# Indian Research and Development Ecosystem for Self-Reliance

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*This article draws the readers' attention to the fact that the Indian R&D ecosystem is interdependent and therefore, there is a need to first understand the nuances of the existing system. Once this is understood by the stakeholders, the present challenges in developing robust indigenous capabilities can be overcome and fleeting opportunities exploited to further strengthen the R&D ecosystem and accelerate India's pace of attaining self-reliance. Accordingly, the myriad R&D and S&T organisations formed in India post Independence and up to the present day have been covered while those organisations perceived to play a more important role have been dealt in detail. Further, the policies of the past and present governments that sought or are seeking to pave the vision of making India 'Viksit Bharat' by 2047 have been dwelled upon while the aim and logic of institutionalised government schemes have been defined and subsumed in their descriptions. Consequently, the article for the first time has strung a logical narrative wherein India's dream of developing an R&D ecosystem for self-reliance can be realised. Finally, it is argued that the strategic foresight of leaders, long-term investments to build R&D resources, training a future-ready workforce to drive innovations and technologies, supportive government policies, industry partnerships and stakeholders' collaborative*

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*synergy are quintessential for the rise, growth and success of the Indian R&D ecosystem for self-reliance.*[1]

**Keywords**: *Research & Development, Self-Reliance, R&D ecosystem, India*

## Overview

The research and development (R&D) ecosystem is a network of research resources comprising civil and military, public and private, national and international, business industries, universities, research institutes, government ministries/departments/agencies, organisations and individuals that drive innovation activities and technological development.[2] These stakeholders form partnerships and work in collaborative R&D networks to create new knowledge/technologies/ideas and develop solutions to transform them into a commercially viable product or service.[3] New products/services developed in multiple sectors address economic and societal challenges, drive trade and industrial growth, increase competency, capture markets, bring in foreign exchange, and helps the country realise its goal of self-reliance.

Self-reliance impacts national security and pertains to a country's ability to meet most of its needs without depending on external sources. It involves developing robust indigenous capabilities in education; basic, applied and developmental research; science, technology and innovation (STI); design and development of products and services; high-end engineering and manufacturing to drive novelty, enhance productivity, improve quality and ensure sustainability.[4]

R&D ecosystem focuses on R&D activities, while the Science and Technology (S&T) ecosystem encompasses a broader scope including S&T interventions for societal development.[5] R&D ecosystem emphasises innovation, technology, commercialisation and private sector involvement.[6] In contrast, S&T ecosystem integrates research, development and technology to address national priorities like clean water, healthcare and climate change.[7] Hence, S&T ecosystem encompasses R&D Ecosystem.

## Global R&D Ecosystems

### Approaches

Global approaches to R&D ecosystem illustrate strategic outlay in R&D, high-quality education, skill development, in-house technological progress and industry teamwork to foster innovations in economy. To achieve self-

reliance, countries like Japan, South Korea, Taiwan, Singapore and Hong Kong prioritised indigenous technology advances for high-end manufacturing while China adopted low-end manufacturing to become a supply chain hub and attain global leadership.[8]

In contrast, Thailand, Malaysia, Indonesia and Vietnam prioritised off-shore low-end manufacturing for job creation with lesser emphasis on self-reliance. India, with higher global aspirations, is tailoring its own R&D ecosystem to develop emerging technologies, build in-house manufacturing capabilities and achieve self-reliance in an ever-evolving technology race.[9]

**Trends**

Global R&D landscape over the years has witnessed central government's share of total R&D decrease while that of the business industry increase.[10] This has had an impact on how countries, including the US and India access higher technologies to attain technological competence, sovereignty and superiority.[11]

Military technological developments in the past had a spillover effect for commercial applications. Today, countries are reverse-leveraging, where civil technological innovations are increasingly being adopted for defence applications. This has necessitated both military and business/industry organisations to adapt for accessing and integrating technologies.[12]

Collaborative partnerships and knowledge exchange between the academia, public and private institutions to generate innovations and build a strong R&D ecosystem to enhance technological abilities, address future acquisitions and expedite commercialisation of technologies is essential.[13]

Global conflicts are repeatedly reiterating the need to strengthen national defence R&D ecosystems for self-sufficiency. This calls for comprehensive R&D arrangements, private sector involvement, improved in-house manufacturing capabilities and mission-oriented programmes to build military technologies and products for both India and the world, thereby reducing dependence on external sources.[14]

International collaborations through strategic partnerships between countries or amongst domestic/international R&D stakeholders to harness mutual expertise, fund innovations, create opportunities and exploit multi-sector scheduling to integrate and/or scale-up industrial manufacturing can accelerate attainment of technological sovereignty.

In an interconnected world, studying approaches and trends in global R&D ecosystem, can enable charting out plans and methodologies to

strengthen the country's technological base and industrial capabilities for strategic autonomy. Further, R&D has expanded in scope to encompass additional activities for driving innovations such as developing Centres of Excellence (CsOE); Research Parks/Centres and Institutions;[15] Innovation Centres and Clusters; Technology Innovation Hubs (TIHs), Business Innovation Incubators (BIIs), Accelerators, Industrial/Defence Corridors, Venture Capitalists, etc., to encourage innovations, help new innovators scale-up and nurture an innovative ecosystem in the country.

## The Indian R&D Ecosystem

### Approach

India's scientific policy resolution of 1958 resolved to 'foster, promote and sustain' the cultivation of science and scientific research in all its aspects. Technology then was expected to flow from the country's established science infrastructure. Technology Policy Statement of 1983 emphasised requirement to attain technological competence and self-reliance. S&T policy of 2003 brought S&T together, emphasised need for investment in R&D, called for integrating programmes of socio-economic sectors with national R&D system to address national problems and creating a national innovation system … scientific research utilises money to generate knowledge and by providing solutions, innovations converts knowledge to wealth and/or value. Innovations thus imply S&T based solutions deployed in the economy and/or society. Accordingly, India declared 2010-20 as the 'Decade of Innovation' and the Government established the National Innovation Council (NIC) to implement the 'Decade of Innovation'.[16]

