed to Research

Since its inception, ICMR has been an enabler of success for improved and accessible health systems across the nation. Through its research capacity and several areas of expertise, it has played a pivotal role in establishing evidence-based theories and diagnostics that have directly impacted government schemes as well.

The apex organisation has been instrumental in improving the health landscape of the country over the years and ever since Independence. ICMR is committed to strengthen its research to benefit the society in the future too.





75 YEARS OF INDIA'S **INDEPENDENCE AND 80 YEARS OF CSIR**



Shekhar C. Mande Secretary, Department of Scientific & Industrial Research Director-General, Council of

Scientific & Industrial Research



G. Mahesh Senior Principal Scientist Council of Scientific & Industrial Research



Geetha Vani Rayasam Senior Principal Scientist Council of Scientific & Industrial Research

EVENTY-FIVE years of Indian independence, being celebrated nationwide as Azadi ka Amrit Mahotsav, is a momentous occasion for every Indian citizen. This is an occasion to remember and reflect on the sacrifices made by the millions of Indians in attaining our freedom. It also is a time to look back at the achievements and progress that we have made in these seventy-five years gone by. It is also an opportunity to envision a future that will have, among other things, science, scientific and traditional values at the core of India's development in the coming years.

India has made giant strides in its 75 years in almost all sectors. Be it health, education, transportation, communication, agriculture, science, and many other sectors, India has done very well. That said, there is always scope for improvement, and we need to take giant strides forward. India has a teeming youth population that allows the nation to dream of a vibrant future.

It is a future that is laced with the raw energy and sparkling enthusiasm of the youth of this country.

CSIR, the early years

The science and technology ecosystem of India, primarily shaped by the efforts and programmes of the Ministry of Science and Technology, has done exceedingly well in embedding science into the nation's development. And when one speaks of science in India, the Council of Scientific and Industrial Research or CSIR is inextricably linked to the hundreds of technologies that CSIR has given to the nation. The 75th year of Indian independence is even more special to CSIR because CSIR enters its 80 years of gloriously serving the Indian society through S&T interventions.

The CSIR came into operation on 26 September 1942. Dr S.S. Bhatnagar, the first Director-General of CSIR. is revered as the father of research laboratories in India. In 1943, the

Governing Body of CSIR approved a proposal of Dr S.S. Bhatnagar to establish five national laboratories the National Chemical Laboratory, the National Physical Laboratory, the Fuel Research Station, the Glass & Ceramics Research Institute and the National Metallurgical Laboratory. Today, thirty-seven CSIR laboratories, including the 12 laboratories founded by Dr S.S. Bhatnagar, play a vital role in India's science and technology programmes.

Since early times, scientific research for technology development that can catalyse the growth of Indian industries was embedded in CSIR's operations. CSIR and its laboratories have evolved hundreds of technologies and products founded on science, scientific principles and scientific values. And many of these technological developments have come in the face of challenges and regimes of technology denials to India.

Although a large part of the CSIR budget comes from public funding, considerable financial resources are raised from other sources, especially industries. When CSIR was established in 1942, CSIR appealed to the society for funding it, and the public donated a sum of Rs 44,000, which was a big sum of money at that time. This might be perhaps the earliest crowdsourcing of its kind to fund scientific research and development. Even at that point in time, industrial houses like Tata helped CSIR by funding. It is a matter of pride that CSIR partners with these and other industries to this day. Several decades later, CSIR and Cipla would give the world several low-cost anti-HIV drugs, and CSIR and TATA would develop a novel COVID-19 diagnostic kit.

Laying the foundation with basic research and industry association

Investment in basic science is essential. The fruits of such investment can be reaped in the form of technologies at the right time. The most recent story that exemplifies this is FNCAS9 Editor-Limited Uniform Detection Assay (FELUDA), CSIR's COVID-19 CRISPR-Cas based diagnostic kit. The CSIR-Institute of Genomics and Integrative Biology (CSIR-IGIB) had been working on the CRISPR-Cas based diagnostic kit for sickle cell anaemia for quite some time. When COVID-19 hit, the CSIR-IGIB team could quickly reorient this technique for developing a COVID-19 diagnostic kit. Not just developing the technology, but in partnership with TATA, CSIR has been able to go through the value chain to deliver the product in a record time to the market.



CSIR-IICT developed a cost-effective process for Favipiravir

CSIR has had a long and fruitful association with a large number of industries. During the most difficult and critical time when the COVID-19 pandemic hit India last year, CSIR laboratories churned out nearly one hundred COVID-19 technologies in a short span of six months. What is important is, CSIR laboratories were able to transfer over 60 technologies to many industries.

CSIR has had a long association with the pharmaceutical companies, and it takes pride in being the fountainhead of the generic pharma industry in the country. India produced some of the most affordable anti-HIV drugs. The credit for this goes to two of the CSIR laboratories, the CSIR-National Chemical Laboratory (CSIR-NCL) and the CSIR-Indian Institute of Chemical Technology (CSIR-IICT) that made the drug formulation process very cheap and handheld the pharma industry to manufacture the drugs at low cost and CSIR went global with these drugs. History repeated itself when during the COVID-19 pandemic last year, CSIR-IICT developed a cost-effective process

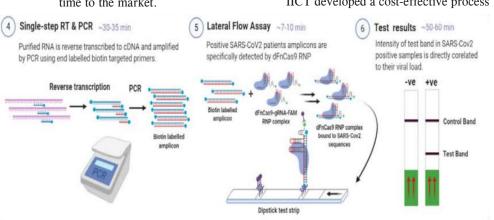
for Favipiravir, and the process was transferred to Cipla. The drug was brought into the market in a quick time.

India has a rich legacy of traditional knowledge. Many of the ancient medical practices have been documented. However, these need to be validated from a modern scientific perspective. In this regard, CSIR has been involved in clinical trials of several ayurvedic formulations, and we have introduced several plantbased drugs. It is a matter of pride that during COVID-19, the first-ever phytopharmaceutical clinical trial was brought forth by CSIR in collaboration with Sun Pharma and the International Centre for Genetic Engineering and Biotechnology (ICGEB).

CSIR today is at the forefront to examine traditional medicines from the modern and scientific perspective, and the clinical trials in progress along with the Ministry of AYUSH will go a long way in validating the Indian systems of medicines such as those from the Ayurveda, Siddha and others from a modern scientific perspective.

Technologies of the early years

CSIR, being one of the earliest S&T organisations in the country, was naturally bound to the challenges that a newly independent country faced. CSIR needed to participate in all those challenges. For example, when the Green Revolution was happening, of the immediate challenges was mechanisation in agricultural operations. The **CSIR-Central** Mechanical Engineering Research Institute (CSIR-CMERI) in Durgapur



FELUDA, CSIR's COVID-19 CRISPR-Cas based diagnostic kit



Swaraj tractor built by CSIR-CMERI

made the first tractor, the 20 HP Swaraj, licensed to Punjab Tractor Ltd. Likewise, when agri-pesticides had to be made, the CSIR-Indian Institute of Chemical Technology (formerly RRL, Hyderabad) produced several pesticides. These are a couple of integral roles that CSIR played during the Green Revolution.

CSIR's indelible voters' ink is an oft-told story, one that will always remain a cherished contribution of CSIR, not just because of its innovation but because it touches every voting adult in this greatest of democracies. Beginning with leaving an indelible mark on the fingers, hundreds of CSIR products and technologies have footprints on the lives of every Indian.



Indelible voters' ink – A CSIR innovation

In the 1970s and 1980s, when the buffalo milk had to be converted into powder form for transportation and as baby food, the CSIR-Central Food Technological Research Institute (CSIR-CFTRI) developed the required technology. That was a path-breaking innovation, and many do not realise that the Amul milk powder that is so widely used to feed infants is based on a CSIR technology.



CSIR's Kisan Sabha App connects farmers directly to transporters

During 1980, an era of technology denials, India faced difficulties supercomputers purchasing for academic and weather forecasting purposes. CSIR took upon challenge, and the denial saw the arrival of CSIR's supercomputer. In 1986, the CSIR-National Aeronautical Laboratory (now National Aerospace Laboratories) initiated the Flosolver project, a parallel computing product for computational fluid dynamics. This outstanding effort had a far-reaching impact on how the world looked at India in that era of technology denials.

CSIR's Central Mechanical Engineering Research Institute in Durgapur played a vital role in designing the Mark II hand pump to draw groundwater. The installation of lakhs of Mark II pumps alleviated the problem of drinking water in many rural areas. To this day, this CSIR technology quenches the thirst of people in rural areas.

CSIR and innovations

India is a land of innovations. We see innovations all around us. From school children to the elderly, we have seen many examples of simple contraptions devised primarily to ease the way of doing things. Some of these frugal innovations serve immense practical purposes. On the other hand, science and technology-led innovations are also fundamental to any society. We have witnessed such S&T based innovations in various sectors, including strategic sectors such as space and defence.

Recently, CSIR-Centre for Cellular and Molecular Biology (CSIR-CCMB), in collaboration with the Indian Institute of Rice Research (IIRR), developed an improved variety of Samba Masuri rice with low Glycemic Index (GI) and blight resistance. Rice with low GI is considered suitable for people with diabetes. Consumption of food with low GI results in the slow release of glucose into the bloodstream, reducing the ill effects of diabetes. The CCMB-IRRI rice variety has the lowest GI of 50.99 against the usual 53 to 70 in several rice varieties. And being blight-resistant, it has a better yield and being a suitable grain type; the variety has enhanced its market potential and profit for farmers.

During the COVID-19 induced lockdown, when the farmers had difficulty transporting their produce to the vegetable markets or mandis, CSIR developed the Kisan Sabha App that connects the farmers directly with the transporters. The two key partners, the transporter and the farmers are connected directly without middlemen. Available in twelve Indian languages, this has brought about efficiency in the movement of agricultural produce and, without the middlemen, the profit margins of both the farmers and the transporters have increased.

India is the third country in the world to have its indigenous probe for DNA fingerprinting. It is a matter of pride that the DNA fingerprinting technology was developed by CSIR's Centre for Cellular and Molecular Biology. The technology has enabled



Ksheer Scanner developed by CSIR-CEERI for checking milk adulteration

providing justice to people, including those in many high profile criminal cases. Due to CCMB's efforts, the Centre for DNA Fingerprinting and Diagnostics (CDFD) under the Department of Biotechnology came into being.

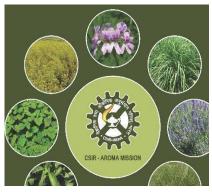
To detect adulteration in milk, CSIR-Central Electronics Engineering Research Institute (CSIR-CEERI) has developed Ksheer Scanner. CSIR also has a technology for detecting adulteration in mustard oil. CSIR gave the world, Saheli, the first non-steroidal once-a-week oral contraceptive pill. The pill is part of India's family planning programme and is exported to several countries globally.

Parboiling of rice is an ancient traditional process of India. As we know, the parboiling of rice has many advantages. It reduces grain breakage during milling, greatly improves the vitamins and other nutrients in the polished rice grain, increases the oil in the bran, reduces proneness to insect infestation, changes the rice's cooking and eating quality, and reduces the rice's quality loss of nutrients during cooking. The technology for parboiling and drying plant - 4 tonnages per hour (TPH) capacity has been developed at CSIR-Central Food Technological Research Institute, Mysore, using the appropriate equipment for optimal product recovery of the right quality.

The CSIR Heeng Story

In the year 2020, CSIR introduced the cultivation of asafoetida or heeng in India for the first time. Despite India being the largest consumer of heeng globally, this household spice is not cultivated in India and is imported from Afghanistan, Iran and other countries. CSIR's Institute of Himalayan Bioresource Technology (CSIR-IHBT) carried out ecological niche modelling to investigate landscapes that meet the ecological requirements of the asafoetida plant. Based on these studies, the Institute identified Ladakh, Himachal Pradesh, Jammu & Kashmir, and Uttarakhand as suitable regions for heeng cultivation in India.

The challenging process of introducing the plant in India began in 2017. CSIR-IHBT contacted several countries for obtaining the requisite



plant material. The ICAR's National Bureau of Plant Genetic Resources (NBPGR) issued an import permit for bringing the heeng seeds to India. After that, several scientific interventions were introduced by CSIR-IHBT right from germination through nursery raising and transplantation and field trials in different locations. Institute did hydroponic cultivation and mass propagation of heeng using tissue culture techniques. Molecular and biochemical studies such as DNA barcoding for authentication of the plant species, volatile compounds and metabolites profiling were also carried out.

Be it COVID-19 technologies or the introduction of heeng, CSIR is focused on the nation's Atmanirbhar Bharat vision.

Aroma mission of CSIR

A more recent contribution of CSIR that has touched the lives of thousands of farmers, improving their profit and creating hundreds of entrepreneurs is the Aroma Mission. CSIR introduced and hand-held the cultivation of medicinal and aromatic plants in many

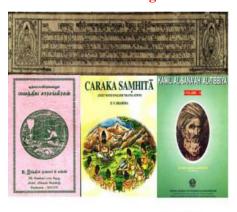


The Aroma Mission of CSIR has improved farmers' incomes

regions of the country, including the remote northeast regions and facilitated setting up distillation units for farmers to produce the aromatic oils.

CSIR also played a vital role in mentha, lavender and saffron cultivation in the country. The Aroma Mission has been a very successful programme of the country that, in the coming years, will pan out across the country and have hundreds of acres and thousands of farmers cultivating and producing medicinal and aromatic plants and developing plant-based products thus enabling higher earnings and profits.

Intellectual property and traditional knowledge





SANSKRIT & TIBETAN VERS ASTĀNGA-HRDAYA OF VĀGHI

TKDL developed by CSIR documents India's traditional knowledge

Lagunage de Lengus andun

In the 1990s, CSIR, through its rather aggressive intellectual property protection efforts, laid the foundation of IP protection in the country. CSIR, while carrying out cutting-edge scientific research, is also very mindful of the traditional systems and the ancient scientific knowledge of this country. When attempts were made to misappropriate some of India's



Tejas, light-weight combat aircraft, developed by CSIR-NAL

traditional knowledge concerning neem, turmeric, basmati and so on, India, led by CSIR, fought nothing less than a battle to prevent the misappropriation of India's traditional knowledge.

This also led CSIR to set up the Traditional Knowledge Digital Library (TKDL), which now has been twenty years in existence. TKDL continues to document India's traditional knowledge and pushes back or fights any attempt by anyone to appropriate India's ancient expertise as their own.

CSIR and the strategic sectors

Defence and space are two exceedingly important strategic sectors that have implications for national security as well. While India has very efficient and dedicated space and defence programmes and systems, institutions such as the CSIR also contributed to these sectors.

Head-Up Display (HUD) is an essential aid to aircraft pilots, especially in fighter aircraft. It is a transparent display that presents data without requiring the pilot to look away from their usual viewpoint. HUD displays flight information such as altitude, airspeed, angle of attack, navigation, weapon aiming and other flight information in the collimated form so that the pilot can view the information with his head "up" and looking forward, instead of looking down on other instruments mounted in the cockpit. This high-tech system has been developed by the CSIR-Central Scientific Instruments Organisation (CSIR-CSIO) in Chandigarh. CSIO began developing the technology from scratch after the UK, USA, France, and Israel declined to share it with India. This technology was first adapted for the indigenous light combat aircraft Tejas.

And talking of lightweight combat aircraft, one of the challenges in the aircraft industry has been to lower the aircraft's weight. This is done by using lightweight materials such as composites. It is no small achievement that Tejas, the light Indian aircraft, comprises composite materials that are 45% of its weight. Out of this, about 25% was designed and developed at CSIR-National Aerospace Laboratories (CSIR-NAL). Over the years, CSIR-NAL has developed many other critical technologies for Tejas and the aviation sector in general.

Autoclaves are required manufacture superior quality structural components containing high fibre volume fraction and low void content. The autoclave is a pressure vessel that provides the curing conditions for the composite where vacuum, pressure, heat-up rate and cure temperature are controlled. High processing pressures allow the moulding of thicker sections complex shapes. Honeycomb sandwich structures can also be made to a high standard, typically at lower pressures.

CSIR-NAL has successfully Indigenous developed state-of-art to process Autoclave Technology advanced lightweight composites integral to modern-day civil and military airframes. The autoclaves' size ranges from smaller lab-scale to very large sizes up to 5m working dia and 12m working length. These meet the requirements of the aerospace industry, research and educational institutes.

In the last 7-8 years, several autoclaves have been supplied to various organisations in the strategic sector and academic institutions. About 500 million rupees worth of business has been generated as of date. The autoclave technology has successfully

promoted the local ecosystem, mitigating imports and creating millions of employment man-hours.

Large sums of money are spent every year on aviation fuel. To lower the cost and also reduce pollution, CSIR has been working on developing biofuel. In December 2018, the Indian Airforce Pilots flew India's first military flight using blended bio-jet fuel. The fuel, made from Jatropha oil, was processed at CSIR-Indian Institute of Petroleum (CSIR-IIP), Dehradun. It was a proud moment for CSIR and the country when the first biofuel flight of the Indian Air Force did a flypast on India's Republic Day in 2019. Biofuel technology holds a lot of promise as it is carbon-neutral, reduces air pollution, and is likely to bring down import bills on crude oil.

From space to the seas

The year 2021 marks India's 40th scientific expedition to Antarctica. The Indian journey marks four decades of the country's scientific endeavour to the southern white continent. The Indian Antarctic expeditions began in 1981. As we know, the Indian Antarctic programme built three permanent research base stations in Antarctica - named Dakshin Gangotri, Maitri, and Bharati. As of today, Maitri and Bharati are operational.

Currently, the National Centre for Polar and Ocean Research (NCPOR), Goa, manages the Indian Antarctic programme. However, we might recall that the first Indian expedition to Antarctica was launched from CSIR-National Institute of Oceanography (NIO), Goa, which comprised 21 scientists and support staff led by Dr S.Z. Qasim, the then Director for the CSIR-National Institute of Oceanography.

CSIR-National Institute of Oceanography has been undertaking scientific expeditions in the oceans for several decades now. Even during the ongoing COVID-stricken year, CSIR-NIO undertook the largest scientific expeditions ever with 30 scientists that will cover 11,000 nautical miles in 90 days aboard the NIO research vessel Sindhu Sadhana.