### Ecosystem Evolution: Independence to Globalisation

Post-independence in the 1950s and 1960s, India invested greatly in state-run heavy industries of core and strategic sectors. This gave good results and kept India ahead of most developing countries. Later, in the 1970s and 1980s, more important national priorities hindered investment and infusing of modern technologies in the heavy industries. Private sector supported state-run core sectors and enjoyed near monopoly in non-core sectors especially in a protectionist Indian market. Investments to modernise either the light industry for developing contemporary consumer products or the services sector remained a low priority. Industrial ecosystem in country thus exhibited little productivity, poor quality and low-end technologies.[17]

India during the 1950s to 1980s (known as the lost decades for India) entirely missed out on the 'Third Industrial Revolution' when compared to the other countries of the region. Consequently, during these decades, growth of electronic goods, microprocessors, personal computers, mobile phones due to offshore manufacturing and global value chains benefitted Asian and other developing countries. The impact of missing out during these lost decades was such that, India despite being world's second-largest smartphone market does not make any of them and manufactures only a small portion of modules and solar photovoltaic cells used in these phones.[18]

**Ecosystem Evolution Post 1991**

India remained a protectionist economy until 1991 when liberalisation, privatisation and globalisation reforms were launched. Globalisation implied dismantling trade barriers between nations to integrate the economies with financial flow, trade in services and goods, corporate investments between nations and rapid progress in the area of technology.[19] This enabled India to open up its market to foreign multinational corporations (MNCs) and India joined the World Trade Organization. With the easing of controls, advanced technologies were readily available and could be brought at a relatively lower cost. The Public Sector Undertakings (PSUs) due to lack of technology infusion were inherently inefficient and non-productive and thus unsuitable for a cut-throat globalised market. Further, with the entry of foreign MNCs, Indian private sector companies diverted to technology imports and collaborations and thereby drifted away from the goal of self-reliance. Nevertheless, the events fostered collaboration with global MNCs, attracted foreign investments and helped the Indian R&D ecosystem.[20]

The private sector with limited stakes in heavy industries has thus traditionally accounted for a meagre share of R&D expenditure, especially when compared to other advanced economies. The Indian private sector's R&D by foreign MNCs had also limited to the IT and biotechnology industry. Nonetheless, since the 1990s, corporate R&D spending in the two sectors, by both Indian and foreign firms increased and got ploughed in to develop R&D resources in India.

The Indian R&D ecosystem's rise in the 1990s and the new millennium was attributed to the pharmaceutical, biotechnological, IT, communication and automotive industries. An industry-centric approach in the engineering sectors attracted investments, fostered innovations, provided cost-effective

services and technological advancements to position India as a key player in the global research output.[21]

India's emphasis on education provided a technically capable talent pool and its strategic culture of having educated engineers produced skilled professionals. This made India a favourable destination for R&D activities and investments. Consequently, hundreds of MNCs have established their Global Capability Centres (GCCs) in India.

India actively promoted international collaborations in R&D through partnerships with countries like the US, Japan, Germany and the UK. These collaborations facilitated knowledge exchange, encouraged technology transfer and joint research to enhance India's R&D capabilities, expertise and global standing.

India's R&D ecosystem emphasises the need for autonomy by recognising the importance of indigenous efforts in driving innovations and technological improvements. Accordingly, continuous efforts were made to harness the potential of national PSUs for indigenous R&D efforts.

**Ecosystem Evolution Post 2014: India's Multifaceted R&D Strategy**

The National Development Council (NDC) was established in 1952 and comprises the Prime Minister, Union Cabinet Ministers and Chief Ministers or representatives of States and Union Territories. NDC is the Governing Council of the National Institution for Transforming India (NITI) Aayog, which itself replaced the Planning Commission in 2015.[22] NDC is responsible for examining the National Development Plans (NDPs) circulated by the NITI Aayog. India from mid-2014 onwards, in consonance with the NDPs and in pursuit of its goal of self-reliance has embarked on a multi-pronged R&D strategy of launching various near-synchronised flagship campaigns. These include 'Make in India' to strengthen domestic manufacturing, 'Skill India' to train a future ready multi-sector workforce, 'Digital India' to promote digital literacy, 'Startup India' to promote start-ups, innovations and entrepreneurial culture, 'Stand Up India' to make loans up to Rs 1 crore available to women and SC/ST borrowers to increase inclusivity and participation, 'Invest India' to simplify the business environment for investors and 'Atmanirbhar Bharat' 2020 to make Indians independent and self-sufficient in all senses. A clarion call has been made for a 'Viksit and Saksham Bharat' implying to make India a competent and developed nation by 2047 (the 100th year of independent India).

## Building Indian Innovation Ecosystem

**National Innovation Foundation (NIF)**

The National Innovation Foundation (NIF), established in year 2000, is an autonomous institution under DST and cultivates creativity, fosters collaboration and drives impactful change through innovations at grassroots level for improving lives of citizens. The NIF team has scouted and documented over 3,00,000 innovations through their *shodh-yatras*, campaigns, biennial competitions and supports innovations by enhancing their value through R&D, design improvement, prototyping, testing, patent applications and plant variety registrations, besides facilitating diffusion of these innovations helping technology transfer and business incubation.[23]

**Atal Innovation Mission (AIM)**

The Atal Innovation Mission (AIM), set up in 2016 under the NITI Aayog is the government's flagship initiative to promote a culture of innovation and entrepreneurship and has ensured a holistic approach in creation of a problem-solving innovative mindset in schools by creating an ecosystem of entrepreneurship in universities, research institutions, private sector and MSMEs.[24]

*Atal Tinkering Labs (ATL): At the School Level*

AIM launched an ATL programme to foster curiosity and innovation in young minds, between Grade 6 and Grade 12 using 21st century tools and technologies such as Internet of Things, 3D printing, rapid prototyping tools, miniaturised electronics, do-it-yourself kits, robotics, etc. Till date, the AIM has established 10,000 ATLs in schools across the country.[25]

*Atal Incubation Centres (AICs): Building Start-ups and Entrepreneurs Ecosystem of India*

AICs are business incubators established by AIM at universities, institutions and corporates to foster world-class innovation and support dynamic entrepreneurs who want to build scalable and sustainable enterprises. AIM has successfully operationalised 72 AICs across India. AICs enable start-ups by providing technical facilities, resource-based support, mentorship, funding support, partnerships and networking, co-working spaces and lab facilities among others. Over 3,500 start-ups have been incubated at AICs and created more than 32,000 jobs in the ecosystem. About 1,000 startups

have women leaders and founders. AICs support start-ups from diverse areas of Health-tech, Fin-tech, Ed-Tech, Space and Drone Tech, AR/VR, Food Processing, Tourism, etc.[26]

**Defence Innovation Ecosystem**

*Innovations for Defence Excellence (iDEX)*

Innovations for Defence Excellence (iDEX), a scheme launched in 2018 by the Department of Defence Production of the Ministry of Defence, Government of India, provides an ecosystem to foster innovation and technology development in defence and aerospace sectors by engaging innovators and entrepreneurs to deliver technologically advanced solutions for modernising the Indian military. iDEX engages industries including MSMEs, start-ups, individual innovators, R&D institutes and the academia, provides them grants/funding and other support to carry out R&D, which has good potential for future adoption for Indian military needs.[27]

The core objectives are to facilitate rapid development of new, home-grown and innovative technologies to meet the needs of the military in shorter timelines, create a culture of engagement with innovative start-ups to encourage co-creation and empower a culture of technology and co-innovation within the defence and aerospace sectors.[28]

iDEX since inception has undertaken over 350 challenges, received 7500+ applications, shortlisted 1300+ applicants, announced 362 winners, awarded 300+ contracts and approved grants worth Rs 330 crores.[29]

*Technology Development Fund (TDF)*

The Technology Development Fund (TDF) scheme launched in 2018 by the Defence Research and Development Organization (DRDO), extends financial support and expertise to upgrade existing defence products/systems, processes and their applications by reducing production costs, improving functionality and quality, promoting 'Make in India' for the development of futuristic technologies with defence applications.

The scheme enlists requirements of the Service Headquarters of upgrading products/systems and futuristic defence technologies as projects for which eligible stakeholders apply.

TDF since inception in 2018 has received over 4,000 applications, recognised 60+ technologies and approved grants worth more than Rs 274 lakhs.[30]

*Services Innovation Ecosystem*

The three services of the Armed Forces have their own innovation organisations, which identify service-specific requirements of future defence technologies, products and systems. These through institutionalised mechanisms are disseminated to the National R&D Ecosystem in the form of 'Innovation Challenges' to iDEX, 'Technology Development Projects' to DRDO, 'Import Substitution of Defence Items/Products' to Industries including start-ups and MSMEs, 'Make Projects' by public sector or private sector or on a Public–Private Partnership (PPP) Model, 'Mission Mode Projects' by the DRDO, De-novo home-grown defence systems or sub-systems under the 'Development-cum-Production Partner Route' or the 'Strategic Partnership Model', etc. Services also run in-house service-specific 'Ideas and Innovation Competitions' to encourage innovative minds and foster an innovative culture within the Services.

## India's R&D Architecture

As the S&T ecosystem encompasses the R&D ecosystem, it would be prudent to develop an understanding of the S&T ecosystem of India. This comprises S&T departments of the central government, central socio-economic and other ministries, S&T department of state governments and of non-government organisations, in-house R&D in private industry and independent research institutes.[31]

The central government's major ministries/departments and their scientific agencies, which undertake R&D are broadly discussed next.[32]

The Ministry of S&T (MST) has three departments—Department of S&T (DST), Department of Scientific and Industrial Research (DSIR) and Department of Bio-technology (DBT).

DST has the Science and Engineering Research Council (SERC), National Innovation Foundation (NIF), Technology Development Board (TDB), National Council for S&T and Communication (NCSTC), National S&T Entrepreneurship Development Board (NSTEDB)—with technology parks and business incubators, technology information forecasting and assessment council (TIFAC) and the patent facilitating cell (PFC).[33]

DSIR has the Council of Scientific and Industrial Research (CSIR), Consultancy Development Centre (CDC) and the National S&T Entrepreneurship Development Board (NSTEDB) while the DBT has autonomous institutes and PSUs such as Biotechnology Industry Research Assistance Council (BIRAC) and Regional Centre for Biotechnology (RCB).

The other ministries and their agencies undertaking notable R&D activities are the Ministry of Agriculture (MoA) with the Indian Council of Agricultural Research (ICAR), Ministry of Earth Sciences (MoES) with their universities, the Ministry of Health and Family Welfare (MoHFW) with the Indian Council of Medical Research (ICMR), Ministry of Defence (MoD) with DRDO and the Ministry of Mines. Other departments include the Department of Atomic Energy (DAE), Department of Space (DOS) and the Department of Defence (DOD).[34]

**The Office of the Principal Scientific Advisor (PSA) of India**

At the apex level, the Indian government in November 1999 established the office of the Principal Scientific Advisor (PSA) with the aim of providing pragmatic and objective advice to the Prime Minister and the Cabinet in matters of S&T. The PSA's role includes enabling future preparedness in emerging domains of S&T, formulating and coordinating major inter-ministerial S&T missions and nurturing effective public–private linkages to drive research and innovation.[35]

**The Science, Technology and Innovation Advisory Council**

In 2018, a key initiative of the office was constituting the Prime Minister's Science, Technology and Innovation Advisory Council (PM-STIAC), to assess the status of various S&T related matters, comprehend challenges, formulate interventions, develop a futuristic roadmap and oversee implementation by concerned S&T ministries/departments/agencies. PM-STIAC also directs to formulate, converge, collaborate, coordinate and implement multi-stakeholder policy initiatives, mechanisms, reforms and programmes. Initiative aims for a synergised collaborative S&T; future preparedness by formulating/coordinating S&T missions; providing enabling ecosystem for techno-entrepreneurs; driving innovation and technology, developing innovation clusters and fostering effective public–private linkages.[36]

**PSA's National Missions**

The PM-STIAC facilitates through its national missions aligned to national interest, a process of collaboration and focus to solve complex problems in a reasonable time-frame. Missions of national importance aim to understand and conserve our biodiversity and develop sustainable processes, leverage health for personal well-being, recover wealth from waste, develop and use artificial intelligence, quantum computing, connected mobility solutions and

other technologies to address frontier scientific questions and challenges, thereby enabling sustainable development.[37]