CSIR and the leather sector

leather industry occupies prominence in the Indian economy because of its massive potential for employment, growth and exports. The leather and footwear industry directly employs approximately 4.5 million people, with more than 30% being women. The CSIR-Central Leather Research Institute (CSIR-CLRI) has interwoven its research efforts to meet industry training needs since the time

industry was operating in the cottage sector. The Institute has given several technologies to the leather sector. Some of the latest technologies include waterless chrome tanning process, electro-oxidation based zero wastewater discharge, smart leathers, compost for agricultural applications, product for dry tanning, high-value collagenous products and activated carbon from trimming and fleshing wastes, preservation-cum-unhairing process and biogas for energy conservation. The transfer of such technologies to the leather and leather product industries (existing and start-ups) has increased the existing employee base and new job creation.

Science and the public

Apart from its intense R&D efforts, CSIR has been engaged in inculcating scientific temper in school children. The CSIR's Jigyasa program is a unique platform for bringing scientists and teachers to nurturing young minds. This program envisages opening up the national scientific facilities to school children, enabling CSIR scientific knowledgebase and facility to be utilised by schoolchildren. This model of engaging school children also has been extended to other schools in addition to KVS. To date, over 3,00,000 school students have participated in the Jigyasa programme.

The engagement of scientists and scientific institutions with the public is vital. It is the duty and responsibility of scientists to communicate and share their scientific research with their peers and the public. The citizens have a right to know, and importantly, such communication efforts can inspire the younger generation to take up science. CSIR is conscious of these facts and has a system in place for public engagement and outreach. During the COVID-19 pandemic, outreach became a regular feature, and we had numerous webinars in several Indian languages that addressed various aspects of COVID-19. We received very favourable responses from the public. Recently, we have initiated a webinar series that is showcasing the



CRIR-NIO's RV Sindhu Sadhana undertook the largest scientific expedition recently



Students interacting with former S&T Minister and President of India as a part of Jigyasa programme

success stories of CSIR. We plan to showcase at least 80 success stories as a part of the *Azadi ka Amrit Mahotsav* celebrations.

Fostering and catalysing technology development

In addition to doing its research and technology development, CSIR fosters and catalyses technology development by researchers and technologists in other organisations. This is done through the different programmes. One such programme is the New Millennium Indian Technology Leadership Initiative (NMITLI). NMITLI seeks to catalyse innovation centred scientific and technological developments as a vehicle to attain for Indian industry a global leadership position, in selected niche areas in a true "Team India" spirit, by synergising the best competencies of publicly funded R&D institutions, and private academia industry. This most extensive public-private partnership R&D programme in the country has given numerous innovative technologies.

A recent innovation has been the development of dental implants. Under the NMITLI funded programme, researchers from the Maulana Azad Institute of Dental Sciences and the Indian Institute of Technology developed dental implants that cost half the price of the imported implants.

CSIR-Central Salt and Marine Chemicals Research Institute's spent wash management technology that recovers potash, a beneficial fertiliser, from the waste of sugarcane processing industries has also been noteworthy. This waste to wealth technology of CSIR-CSMCRI not only recovers valuable fertiliser but also lowers pollution and even yields cattle feed.

With CSIR entering its 80th year of existence, it is only natural that many CSIR institutes and laboratories are celebrating their own milestones. Earlier this year, CSIR-National Physical Laboratory (NPL) celebrated its 75th anniversary. Shri Narendra Modi, Honourable Prime Minister, graced the celebratory event and gave his inaugural address. CSIR-NPL has been the standards bearer of the country and, on its 75th anniversary, dedicated the National Atomic Timescale and Bhartiya Nirdeshak Dravya Pranali (Indian Reference Materials) to the Nation.

It is indeed heartening that CSIR has been receiving the support and patronage of India's highest offices. Such support strengthened by the decades of solid and long-lasting partnerships with Indian industries and the acknowledgement of the public of CSIR's contributions has kept the wheels of CSIR rolling for 80 long years now.

The contributions of CSIR to the nation are so vast and varied that the likelihood of a direct or indirect CSIR footprint in any sphere is very high. Solid waste management, electricity generation from vegetable or plant

wastes, environmental protection, mine safety, construction of low-cost hazard resistant houses, unravelling India's underwater cultural heritage, one could go on.

Needless to say, CSIR has played a significant role in the 75 years of Indian independence. It is difficult to recount all the manifold contributions of CSIR of its last eighty or so years in a few pages. In recent years, we have initiated steps to transform CSIR into a globally competitive organisation. The transformation entails a series of essential changes to align to the changing times and fulfil new societal needs. Earlier this year, two national institutes, the CSIR-National Institute of Science Communication and Information Resources (CSIR-NISCAIR) and the CSIR-National Institute of Science, Technology and Development Studies (CSIR-NISTADS) were merged to form the CSIR-National Institute of Science Communication and Policy Research (CSIR-NIScPR). The creation of the new entity will strengthen S&T communication and S&T policy research in the country.

It is a long road ahead for CSIR, but what is certain is that a *New CSIR* for a *New India* will continue to play a critical role in India's science and technology ecosystem for many more decades to come.





DEPARTMENT OF ATOMIC ENERGY A PROUD SYMBOL **OF AATMANIRBHAR** BHARAT



Shri K.N. Vyas Secretary, Department of Atomic Energy; Chairman, Atomic **Energy Commission**



Dr M. Ramanamurthi Raja Ramanna Fellow, DAE

S the country approaches the 75th Anniversary of her Lindependence, it is indeed an occasion to celebrate and rejoice in her growth, progress, triumphs and achievements. Much has been accomplished in this long march after her rebirth, rising from the ashes of a fledgling and impoverished nation to become one of the largest economies of the world.

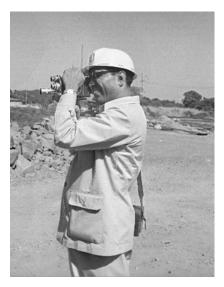
This task of nation-building has been a multi-pronged effort, facilitated by a sustained pursuit of growth across agricultural, infrastructural, energy, industrial, health and educational sectors amongst many others. The green revolution has made the nation selfsufficient in food grain production and visionary infrastructural developments have made it an industrial powerhouse. The nation today generates surplus electricity and a vast network of educational institutions have created a large pool of trained and expert human resources in science, technology,

arts, social sciences, management, humanities and many other domains.

Science and technology have played a pivotal role behind every facet of the growth and transformation of the nation over the last 75 years. Realising that the socio-economic progress of the nation hinges upon a robust science and technology infrastructure, a large spectrum of science and technology institutes and centres, including the Department of Atomic Energy (DAE), were set up across the country covering a gamut of domains requiring rapid progress, in order to propel the nation forward on a path of growth and development.

The Birth of DAE

Atomic Energy Commission constituted in 1948 soon independance and the Department of Atomic Energy was established in 1954. The mission statement of DAE is "To harness the power of the atom towards enhancing energy security, health security, food security and national security and to carry out developments and innovations in the use of Nuclear and Radiation Technology leading to economic and social benefits to the nation and a better quality of life to its citizens".



Dr Homi Bhabha during the construction phase of AEET

"As of today, it is estimated that the use of nuclear energy emissions avoids carbon roughly equivalent removing one-third of all cars from the world's roads."

Right since its inception, the visionary founder Dr Homi Jehangir Bhabha had the foresight to realise that the nation would need to be self-reliant in this sphere in order to gain complete mastery over the technology and forge an independent path. However, the foundations for science and technology R&D were poorly developed in the country at that stage. DAE, therefore, embarked on R&D programmes in numerous disciplines to support its programmes and has today emerged into a distinctive organisation, not only as a hub for R&D in all aspects of the nuclear fuel cycle but also for carrying out pioneering cutting-edge research work in associated areas of relevance.

Over the decades, this blend of activities and disciplines has led to the creation of several world-class institutes and units of DAE, comprising a vast network of 30 research centres, public sector units, aided institutes and service organisations around the country, having footprints spanning across multiple sectors such as energy, healthcare, agriculture, food preservation, drinking water, environment, etc. A few salient



Panoramic view of research reactors CIRUS and DHRUVA

aspects of our diverse contributions shall be touched upon in this article to provide glimpses of our vast range of activities and achievements.

Reactor Technology

Electricity is one of the foremost requirements to run the engine of growth. In the early days of the nuclear energy journey, many nations understood the importance of this powerful source of energy and embarked on nuclear energy programmes on a massive scale. India too decided to include nuclear energy in the energy basket of the nation to augment electricity production in the country.

The journey to master the technology began in right earnest with the setting up of the first research reactor in India and Asia - the Apsara

reactor at Trombay in 1956. Built in a short span of one year, this reactor gave the confidence, set the tone and provided the thrust for sustained growth of the Indian nuclear sector thereafter. A second research reactor CIRUS was built in 1960 and two power reactors were commissioned at Tarapur soon after. Two more research reactors Dhruva and Apsara-U as well as 22 power reactors have since been constructed, commissioned and being operated by DAE. Six power reactors are under construction and several more are in the pipeline.

Radioisotopes produced research reactors Dhruva and Apsara (U) are the key requirements in almost all applications of radiation technology - healthcare, agriculture and food preservation. Dhruva is the workhorse for the production of radioisotopes in the country. In addition to radioisotope production. material irradiation and neutron radiography facilities in the research reactors support the power programme towards material characterisation and diagnostics.

It is important to mention that nuclear power plants produce no greenhouse gas emissions during operation, and over the course of their life-cycle, they produce only 33% of the emissions per unit of electricity when compared with solar and 4% when compared to thermal power plants. As of today, it is estimated that the use of nuclear energy avoids carbon emissions roughly equivalent to removing onethird of all cars from the world's roads.



Kakrapar Atomic Power Station - Site view



APSARA (U) during the stage of final commissioning

Healthcare

There is minimal awareness of the enormous contributions being made by DAE in the healthcare sector of the country. Nuclear Medicine is a branch of medicine requiring the use of specialised pharmaceuticals known as radiopharmaceuticals, which are drugs tagged with radioactive elements and used for diagnostic as well as therapeutic purposes. Millions of procedures are being carried out every year using radiopharmaceuticals.

diagnostic The procedures produce functional imaging of the organ after the radiopharmaceutical is administered. This is akin to an online live image of the functioning organ such as heart, brain, kidneys, liver, etc., enabling precise pinpointing of the malfunctioning segment of an organ, aiding in accurate diagnosis therapy. Nuclear medicine procedures can diagnose abnormalities in the early stages of diseases such as cancer, neurological disorders and heart ailments, facilitating timely commencement of treatment. Just as novel drugs for better outcomes are being continuously developed by the pharma industry, DAE is involved in

"The cost for eye and liver cancer treatment in the country is expected to be considerably lowered with the availability of these new-age procedures at an affordable

Table 1: Recently developed Radiochemicals/ Radiopharmaceuticals/Freeze-dried kits

Sl. No.	Product Name	Application
1.	^{99m} Tc-Hynic-TOC/HYNIC- TATE	Neuroendocrine tumour imaging
2.	^{99m} Tc-HSA-Nanocolloid	Detection of sentinel nodes in breast and other cancers
3.	^{99m} Tc-UBI (29-41)	Infection imaging
4.	^{99m} Tc-HYNIC- [cyclo(RGDfk)] ₂	Malignant tumour imaging
5.	¹⁸ F-FDG	Cancer diagnosis
6.	Na ¹⁸ F	Bone imaging
7.	¹⁸ F-FLT	Tumour proliferation marker
8.	⁶⁸ Ga-DOTA-TOC/DOTA- TATE/DOTA-NOC	Neuroendocrine tumor imaging
9.	⁶⁸ Ga-PSMA-11	Prostate cancer imaging
10.	⁶⁴ CuCl ₂	Cancer imaging & ⁶⁴ Cu-radiopharmaceutical preparation
11.	¹³¹ I-Lipiodol/ ¹⁸⁸ Re-DEDC- Lipiodol	Liver cancer therapy
12.	¹⁸⁸ Re-HEDP/ ¹⁷⁷ Lu- EDTMP/ ¹⁷⁷ Lu-DOTMP	Bone pain palliation
13.	¹⁷⁷ Lu-DOTA-TATE	Neuroendocrine cancer therapy
14.	¹⁷⁷ Lu-Hydroxyapatite/ ⁹⁰ Y- Hydroxyapatite	Radiation synovectomy
15.	¹⁷⁷ Lu-PSMA-617	Prostate cancer therapy

the development of novel organ and disease-specific radiopharmaceuticals improved outcomes. formulates radiopharmaceuticals, coordinates clinical trials, creates harmonised protocols and provides imaging services at its centres.

Cancer therapy is an important wing of DAE operations. Tata Memorial Centre (TMC) under the aegis of DAE is a pioneer in cancer research and treatment in the country. Radiation therapy, as well as radiopharmaceutical formulations, are extensively used at these and other cancer centres of DAE and more than 5 lakh patients receive treatment every year.

Radiation therapy is carried out with external beams of radiation usually from a 60Co source as well as by placing sealed radiation sources close



Eye Plaque developed for the treatment of eve cancer

to the tumour sites to facilitate higher radiation dose deliveries. This type of internal beam radiotherapy is known as Brachytherapy (Brachy in Greek means 'short distance'). Therapeutic radiopharmaceuticals are designed to deliver doses of ionising radiation to specific disease sites and are used extensively in treatments of thyroid and neuroendocrine tumours as well as for bone pain palliation. The radiochemical

"All diagnostic and treatment procedures at DAE centres are provided at a fraction of the cost incurred at privately run establishments, making them affordable to a large section of the society."

moiety makes the drug molecule more potent and helps in reducing the cycles of cancer treatment required to be administered, alleviating patient distress.

The development of Ruthenium-106 plaques for the treatment of eye cancer and Yttrium-labelled glass microspheres (named BhabhaSphere) for the treatment of liver cancer are two recent noteworthy developments. The production of Ru-106 eye plagues and Yttrium labelled glass microspheres require specialised skills and expertise making them expensive in the international market. These are lowcost import substitutes, costing about one-tenth of the equivalent imported products. Their use has been cleared by the regulatory authority and several patients have received treatment at TMH with excellent outcomes. The cost for eye and liver cancer treatment in the country is expected to be considerably lowered with the availability of these new-age procedures at an affordable cost.

The recent commissioning of India's largest medical cyclotron facility in Kolkata, Cyclone-30 has enhanced the capability of DAE to produce cyclotron-based radioisotopes for healthcare applications. Production and regular supply of ¹⁸F-FDG (PET detection of cancers) have been initiated from Cyclone-30 to cater to the need of this extremely important short-lived radiopharmaceutical in the eastern region of our country. Gallium-68 is being produced in the country for the first time using this medical cyclotron. Gallium-based radiochemicals such as 68GaCl₂ (PET radionuclide used for imaging of neuroendocrine cancers, prostate cancer, etc.) and 201TlCl (myocardial perfusion imaging agent) for clinical utilisation are in the process of obtaining regulatory clearance.



Cobalt Teletherapy machine – Bhabhatron

Equipment for robotic surgeries, DNA microanalysis, early-stage cancer detection equipment. teletherapy machines, a blood irradiator using Cs-137, and a radioisotope extracted from nuclear waste have also emerged from the R&D efforts at DAE centres.

All diagnostic and treatment procedures at DAE centres are provided at a fraction of the cost incurred at privately run establishments, making them affordable to a large section of the society.

Nuclear Agriculture

Biological systems continuously undergo mutations on a very slow time scale, governed by environmental conditions or on exposure to extraneous influences. However, direct exposure to ionising radiations such as gamma rays from a radioisotope can induce accelerated mutations.

The Bhabha Atomic Research Centre (BARC) has an extensive programme on creating induced mutations in various crops, a technique known as mutation breeding. The method involves exposing seeds to controlled dose of gamma radiation, leading to favourable as well as unfavourable mutations in them. Seeds with desirable traits are selected and multiplied. Extensive field trials are carried out in collaboration with state agricultural universities like Indira Gandhi Krishi Vishwavidvalava (IGKV), Raipur, Dr Panjabrao Deshmukh Krishi Vidyapeeth (DPDKV), Akola and many others.

The seeds are eventually released for cultivation by the State Variety Release Committee and notified by the Central Crop Variety Release and Notification Committee, Ministry of Agriculture & Farmers' Welfare, Government of India. Forty-nine Trombay crop varieties including rice, mustard, groundnut. mung bean, and cowpea with improved characteristics like higher yield, early maturity, improved disease resistance, drought tolerance, etc., have been

Table 2: Trombay varieties released & notified

Table 2. Hombay varieties released & nothice		
S.No.	Crop	No. of Varieties Released
1.	Groundnut	15
2.	Soybean	2
3.	Mustard	4
4.	Sunflower	1
5.	Linseed	1
6.	Mungbean	8
7.	Urdbean	5
8.	Pigeon pea	5
9.	Cowpea	2
10.	Paddy	5
11.	Jute	1
	Total	49

"A recent contribution to food preservation is development of a liquid nitrogen-based system for refrigerated transport vegetables, fruits, seafood, etc. improving the economics and profitability for growers, farmers and traders."

developed using the radiation-induced mutation breeding techniques and are cultivated extensively in the country.

In recognition of their exceptional contributions to mutation breeding programmes, the mutation breeding team of BARC has been conferred the 'Outstanding Achievement Award' by IAEA in 2021.

Food Preservation

Pest infestation, contamination and mould infestation are major problems faced by the agricultural sector, leading to substantial losses to the extent of 20-30% of the produce. Prevention of post-harvest spoilage is, therefore, a national imperative.

Food preservation is conventionally carried out using chemical additives such as sorbates, benzoates, parabens, sulphites, nitrites, nitrates, Radiation processing provides a healthy and eco-friendly solution to this problem as it eliminates the use of chemicals in food preservation. The method involves exposure of food and agricultural commodities to measured doses of gamma radiation. This process results in favourable outcomes such as disinfestation of pests, delayed ripening, inhibition of sprouting and elimination of pathogens and microorganisms causing spoilage. Radiation processing is the only method of killing pathogens in raw and frozen food.

The radiation beam produces its effect by merely depositing its energy and does not lead to any radioactivity being generated in the target material. Radiation processing of food is a method approved by various organisations such as IAEA, WHO, FAO and FSSAI. DAE has developed irradiation technology for the preservation of fruits,



Liquid nitrogen based Reefer undergoing road trials

vegetables, pulses, spices, seafood, etc. by radiation processing and transferred the technology to private entrepreneurs. Several such commercially operated facilities are available around the country.