**Empowered Technology Group (ETG)**

Another initiative of the office was constituting the Empowered Technology Group (ETG) by the Cabinet. The ETG is an institutionalised structure to proactively enunciate, harmonise and oversee national-level policies pertaining to procurement and induction, R&D in technologies with large outlays in resources and render advice to determine 'direction and trajectory of government's R&D and Technology Development Programmes'.[38]

**Science Technology and Innovation Policy (STIP)**

The Government of India's fifth National Science Technology and Innovation Policy (STIP) is to be initiated jointly by the Office of the PSA and DST and expected to be a comprehensive and pragmatic policy aimed to re-orient STI in terms of priorities, sectoral focus and strategies. Consultation processes on four interconnected tracks as envisioned to formulate the STIP have started and are running simultaneously. Key new features expected are bottom-up, decentralised, experts-driven, evidence-informed and inclusive to provide a holistic outline for a scientific future.[39]

**Industry–Academia Collaboration**

Office of the PSA through its Strategic Alliances division promotes partnerships between industry, academia, research foundations, start-ups, MSMEs through coalitions and consortiums, both national and international. Deliberations are initiated by the division after demands from industries and foundations are fed into the academia and start-up ecosystem for strategising the development of their innovative solutions. Such Industry–Academia collaborations have led to joint R&D or contracted industry R&D; establishment and development of COEs by industry in academia and finding innovative solutions for social development. 'The division till date has undertaken around 250 projects that benefitted 23 academic institutions and around 80+ start-ups.'[40]

**Manthan Platform**

The platform provides an overview of social impact of S&T based solutions and aims to empower stakeholders to increase interactions amongst researchers/innovators to facilitate R&D/innovation, exchange challenges on emerging technologies, other scientific interventions and those having a social impact.[41]

## Anusandhan National Research Foundation

The Anusandhan National Research Foundation (NRF) Bill, 2023 was passed by both houses of parliament in August 2023 and the Act will repeal Science and Engineering Research Board (SERB) established by an Act of Parliament in 2008 and subsume it. The Act will pave the way to establish NRF that will seed, grow and promote R&D and foster a culture of research and innovation throughout India's universities, colleges, research institutions and R&D laboratories. The Act will establish NRF as an apex body to provide high-level strategic direction of scientific research, innovation and entrepreneurship in the country in fields of natural sciences including mathematical sciences, engineering and technology, environmental and earth sciences, health and agriculture. It envisages spending of Rs 50,000 crores for five years, out of which Rs 36,000 crores, almost 80 per cent, is going to come from non-government sources, from industry and philanthropists, from domestic as well as outside sources.[42]

DST will be the administrative Department of NRF which will be governed by a Governing Board consisting of eminent researchers and professionals across disciplines. Since scope of the NRF is wide-ranging—impacting all ministries—Prime Minister will be the ex-officio President of the Board and Union Minister of S&T & Union Minister of Education will be the ex-officio Vice-Presidents. NRF's functioning will be governed by an Executive Council chaired by the PSA to the Government of India. NRF will forge collaborations among the industry, academia and government departments and research institutions, and create an interface mechanism for participation and contribution of industries and State governments in addition to the scientific and line ministries. It will focus on creating a policy framework and putting in place regulatory processes that can encourage collaboration and increased spending by the industry on R&D.[43]

## Department of Science & Technology

The Department of Science & Technology (DST) established in 1971 is a nodal department for organising, coordinating and promoting S&T activities in India. The DST's important responsibilities include the following: formulation of S&T policies, advise, R&D through its research institutions or laboratories for development of indigenous technologies, their standardisation and applications in co-ordination with the concerned

Ministry or Department, integration of S&T areas having cross-sectoral linkages, financially sponsor research design and development, grants-in-aid to scientific research institutions, scientific associations and bodies, international S&T cooperation including appointment of scientific attaches abroad, support professional science academies promoted and funded by DST, NIF promotes domestic technology ventures involving commercialisation, institutional S&T capacity-building including setting up of new institutions and institutional infrastructure, promotion of S&T at the State, District and Village levels for grassroots development through State S&T Councils and other mechanisms.[44]

**DST Schemes and Programmes**

The DST supports grants-in-aid to scientific research institutions, scientific associations and fellowships to students and research scholars through schemes/programmes involving human and institutional capacity-building, R&D, technology development, innovation and entrepreneurship, science and society linkage. These are designed with the specific objective of promoting research and innovation in specific domain/field(s) for target stakeholders.[45]

**DST's Human Capacity-Building Programme**

*Innovation in Science Pursuit for Inspired Research (INSPIRE)*

The Innovation in Science Pursuit for Inspired Research (INSPIRE) programme by DST is to build human resource pool for strengthening S&T ecosystem and expanding R&D base of country. It does not conduct competitive exam(s) and relies on existing educational structures for identification of meritorious youth from school, college and university level. It provides scholarships, fellowships and research exposure training by nurturing bright students to study basic and natural sciences and pursue research careers in both basic and applied science areas including engineering, medicine, agriculture and veterinary sciences. The components of the scheme are discussed.

The INSPIRE Internship provides exposure to the top 1 per cent students at Class X Board level by organising Science camps to interact with Science icons from India and abroad, including Nobel Laureates and help think out-of-the box and choose science subjects for studies.[46]

The Scholarship for Higher Education (SHE) aims to encourage meritorious students to study basic and natural sciences at undergraduate

level through 12,000 scholarships every year given to meritorious students in the age group 17–22 years.[47]

The INSPIRE Fellowship offers 1000 Fellowships every year to bright students in the age group of 22–27 years to pursue PhD in basic and applied sciences.