India is the second largest fruits and vegetables and third largest fish producer in the world. However, a substantial portion of the produce gets wasted due to the spoilage caused by the lack of cold chain facilities for storage and transport. An important recent contribution to the food preservation agenda has been the development of a liquid nitrogen-based system for refrigerated transport of vegetables, fruits, seafood, etc.

Liquid nitrogen is a by-product of oxygen generation plants used extensively in industrial and medical sectors. A large untapped capacity, therefore, exists in the country for the generation of liquid nitrogen, making it relatively inexpensive. The technology is also an environmentally friendly solution since the use of diesel or CFC gases has been completely eliminated. These refrigerated vans or reefers as they are known, have been named SHIVAY (Sheetal Vahak Yantra). A significant advantage of SHIVAYs is that they possess multimodal logistical flexibility, being customisable to suit the mode of transport available at the sourcing location of the merchandise railways, roadways or waterways.

The systems require minimum maintenance due to very few moving parts and are therefore rugged enough to be deployed even on rough road conditions. An incubation agreement has been signed with Tata Motors

Limited (TML) to jointly develop SHIVAYs for vehicular applications. This technology, when extensively deployed, will substantially reduce wastage and not only improve the economics and profitability for the growers, farmers and traders but also benefit the eventual end-users. An upgraded version of the system, "SHIVAY-V", has been designed for reaching even lower temperatures of up to -70°C and can be used for storage and transport of vaccines requiring such low temperatures.



View of a bay in food irradiation facility

In addition to the technologies detailed above, several other products and applications to serve the agriculture and food sector have emerged over the years, such as solar dryers, disinfectors, soil testing kits and various kinds of food processing techniques.

Technologies for Smart Cities

One of the objectives of the smart cities mission is to provide clean and sustainable environment through the application of 'smart solutions'. DAE has developed a bouquet of technologies which can be deployed to meet this objective.

Sludge Hygenisation: This is a dual-purpose technology for hygenisation of sewage sludge as well as for its conversion to organic fertiliser. Dried sewage sludge is irradiated with gamma rays to eliminate pathogens and dormant seeds. The irradiated sludge is then enriched with micronutrients by inoculation with Bio-NPK and used as fertiliser. A plant has been commissioned by the Ahmedabad Municipal Corporation.

Hybrid Granular Sequencing Batch Reactor (HgSBR) for Sewage **Treatment:** Wastewater contains fibrous impurities, known as floccular mass, making it difficult to purify and recirculate. DAE has developed a treatment technology for the conversion of floccular mass to granular mass (contaminants aggregated into larger particles) which settle at the bottom of the tank. Pure water is decanted and can be reused for industrial consumption. These plants incur considerably lower operational and maintenance costs as compared to a conventional sewage treatment plant. A 150 KLD plant has been recently commissioned at Kalpakkam, Tamil Nadu. A large 1500 KLD plant at Kalpakkam and a 40 KLD plant at RVNL, New Delhi, are under construction.

Nisargruna (repaying Nisargruna: our debt to nature) is an organic waste management technology for the treatment of biodegradable waste such as food waste, municipal waste, abattoir waste, dung, etc. Pathogen and weed free carbon-rich manure and biogas are useful by-products. The technology has a modular design and is, therefore, scalable from 10-100 kg/day, making



Biomethanation plant Nisargruna

it amenable for installations in small as well as large establishments generating such waste. Biogas equivalent to 2 LPG cylinders can be generated from each metric tonne of waste.

Plasma Pyrolysis: Graphite-based plasma pyrolysis system has been developed for the thermal disintegration of organic mass into hydrogen, CO2 and lower hydrocarbons. Almost 99% of organic mass gets converted into combustible and toxic molecules are completely eliminated. Plasma pyrolysis is approved under the Gazette of India for safe disposal of Bio-Medical Waste.

Water **Purification:** DAE has developed low-cost water purification systems using membrane filters for ultrafiltration of impurities. These systems require no electricity and call for minimum maintenance, thereby making them rugged and versatile. Technology has been transferred to several entrepreneurs and the systems are commercially available and in wide use.

Water Desalination: A technology for the desalination of seawater has been developed using nuclear waste heat. Two such plants have been set up at Kalpakkam and are supplying potable water to the nearby township. The freshwater resources of the country are rapidly depleting due to overuse and seawater desalination technologies will be required to be increasingly deployed in the future. This technology provides a cost-effective and viable solution and can be considered as a technology for the future.

Looking Ahead

The motto of DAE is 'Atoms in the Service of the Nation' and the organisation has lived up to this mandate by delivering numerous pioneering and one-of-its-kind technologies to the nation. Work on serving and building upon this mandate continues unabated, by way of enhancing capacities and developing innovative technologies for the nuclear sector as well as for societal benefits.

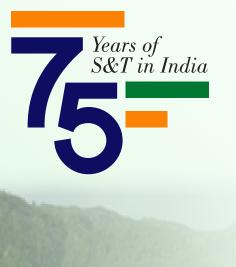
Increasing radioisotopes production is essential towards the expansion of several societal applications and the department is actively working towards augmenting this capacity by building reactors in the PPP mode

Eight cancer hospitals have been brought into the DAE fold and several new ones are under construction. A National Cancer Grid has been established to link major cancer centres, research institutes, patient groups and charitable institutions across India for establishing uniform norms for prevention, diagnosis and treatment of cancer, providing specialised training and education in oncology and facilitating collaborative research on cancer. This is expected to lead to a sharing of the knowledge and harmonisation of diagnosis and treatment protocols across the country.

DAE has thrived over the decades building an R&D ecosystem facilitating a continuous update of its knowledge base. The Homi Bhabha National Institute (HBNI), a 'Deemed to be University', was established under its aegis in 2005 to provide a platform for further strengthening the R&D infrastructure. HBNI is an umbrella institute of 11 DAE units and constituent institutions primarily focussing on educational, research and developmental activities in the sphere of nuclear sciences and engineering and cutting-edge basic and applied research. Within a span of 16 years, HBNI has established itself as a high-quality research institute accredited by NAAC and its research activities have yielded rich dividends towards enhancing our capabilities in several domains.

DAE has attained the stature of a premier institution in the country by the dint of hard work supported by a strong organisational culture, state-of-the-art infrastructure, motivated workforce and pathways to excellence forged over six decades of its existence and will continue to deliver yeoman service to the nation in the future.





MINISTRY OF EARTH **SCIENCES CONTRIBUTING TOWARDS A WEATHER-READY & CLIMATE-SMART INDIA**



Dr M. Rajeevan Secretary, Ministry of Earth Sciences



Dr Gopal Ivengar Scientist G & Adviser, MoES



Dr Bhavya Khanna Scientist D (Communication in science)

ROM urban dwellers who google weather forecasts, air quality updates, and information on earthquakes, to rural habitants who require information about monsoons, ocean state forecasts, alerts for tsunamis and extreme weather, from researchers who seek a once-in-alifetime opportunity of exploring Antarctic and Arctic to those who aspire to implement innovative solutions for societal benefit, the Ministry of Earth Sciences (MoES) touches the everyday lives of crores of Indians.

MoES came into being in 2006, it is the youngest of all scientific ministries in India. MoES, known earlier as the Department of Ocean Development (DOD; 1981-2005), was granted the mandate of providing services for weather, climate, ocean and coastal state, hydrology, seismology, and natural hazards; sustainable exploration and harnessing of marine resources; and exploring the three poles of

the Earth (the Arctic, Antarctic and Himalayas). In a relatively short span of four decades, the contributions from MoES (and erstwhile DOD) to India's bright and better future are many, unique, and significant.

Weather, Climate & Ocean Forecasts - Among the Best in the World

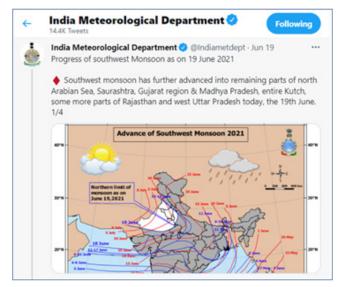
MoES has tremendously improved forecasts of monsoon, weather,

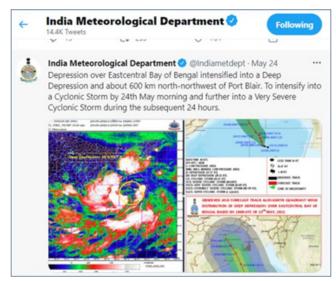
climate, and ocean state in the country. Improvements in monsoon, weather, and climate forecasts have been possible as part of a targeted activity of the MoES called the National Monsoon Mission (NMM). Today, India is a world leader in monsoon. weather and climate prediction tools. Accurate prediction tools are necessary to address sectors such as agriculture, water, health, and energy vital to the economy.





Doppler Weather Radars at Mumbai and in Sonmarg, Jammu & Kashmir





Forecasts of monsoon 2021 (left) and cyclone YAAS that occurred in May 2021 (right) were released by the India Meteorological Department (IMD) with a significant lead time on the latest modes of digital/social media

India has a wide network of Doppler Weather Radars (DWRs) covering almost all major cities, metros, coastal areas, and ports. DWRs are highly specialised radars for weather monitoring that can provide real-time data on rainfall, wind, storm, etc. The Ministry is installing radars at various locations in the country including the Andaman and Nicobar Islands, metros (Delhi, Mumbai, Kolkata), central and NW Himalayas. Over the years, the MoES has also been using satellite data from both Indian and international institutions improve weather tο prediction significantly.

A recent survey by the National Council of Applied and Economic Research (NCAER) found that an investment of nearly 1,000 crores in the Monsoon Mission (MM) and High-Performance Computing MoES has yielded almost fifty-fold gains to farmers, livestock owners and fisherfolk in the country. Today, India has expertise in providing accurate monsoon forecasts for as long as three weeks in advance, that too at a seasonal time scale, covering almost the entire span of the country.

In addition, the country is equipped to forecast extreme weather events such as cyclones with a lead time of up to 10 days. For example, the forecast of cyclone YAAS in May 2021 by India Meteorological Department,

Delhi, was released more than a week before the cyclone hit the Indian coast.

An Integrated Flood Warning System is now available for Chennai and Mumbai. Forecasts on areas of inundation during the floods caused by high rainfall are also provided to state governments. Systems for flash flood guidance and air quality early warning are available in the country. These warning systems aid disaster management authorities to initiate timely action and reduce impending damage to life and property.

For ocean state forecasts. INDOFOS (INDian Ocean FOrecasting System) set up by MoES at the Indian National Centre for Ocean Information Services (INCOIS), Hyderabad, can predict height, direction and period of waves, sea surface currents and temperature, wind speed and direction, and astronomical tides and oil-spill trajectory in the Indian Ocean, well in advance with a lead time of 5 to 7 days. This information is beneficial for maritime communities such as fisherfolk, Indian Navy, Indian Coast Guard, merchant and passenger shipping agencies, offshore oil and gas exploration industries, research organisations and coastal communities. For example, high tide forecasts help fisherfolk plan their trips and avoid impending dangers.

The development of a Small Vessel Advisory Services System and Swell Surge Forecast System is the latest feather in the cap of MoES ocean state forecast services. Additionally, special ocean state forecasts are supplied to neighbouring countries such as Comoros, Madagascar, Maldives, Mozambique, Seychelles and Sri Lanka.

By developing and implementing next-generation computer models and technologies such as artificial intelligence and machine learning, the MoES aims to equip India in predicting extreme weather events such as heavy rainfall, cyclones, floods, heatwaves, etc., in much advance, at various time scales and geographical spreads.

Ocean S&T Services

India enjoys a unique opportunity to harness oceanic resources with a long coastline of $\sim 7,200$ km, a dedicated space in the Central Indian Ocean, and an extended exclusive economic zone of over million square kilometres. To best utilise this opportunity, MoES, with its institutes including the National Institute of Ocean Technology (NIOT) and National Centre for Coastal Research (NCCR) in Chennai, has been working tirelessly to develop and implement reliable technologies for harnessing oceanic resources for the country.







An open sea cage is nearly 9 metres wide moored to a suitable location in the sea (left). The cage is used to culture marine fish in a controlled yet natural sea environment (middle). Fishes are harvested when the desired size is attained (right) and sold in the open market.

NIOT has been conducting several societal and capacity building programmes, some in very niche areas of ocean technology, such as marine infrastructure. In collaboration with NCCR, NIOT has worked towards protecting shores from erosion and harnessing renewable energy from waves, tides, and offshore winds in the past decade. Several innovative and scientifically benefitting products have been developed or indigenised in these years, such as wave-energy powered navigational buoys and offgrid turbines. Beaches at Pondicherry Kadalur, Periyakuppam that were lost in the recent past have been restored because of the meticulous efforts of MoES along with the local governing bodies. MoES even supports other countries such as Vietnam to implement effective measures to restore lost beaches.

NIOT and INCOIS have set up an Ocean Observation Network (OON) to facilitate real-time in-situ oceanographic data of the world's oceans. At present, OON consists of a vast network of several high-end types of equipment such as buoys, moorings, drifters, ship-board automated weather stations, etc., along the Indian coast.

Amongst the most life-transforming technologies implemented by MoES



the low-temperature thermal desalination technology set up in Lakshadweep. The water plants convert salty seawater into potable water for islanders. As a result, incidents of water-borne illnesses have reduced in the Lakshadweep islands. It is pertinent to note that these water plants run entirely on renewable energy, hence, the water produced is cost-effective and sustainable. MoES is now working on setting up more such plants in other locations of India.

In the last decade, MoES has implemented projects on open sea-cage culture and production of biodiesel from microalgae. These technologies have improved the livelihoods of coastal dwellers tremendously. Almost every day, about 7 lakh fisherfolk families receive advisories on the Potential Fishing Zone (PFZ), a flagship programme of MoES that directly benefits coastal communities. The PFZ advisories help them to locate areas of abundant fish in the ocean. PFZ advisories are disseminated through mobile apps, SMS alerts, social media, and helpline numbers.

A Search and Rescue Aid Tool (SARAT) with a mobile app is in place to track lost objects and persons in the sea. Other useful mobile apps such as Damini to issue lighting alerts,



Puducherry had almost no beach in 2016, although sea walls were present that protected the coastline (left). The beach was restored by the meticulous efforts of the MoES and growing in 2020 to nearly a kilometre (right).

Meghdoot to issue weather advisories to farmers, and the Mausam, Umang, and RAIN-ALARM apps for updates on weather are also available.

NIOT has begun work to develop a deep seabed crawler, remotely operated deep-water vehicle, in-situ soil tester, unmanned submersible, and deepocean drill. Together, this equipment can help in mining nodules of highvalue metals from the seabed and locate hydrothermal sulphide sites in the southern Indian Ocean.

Another very useful technology under development is a manned submersible that can transport up to three humans with equipment to a depth of up to six kilometres below the sea surface. Futuristic research projects on underwater acoustics are in the pipeline. Underwater acoustics is the study of sound waves travelling inside water. Such projects can help develop innovative underwater instruments and sensors for imaging, detecting, and characterising ambient noise in Indian waters. These would be particularly useful for sectors such as defence.

MoES, through the National Centre for Coastal Research (NCCR), Chennai, works on unique aspects of coastal science such as monitoring water quality, marine litter and pollution, and diversity and health of coral reefs at the Gulf of Mannar. Data from these studies are vital for managing strategic areas of India's blue economy, such as conserving coastal ecosystems and marine spatial planning.

In June 2021, the Cabinet approved the Deep Ocean Mission, a unique flagship programme of the MoES, making India a world leader in ocean science and technology. It will expand





Low-temperature thermal desalination water plant set up in Lakshadweep islands by MoES converts seawater to potable water for islanders

the exploration and utilisation of deepsea resources even further for societally benefitting activities. The aim also is to make India self-reliant in ocean technology, create more jobs in this field, and enhance the capacity building of institutions working in this sector.

Research at the Earth's Poles

The National Centre for Polar and Ocean Research (NCPOR), Goa — an autonomous institute under the MoES. is the only organisation in India that provides opportunities to researchers for conducting field experiments at the Earth's poles (the Arctic in the north and Antarctic in the south). The polar expeditions coordinated by MoES help execute specialised scientific projects at the Earth's poles, which seems impossible elsewhere in the country.



NCPOR administers the Indian Antarctic Programme and maintains three permanent Indian research stations in Antarctica (Dakshin Gangotri since 1984, Maitreyi since 1989, and Bharati since 2012) making cutting-edge polar research possible. Notably, India is among the few countries to have multiple year-round research bases in Antarctica. So far, NCPOR has successfully concluded 41 scientific expeditions to the southernmost continent.

Moreover, India is also consultative party to the Antarctic Treaty System, implying that it has the right to participate in the decision-making processes in the yearly Antarctic Treaty Consultative Meetings. India is also a member of many international bodies that govern Antarctic science and policy.



In the Arctic, India has held an Indian Arctic station called Himadri at Svalbard, Norway, since 2008. It has been a member of the International Arctic Science Committee since 2012 and was granted an Observer status in the Arctic Council in 2013. NCPOR has deployed a moored observatory called IndARC since 2014 in the Kongsfjorden fjord, halfway between Norway and the North Pole, to monitor the upper ocean. The country has benefited by coordinating visits of nearly 200 scientists to the Arctic, which has yielded more than 100 research publications on Arctic science.

NCPOR has also initiated a programme to understand the complex behaviour of Himalayan glaciers. The Himalayan Cryosphere Programme operates through a research station called Himansh in the western Himalayas. The programme has monitored six Himalayan glaciers spread across 230 square km in the Chandra basin. NCPOR has collaborated with several Indian universities and institutes under the Himalayan Cryospheric Observation and Modeling (HiCOM) programme to collect information on glacier melt, snowmelt, rainfall, etc. In the future, HiCOM would also monitor the thickness of glaciers and glacier lakes in India.

In the Southern Ocean, India has actively pursued research since 2004. It launched a multidisciplinary and multiinstitutional annual expedition from Mauritius to Prytz Bay in Antarctica to collect data on the upper Southern Ocean and atmosphere. This research has helped improve the understanding of factors affecting climate change and significantly increased India's scientific publications in this area.



Bharati in Antarctica (left), Himadri in the Arctic (middle), and Himansh in the Himalayas (right) are research stations set up by MoES to provide unique opportunities for scientific research at the Earth's poles.





The Indian Tsunami Early Warning Centre (ITEWC) set up by MoES at the Indian National Centre for Ocean Information Services (INCOIS), Hyderabad (left) and a buoy moored in the ocean for collecting data on tsunamigenic earthquakes (right)

Making India Tsunami-readv

The great Indian tsunami of 2004 caused enormous damage to life and property in many south-east Asian countries, including India. Today, thanks to MoES, our country is equipped with a state-of-art tsunami early warning system that can issue a tsunami alert with a lead time of nearly ten minutes before a tsunami-genic earthquake occurs in the Indian ocean.

The Indian Tsunami Early Warning Centre (ITEWC), set up by MoES at the Indian National Centre for Ocean Information Services (INCOIS), Hyderabad, is among the world's best. ITEWC has provided timely tsunami advisories to stakeholders, including the public and disaster management authorities, for a decade now. Between 2014 and March 2021, ITEWC monitored 234 tsunamirelated earthquakes of magnitude ≥6.5 and provided timely tsunami-related advisories and warnings. ITEWC is designated as a Tsunami Service Provider for the Indian Ocean region by the Intergovernmental Oceanographic Commission (IOC) of UNESCO and provides advisories to 25 Indian Ocean rim countries. Scientists from INCOIS are contributing members of the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning Mitigation System towards improving global tsunami services.

Although ITEWC is primarily focused on monitoring and warning tsunamis, it also plays a vital role in providing technical inputs and creating community awareness and preparedness. It conducts regular capacity building activities such as Tsunami Standard Operating Procedure

workshops, training, and sensitisation modules for disaster management officers and hosts regional workshops and training for Indian Ocean member states.

In 2020, two villages in Odisha (Venkatraipur in district Ganjam and Noliasahi in district Jagatsingpur) had implemented the INCOIS Tsunami become programme and Tsunami Ready Communities. They were certified by IOC-UNESCO as Tsunami Ready. India has become the first country to implement the Tsunami Ready programme in the Indian Ocean Region with this recognition. INCOIS has also recently completed mapping of highly tsunami vulnerable coastal regions using 3D Global Information System (GIS) techniques and is now moving towards hosting a dedicated 24X7 tsunami web portal.

Cutting-edge Research on **Climate Change**

Climate change scientists utilise Earth System Models (ESMs) that integrate interactions among the Earth system components such as atmosphere, ocean, land, cryosphere and biosphere, and predict climate under a wide variety of conditions. ESMs are being used in

recent times to understand the impact of human-induced perturbations (such as greenhouse gas and aerosol emissions, land use and land cover changes, etc.) on the global climate system.

The MoES has developed an advanced ESM facility at the Indian Institute of Tropical Meteorology (IITM), Pune, called IITM-ESM. It has a global climate modelling framework that allows ultra-modern studies on climate change, including deriving climate projections for the future. Notably, IITM-ESM is the first climate model from South Asia that has contributed to the sixth assessment report of the Intergovernmental Panel on Climate Change. In the next five to seven years, MoES plans to set up a next-generation IITM-ESM. It would improve numerical modelling, climate change assessments, and prediction of monsoons manifold.

Expanding Seismology Research

The National Centre for Seismology (NCS) in New Delhi is equipped to collect real-time data and accurate information on earthquakes, such as their location and depth. The data is disseminated within a few minutes to the public and stakeholders through the



Location of the 3 km deep borehole at Gothane, Karad (marked as a red dot on the map) in Maharashtra (left) and the drilling site of the BGRL near Koyna (right)





A cloud raining after cloud seeding experiment as part of CAIPEEX IV and the aircraft used for seeding the cloud. The rainfall after cloud seeding was measured through a network of automatic rain gauges placed on the ground surface in Solapur, Maharashtra.

latest digital communication modes, including social media.

MoES has a network of 115 stations across the country called the National Seismic Network to monitor earthquakes and provide valuable information about their distribution, type, and risk in various settings. A unique project of the NCS is the scientific deep drilling in Koyna, Maharashtra, to address specific questions around the physics of earthquakes. A deep borehole laboratory called Borehole Geophysics Laboratory (BGRL) set up in 2015 near Koyna, is equipped with specialised equipment, nearly 4 km into the Earth's interior to understand what makes Koyna a hub for seismological activity. Very few countries have such an elaborate facility to study earthquakes.

Studies undertaken by MoES in BGRL have shown that earthquake activity in Koyna is modulated by the annual monsoon loading and postmonsoon unloading cycles of the Sivaji Sagar reservoir. Although it was known that frequent earthquakes in Koyna began after the impoundment of the Sivaji Sagar reservoir in 1962 but what causes the earthquakes was unknown. In the coming years, scientific deep drilling will expand to up to 7 km below the Earth's surface. This would facilitate detailed observations of changes in physical and mechanical properties of rocks at a depth where the energy that causes earthquakes is released. The knowledge gained from this project will help understand triggered earthquake activity in India and other parts of the world.

An important offshoot of the BGRL project is the study of life under extreme conditions. Drilling through the deep Earth has provided an opportunity to discover microbial life that can withstand temperatures of nearly 80 degrees Celsius. This interdisciplinary research aims to unravel subsurface microbial diversity and aids the global quest of understanding the limits of life, mechanisms of microbial interaction with the environment, their adaptation and their function in this planet and beyond.

Mitigating Water Scarcity

Several areas in our country are battling drought or water scarcity. How useful would it be to make clouds pour in regions that are water tense? The Indian Institute of Tropical Meteorology (IITM) in Pune, an institute under MoES, has been working on a unique project called CAIPEEX that aims to enhance rainfall in droughtprone regions by using an innovative technique called cloud seeding.

CAIPEEX or Cloud Aerosol Interaction and Precipitation Enhancement Experiment, is a special

exploratory project at IITM that examines which clouds can be used to enhance rainfall and how should they be seeded to make it rain in a droughtprone area. Cloud seeding uses few (that is, two to four) cylindrical flares containing calcium chloride transported into the cloud using an aircraft. At the cloud base, the aircraft burns these flares within 6-8 minutes. The burning of flares releases Calcium chloride molecules inside the cloud, which settles on the water vapour molecules in the cloud, causing the clouds to downpour. The feasibility of using cloud seeding to enhance rainfall in tropical regions such as India was unknown until the recent past.

In Munnar, Kerala, the MoES maintains India's highest cloud physics observatory at an altitude of 1820 metres above sea level. The observatory is equipped to study cloud physics which would improve understanding of thunderstorms, lightning, and mountain weather in a big way.

The Indian leadership has always maintained that science must be strongly inclined to service citizens. The father of our nation, Gandhi Ji, considered science without humanity a sin. Shri Jawahar Lal Nehru, first Prime Minister of India and a strong protagonist of scientific temper in the Indian society, advocated science for societal benefit. The current Prime Minister of India, Shri Narendra Modi, has insisted that science must meet the rising aspirations of Indians. The MoES, through its socially benefiting services and achievements, strives to live up to goals set by the visionary leadership of India for a bright and better future.



The highest Cloud Physics Laboratory of India at Munnar, Kerala, set up by the National Centre for Earth Science Studies (NCESS), Thiruvananthapuram, an institute under MoES





THE JOURNEY OF **BUILDING DEFENCE TECHNOLOGICAL** CAPABILITY



Dr G. Satheesh Reddy Secretary, Department of Defence Research & Development and Chairman, DRDO

ROGRESS in science and technology is the very foundation of enhancing the comprehensive national power of the country and strengthening national security in every domain. The technological backbone of any armed force of a nation is indigenous defence research and development. In India, the Defence Research and Development Organisation (DRDO) has played a pivotal role in developing defence systems encompassing advanced technologies and providing critical fighting capabilities to the armed forces.

The genesis of DRDO can be linked to the creation of the Directorate of Technical Development (DTD) in 1945 - post World War II. Two years later, India became independent leading to the appointment of the Scientific Advisor to the Prime Minister. Establishment of the Defence Science Organisation (DSO) happened in 1948 and under this first laboratory was created in 1950. In 1958, the Defence Research and Development Organisation (DRDO) was formed by merging DSO and DTD, with Scientific Adviser to Raksha Mantri as its Head. DRDO had 10 laboratories at that time.

Today, DRDO has grown into a leader in the domain of strategic systems and other defence technologies. Starting from the design of simple equipment to the development of the most advanced systems DRDO has continued its quest for indigenous defence systems development. From the first grant of Rs 15 Lakh in 1950 and a yearly budget allocation of Rs 3.17 Crore in 1961-62, DRDO now has a budget allocation of about Rs 20,000 Crore for the fiscal year 2021-22. In spite of the denials and embargos from various control regimes, DRDO has been persistently moving in the direction of defence technology growth.

In the process of developing contemporary and advanced systems for defence, DRDO has acquired a large number of inherent diverse technical capabilities. These include design, development and integration of highly complex systems using technologies. cutting-edge **DRDO** various domains across defence applications - Aeronautics, Combat Vehicles, Naval Systems, Missiles, Armaments, Electronics, Engineering Systems, Instrumentation, Information Systems, Special

Materials, Life Sciences, Advanced Computing, Warfare Simulation and Training.

Missiles. **Armament** and **Ammunition**

Starting from the mid-eighties of the previous century, the technology demonstration of ballistic missiles has culminated into India's missile deterrence programme consisting of Prithvi and Agni series of ballistic missiles meeting different ranges and requirements. India is the seventh country in the world to have long-range ballistic missiles.

India is also the fifth country in the world to have developed an indigenous ballistic missile defence programme. Ballistic Missile Defence systems to intercept targets in exoand endo-atmospheres are designed and developed by DRDO. Mission Shakti, the anti-satellite technology is a milestone towards building the Nation's strength to defend its space assets. India is the fourth nation in the world to have demonstrated this capability based on indigenous technology.

The development of Air-to-Air, Surface-to-Air, Anti-Tank Missiles,



Agni

Smart Bombs, Guided Rockets, Air launched Missiles and Anti-Radiation missiles for different segments of defence operations has not only enhanced our defence capability but given a big boost to our international image and also saved a large share of foreign exchange.

'Astra', the first indigenous beyond visual range air-to-air missile has enabled India to join the select group of nations that possess a weapon of this capability and performance. After integration with Su-30MKI aircraft, it is planned to be integrated on the indigenous Tejas, upgraded Mirage 2000 and MiG-29 fighter aircrafts.

Mk-2 with two-pulse Astra propulsion is being developed to further enhance the kill zone of Astra Mk-1 missile. Astra Mk-2 will achieve a longer kill range, one of the highest amongst all air-to-air beyond visual range missiles available across the world thus far. To further increase the 'kill range' to nearly double of the Mk-2 and ensure the wider 'no escape zone', DRDO has successfully tested and validated the solid fuel ducted ramjet propulsion technology.

BrahMos is the fastest supersonic cruise missile of its kind in the world that can be launched from the ground, aircraft and ship. The latest development is that an air-launched

"DRDO has delivered multiple bridging systems to the Indian Army which are deployed at strategic locations."

variant of BrahMos became operational on Su-30MKI fighters of Indian Air Force.

Surface-to-Air Akash Missile (SAM) is deployed with the Indian Air Force and Indian Army to defend the air space of the country, quick reaction SAM has been developed for mobile air defence applications, which will enter into production shortly. DRDO in partnership with Israeli Aerospace Industries has developed medium range surface to air missile with a longer kill range for the tri-services application.

Akash-NG SAM is being designed and developed for providing air defence cover against fighter aircrafts, helicopters, UAVs, sub-sonic cruise missiles and low radar signatures targets. Long Range Surface-to-Air Missile is being taken up by DRDO to increase the air defence against air threats emanating from longer ranges.

DRDO has also developed the smart anti-airfield weapon, which is a state-of-the-art deep-penetration and high explosive glide bomb designed to target runways of an airfield from stand-off distance with great precision.

generation anti-radiation New missile called Rudram series, air-toground, long-range, precision, standoff supersonic weapons are being developed for varying ranges for launching from the aircrafts of IAF.

Multiple missiles for Navy are being developed. These include



Astra



ASAT Interceptor

helicopter-launched short range naval anti-ship missile and aircraft launched medium range anti ship missile. Only USA, Russia and China have the capability to launch anti-ship missiles.

The long range anti-ship missile is a land launched medium-range antiship missile, which will be able to target naval surface targets. Extended range anti-submarine rocket is a shiplaunched rocket being developed by DRDO for anti-submarine warfare. Long Range long range land attack cruise missile is being developed with launching capability from ship and land platforms against land targets.

Third generation fire and forget anti-tank missile Nag and Helina helicopter launched anti-tank missile are equipped with an infra red imaging seeker with 'Lock-on Before Launch' capability. Man-Portable Anti-Tank Guided Missile (MPATGM) is in advanced stage of development. In addition, the laser guided anti tank missile for MBT is in final stages of development.

Stand-off Anti-Tank (SANT) Missile is a helicopter launched antitank missile equipped with an active radar seeker with 'Lock-on Before Launch' capability.

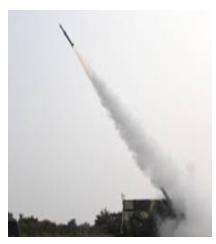
India has been building many systems for the Indian Army. The Main Battle Tank (MBT) Arjun has been

"India is the 7th country in the world to have long-range ballistic missiles; 5th in the world to have developed an indigenous ballistic missile defence programme and 4th nation in the world to have demonstrated anti-satellite technology."

developed by DRDO for the Army keeping in view Indian conditions. The tank has been in service with the Indian Army since 2004 and Arjun MK-1(A) is being inducted with many improvements over Arjun MK-1. The New Generation Main Battle Tank (NG-MBT) is envisaged as the futuristic MBT of the Indian Army. It will be a medium tank powered by 1500 HP engine and armed with a 125 mm smoothbore gun. Allelectric turret drive, explosive reactive armour and active protection system are being developed for the new generation of

DRDO has delivered multiple bridging systems to the Indian Army which are deployed at strategic locations. Recently, Mountain Foot Over Bridge has been developed and will be shortly delivered for active use in the field by production agency.

Pinaka free flight rocket system has been the workhorse artillery weapon for the Indian Army for many years. Pinaka rockets are launched from a multi-barrel rocket launcher



Akash-NG



Brahmos

which has the capability to launch a salvo of rockets. DRDO has developed the extended range Pinaka-ER with improved propulsion and new warhead configurations.

ATAGS 155 mm gun has been developed with the longest firing range in the world. 155 mm shells also have been developed for ATAGS indigenously so that there will not be any deficiency. The gun can fire existing ammunition being used by erstwhile Bofors and other guns.

An advanced version of the hand grenade, Multi-Mode Hand Grenade, with several security features has been developed and is being produced in large numbers by Ordnance Factory and private industry. DRDO has also designed 5.56x30 mm Joint Venture Protective Carbine (JVPC) which has features like high reliability, low recoil, retractable butt, ergonomic design, single hand firing capability, and multiple Picatinny rails.

Unmanned Aerial Vehicles (UAVs)

DRDO developed UAV Lakshya has been proven and is being successfully utilised by the Services. It is a costeffective re-usable subsonic aerial target system powered by a gas turbine engine and launched either from land or ship.

Nishant is a multi-mission UAV with day/night capability used for battlefield surveillance and reconnaissance, target



Abhyas

tracking & localisation, and artillery fire correction. A sophisticated image processing system is used for analysing the images transmitted from the UAV.

Rustom-I is an all composite, 800 kg class remotely piloted aircraft system having capabilities of Intelligence, Surveillance, Reconnaissance, Target Acquisition/Tracking and Exploitation. Rustom-I is the first Indian remotely piloted system to have conventional take-off and landing capability. It has autonomous flight mode and Get-to-Home features.

Rustom-II is platform being developed for long duration surveillance and reconnaissance, target identification, target tracking and battlefield damage assessment. It can carry a variety of various electro-optical and intelligence payloads. This will provide continuous wide area coverage and yet be able to identify small targets. Another multi-mission UAV is being developed to carry out Intelligence, Surveillance, and Reconnaissance (ISR) roles.

Abhyas being developed is expendable, low cost, high speed unmanned aerial target fitted with sensors and is GPS enabled. It will have onboard actuators, a flight control computer and a miss distance indicator. In addition, supersonic aerial targetis also under development.

Fighter Aircrafts

Developing fighter aircrafts is an extremely complex process involving cutting-edge technologies in numerous fields. First Technology Demonstrator of Tejas, flew its maiden flight on 4 January 2001. Since then, Tejas prototypes and limited series production aircraft flew over 4,400 development flight test sorties culminating in



LCA- Tejas

its initial operational clearance in December 2013 and final operational clearance in February 2019. Tejas development timelines achieved by India are comparable with those of many other contemporary aircraft designed elsewhere in the world.

Tejas Mk-1 is an all-weather multi-role fighter capable of carrying close combat and beyond visual range air-to-air missiles coupled with multimode air-interception radar for the air defence role. It is capable of delivering all types of conventional bombs and Laser Guided Bombs in the ground attack role. Tejas Mk-1 is the smallest and lightest in its class of contemporary supersonic combat fighter aircrafts. The aircraft is equipped with advanced avionics systems and sensors for an excellent flying experience.

deck-Technologies for based landing and take-off have been successfully developed demonstrated as part of the LCA-Navy programme. Two prototypes of the Naval version of the LCA, Navy Trainer and Navy Fighter, successfully undertook maiden arrested landing and ski-jump take-off onboard INS Vikramaditya in January 2020. Both the aircrafts conducted a total of 18 ski-jump take-offs and 18 arrested landing onboard INS Vikramaditya in five days. DRDO has nurtured and hand held the Indian industry to reach the level of manufacturing the stringent meet quality assurance requirements specified for aviation equipment. This is a major contribution towards self-reliance in the manufacturing of the product and its life-cycle support. LCA project has made India 'AtmaNirbhar' in most contemporary technologies related to fighter aircrafts.

DRDO has started the design and development of the next-gen fighter aircraft LCA Tejas Mk-2, the 4.5+ generation multi-role fighter aircraft. Tejas Mk-2 will incorporate more weapon stations capable of carrying higher weapon load compared to Mk-1 and retractable air-to-air refuelling probe.

Medium Advanced Combat Aircraft (AMCA) is India's Fifth Generation Stealth Fighter Aircraft (FGFA) and is being developed indigenously by DRDO. Only USA, Russia and China have so far developed FGFA. AMCA will include every advanced stealth technology. The aircraft will be equipped with state-ofthe-art indigenous radar, inbuilt feature for passive detection of aircraft and internally mounted electronic warfare suite. AMCA will be a twin-engine fighter primarily designed for stealth to enable it to penetrate deep inside enemy territory and attack heavily defended targets with the help of net "DRDO has started the design and development of the nextgen fighter aircraft design of LCA Tejas Mk-2, the 4.5+ generation multi-role fighter aircraft."

centric warfare operations and data fusion based enhanced situational awarenessfor the pilot.