The INSPIRE Faculty Fellowship provides opportunities to 100 persons every year with PhD qualification in the age group of 27–32 years with attractive fellowships for five years to carry out research in both basic and applied science areas.[48]

The INSPIRE-MANAK (Million Minds Augmenting National Aspiration and Knowledge) Scheme caters to school children in the age group of 10–15 years and studying in Classes 6–10 to study science and pursue research. The scheme targets 10 lakh ideas from more than 5 lakh middle and high schools across the country every year. Out of these, one lakh ideas are eligible for an award of Rs 10,000 each. All middle and high schools are eligible to participate and can provide nominations of five students through online mode, every financial year, including a brief idea of the projects students intend to make. Selected students participate in District, State and National level exhibitions and competitions and are provided mentorship at premier educational and technical institutions of the country. Top 60 projects are rewarded as national winners by NIF, the resource partner under this scheme.[49]

## DST'S Institutional Capacity-Building Programmes

### *R&D Infrastructure Division*

The R&D Infrastructure Division aims to strengthen S&T infrastructure of country by nurturing well-equipped R&D labs in academic/research institutes/universities for a strong culture of research collaboration between institutions across disciplines. It has six schemes with the objective of establishing R&D labs, training, upgradation of facilities for a self-reliant India.[50]

### *FIST (Fund for Improvement of S&T Infrastructure in Universities and Higher Educational Institutions)*

This scheme is operated in competitive mode for support at four levels. The financial support delineates six basic purposes of equipment, infrastructural facilities, networking and computational facilities, industrial R&D support,

SSR activities and maintenance. Total financial support is limited to Rs 1.50 crore (Level A), Rs 3.0 crore (Level B), Rs 5.0 crore (Level C) and Rs 10.0 crore (Level D). The programme prefers supporting interdisciplinary problems, solution-centric translational research and enhancing the scope for participation of industries/start-ups with new ideas, aiming for an 'Atmanirbhar Bharat'.[51]

*PURSE (Promotion of University Research and Scientific Excellence)*
The scheme is to strengthen research capacity of performing Indian universities by providing support for the research ecosystem and strengthening the R&D base of universities in the country. DST has restructured and re-oriented PURSE in 2020. A combination of i10-index of faculty members in the university, H-index of the university along with NIRF ranking is used to formulate the new criteria for selection of universities under PURSE.[52]

*SAIF (Sophisticated Analytical Instrument Facilities)*
This scheme is implemented regionally to provide facilities of sophisticated analytical instruments to research workers and institutions which do not have such instruments that enable them to pursue R&D activities. Institutions acquiring such facilities can keep pace with developments taking place globally.

*SATHI (Sophisticated Analytical & Technical Help Institutes)*
This scheme initiates setting up of shared, professionally managed S&T infrastructure facility that is readily accessible to academia, start-ups, manufacturing units, industries and R&D Labs. The Centres will be equipped with major analytical instruments and advanced manufacturing facilities, which is usually not available at institutes/organisations. The aim is to provide professionally managed services with efficiency, accessibility and transparency of the highest order under one roof to service demands of the industry, start-ups and the academia.[53]

*STUTI (Synergistic Training programme Utilising the S&T Infrastructure)*
This programme was designed to cater to HR and capacity-building through open access to S&T infrastructure across the country by organising short-term courses/workshops on awareness, use and application of various instruments and analytical techniques.

*SUPREME (Support for Upgradation Preventive Repair and Maintenance of Equipment)*
The DST launched a new programme in 2023 called 'SUPREME' to provide financial support for repair/upgradation/maintenance/retrofitting or acquiring additional attachment to increase functional capabilities of existing analytical instrumentation facilities, and is supported by DST in various institutions/laboratories/academic institutions.[54]

**National S&T Entrepreneurship Development Board (NSTEDB)**
The NSTEDB established in 1982 by the Government of India supports programmes on STI based entrepreneurship and technology-intensive ventures/start-ups. With a thrust on start-up programmes by national initiatives of Start-Up India and Stand-Up India, a new programme was launched, which enables innovators and start-ups to translate ideas into successful start-ups. DST nurtures and empowers innovators and start-ups since their initial phase of start-up journey.[55]

The major objectives of NSTEDB include developing high-end entrepreneurship for S&T manpower's self-employment by utilising S&T infrastructure and using S&T methods; conducting informational services relating to promotion of entrepreneurship; networking agencies of support system, academic institutions and R&D organisations to foster entrepreneurship; implementing of programmes and act as a policy advisory body with regard to entrepreneurship.

*NIDHI (National Initiative for Developing and Harnessing Innovations)*
NIDHI is a programme developed by the Innovation and Entrepreneurship Division under NSTEDB of DST and since 2016 has been promoting S&T based entrepreneurship and start-up ecosystem across India. The programme works in line with national priorities and goals and focuses to build an innovation-driven entrepreneurial ecosystem with the objective of national development through wealth and job creation. NIDHI aims to nurture start-ups through scouting, supporting and scaling of innovations and is developed keeping in line new national aspirations and DST's experience of three decades of promoting innovative start-ups. The components of NIDHI are designed to support ideators and innovators since their early start-up journey and link them to the entire market value chain, as discussed.[56]

*NIDHI: Entrepreneur in Residence (EIR)*
It provides fellowships and inspires graduating students to take up entrepreneurship.

*NIDHI: Promotion and Acceleration of Young and Aspiring Technology Entrepreneurs (PRAYAS)*
It supports innovators and start-ups technically and financially from the stage of Idea to Prototype.

*NIDHI: Inclusive-Technology Business Incubator (iTBI)*
The programme increases outreach of incubation programmes in terms of geographies, gender, etc.

*NIDHI: Technology Business Incubator (TBI)*
It supports and nurtures knowledge-driven innovative start-ups into successful enterprises.

*NIDHI: Seed Support Programme (SSP)*
It provides early-stage funding to start-ups with promising ideas/innovations to help graduate to the next level.

*NIDHI: Accelerator*
It helps in fast tracking a start-up through focused intervention.

*NIDHI: Center of Excellence (CoE)*
It creates a world-class facility to help start-ups go global.

The programme guidelines for each component are available on the DST website as separate links.

In addition, other programmes include training programmes, women entrepreneurship promotion programmes, Public-Private Partnership, international collaboration programmes, and other special initiatives.[57]

**DST's National Missions**
The national missions are aligned to national interest and planned by PM-STIAC. Few approved national missions pertain to Nano Science and Technology; Geospatial Programmes; Interdisciplinary Cyber Physical Systems; Quantum Technologies & Applications; Super Computing; Strategic Knowledge for Climate Change and Sustaining the Himalayan Ecosystems.