Radars and Surveillance **Systems**

The contribution of DRDO in improving the air defence ground environmental system of the Nation is immense. Many radars have been designed and developed by DRDO, which are network ready.

Weapon locating radar called Swathi to identify the location of hostile artillery, mortars and rocket launchers, based on the projectile trajectory has been developed exclusively for army applications. This radar has got export orders also. Battle field surveillance radar has been developed for frontline units of the Indian Army and hundreds of these radars are already being used in the field. Low level tracking radar for applications in mountains has been developed and is being used by the Indian Army.

Through wall imaging radar, a sensor used for detection and location of static and moving targets, especially human beings behind walls, is under development. foliage penetration radar is under development for detection of personnel and vehicles hiding behind camouflaged tree and forest cover for low-intensity conflict. Many of the DRDO developed radars are integrated to provide a composite air situation picture to display and control every airborne platform over the entire Indian airspace including the island territories.

The lower range 'Aslesha' low level light weight radar can be carried by two people. It can also be carried under slung below a helicopter. These radars are deployed to plug gaps in the air defence surveillance especially in mountainous and remote areas.



AEW&C (Netra)

'Arudhra' medium powered and 'Ashwini' low level tracking radars are in final stages of testing and will be used for providing air defence surveillance in three dimensions at different ranges. These will be configured specifically for use in mountain regions to ensure maximum coverage.

Active electronically scanned array based indigenously developed 'Uttam' radar for fighter aircraft has been flight tested on the LCA aircraft. The performance of the radar is very promising. Uttam radar will be equipped in Tejas and AMCA fighters.

Two indigenously developed 'Netra' Airborne Early Warning & Control (AEW&C) aircrafts are operating with IAF. 'Netra' AEW&C aircraft are equipped with indigenously developed mission systems for air situation picture of the battlefield.

DRDO developed ground based mobile electronic systems having electronic surveillance measures and communication surveillance measures have been deployed.

Tripod mounted compact Anti-Drone system integrated with jammer, electro-optical tracking system, and radar was successfully demonstrated during August 2020. Detection, jamming, and destruction of Drones were successfully demonstrated. The system was deployed for security during Republic Day celebrations 2021.

The laser dazzler developed by DRDO is used as a non-lethal method for warning and stopping suspicious vehicles/boats/aircraft/UAVs approaching secured areas during both day and night. It is capable of dazzle and thereby suppresses the person's/

optical sensor's actions with disability glare in case of non-compliance to orders. It also dazzles and distracts aircraft/UAVs.

Electronic Warfare Systems

Electronic Warfare (EW) plays a crucial role in modern day air combat. Several elements of EW self-protection suite developed by DRDO are installed on IAF fighter and transport aircraft and helicopters. These are radar warning receivers, countermeasures dispensing system, missile approach warning system, jammers etc. DRDO has developed software defined radios in 5 form-factors to provide wireless secure communication capability to both mobile and fixed forces as required by the Indian Navy.

Naval Systems and Applications

DRDO has worked on the development of materials for the construction of naval platforms. High strength steels for the construction of submarine hulls have been developed. Henceforth, all Indian submarines will be made with Indian steel. Besides, for shipbuilding DRDO has developed steel plates that are about one fourth to one eighth the cost of imported plates.

Some other technologies developed by DRDO include titanium sponge produced indigenously from the sands of Kerala; rubber tiles to reduce transmitted noise for submarines; epoxy putty for fixing the tiles; air independent propulsion system that enhances the submerged endurance of the submarine.

DRDO is in advanced stage of development of submarine periscope. Submarine hoistable masts



Anti-Drone System

periscope, radar and communication antennae are also being developed. DRDO is developing a universal vertical launcher capable of launching all the indigenous missiles onboard Indian Naval Ships.

Sonars developed by DRDO are in use in various ships and submarines of the Indian Navy. The Sonar suites are being productionised by M/s BEL. Sonar domes and sonobuoys developed by DRDO are also being used by the Indian Navy.

Weapons Underwater and **Countermeasure Systems**

DRDO has developed multi-purpose torpedoes along with Torpedo fire control systems for the Indian Navy. Advanced light weight torpedo is an anti-submarine, electrically propelled, self-homing torpedo which can be launched from ship and rotary-wing aircraft. Varunastra is ship launched, heavy weight, electrically-propelled, anti-submarine torpedo capable of targeting quiet submarines, both in deep and shallow waters in an intense countermeasure environment.

Electrical heavy weight torpedo, a new generation torpedo that can be launched from both ships and submarines for anti-submarine warfare, is under development. Jalastra, a

"An **Anti-Drone** system integrated with jammer, electro-optical tracking and system deployed for security during 2021 Republic Day celebrations."

medium weight torpedo capable of being launched from naval platforms, is also under development.

For launching light weight torpedoes from onboard Indian ships with anti-submarine warfare role, DRDO has developed triple tube launchers, which are being productionised by the private industry and are deployed on many Indian Navy Ships.

Mareech advanced torpedo defence system is a torpedo detection and countermeasure system capable of detecting, confusing, diverting and decoying incoming torpedoes. DRDO has also demonstrated missile assisted release of light weight anti-submarine torpedo system for underwater warfare operations far beyond torpedo range.

Other Systems

Advanced support systems have been developed by DRDO to enhance survivability, sustainability, mobility, performance and habitability of soldiers in extreme & toxic environments, high altitudes, deserts, underwater, aerospace, closed micro-environments of ships, aircrafts and areas of low intensity conflicts. Some examples are life support systems (i.e., Oxygen Support System, Protective clothing & equipment) and communication Systems.

Heavy drop parachutes, Combat Free Fall systems and a number of other personnel parachutes are being used by the Parachute Regiment and Special Forces for combat/special missions at about 30,000 ft. Pilot parachutes for Mig-21, Mig-27, MiG-29, Su-30 MKI, Jaguar and Mirage-2000 have also been indigenised.

State-of-the-art food technologies including post-harvest technology; ready-to-eat food products; packaging systems and processing technologies for fresh and processed food for Armed Forces have been developed. Glacier caps, face masks, jackets, glacier gaiters, gloves, ponchos for protection of head from cold in Glacier region are being used by Indian Army.

Technologies have been developed related to protection against explosives

and fire. Advanced oxidation process technology is developed for the treatment of toxic and hazardous effluents. Stabilisation/solidification technology is developed for the disposal of toxic heavy metals and other concentrated toxic/hazardous organic wastes. DRDO has also developed precipitative, adsorptive and electrochemical techniques for the treatment of heavy metals and polyurea based polymeric coatings for blast mitigation.

DRDO is also equipped with many advanced test facilities for the development of defence technologies. Hypersonic wind tunnel test facility, shore-based test facility, manoeuvring basin, EMI/EMC setups, shock and vibration setups for various parameters, aeronautical test range and many other facilities are also being used by Indian industry for making the defence systems.

Glorious History & Bright Future

During the journey of 63 years after its inception, DRDO has been continuously developing defence systems for the Nation, often in collaboration with various R&D laboratories.

While a brief glimpse of some of the systems has been provided here, there are many other systems that have been developed and deployed in the service of the nation.

DRDO is working on upcoming technologies like Quantum, Hypersonics, advanced materials for defence applications, network enabled defence systems and AI for defence. and Artificial Intelligence for Defence. Hypersonic Technology Demonstrator Vehicle (HSDTV) has been successfully tested last year, making India the fourth country in the world to have demonstrated this technology. DRDO



Hypersonic Wind Tunnel

"While close hand-holding of DRDO with Indian industry partners has helped spawn a robust defence industry in the country, DRDO is also promoting innovation in startups and students through its various schemes."



Hypersonic Technology Demonstrator Vehicle

laboratories are working on a well laid out plan for the next generation of missiles, aircrafts, tanks, sensors, underwater systems and armaments.

While close hand-holding of DRDO with Indian industry partners has helped spawn a robust defence industry in the country, DRDO is promoting innovation in startups and students through its various schemes. DRDO of the 21st century is taking up challenging assignments with an eye on the future defence preparedness of the country.





INDIAN **AGRICULTURE JOURNEY FROM BEGGING BOWL TO SUSTAINABLE FOOD** SECURITY



Dr Trilochan Mohapatra

Secretary, Department of Agricultural Research and Education (DARE) Director-General, Indian Council of Agricultural Research (ICAR)



Dr P.K. Rout

Principal Scientist Office of Secretary (DARE) and DG (ICAR)

IVILISATION, as it is known today, could not have evolved, nor can it survive, without an adequate food supply" - this quote by Norman Borlaug underlines the importance of agriculture for mankind.

The Indian situation amply testifies to this eminent quote. We have made significant strides to attain and sustain food self-sufficiency. Today, Indian agriculture is rapidly transforming with the technological infusion, policy reforms, fast-changing food habits and growing trade opportunities. Agricultural growth is critical for sustainable and inclusive economic growth.

Indian Agriculture and rural life have undergone tremendous transformation since independence. Agricultural development integral part of overall economic growth and was the main source of national income and occupation at the time of Independence. It contributed about 50 per cent to India's national income and around 72 per cent of total working population was engaged in agriculture at that time. Although the contribution of agriculture to national GDP is decreasing over the years, it is important that the growth of other sectors and overall economy depends on the performance of agriculture to a considerable extent. Because of these reasons agriculture continues to be the dominant sector in the Indian Economy.

At the present juncture, when the entire economy shrank due to the COVID-19 pandemic, the agricultural sector registered growth

agricultural production also continued to grow like past years. Agriculture has sustained its growth momentum despite a slowdown in the economy - the sector grew by 4% during the year 2019-20. India has 159.7 million hectares of arable land (second largest after the US) and experiences all the 15 prominent climates existing across continents and has 46 out of 60 soil types that are there in the world.

"The growth of other sectors and overall economy depends on the performance agriculture to a considerable extent. Because of these reasons agriculture continues to be the dominant sector in the Indian Economy."

The post-Independence journey of Indian Agriculture has been quite impressive despite several limiting factors such as uncertainties of weather, soil health, declining increasing atmospheric temperature and emergence of more virulent pests and pathogens. Our food-grain production has crossed the 300 million-ton mark during 2020-21. Technological advancements in agriculture have been influential in driving changes in the farm sector. Although the amount of land and labour used in farming declined, the total farm output increased more than 5 times between 1950-51 and 2020. Similarly, the yield (kg/ha) has increased about four times during the same period.

Agricultural Research System

India has one of the largest and wellcoordinated public agricultural research systems in the world. The Indian Council of Agricultural Research (ICAR) is an autonomous organisation under the Department of Agricultural Research and Education (DARE), Ministry of Agriculture and Farmers Welfare, Government of India. ICAR was established on 16 July 1929 as a registered society under the Societies Registration Act, 1860.

The historical development of agricultural research goes back to the year 1869, when the Imperial Bacteriological Laboratory established in Pune, which was subsequently shifted to Mukteshwar (Uttar Pradesh) and now is part of the Indian Veterinary Research Institute,

Izatnagar, Bareilly. The Imperial Agricultural Research Institute was established at Pusa, a village in the Darbhanga district of Bihar in 1905 with donations from Henry Phipps of the USA. There was a disastrous earthquake in 1936 and the institute was shifted to New Delhi, and today it is known as the Pusa Institute (Indian Agricultural Research Institute). ICAR was established in the year 1929.

ICAR is responsible for planning, coordinating and promoting agricultural research, technology development, knowledge dissemination and education in the country. It also coordinates policy development in agricultural research, education and extension and manages agricultural education to quality human resource development. Its institutes cover a broad range of categories: crops, horticulture, natural resources, agricultural engineering, veterinary and animal science, and fisheries. ICAR also supports a network of 723 entities known as Krishi Vigyan Kendras (KVKs) and responsible for frontline extension for technology application, adoption, knowledge management and capacity development for Agri-based Rural Development.

90-year-old organisation has played a major role in promoting excellence in higher education in agriculture and coordinating education in all State Agricultural Universities (SAUs) and Central Agricultural Universities (CAUs). ICAR is directly involved in undertaking fundamental as well as applied research in traditional

"India 159.7 million has hectares of arable land (second largest after the US) and experiences all the 15 prominent climates existing across continents and has 46 out of 60 soil-types that are there in the world."

and frontier areas to offer solutions to problems relating to agriculture. The research is carried out through a chain of 102 ICAR institutes, 71 All India Coordinated Research Projects, 3 Central Agricultural Universities, and 67 State Agricultural Universities.

ICAR has focussed on different aspects of Agricultural Research such as food security and supply; food, nutrition and human health promotion and next-generation food system; climate and energy needs; sustainable use of natural resources; food safety; small business innovation and product development; agricultural education and workforce development working towards rural prosperity.

Agricultural Revolutions in India

ICAR has played a pioneering role in ushering the Green Revolution and subsequent developments in agriculture in India through its research and technology development, thus making a visible impact on national food security. The introduction, development and widespread adoption of semi-dwarf,





Green revolution postal stamp

photo-insensitive, input-responsive and high yielding varieties of wheat and rice in the late 1960s brought an unprecedented transformation in the national agricultural economy and food security, under the leadership of ICAR.

In just four years, 1966 to 1970, India's wheat production doubled, from 11 million tons to over 21 million tons. This was termed the "Green Revolution" by William Gaud of the USAID in 1968, and the same year, the government of India commemorated it by issuing a postal stamp. About 80% of the production gains were attributed to yield enhancements, underpinning the driving role of technology. This transformed the nation from a state of ship-to-mouth in the 1960s to the state of Right to Food today.

Enhancing Productivity

At the time of independence, the challenge was to provide adequate food to our growing population. Today, the challenge is to provide safer and nutritious food to promote better health. The world is undergoing several transformative changes such as growing changing population, lifestyles, expanding urbanisation and accelerated climate vagaries that are throwing new challenges for the national agricultural research system.

In the Indian context, the key issues agricultural productivity affecting include decreasing sizes of agricultural land holdings, continued dependence on the monsoon, inadequate access to irrigation, imbalanced use of soil nutrients resulting in loss of fertility of soil, uneven access to modern technology in parts of the country, lack of access to formal agricultural credit, limited procurement of food grains by government agencies, and failure to provide remunerative prices to farmers.

Crop Production

ICAR played a significant role in development technology enabling

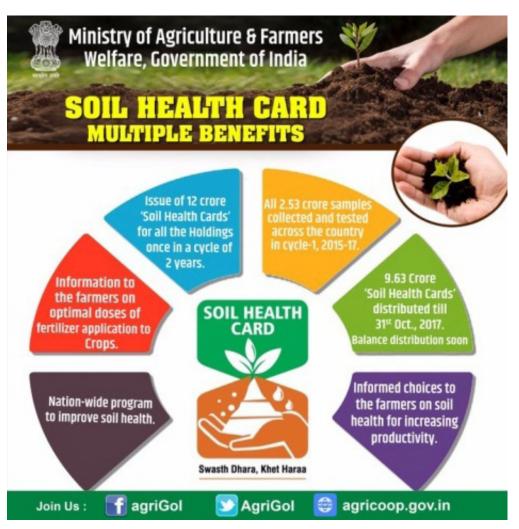
productivity enhancement, and management of natural resources. Genetic enhancement is a major option to bridge the demand and supply gap under normal situations as well as under stressful environments. Research has contributed towards the genetic alteration of crops, improving soil productivity and controlling weeds and pests.

Our research programme focussed on cereals, oilseeds, pulses, fibre crops, forage crops, sugar crops, and horticultural crops. The new varieties not only give higher yield but also tolerate various biotic and abiotic stresses due to environmental factors. The enhancement of productivity, as well as nutrient content, has also assumed significance in more recent years.

this direction, ICAR has released 5999 varieties for cereals, oilseeds, pulses, fibre crops, forage crops, sugar crops and other crops. This list includes 55 varieties developed through marker-assisted selection to fulfil various requirements of farmers. Short-duration varieties of paddy such as PR 121 and PR 126 need 15-25% lesser irrigation than long-duration varieties like PUSA 44 and thus reduce water footprint.



Honourable Prime Minister of India dedicating 17 biofortified varieties to the nation



Soil health cards have been prepared and distributed to farmers by ICAR

During the past five-six years, 71 biofortified varieties in different crops were developed to provide nutritious food and address the problem of malnutrition in our country. These crops are naturally biofortified with vitamins, minerals and amino acids and have reduced level of anti-nutritional factors. Honourable Prime Minister of India dedicated 17 biofortified varieties to the nation in October 2020. These varieties have been brought under the seed chain to make biofortified foodgrains available to the public distribution system. It is estimated that the biofortified crop varieties are grown in more than 4 million ha in the country.

ICAR has emphasised developing good agricultural practices, precision farming, regional plans, climate-resilient and watereconomising technologies to enhance productivity and income security to farmers. Stress tolerance traits such as disease resistance, drought tolerance submergence tolerance were transferred to high yielding crops resilient to adverse climatic variations. About 1020 climate-resilient varieties that withstand various biotic and abiotic stresses in different climatic and soil types have been developed during the period 2015-2021.

ICAR has focused research on Agri-Genomics and genome editing. Genome editing is a precision mutagenesis tool for genetic improvement of crops. Transgene-free genome-edited mega rice cultivar MUT1010 with

major contribution ICAR is the eradication of Rinderpest disease the country. Rinderpest was declared eradicated in 2011, making it the first animal disease to be eliminated in the history of humankind. centuries. **Rinderpest** caused the death of millions of cattle, buffalo, yak and wild animals, leading to famine and starvation."

enhanced yield and stress tolerance was developed by editing four different genes. Reference genomes sequence of wheat, pigeon pea and jute has been developed. Development of 50K SNP Chip for rice has been developed to be used for marker-assisted breeding of rice

ICAR works various on horticultural crops such as fruits, vegetables, flowers, spices, plantation crops, and medicinal and aromatic plants. A total of 1,596 high-yielding varieties and hybrids of horticultural crops (fruits, vegetables, ornamental plants, plantation and spices, medicinal and aromatic plants and mushrooms) have been developed. As a result, the productivity of horticultural crops like banana, grapes, potato, onion, cassava, cardamom, ginger, turmeric has increased significantly.