Formulating mission-mode projects such as the National Mission on Interdisciplinary Cyber-Physical Systems and National Mission on Quantum Technologies and Applications, is essential for directing R&D efforts towards specific goals and addressing critical defence challenges. These projects help

in channeling resources, expertise and efforts towards achieving strategic objectives in defence technology development.[58]

**Technology Development and Transfer**

DST supports Technology Development Projects (TDP) in materials, devices and processes. The TDP programme supports activities aimed at developing technologies both in advanced/emerging areas and in traditional sectors/areas. Under the programme, feasibility of fresh ideas/concepts is also assessed for potential conversion into useful technology/product.[59]

*The Mandate of TDP*

Convert proof-of-concepts for technologies/techniques/processes/products into advance prototypes for validation and demonstration in actual field settings. Commercialisation of these technologies needs further assessment/ incubation, which does not fall within the scope of TDP. The onus of transfering technology developed under TDP project to the industry ideally falls on the host institutions. Proposals for incremental R&D over existing technologies are considered for support. Projects related to design and development of software/ IT, as required for products and processes, as a part of TDP are considered. Pure software development does not fall under the scope of the programme. The aim is to support R&D for development of innovative technologies in identified areas, promote application of advanced technology for improving performance and value addition to existing technology, capacity-building in the area of technology development.[60]

Project Proposals could be submitted for financial support by scientists/ engineers/technologists working in academic institutions/registered societies/ R&D institutions/laboratories having adequate infrastructure/facilities to carry out Technology Development work/prototype building. TDP undergoes screening to assess the relevance of proposal and suitability as per mandate, a peer review to facilitate broad-based consultation and recommendations by the respective core group (PAC/EAC) for financial support.[61]

**International S&T Cooperation**

International Cooperation Division of DST is mandated the responsibility of negotiating, concluding and implementing STI agreements between India and other countries and providing interventions on STI aspects in international forums. The responsibility is carried out by the International Cooperation (IC) Division in consultation with the Ministry of External Affairs, Indian missions abroad, S&T counselors at Germany, Japan, Russia

and USA, stakeholders in scientific, technological and academic institutions, governmental agencies and with various industry associations in India.[62]

International Cooperation in STI is realised through bilateral cooperation with developed and developing countries, multilateral and regional cooperation and thematic cooperation.

Under bilateral cooperation, India has STI Cooperation Agreements with 83 countries. In the recent years, cooperation has strengthened significantly with Australia, Canada, EU, France, Germany, Israel, Japan, Russia, UK and USA. Cooperation with African countries has also got strengthened through India Africa S&T Initiative. The soft prowess of S&T has been leveraged to engage with several countries under India's Act East policy and with some neighbouring countries.[63]

Under multilateral and regional cooperation, the IC Division is mandated to foster India's regional and multilateral engagements and partnerships in the fields of S&T. These engagements are done through cooperation frameworks at the inter-governmental level to make positive contributions for gainful consequences and spin-offs for enlarging India's pursuit of influence in global arena/platforms and mainstreaming STI into international diplomacy and foreign relations; leveraging foreign alliances and partnerships to accelerate key priorities and programmes devoted to strengthening India's national S&T/R&D competencies–capabilities–access to technologies in synergies with national flagship programmes.[64]

Some major functions of the IC Division related to forging India's regional and multilateral partnerships in STI being performed include negotiation, conclusion, implementation and monitoring of India's international regional and multilateral S&T cooperation agreements and related S&T Programme of Cooperation (India's S&T cooperation with EU, ASEAN, BRICS, IBSA, SAARC, BIMSTEC, ASEM, EAS); India's engagements vis-à-vis S&T aspects of the UN and other international organisations (India's S&T engagements with NAM S&T Centre, UNESCO-TWAS-ICTP, UNCSTD, OECD, IOR-ARC, G-20); Indian perspectives at S&T Ministerial Multilateral Platforms and its spin-offs.[65]

Under thematic cooperation, the IC Division is partnering in international programmes pertaining to Solar Alliance, Mission Innovation, AIDS Vaccine Initiative and Laser Interferometer Gravitational-Wave Observatory (LIGO).

The IC Division supports three bi-national S&T centres, which are independent entities established under inter-governmental arrangements and include Indo-French Centre for Promotion of Advanced Research

(IFCPAR/CEFIPRA), Indo-US S&T Forum (IUSSTF) and Indo-German S&T Centre (IGSTC).[66]

**MEGA Facilities for Basic Research Scheme**

This scheme is aimed to create mega facilities and launch mega projects inside and outside the country to access such state-of-the-art facilities for Indian scientific community, especially from the academic sector for pursuing basic research. Due to technical complexities and requirement of large resources, such projects are multi-agency, multi-institutional and often, international. DST and DAE are jointly promoting most of such projects in the country.[67]

## State of India's R&D Ecosystem

**India Global Rankings: 2023**[68]

India stands third among world's most desirable locations for technological investments. It is in top three countries with more than 1,250 Global Capability Centres (GCCs), where companies can outsource their product development and receive product engineering services. Also, it ranks 3rd globally in the number of PhDs awarded in Science and Engineering as per the National Science Foundation (NSF), USA's 'Science and Engineering Indicators-2022'.

As per the NSF database, India ranks 3rd in Science publication output in Science journals.

It is 4th in research output in the period 2017–22 behind only China, US and the UK.

India is 5$^{th}$ in number of researchers per million population, and 5$^{th}$ in Global R&D Funding Forecast 2021.

It features in top five when it comes to space exploration and is thus among top nations for scientific research. India witnessed investment of over Rs 1,000 crore (US$ 120.21 million) in Space Start-ups in the last nine months of 2023 (April–December 2023).

As of 2021, more than 70 per cent of 50 most innovative firms across the world have an R&D centre in India.

India ranks 6th in publishing number of peer-reviewed research papers, and 7$^{th}$ in Indian Resident Patent Filing, as per the WIPO-2022 Report.

India is 39th in Global Innovation Index 2023, which is an improvement from 46th position in 2021.

There are about 7,888 research institutions in India as in 2021, of which 66 per cent are in the private sector.

## Challenges of Indian R&D Ecosystem

### Multiple Players

Indian R&D ecosystem is impacted by academia, industry and the government's actions. The Indian academia has one of the world's largest network of educational institutes. An 'All India Survey of Higher Education 2018-19' pegged numbers at nearly 40,000 colleges and 993 universities. These Higher Education Institutes (HEIs) are test-beds for driving innovations; carrying out basic, applied and developmental research; and, publishing research papers and research publications. Indian public and private industries including start-ups, MSMEs, subsidiaries or JVs of foreign MNCs in India have to drive translational research for rapid prototyping of ideas, materials and designs of new products, services or processes to file and register patent. For domestic and foreign R&D stakeholders, the government has to formulate policies, programmes, schemes for investment, incentives/subsidies, taxations, excise and other regulations.

### Low R&D Funding

As per the Economic Survey 2022, India's Gross Domestic Expenditure on R&D (GERD) as a percentage of Gross Domestic Product (GDP) stood at 0.66. The percentage expenditure for the last couple of years has been on decline and slipped from 0.8 per cent in 2021 to 0.66 per cent in 2022 and at 0.56 per cent of GDP in 2023. GERD is much higher for South Korea (4.9), Germany (3.2), US (2.9), China (2.3) and even low middle income economies (1.5).[69] The DST Report 2022 on funding allocated to R&D in 2020–21 stated that 84 per cent GERD expenditure incurred to central government sources came from 12 major science agencies. Strategic sectors accounted together for 60.5 per cent of the amount—DRDO (30.7 per cent), Department of Space (18.4 per cent) and Atomic Energy (11.4 per cent). Of this, 36.2 per cent went to general R&D agencies like ICAR, CSIR, DST, DBT, ICMR, etc., while only 3.3 per cent was allocated to R&D in electronics, IT and renewable energy.[70]

### Universities' Dependence on Grants

Many universities depend on DST, DBT, ICMR and CSIR for extramural support. The dependency creates a situation where quality of research at the

doctoral level is hampered whenever less funding is provided to these public institutions.

**Future-Ready Skill-Sets Required**
Currently, there is a lack of adequate skill-sets and expertise in many emerging technology fields. Also, due to lower remuneration and lack of ecosystem opportunities, the best talent migrates to foreign countries and is not available for undertaking quality research.

**IPR Violation Phobia**
The fear of IPR violation acts as a big impediment to creating something unique and innovative. Further, poor IPR compliance discourages foreign investment flow into the field of R&D.

**Obsolete Curriculum**
In many universities, the curriculum has not been revised to address current and future requirements. Further, there is less emphasis on R&D due to which many universities are unable to duly utilise the research grant provided to them.

**High Fiscal Deficit**
The country's fiscal deficit has encouragingly shrunk from 9.3 per cent in 2020–21 (attributed to the impact of COVID-19) to 6.4 per cent in 2022–23. This is still high and impedes higher allocation to R&D sector as the focus continues to be on reducing the fiscal deficit further.

**Poor Private Sector Participation**
In the financial year 2023, the private sector contributed a dismal 36.4 per cent of the total R&D expenditure in the nation. This is way less than the average 68 per cent expenditure by private players in developed countries.[71]

## Recent Government Measures to Improve India's R&D Ecosystem

**National Education Policy (NEP) 2020 and Research Foundation**
NEP 2020 identifies enhancing India's overall research capacity as a key area of focus. It aims to raise the level of rigour in research management in

Indian Higher Education Institutions (HEIs), set up start-up incubation centres and promote greater linkages between industry and academia for interdisciplinary research. The policy also proposed establishment of NRF as a nodal agency for research funding and recognition at national and state levels.[72]

**Defence R&D Capability-Building**

To enhance strategic capabilities and develop advanced technology/products, recent initiatives/policies of the government are discussed next.

*DRDO Young Scientist Laboratories (DYSLs)*

The DRDO has established five DYSLs to provide solutions in advanced technology areas of artificial intelligence, quantum technologies, cognitive technologies, asymmetric technologies and smart materials to tackle emerging challenges in military warfare.[73]

*Industry-led Design and Development*

In March 2022, Government of India announced 18 major defence platforms for industry-led design and development.[74]

*Positive Indigenisation Lists (PILs) of Services and DPSUs*

Notification of five PILs of services comprising cumulatively of 510 items and four Positive Indigenisation lists of a total of 3,738 items of DPSUs for which there would be an embargo on their import beyond the timelines as indicated against them, will promote indigenisation for self-reliance.

*Indigenisation Portal SRIJAN*

The government launched an indigenisation online portal named SRIJAN to facilitate indigenisation by the Indian industry including MSMEs.[75]

*Twenty-five per cent of the Defence Budget to Develop Defence Technology in the Country*

Budget FY 2023 opened defence R&D for the industry, start-ups and academia. About 25 per cent of the defence budget for R&D activities was earmarked to promote development of defence technology in the country and sunrise opportunities identified in areas of artificial intelligence, geospatial systems, drones, semiconductors, space, pharmaceuticals, genomics green energy and clean mobility systems.[76]

**Encouraged Academia–Industry Collaborations in R&D**

*DRDOs CsOE*
The DRDO established 15 DRDO Industry–Academia CsOE in Indian universities to create world-class research hubs for developing cutting-edge technologies by harnessing combined strength of academia, students, research fellows, niche technology industries and DRDO scientists in driving defence R&D.[77]

*IIT Research Parks*
IITs have established world-class research parks in collaboration with business industries to provide dedicated spaces for R&D and incubate deep-tech start-ups. Successful collaboration has led to the development of cutting-edge technologies and global successes in the defence sector.[78]

*Indian Space Research Organisation (ISRO) Partnerships*
ISRO's MOUs with B-Schools and private organisations will leverage academic expertise and industry resources to drive advancements in space technology and research.[79]

*Innovation Vouchers and Incubation Centres*
These are for students and start-ups and serve as successful examples of industry–academia collaborations in India's defence R&D ecosystem. These schemes incentivise partnerships, facilitate R&D in defence technologies and contribute to the growth of the defence R&D ecosystem.[80]

**Tax Incentives for R&D**
The purpose of tax incentives is to attract foreign and domestic investors to India's R&D ecosystem.