Quality standard for export purpose has been developed for apple, mango, grape, banana, orange, guava, litchi, papaya, pineapple, sapota, onion, potato, tomato, pea, and cauliflower. using biotechnological tools, transgenics in brinjal and tomato have been developed. Improved techniques for the production of disease-free quality planting material have been developed for citrus, banana, guava, potato, cassava and sweet potato. Micro-propagation techniques have been standardised for various fruits, spices and other vegetative propagated plants and widely utilised for rapid and mass multiplication of various species. Organic farming, coastal agriculture and Island ecosystem have been addressed to enhance productivity and manage carbon emissions in the region.

Integrated Pest Management (IPM) was adopted as a major thrust area of crop protection. IPM aims at minimal use of hazardous chemical pesticides by using alternate pest control methods and techniques. Bacillus and neembased pesticides are being granted regular registration status under the Insecticides Act, 1968. IPM modules have been used for pest management in Basmati rice (Export quality), cotton, vegetables, fruits, pulses and oilseed. Implementation of ICT based pest monitoring is being carried out in pulses.

ICAR has revolutionised quality seed production and strengthened the system to address farmers' needs. Seed hubs for pulses (more than 150), oilseed (more than 35) and millet were established in SAUs, ICAR Institutes and KVKs for accelerated production within a specific time frame.

Land use maps and soil survey maps have been prepared for effective land utilisation for sustainable use of natural resources. Soil resource maps of the country (1:1 million scale), states (1:250,000 scale) and 55 districts (1:50,000 scale); soil degradation map of the country (1:4.4 million scale) and state soil erosion maps (1:250,000 scale) have been prepared and are being used by various agencies.

Animal Husbandry

Animal husbandry is an integral part of our agricultural system and animal genetic resources are our traditional strength. ICAR focuses on several species like cattle, buffaloes, goat, sheep, camel, pig, horse, donkey, yak, mithun, poultry, and duck. It carries out

"Poultry is one of the fastestgrowing segments of the agricultural sector in India with around 8% growth rate per annum. India is one of the world's largest producers of eggs and broiler meat."



Happy Seeder (Source: Wikipedia)

basic and strategic research in cuttingedge technologies in animal genetics and breeding, nutrition, physiology and reproduction, animal health and animal products technology.

The focussed research areas in animal science include germplasm conservation and improvement, livestock nutrition, preventive health care, vaccine production and handling emerging diseases, and milk and meat product development. livestock population of India has been characterised in their natural home tracts to identify and register 197 breeds and get them notified in The Gazette of *India*. This includes 50 breeds of cattle, 17 breeds of buffaloes, 34 breeds of goats, 44 breeds of sheep, 9 breeds of camel, 7 breeds of horses, 19 breeds of chicken and 3 breeds of dog.

Vaccines and diagnostics have been developed for the effective control of livestock diseases. Vaccines/vaccine candidates developed include H5N2 DIVA marker vaccine against Avian Influenza virus, Sheep pox vaccine (Srinagar strain), VLP based IBD vaccine for poultry, Classical Swine Fever live attenuated vaccine, Equine Influenza vaccine for respiratory viral infections, brucella vaccine and Thermo-tolerant type 'O' FMD Vaccine candidate.

Milk Revolution

During the 1950s and 1960s, India was a milk deficit nation and was importing milk/milk powder. Operation flood was launched to expand dairy cooperatives and infrastructure development. The

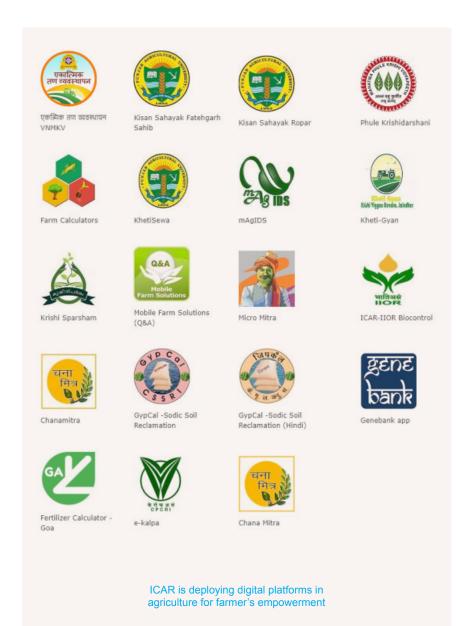
dairy industry is growing steadily at 6.4%, well above the global annual growth rate of 2.2%. The per capita availability of milk in the country increased to 394 gm/day in 2018-19, which is much higher than the world average of 294 gm/day.

Genetic improvement of livestock species is being carried out to increase production performance with respect to milk yield, body growth and reproductive performance. The conservation of animal and avian genetic resources is the priority of ICAR and several breeds of cattle, goat, sheep, camel and poultry have been conserved in their original habitat as well as in the form of embryo, semen and DNA. Production of cloned buffalo calves has been carried out from dead progeny-tested buffalo bull (from seminal plasma-derived somatic cell) and Wild buffalo through inter-species cloning.

Fisheries

Blue Revolution has enhanced fish production and has made India the second largest fish producing country in the world. To diversify fish production at commercial scale, breeding and seed production technology of several food fishes and ornamental fishes has been developed. A genetically improved uniform rohu called Jayanti Rohu with 17% higher growth realisation per generation developed through systematic selective breeding.

diversification Species freshwater aquaculture for over a dozen



important fish species such as carps and freshwater prawns has been successful including packages of practices of their breeding and seed production. Marine cage-culture has been used for farming high-value fish species and technical support has been provided to install cages along the Indian coasts. Similarly, several value-added fish products, products of aquaculture importance and nutraceuticals from seaweeds have been developed.

Mechanisation and Digitisation of Agriculture

Farm implements and machines were developed for improving farm mechanisation in the country to save time and labour, reduce drudgery, cut down production cost, reduce postharvest losses and boost crop output and farm income.

Precision machinery has been developed for efficient agricultural operations in irrigated, rain-fed and hill agriculture, horticulture, livestock and fisheries production. The machineries are fuel-efficient and designed to meet our social and environmental conditions (small land holdings, difficult terrain and different farming systems).

Since women are the main workforce of agriculture, machines like maize-sheller, okra-picker, etc.

"ICAR has played a major role in promoting excellence higher education agriculture and coordinating education all state agricultural universities and central agricultural universities"

have also been developed keeping in mind their specific requirements. Energy management and utilisation of conventional and non-conventional sources in agricultural energy production and processing activities are some of the focussed areas of current research.

ICAR has developed 210 technologies/implements/ machines and about 23197 prototypes of farm machines. A mechanised solution was also provided for rice crop residue burning leading to reduction in fire events from 127774 in 2016 to 61332 (about 52%) during 2019 through in-situ residue management using a machine called Happy Seeder.

ICAR vigorously pursued the deployment of digital platforms in agriculture and the application of ICT for farmer's empowerment. More than 180 mobile apps have been developed on different aspects of farm and farmer-related services. KVKs are also providing mobile agro-advisories and other services to farmers. KVKs have even been linked with common service centres to provide demand-driven information and services to farmers.

Education and Innovation

Agricultural education is promoted by ICAR by establishing new central agricultural universities. The accreditation of SAUs is being carried out to enhance the quality of education and standards in SAUs. National Higher Agricultural Education Project (NHAEP) is being implemented to provide training to students and faculty members in cutting edge technologies and emerging areas of science.

ICAR has also established Netaji Subhash International the

Prime Minister has envisioned making India a USD 5-trillion economy by 2024-25. The agriculture sector is aiming to contribute at least USD 1 trillion and to provide a momentum to our economic development."

Fellowship for overseas doctoral degree programme. IARI-Jharkhand and IARI-Assam have been established in Jharkhand and Assam, respectively. Rajendra Agricultural University, Samastipur, Bihar was upgraded to Rajendra Prasad Central Agricultural University for enhancing education quality in Eastern India.

ICAR has also been engaged in the development of efficient and effective technology transfer systems for shortening the time lag between technology generation and adoption. The motto of the Council, "Agri Search with a Human Touch" speaks volumes of the importance that the Council attaches to transfer of technology to the major stakeholder — the farming community. Similarly, ICAR established 50 Agribusiness Incubators (ABI) since 2016 and supported 1476 start-ups/entrepreneurs/incubatees during 2014-20.

ICAR Technologies - Making **Impact**

Basmati rice is a highly valued agricultural commodity in the international market for its cooking and eating quality. About 90% of Basmati rice trade in overseas market is shared by India.

USA Basmati 1121 semi-dwarf variety was developed by ICAR-IARI in 2003. It has an advantage over traditional basmati varieties which were tall, prone to lodging, photoperiod sensitive and low-yielding. This variety has extra-long slender grains (cooked length up to 22 mm), pleasant aroma and requires less cooking time. It gives an average yield of 4.0 t/ha over 2.5 t/ha of traditional basmati varieties.

Consequently, export earnings from Basmati varieties increased nearly six-fold. from Rs. 5,573 crores in 2006-07 to Rs.32,806 crore in 2018-19 (at 2018 prices). The annual export earnings from PB-1121 are estimated at Rs.19,939 crore (i.e. US\$ 2926.7 million) during Triennium Ending (TE) 2018-19.

HD 2967 is a semi-dwarf wheat variety developed by ICAR-IARI. It was first released for the North-Western Plains Zone (NWPZ) during the year 2011 and later extended for cultivation in the North Eastern Plains Zone (NEPZ) in 2014-15. This variety gives an average grain yield of 5.04 t/ha in NWPZ and 4.54 t/ha in NEPZ. The total economic surplus generated from HD 2967 is estimated at Rs. 62,405 crore (at 2018 prices) during the past eight years (2011-2018). The total economic surplus generated from this variety was estimated at Rs.12,889 crore for TE 2018-19 (at 2018 prices).

India is the largest producer of pomegranate in the world with nearly 86% of area under Bhagwa variety (2.05 lakh ha). The annual economic benefit for the year 2017-18 is Rs 9,617 crores at 2018 prices. Bhagwa variety holds a major share in the pomegranate exports from India. On the export front, pomegranate export earnings increased from Rs 21 crore from 10,315 MT in 2003-04 to Rs 688.47 crore (98.98 million US\$) from 6.78 lakh MT. The direct total economic surplus/benefits since the adoption of dogridge rootstock for raising grape crops was 15,212 crores during 1996-97 to 2017-18 (at 2018 prices). The economic surplus for the year 2017-18 was Rs.1,721.6 crore. Exports of fresh grapes earned a foreign exchange of US\$ 334.91 million (Rs.2,335 crore) while the value of export of raisins was the US\$ 26.217 million during 2018. Nearly 90% of these exports are based on the fruits obtained from grapes raised on dogridge rootstock.

Future Perspective

The Food and Agriculture Organisation (FAO) of the United Nations defines food security as a situation where all

people have, at all times, physical and economic access to sufficient, safe and nutritious food that meets the dietary needs and food preferences for a healthy and active life. According to FAO estimates in The State of Food Security and Nutrition in the World, 2020 report, 189.2 million people are undernourished in India.

Mainstreaming of biofortified crops and consumption of more fruits and vegetables would be desirable for better nutrition outcomes. Economy and Ecology should move together. The major priorities for India are to adopt a comprehensive strategy for enhancing public expenditure on agricultural research and education, processing, market infrastructure and market intelligence. The digital revolution has opened new windows for Indian farmers. Technologies like precision agriculture, e-extension, drone-led operations, smart warehousing and transport optimisation, real-time yield estimation and price information, credit and insurance management and e-marketing have proven their applicability in making agriculture predictable and profitable.

ICAR is also gearing up research to limit carbon emission in agriculture to fulfil our global commitment. The multidimensionality of doubling farmers' necessitates transforming income productionagriculture from a centric to a holistic agri-food system. Research reorientation now demands greater thrust on innovation to bridge knowledge and technology gaps to address supply chain management in agriculture.

The Prime Minister has envisioned making India a USD 5-trillion economy by 2024-25. The agriculture sector is aiming to contribute at least USD 1 trillion and to provide momentum to our economic development. The slogan of Jai Jawan, Jai Kisan, Jai Vigyan encourages agricultural science and technology to remain globally competitive as well as achieving the goal of Atmanirbhar Bharat.



Years of S&T in India **Dr Renu Swarup** Secretary Department of Biotechnology (DBT)

DEPARTMENT OF BIOTECHNOLOGY

Building a strong
Biotechnology Research and
Translation Ecosystem



Dr A. Vamsi KrishnaScientist-E
DBT



NDIA was one of the first countries to establish an independent Department of Biotechnology under the Ministry of Science and Technology in 1986. This was a major step in promoting bioscience research. translational education and entrepreneurship. The National Biotechnology Development Board was established in 1982 followed by the launching of post-graduate programme in 6 universities in 1985, establishing the National Institute of Immunology (DBT-NII) as well as the Biotechnology Information System Network and many mission programmes on Agriculture and Medical Biotechnology. focus has been on the generation of skilled workforce, biotech products, processes and technologies to enhance efficiency, productivity, safety and cost-effectiveness of agriculture, food and nutritional security; affordable health and wellness; environmental safety; clean energy and biofuel; and bio-manufacturing. Emphasis has been

laid on technology-oriented research to improve the lives of millions.

Atal Jai Anusandhan Biotech UNaTI (Undertaking Nationally relevant Technology Innovation) Mission

Atal Jai Anusandhan Biotech UNaTI (Undertaking Nationally relevant Technology Innovation) Mission was launched in February 2019 with a major focus on improved agric ulture, affordable healthcare, clean energy and cutting-edge frontier science. A brief on the UNaTI mission is enumerated below:

GARBH-ini a unique pregnancy cohort comprising more than 8000 women was established to study Pre Term Birth (PTB).

AMR Mission will assure readiness for diagnostics, therapeutics and preventive measures against drugresistant microbes. A National AMR-specific Pathogen priority list for India to prioritise R&D work in AMR was developed in collaboration with WHO, Country Office, New Delhi.

Ind-CEPI Mission is an India-centric collaborative mission aligned to the global initiatives of CEPI (Coalition of Epidemic Preparedness Innovations) being implemented at BIRAC. Under this mission, an eCourse Series "Strengthening Clinical Trial Research Capacity in Neighbouring Countries" benefitted more than 750 participants from neighbouring countries like Afghanistan, Bangladesh, Bhutan, Maldives, Mauritius, Nepal and Srilanka.

UNATI Mission Clean Technologies for Swachh Bharat: DBT has developed various technology platforms designed to convert different solid, liquid and gaseous wastes into renewable fuels, energy and useful



products such as food, feed, polymers and chemicals. Ten promising clean were identified technologies demonstration at different sites across India, in collaboration with local stakeholders such as municipalities. The identified technologies include bio-methanation, constructed wetland, bio-toilets, chemical & membrane-free water purification, etc.

Fortified Wheat Nutritional **Improvement:** Anthocyanin rich biofortified coloured wheat lines were developed by National Agri-Food Biotechnology Institute (NABI), Mohali. 18 MoUs with companies from 9 states and Non-Disclosure Agreements with 9 companies from 4 States involved in contract farming and making food products were signed.



Building a strong Biotech Foundation

Setting up Institutions and COE's

The early emphasis was also on the strengthening of scientific infrastructure in the country. The institutions which had a strong culture of bioscience research such as IISC-Bangalore, TIFR-Mumbai, CCMB-Hyderabad, MKU-Madurai, etc. were fortified with the latest scientific infrastructure. To support research in biotechnology, DBT established 16 Autonomous institutions. DBT has also established PSUs, Bharat Immunologicals and Biologicals and the Indian Vaccines Corporation limited (IVCOL) in 1989 and BIRAC in 2012. Further, to boost research in the University system and in other institutions, a Centre of Excellence scheme was initiated in 2007-08 to cover basic research, translational science and Industrial partnership. A total of 75 COEs were established. These are all theme based centres focussing on translational research.

Creating a Strong Human Resource and Infrastructure Base

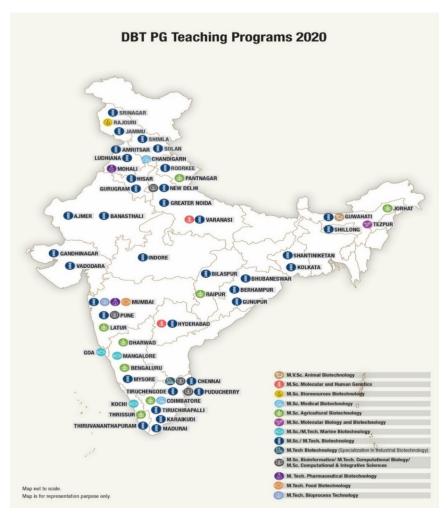
DBT gave emphasis to training and skilling to the next generation of biotechnologists. PG programme was expanded to cover 29 Universities by 1995, which helped to create a critical mass of biotechnologists to bridge the

gap with the western world. The PG programme is now operative in 70 Universities. 240 UG colleges accorded Star college status benefitting 131867 students and setting up 39559 faculties.

DBT-JRF programme provided attractive fellowships to students across the country to pursue doctoral studies. On the other hand, the DBT-RA programme provided an excellent platform to PhD holders do advanced research towards their development as independent researchers. Ramalingaswamy fellowship has reversed brain drain by attracting 487 fellows so far, out of which 261 fellows sought regular faculty positions. BIOCARE programme was instrumental in the enhancement of participation of women in science by supporting over 200 young women scientists.

Skill Vigyan Programme for entrylevel students (10+2 and Graduates in Biotechnology) in partnership with State Councils of Science & Technology has been implemented Arunachal Pradesh, Himachal Pradesh, Meghalaya, Odisha, Punjab, Uttarakhand, Karnataka, Telangana, and Andhra Pradesh. Our target is to cover all States and UTs by 2022.

The Scientific Infrastructure Access for Harnessing Academia University Research Joint Collaboration (SAHAJ) programme has created a







"National Service Facility/Research Resource/Platform" and facilitated access to resources that could not be provided by any single researcher's laboratory or scientific department. The response to SAHAJ portal has been immense and can be witnessed from the fact that 2.40 lakhs users have accessed the equipment/services listed under the SAHAJ portal since its inception and Rs 18.32 crores was generated.

National Genomics Core with its hub in NIBMG-Kalyani, and centres in CDFD-Hyderabad, and the University of Allahabad was established to provide consultancy and services to the academia, clinics and the industry using high-throughput sequencers and high-density microarrays in human-, bacterial- and meta-genomics.

Nine Biotech Parks were established in the States of Uttar Pradesh, Tamil Nadu (2 parks), Karnataka, Kerala, Telangana, Assam, Jammu & Kashmir, Chhattisgarh.