*R&D Tax Deductions for Research Activities*
The government offers 200 per cent super deduction to DSIR-approved R&D facilities for in-house expenditure, including capital expenditure for businesses engaged in biotechnology or manufacturing specific products to incentivise companies to invest in R&D activities.[81]

Companies making specified payments to prescribed entities conducting R&D in India can benefit with a super deduction of 125 per cent to 200 per cent. This encourages collaboration with research institutions and supports growth of the R&D ecosystem in the country.[82]

Apart from super deductions, 100 per cent deduction is available for R&D expenses (excluding land) that do not qualify for above super deductions. Deduction cover expenses related to R&D employee salaries, materials consumed and other R&D costs within three years preceding the commencement of business. There is no cap on benefits available for R&D in India, providing a favourable environment for companies to invest in research and innovation.[83]

Businesses must follow specific procedures and fill necessary forms for claiming R&D tax deductions, depending on the nature of the contribution or research activity.[84]

*Research Linked Incentives (RLIs)*

RLIs provide impetus to the industry to increase R&D investments and encourage collaborations with the academia to co-innovate. RLIs provide incentives based on progress in product development, with higher incentives at advanced stages.[85]

*Patent Box Regime and Recalibration Requirement*

India's Patent Box regime offers a concessional tax rate of 10 per cent on royalty income generated from patents. The scope requires to be enlarged to include income generated from commercialisation of patented products. Additionally, income from exploitation of intellectual property registered overseas, exclusively licensed to Indian companies, should be included under this regime too.[86]

*Corporate Tax Concessions*

The government can offer tax concessions to companies that allocate at least 10 per cent of revenues to R&D and with a minimum threshold that needs to be increased. This incentive can encourage companies to invest more in R&D activities.[87]

*Innovation Bonds Tax Concessions*

To provide low-cost funding and support to R&D projects, the government can introduce long-term, secured 'innovation bonds' that are tax-free to raise funds from public to finance R&D projects, similar to how tax-free infrastructure bonds were utilised by public sector companies for long-term projects.[88]

**Subsidies**

The Indian government offers various types of subsidies and schemes to support and incentivise R&D spending in India, promote innovation and

support development of indigenous technology. They are available to various sectors, including biotechnology, electronics, information technology, renewable energy and scientific research. Some are discussed next.

*Support for International Patent Protection in Electronics & Information Technology (SIP-EIT)*
This scheme encourages innovation and recognises value and capabilities of Global IP. It provides financial assistance up to Rs 15 lakhs per invention or 50 per cent costs required in filing/processing of patent applications. It supports SMEs and technology start-ups in Electronics and IT.[89]

*Multiplier Grant Scheme (MGS)*
The objectives of the MGS are to nurture and strengthen linkages between the academia and the industry and encourage academic R&D institutes to conduct research that can be commercialised. This is facilitated by providing grants to institution level R&D work that is supported by industry. The government provides financial support up to twice of that provided by industry for the project.[90]

*R&D Funding Scheme*
Grants-in-aid are available from the Ministry of Electronics and Information Technology (MeitY) for undertaking research projects relevant to electronics and IT. Amounts vary depending on projects. Any Indian company with an R&D unit approved by DSIR is eligible to apply.[91]

*CSIR Research Grants*
CSIR administers research grants through the Human Resource Development Group. Experts/Scientists working in private sector research labs are eligible for the grant, which awards stipends up to Rs 30,000 per month as a research fellowship.[92]

*Project Finance through the Technology Development Board (TDB)*
The TDB facilitates development of indigenous technology by placing the cess collected through import of technology into financial assistance for companies that are attempting the development and commercial application of indigenous technology or adapting imported technology to wider domestic applications. In-house R&D units recognised by DSIR are eligible to receive financial assistance. The assistance is provided in the form of equity participation, loans and in certain cases, grants.[93]

*Global Innovation and Technology Alliance (GITA)*
Alliance offers soft loans and grants for joint R&D efforts to Indian applicants. Researchers and managers representing Indian companies are eligible for participation in partnership with a counterpart company from certain countries.[94]

**Imprint Initiative**
The IMPacting Research, Innovation and Technology (IMPRINT) Scheme is a pan-IIT and IISc joint collaboration. This scheme was launched in 2015 and aims to provide solutions to most relevant engineering challenges by translating knowledge into viable technology in ten select technology domains.[95]

**IPR Laws**
The WTO Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) is the most comprehensive multilateral agreement on intellectual property (IP). India is a signatory to TRIPS and has enacted its domestic IPR laws to foster IPR creation and curtail its violation.[96]

## The Way Ahead

Countries are increasingly focusing on R&D programmes to gain a competitive edge in the fast-evolving technology landscape of the world. India too needs to leverage this opportunity of developing niche emerging and critical technologies for which more investments need to flow in for R&D. This warrants an increase in budgetary allocation to R&D and other supportive steps by the government. The Economic Survey of 2020–21 had suggested that the country needs to increase its GERD from around 0.7 per cent to over 2 per cent of its GDP.

In most developed countries, defence-related R&D is undertaken by the private sector. In India, this expenditure is mostly borne by public funding. This trend needs to reverse at the earliest. Further, higher spending in R&D by the private sector can happen as the manufacturing sector expands in the country.

The scale of Joint Public–Private research projects is much higher in developed countries in comparison to India. With the increased allocations suggested above, joint R&D projects between public institutions and start-ups/industries can also be supported.

The Rs 50,000 crore that have been committed to establish NRF is welcome and could be immediately used to plug the deficits in extramural and other grants provided to autonomous universities and institutions by CSIR, DST and other agencies.

An online platform that can hold all information on projects granted with public funding could be developed for better information sharing. The National IPR Policy of 2016 should be duly adhered to in order to gain investor confidence and attract more investment in R&D.

The government should promote Government–Industry–Academia partnership to support the R&D ecosystem in India. The development of Covaxin stands testimony of this effort and this learning experience can be transferred to other sectors like defence and electronics manufacturing, green technologies, etc.

In the next five years, around 5,000 students/scientists need to be trained at doctoral and post-doctoral level in the best laboratories of the world using India's soft power. Simultaneously, post-doctoral work in India should be encouraged by providing better remuneration to young scientists.[97]

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