Discovery, Knowledge **Generation & Cutting Edge** Research

This programme entails nurturing of basic research to create a knowledgedriven biotech sector across different edge areas along cutting interdisciplinary research; Continued support to the pan India BTIS-Network and R&D in Theoretical & Computational Biology with the establishment of a National Biological Data Centre; Development of newer tools for genome editing as well as the application of such tools to address specific unmet needs in a wide range of areas through nanobased interventions and development of protein nanomedicine.

DBT-IISc Partnership Programme Phase-II at IISc, Bengaluru, supports biology research and human resource training and has resulted in more than 240 articles, filing of 3 International and 6 National patents and development technologies. Confocal microscopes, biocore facility, mass spectrometry facility, central animal facility, biosafety level-3, SPR facility, X-ray Crystallography facility and fluorescence-activated cell sorter are a part of this programme support.

Biotechnology Information System Network (BTIsNET) was established in 1986 to provide information resources on genetic data, bibliographic references. and management **DBT** established information. supercomputing facility for in-silico studies in genomics, proteomics and drug design at IIT, Delhi. BTIsNET has now been expanded and structured into Thematic Verticals to connect Bioinformatics databases to a national mission. More than 1280 articles have been published and 56 patents have been filed. Nearly 9000 manpower have been trained including JRF/SRF and RA. A 'Supercomputer' facility established at IIT Delhi has also benefitted the scientific community.

Considering the need for proper data storage, data analysis, data sharing for the first time Indian Biological Data Centre (IBDC) was established. This is the first of its kind in the country. The IBDC will enable life science researchers to deposit biological data in a central repository and thus safeguard data generated using public resources from loss.

A novel protein nanomedicine formulation was developed with tunable pharmacokinetic and biodistribution properties achieved through gold (Au) cluster doping technology. Nano Pharma and Nano Agriculture have been released to give a renewed impetus to product development as well as innovation.

Biotech Interventions for Agriculture Sector

Agriculture Biotechnology programmes support understanding of complex biological problems as well as translational research for the development of improved crop varieties in terms of yield, better adaptability to abiotic/biotic stresses and improved parameters. nutritional Genomic selection and Speed Breeding Facility was supported at IRRI, Varanasi, a first of its kind facility in India to facilitate faster genetic gains through speed breeding for generation advancement. Crop genetic resources are being characterised phenotypically genotypically for approximately 70000 accessions pertaining to rice, wheat, pulses and oilseeds for gene discovery. National Genotyping and Genomics Facility (NGGF) anchored at DBT-NIPGR, New Delhi was established as a single-window service system for advanced genomics technology services that could positively influence the Indian seed industry.

Several new crop varieties including Maize (14), Rice (5), Wheat (4), Soybean (1) have been released.

Large seed size Low seed numbe Small seed size High seed numbe ICCV 93954 ICC 14649 Molecular marker for large seed size rall incre *desi* variety Large seed size

Some of the examples include bacterial blight resistant Samba Mahsuri Rice, high nutrient fortified maize, rice with high zinc content, bread wheat & durum wheat with high yield & micronutrient concentration. Samba Mahsuri improved variety is grown in 90,000 hectares in 4 states and more than 80,000 farmers. A high yielding variety of Chickpea ICCV 93954 has been developed with 13-20% enhancement of yield as well as 15% increase in protein content.

Animal Biotechnology, **Animal** Health and Aquaculture: The world's first IVF buffalo calf (PRATHAM) was born at NDRI Karnal in 1992. Kits for the detection of pregnancy in buffalo were also developed. Embryo transfer technology (ETT) was standardized in cattle, buffalo, goat, equine, camel, mithun and yak. ETT has been adopted by various organizations including Animal Husbandry Department, Govt. of India; NDDB; BAIF for producing elite animals. 3 ETT centres and 14 regional ET labs in different parts of the country were established. ETT demonstration activities at the farmer's level produced a number of cattle and buffalo calves. Efforts towards vaccine yielded development "Improved brucella vaccine".

Translational Research Platform for Veterinary Biologicals (TRPVB) established in TANUVAS has been a game-changer in Veterinary Medicine. TRPVB has commercialised 46 products through technology transfer to industries and has several products/technologies ready for commercialisation.

On the aquaculture front, gene encoding major capsid protein of nodavirus was used to produce the

recombinant vaccine, a bioprocess to enhance the level of essential omega 3 fatty acid, and a process was developed to isolate the protein protease inhibitor from marine bacteria Oceanimonas sp. BPMS22.

Affordable Health Care

Providing affordable healthcare for all is the goal of the programme. The emphasis is on the promotion of Biomedical research, understanding the causes of human diseases such as non-communicable diseases, emerging infections, anti-microbial resistance, genetic disorders, maternal and child health, nutrition issues at the genetic and molecular level, early detection, preventive measures, development of vaccines, innovative tools and therapies, healthcare delivery systems and development of products for medical applications.

Early research programmes resulted in the development of rapid detection HIV diagnostic kit by PGIMER-Chandigarh, NII-Delhi, Cancer Research Institute Mumbai. A vaccine for multibacillary leprosy based on Mycobacterium indicuspranii (MIP) was developed by NII. Fungisome, a liposomal formulation of Amphotericin B, is completely designed, developed and commercialized in India.

ROTAVAC® was introduced through the EPI programme in 9 States, and there was a renewed focus on the development of Dengue, TB, Malaria, Chikungunya and Influenza vaccines. National Biopharma Mission, the firstever Industry-Academia mission has supported 11 vaccine candidates for Flu, Cholera, Dengue, Pneumonia, and COVID.



GARBH-ini (interdisciplinary Group for Advanced Research in BirtH outcomes — a DBT India Initiative) has established a unique pregnancy cohort comprising over 8000 women to study Pre Term Birth (PTB) in 6800 pregnant women, of 12.5% PTBs in the enrolled cohort, 9.5% of PTBs attributed to exposure to indoor air pollution; 7.4% attributed to maternal underweight. Indigenous technology for Fortified Rice Premix consisting of Iron, Vitamin B12 and Folic acid for addressal of anemia was developed.

Finding solutions to pre-term birth, development of technologies for bed to bed transfer of patients, ICU simulator, therapeutic chair for cerebral palsy patients, setting up of Kalam Institute of Health Technology (KIHT) to facilitate focused research on critical components pertaining to medical devices were also carried out.

Sohum for early detection of hearing impairment in children; NeoBreath, a foot-operated Resuscitation Device helping Neonatal care; Sishunetra, a first of its kind and a low-cost wide-field eye screening device for premature and term infants; device to manage faecal incontinence useful in ICUs etc. were some of the devices developed.

Non-synonymous somatic mutations in genes of arachidonic acid metabolism (AAM) pathway act as natural inhibitors and increase the post-treatment survival of oral cancer patients. Kits for diagnosis of TB, dengue and Chikungunya were developed, and AMR mission and Mission for Next-Generation Treatment for Snakebite were launched.

Pan India Genome project to catalogue genetic variation in the Indian population and establishment of NIDAN kendras for management of inherited diseases was launched, 34000 pregnant women and 16000 newborn babies from 7 aspirational districts were screened.

Environment, Clean Energy - Key leads, Technologies, **Products**

Emphasis is being given to the development of cost-effective biofuel technologies and technologies/ processes for waste management and environmental improvement.

Oil Zapper technology that can degrade petroleum oil and sludge was developed, used in the oil fields of Kuwait for the clean-up of around 2.5 sq. km area. Based on this technology, OTBL, a joint venture of ONGC and TERI was set up which has a current value of Rs 100 crores.

10 ton/day biomass demonstration facility based on the novel DBT-ICT Lignocellulosic Ethanol Technology was established. 2G ethanol technology has been successfully demonstrated at 5T/day using rice straw & cotton straw. A new technology to remediate pollution from wastewater of sugar or distillery industry and use it for enhanced production of algal biofuel was developed.

Mission Innovation (MI). global initiative of 22 countries and the European Union to accelerate

global clean energy, innovation was announced in Paris on November 30th, 2015. First Clean Energy International Incubator has been set up under Mission Innovation.

Sustainable Bioresources

Bioresources and Secondary Agriculture biomass biotransformation, bioresource systems analysis and technologies associated with conversion production of value-added products and processes from natural resources are being supported.

Two tissue culture pilot plant facilities were established at TERI New Delhi and NCL Pune with the focus on several important plant species such as Teak, Eucalyptus, Cardamom, Vanilla, Apple, black pepper etc. By the year 2000, the capacity of both the facilities was scaled up to produce more than 2 million plants. In 1999, a National Bioresource Development Board (NDBD) was established as per Cabinet Approval with a mandate for conservation and sustainable of bioresources.

In the National Centre for Microbial Resource (NCMR) more than 1.8 lakhs microorganisms have been deposited and it is the largest culture collection in the world and lifted India to 3rd place among countries among collection of microbes. Indian Bioresource Information Network (IBIN) established to provide relevant information on bio-resources of the country has information available on 28,734 plant species; 1,303 birds;

LOW-COST DEVICES DEVELOPED UNDER DBT

supported Biodesign Programme



Sishunetra



Sohum



NeoBreath

222 amphibians; 175 lizards; 127 mammals; 203 snakes; 39 turtles; 672 fish; 1,075 mollusc; 72 prawns; 2043 butterflies; 471 lichens; 4350 marine animals; 19,926 microbes; 4,634 pests; 23 lab animals; 7 domestic animals; 232 parasites; 295 predators and 5 silkworms. Furthermore. through collaboration with the Department of Space 84% of the Country's forest cover has been characterized. National Certification System for Tissue Culture Raised Plants (NCS-TCP) has certified 513.3 Million and 1,71,100 ha were covered in terms of gross certified volume.

Technology agreement was signed between DBT-ICGEB and industry partner - M/s Sun Pharmaceuticals to take forward the research lead developed (most bioactive extract from a medicinal plant) towards development of an anti-dengue drug both in AYUSH and phytopharmaceutical mode.

Building a strong Innovation based and start-up Ecosystem

Biotechnology Industry Research Assistant Council (BIRAC) has supported technology-driven 1000+ Entrepreneurs, Startups and SMEs through various operational models of cooperation. A network of 60 Bioincubators have been built, creating an incubation space of 6,40,349 + sq. ft.

Active Collaborations: **BILATERAL (16)** Canada 20 Brazil 11 United Kingdom 80 Denmark 11 The United States 11 Finland 41 The Netherlands 10 Spain 10 Sweden 18 Russia 09 European Union 33 Australia 758 Switzerland 11 S. Africa 04

with high-end infrastructure providing access to instrumentation, technical, IP, legal and business mentorship for biotech startups. BIRAC has helped innovators to create a pool of intellectual wealth (297+ IPs filed) and has supported the launch of 150 products and technologies in the market. BIRAC's Incubation Centre BioNEST Network provides the critical nurturing ground for the Biotech Startups across the country. The number of startups is expected to grow to 10,000 by 2024.

International Partnerships

16 bilateral/multilateral cooperation's currently active. Biomedical Research Career Programme (BRCP), Wellcome (WT)/DBT Trust India Alliance has recommended 330 fellowships spread across 121 institutions in 43 cities in the last seven vears.

Societal Programmes and Biotech-KISAN:

Societal programmes have created for platform self-employment generation among the target population by diffusion of proven and field-tested technologies through demonstration, training and extension activities. Biotech-KISAN has linked the farmers with the latest scientific innovations to enhance agricultural production and increasing farmers income.

DBT has set up 15 Bioresource centers so far and the 5 new Rural Bioresource Complexes would benefit 4000 individuals from the SC/ST community, rural unemployed youth and women folk from the Aspirational Districts of Yadgir, Akola & Washim, Virudhnagar. Vizianagram Kadapa. Biofortified antioxidant rich coloured wheat cultivation under organic and agronomic supplementation (Fe, Zn, Protein) implemented in the Aspirational District of Moga and Ferozepur, Punjab has helped farmers to garner Rs 2000 to Rs 4000 higher income per acre after the sale of their produce. Extramural support would benefit around 20,000 individuals (8518 from Aspirational Districts) from rural areas, Aspirational districts, womenfolk, youth, SC/ST and socially backward communities.

Biotech-KISAN has created a platform in each of the 15 agro-climatic zones of the country to connect farmers and scientists to promote



BIRAC Impact

agriculture innovation and take the new interventions to the farmers and farms, increasing farm income and covers 105 Aspirational Districts in the country. 65 interventions for the benefit of the farming community have been introduced and over 75000 farmers have been benefitted so far.

NER Programmes

DBT has given special emphasis to NER to prop up the research infrastructure and the R&D landscape across the region. 10% of the years budget is spent on R&D activities NER. Sophisticated biotech infrastructural facilities were created at NRC on Mithun at Jharnapani, Medziphema (Nagaland) and NRC on Yak at Dirang (Arunachal Pradesh). More than 670 twinning projects have been implemented, advanced research infrastructure created, Seeds of pengba (2 million spawn) and pabda (20 thousand fingerlings) were provided to farmers in Tripura, technology developed for the breeding of 3 commercially viable fish species in NER, 2700 farmers and 48 small scale entrepreneurs have been trained in mushroom cultivation in Bodoland District of Assam, 15 biofertilizer formulations and 10 biopesticides were generated and transferred to five companies/firms for commercialization, 3 promising drought-tolerant lines in Ranjit background (rice) along with 6 OTLs for drought tolerance have been identified etc.

Translational and Bio **Manufacturing Hub - Case Study COVID**

The Department of Biotechnology (DBT) initiated an integrated response to overcome the unprecedented COVID-19 pandemic encompassing the development of indigenous vaccines, novel point-of-care diagnostics and therapeutic formulations, establishment of research resources and offering **DBT-BIRAC** Research services. Consortium was launched and over 100 projects are being supported. More than 50 startups have developed innovative products for COVID-19.



Newly Built DBT-NCCS Central Drugs Laboratory for COVID-19 Vaccine Testing

"Mission COVID Suraksha The Indian COIVD-19 Vaccine development Mission" is supporting 5 vaccine candidates and 19 clinical trial sites along with ramping up of Covaxin production. COVID-19 testing is being supplemented through 21 cities/regional clusters, more than 52.01 lakh samples tested as on date across the hubs. The first infectious disease mobile laboratory (I-Lab) was developed and deployed for COVID testing in inaccessible areas. More than 21935 samples were tested in I-lab.

For indigenous manufacture of reagents, components for biomedical research and to promote import substitution and exports, National Biomedical Resource Indigenization Consortium (NBRIC) a 'Make in India' initiative has been launched.

Manufacturing facility set up at Andhra Med Tech Zone (AMTZ) has so far manufactured 575 lakh tests of RT-PCR(> 10 Lakh diagnostic kits/ day), 3.5 lakh Covid-ELISA tests, 11 lakh Viral Transport Media kits, 3000 IR thermometers, 2000 Pulse oximeters and 6000 ventilators.50 BioNEST incubators spread across the country have responded to the Covid situation and collectively this network has nurtured 100+ Startup solutions for Covid.

To enable the seamless supply of samples for COVID-19 research and innovation 4 Biorepositories have been established at DBT AIs, viz., THSTI, Faridabad (for clinical samples), RCB, Faridabad (viral repository), ILS, Bhubaneshwar and inStem, Bengaluru, (for oro/nasopharyngeal swabs, sputum, blood, urine and stool samples). DBT facility at ILBS New Delhi also functioning as a Biorepository. Over 5000 COVID-19 samples have been stored in THSTI biobank.

Support has been provided under PM-CARES funds to NCCS, Pune and NIAB Hyderabad to reduce the burden on Central Drugs Laboratory, Kasauli, for batch testing and quality control of vaccines. The facility at NCCS, Pune has been notified as Central Drugs Laboratory for testing and lot release of COVID-19 vaccines. On the other hand, the facility at NIAB, Hyderabad is likely to receive necessary notification shortly.

To respond to the need of the hour, a rapid response regulatory framework has been put in placeto support researchers and industries involved in research on COVID-19. Biosafety Regulations for COVID-19, in close coordination with CDSCO, for facilitating expedited approvals/ clearances and a Rapid Response Regulatory Framework for COVID 19 Vaccine development has been issued.

Pan-India 1000 SARS-CoV-2 RNA genome sequencing consortium was initiated by DBT-AIs which completed the initial goal of sequencing of 1000 SARS-CoV-2 genomes. The Indian SARS-CoV-2 Genomic Consortium (INSACOG) has been launched to ascertain the status of new variants of SARS-CoV-2. This consortium consists of 28 labs across the country. INSACOG labs have received around 20000 samples from across India for sequencing and more than 10,000 sequences have been analysed to detect Variants of Concern (VoCs) such as B.1.1.7, B.1.351, P.1, and Variant of Interest such as B.1.617 and other emerging Variants of Interest (VoIs).

DBT-BIRAC supported anti-viral drug - Virafin (pegylated interferon alpha-2b) - developed by ZydusCadila, has recently been accorded restricted emergency use approval, for treatment of moderate COVID-19.

The Department has unveiled the National Biotechnology Development Strategy (NDBS) through stakeholder consultations. Steps are being taken to achieve the target of 150 Billion \$ Indian Biotechnology economy by 2025.





REFORMS AND **ACTION POINTS TO STRENGTHEN** SCIENCE, **TECHNOLOGY** AND INNOVATION **ECOSYSTEM IN INDIA**



Shri Seepana Mohit Rao Young Professional, NITI Aayog



Shri Neeraj Sinha Senior Adviser (S&T), NITI Aayog

NDIA of the 21st century is an emerging country with an aspiration of faster, sustainable and inclusive growth. As Science and Technology (S&T) emerges globally as one of the major drivers of socio-economic development, it has to play a major role in achieving the desired goals.

Dr Ashok A. Sonkusare

Dy. Adviser (S&T), NITI Aayog

The country offers a unique opportunity in the form of the large demographic dividend and a huge talent pool for national development through its excellence, relevance and performance. In the fast-growing Indian economy, there is an increasing demand for scientific inputs for problems in a variety of socio-economic, industrial and strategic sectors. It is high time that India, as a fast-growing nation, converts those challenges into opportunities.

To achieve this, several S&T interventions are required. Some of the emerging challenges being faced by the S&T sector include low investment in R&D; inadequate linkages amongst the academia, the researchers and the

industry; weak innovation ecosystem to convert ideas into useful acceptable products and processes; poor coupling between technology and trade; low base of full-time equivalent scientists per million populations, etc.

The following reforms are needed to strengthen our science, technology and innovation ecosystem.

Reforms in S&T for Societal **Development**

Science & Technology/Research & Development must be geared up for solving national problems by providing clean and potable water, enhancing food productivity and nutritional values, providing affordable healthcare solutions, energy security, tackling climate change and National security through S&T interventions. Such measures are necessary, particularly because the mere development of technologies and technology solutions are not adequate to solve major national problems.

The delivery of R&D outputs and linkages with the user community are essential. End-to-End solutions, based on technologies, call for strong internal linkages amongst the Indian science sector as well as with relevant socioeconomic ministries of both the central and the state governments.

Action Points

- A suitable oversight and monitoring mechanism may be formed to oversee the implementing sectorspecific R&D mission programmes/ projects.
- Six sector-specific Task Forces on R&D mission on water, agriculture, health, energy, climate change and National security may be constituted.

Reforms in S&T/R&D for **Global Impact**

India ranks at the 6th position in scientific publications and 10th in patents, which includes only resident applications.



The total number of patent applications filed by scientists and inventors in India increased to 61,788 in FY 2018-19 (up to December 2018) from 47.857 in the FY 2017-18. India ranks at the 12th position in the Nature Index in 2020 (https://www.natureindex.com/annualtables/2020/country/all), based counts of high-quality research outputs in natural sciences. India improved its rank on the Global Innovation Index for the second year consecutively. From being ranked at the 81st position in 2015, India improved its ranking to 52^{nd} in 2019 and further to 48^{th} in 2020. This shows that Indian R&D has the potential to make a global impact.

Action Points

- Increase public investment in R&D and encourage the private sector to invest in R&D.
- Double the present strength of the total number of full-time equivalent of R&D personnel.
- Focus R&D on emerging disruptive technologies like big data, automation, AI, IoT, Blockchain, Cyber Security, Micro-Electro-Mechanical Systems (MEMS), Nanotechnology, Biotechnology, Energy Storage, Genetics, 3-D printing, etc.
- Formulate mission-mode projects on National Mission on Interdisciplinary Cyber-physical Systems and National Mission on Quantum Technologies and Applications.
- Identify global issues and initiate global collaborative R&D leveraging mechanisms like Global Innovation and Technology Alliance, Department of Science and Technology.

Reforms in S&T/R&D for Breaking Silos, Infusing Team Spirit & Competitiveness

There is a need to work in the mission mode, as an integrated S&T community, and fill the translational gaps through definite goals. It has become imperative to bring in more synergy between the Government, the public and the private institutions also. It is envisaged that different departments/laboratories will work together on identified projects and ensure that not only is the technology developed, but it is also transformed to reach the targeted segment of the society.



Action Points

- Identify multi-agency S&T missions.
- Sign MoUs between S&T departments/labs/institutions and universities to facilitate collaborative and interdisciplinary R&D.
- Create mechanism for mobility of scientists from R&D labs/academic institutions to industry and vice versa
- Create a common portal for facilities available in each lab and academic institutions for sharing them with the research community.
- Revive S&T Advisory Committees (STACs) in each Ministry and Inter-Sectoral S&T Advisory Committee (ISSTACs) of the Department of

- Science and Technology (DST), Government of India, for identifying sectoral S&T interventions.
- User Ministries to contribute 1% of their budget to a non-lapsable fund operated by an Inter-Ministerial body for merit-based R&D funding of socially relevant technologies.
- Identify major areas of S&T interventions for addressing national priorities during the next 3-5 years.
- Identify futuristic S&T areas for international competitiveness.
- Pursue technology development in areas identified in the Technology Vision 2035 of the Technology Information, Forecasting and Assessment Council (TIFAC).

Reform in S&T/R&D for Commercialisation of Technologies Developed in Government Laboratories

Some institutions have in-house mechanisms for technology transfer. However, there is a need to set up a dedicated institution for technology transfer. This will take care of the sourcing, designing, packaging, consultancy, field verification, marketing, backup support and dissemination of technology, etc.

Action Points

- Ensure industry partnership right from the conceptualisation stage of technology development projects.
- Create a comprehensive National Technology Portal of indigenous technologies available for commercialisation. The National Innovation Foundation has recently launched the National Innovation Portal, which includes grassroot innovations which are ready for commercialisation. This portal can be scaled up and its focus may be elevated to include all the national innovations ready for technology translation.
- Create an empowered Technology Commercialisation Cell/Value Addition Centre in each lab, with an appropriate budget, for:
 - * up-scaling the technologies,



Dr Harsh Vardhan, Former Hon'ble Union Minister for Science & Technology, Earth Sciences, Health & Family Welfare dedicates an Innovation Portal developed by National innovation Foundation (NIF) - India to the nation

- * demonstrating industrial-scale pilot production,
- coordinating with investors for incubation of entrepreneurs,
- bridging the gap between industry and development team,
- formal technology transfer,
- commercialisation and marketing and
- technology consultancy services.

Reforms in S&T/R&D for **Strengthening** Start-up **Ecosystem**

India has been ranked 20th among 100 countries, based on the strength of its start-up ecosystem in the year 2020 (https://www.startupblink.com/ startups/india). To develop the Start-up culture, Government grants like Fund of Funds for Start-ups, India Aspiration Fund, Venture Capital Scheme and Multiplier Grants Scheme are currently operational.

Besides, 13 Atal Incubation Centers (AICs) are established by the NITI Aayog to foster 5,000-6,000 innovative Startups. 1500+ start-ups have been incubated in 13 AICs in the first phase, with close to 10% focusing on women empowerment. 5,415 schools have been selected till March 2019, and a target of 10,000 schools has been set for establishing Atal Tinkering Labs by the end of 2020. 13 Start-up Centres, 16 Technology Business Incubators (TBIs) and 6 Research Parks have been approved by the National Expert Advisory Committee (NEAC). This is a joint initiative by the Department Science and Technology Ministry of Human Resource Development under the Start-up India scheme.

Further, Patent Rules, 2003 and Trade Mark Rules, 2017, have been amended to streamline processes and make them more user-friendly. Startups Intellectual Property Protection (SIPP) scheme was launched to encourage innovation and creativity in start-ups. Under this scheme, 80% rebate for patent filing fees and 50% for trademark filing is provided to the start-ups. Support for International Patent Protection in Electronics and Information Technology (SIP-EIT) offers reimbursement of up to 50% of expenses incurred in patent filing on the actual expenditure, whichever is less.

Action Points

- Government authorities can incentivise angel investments by, for instance, abolishing the angel tax or giving other kinds of tax benefits.
- Government should set-up a seed fund and give grants to start-ups as effective initiatives.
- More start-ups should be acquired by large, established companies so that it is easier for them to capture markets.

Reforms in S&T/R&D **Encouraging PPP in R&D**

The competitiveness of the nation is determined by its ability to translate inventions into successful technologies. Such translation can be achieved only by cooperation and collaboration with the private sector. There is a need to evolve operating models of Public-Private Partnership (PPP) in R&D. The following are possible reasons for the PPP in R&D falling short of expectations:

- R&D programmes/projects are risky and the percentage of failure is high.
- Funding agency provides loans to private partners, but in case of failure, honest risk-takers are penalised.
- Funding agencies are hesitant to disburse loans to private industry because of fear of not being able to recover the fund invested.
- Present investment in PPP in R&D is very meagre.
- Excessive auditing.

Action Points

To attract industrial funds into applied research areas, following is suggested:

- Contribution by a start-up company in PPP in R&D, at the demonstration stage, may be exempted from taxation.
- Loan provided to the industry shall carry much lesser rate of interest, compared to the market rate.
- An Innovation Development and Translation Board (IDTB) may be established to administer the fund for PPP in R&D.
- An umbrella fund, i.e. Innovation Development and Translation Fund (IDTF) may be created under the

Promote and establish world-class incubation centres



Support, nurture innovative technology-based start-ups



Guidance on business planning, go-to-market & financial advisory



Facilitate access to labs. investors, innovators, market access and other resources



- Funds under PPP should be nonlapsable.
- Intellectual Property (IP) should be exclusively licensed to the industry, and the Industry concerned will commercialise the product within a specified time scale.

Reforms in S&T/R&D Sector for Improving S&T Management **System**

It has to be recognized that scientific research flourishes in a more relaxed ambience when administrative and financial support system is more a facilitator than a controller. Autonomy, freedom for individual ideas, flexibility to carry forward promising ideas in a selective manner, in a framework driven by peers, liberal funding, a responsive engagement with academic, societal and industrial domains and sustained collaborative exchange with high-quality international research programmes, are key features of a conducive ecosystem for research. Development of technology, addition, needs a more organised and coordinated effort by different groups across disciplines with a strategic vision to create conditions favourable for translation and growth of a specific innovation and technology.

Action Points

- An Apex Body may be constituted which could perform the following functions:
 - critical evaluation of the present state of S&T in India,
 - S&T Policy planning,
 - assessing future S&T needs,
 - sociological study of the impact of S&T,
 - funding R&D in priority, new and emerging areash
- Get rid of the "bureaucratic" mindset of unmindful control in a creative R&D environment and ensure meaningful public accountability and facilitating governance system.

Increase R&D Investment

India's R&D investment has shown a consistent growth trend over the years, but as a fraction of the true GDP, the public expenditure has been stagnant at 0.6% to 0.7% of GDP for the past two decades. India's R&D expenditure, as a fraction of the GDP, is nominal as compared to countries such as the US (2.8%), China (2.1%), Israel (4.3%) and Korea (4.2%) (http://psa.gov.in/ sites/default/files/pdf/RD-book-for-WEB.pdf). The R&D expenditure in India has mainly derived from the Central Government, with marginal contributions from the states and the private sector. This is one of the biggest hurdles for India, which is hampering returns from S&T in India.

Action Points

- Increase R&D investment to at least 2% of GDP.
- Encourage private sector contribute to R&D investment.

Substantial Increase in Full-**Time Researchers per Million**

The UNESCO Institute of Statistics 2019 states that the number of researchers per million population in India stands at 156, which is considerably low as compared to US (~4200), China (~ 1200) , Canada (4300) (http://uis. unesco.org/en/news/rd-data-release). The scarcity of researchers in India is a barrier to India's R&D growth and could prove to be a major challenge, considering factors such as high-quality research opportunities aboard, limited incentives and dearth of high impact research in India.

Action Points

- Provide researchers an Income Taxfree salary.
- Initiate scholarships and research grants for researchers.
- Provide career path for researchers.

Reforms Required **Biotechnology Sector**

Biotechnology is a sunrise industry having the potential to provide solutions to a variety of societal challenges. India's bio-economy valued at \$62.5 Billion in FY 2019-20 (Indian Bioeconomy Report 2020; and expected to be \$128 Billion Industry by 2025 (https://birac.nic. in/webcontent/1594624763 india

bioeconomy rep.pdf). Therefore, the Biotech Sector can play an important role in pushing the economy on a high growth path for which the following reforms are required:

- Improvement in research facilities and world-class Clinical Trial Infrastructure.
- Increase in Government spending on R&D and medical infrastructure.
- Fund Small and Medium Enterprises (SMEs) and start-ups in Biotechnology.
- Offer tax holidays for R&D-related income.
- Extend Tax breaks to cover R&D expenses of Indian companies outside India, as well as spending on the cost of patent filings, clinical development, drug discovery, and licensing.
- Extend R&D tax credits available to biopharmaceutical companies to contract research organisations and companies in other sectors of biotechnology.
- Appropriate steps need to be taken to minimise the go-to-market time for Biotech products by fast-tracking approval mechanism for testing and validating these bio-products in consultation with the Department of Biotechnology.
- Appoint more number of Patent reduce patent examiners to processing time and workload on existing examiners and also establish specialised courts or benches to address Intellectual Property-related matters.
- Incentivize the return of Indian students and professionals who are working abroad in the field of biotechnology.



- Create a not-for-profit research organisation focusing on genomics R&D to better understand the characteristics and biological their variations for development of more accurate healthcare or other protection solutions.
- Establish an independent office for drug review process, which can serve as the single-point-of-contact for the process of drug review and guide companies through the process, and resolve their problems.
- Curtail the number of procedures required for starting a business and obtaining construction permits and make the process of land acquisition simpler.
- Promote mobility of researchers/ scientists between industry and academia.
- Develop Indian standards and certifying products, which could instill faith in indigenous products, by ensuring the effectiveness and quality of the said product.
- Promote internships, apprenticeships, and other parttime opportunities for researchers universities and research institutions to provide them the necessary industry exposure.
- Encourage Import substitution by creating local vendor network, policy drive for indigenous production of raw materials, reagents, components for achieving 100% Made in India value-added final products.
- Encourage **MNCs** bring novel biotech products, future technologies to India by differentially incentivizing them over regular FDI for routine manufacturing.
- Upgrade testing labs to bring them at par with global standards to shun perceptions of low-quality goods.
- Continue to work on India-centric epidemic preparedness through the rapid development of vaccines, supporting the development of Indian vaccines in line with the Coalition for Innovation in Epidemic Preparedness (CEPI) global initiative.

Industry, Academia and Government to work together towards military applications of synthetic biology and Genetic Engineering.

Reforms Required in IT Sector

India's IT industry contributed around 7.7 per cent to the country's GDP and is expected to contribute 10 per cent of India's GDP by 2025. The IT-BPM sector in India stood at US\$ 177 billion in 2019 witnessing a growth of 6.1 per cent year-on-year and is estimated that the size of the industry will grow to US\$ 350 billion by 2025.

India has become the digital capabilities hub of the world with around 75 per cent of global digital talent present in the country (https:// indiainvestmentgrid.gov.in/sectors/ information-technology). Indian IT & ITeS companies have set up over 1,000 global delivery centres in about 80 countries across the world. The computer software and hardware sector



in India attracted cumulative Foreign Direct Investment (FDI) inflows worth US\$ 39.47 billion between April 2000 and June 2019 and ranks second in inflow of FDI. Keeping in view the above, the IT sector has the potential to push the economy on high growth path for which the following reforms are required:

- Concerted R&D efforts towards new and emerging areas such as Artificial Intelligence (AI), analytics, automation, cloud, cybersecurity, mobile, etc.
- Create state-of-the-art cybersecurity and data protection frameworks.
- Prepare a roadmap to expand and upscale the infrastructure related to cybersecurity as well as multi-cloud computing for widespread adoption of work-from-home policy.

- Build capabilities for real-time data visualization and data analytics within India.
- Realise the vision of broadband for everyone and provide affordable high speed Internet to everyone by 2025.
- Scale the Government ир e-Marketplace.
- technology-enabled Introduce remote healthcare in public and private health centres and hospitals.
- Build vibrant electronic device manufacturing ecosystems encompassing assembly, components, design for and smartphones, LEDand LCD televisions and set-top boxes, LED lights, sensors, medical electronic devices, among other goods.
- Revitalize 'Make in India' policy to address the challenges in public procurement of indigenous technologies/products in order to strengthen India's manufacturing sector.

Reforms in S&T Sector for **COVID-19 like Situation**

In view of the recent situation where rapid transmission of COVID-19 brought about disruption unimaginable ways, India needs to brace itself for stressful times ahead and bring necessary reforms to withstand the economic turmoil, which is widely expected in the coming months. The existence of S&T capabilities has never been so crucial for a nation. It has presented institutions with a great opportunity to work together for a common cause.

Organisations such as Defence Research and Development Organization (DRDO), the Council of Scientific and Industrial Research (CSIR), Indian Council of Medical Research and Indian Institute of Technology have shown remarkable swiftness in responding to the critical situation, by continuously striving to bring scientific interventions. In the same light, the following measures may be taken in the S&T sector to leverage this situation for economic benefits:

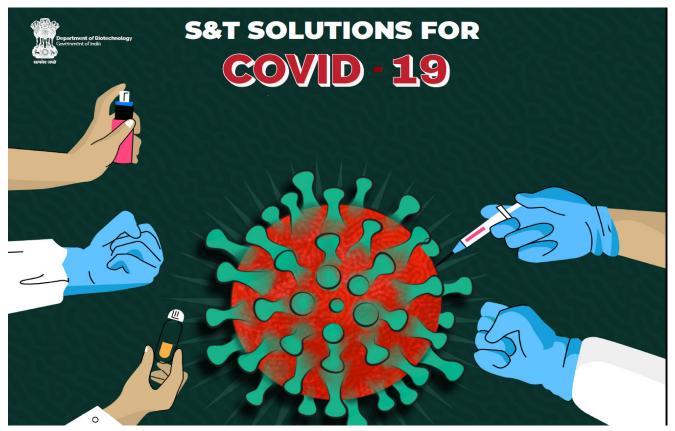


Image credit: DBT

- India has a great economic opportunity to leverage the existing infrastructure manufacture to Personal Protective Equipments (PPEs) and export PPEs for domestic and global consumption, which has evolved as a key concern across different countries in the present time. A dedicated program on manufacturing of PPEs in coordination with different line ministries such as the Ministry of Textile and Ministry of Health and Family Welfare may be initiated.
- Promoting R&D in Mission mode in potential areas such as alternative fabrics/materials/designs for PPEs, low-cost test kits, therapeutic drugs, medical devices etc. Specific public sector enterprises could be identified to manufacture these products in scale for indigenous adoption contributing to import substitutions.
- Appropriate mechanisms need to be developed to fast track prototyping, testing, validation and clinical trials of medical devices such as

- ventilators, splitters, etc. Highquality standards have to be ensured to enable acceptance from global markets. The Member (Health) and Member (S&T) who have been driving the efforts on promoting manufacturing of medical devices need to be continued.
- **Appropriate** management of medical waste is crucial. Manufacturing incinerators and development of alternative waste management disposal systems would not only ensure proper disposal of biomedical wastes related to COVID-19 in India, it could also reduce the cost of disposal of biomedical waste. It also presents an opportunity to serve the global demand for biomedical waste disposal systems.
- Recently ICMR has approved testing facilities in CSIR laboratories for COVID-19, to assist testing and containment of the novel coronavirus. As Laboratories/ R&D Institutions under the S&T

- departments are located in almost all regions of India, measures like mandatory basic training to JRF/SRF to be given on handling equipments/procedures to support health emergencies like Covid-19.
- A Futuristic Technology Division may be set up under each R&D Institution to keep a vigil on probable issues/emergencies that might arise in the future and to address the same, in collaboration with various scientific/medical departments.
- Due impetus needs to be given to R&D and promotion of technical textiles which include protective clothing, sports gears, medical equipment consumables, and etc. Presently most technical textiles are imported. Indigenous manufacturing of these products will reduce India's dependency on imports while boosting production in India.

