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UPSC CIVIL SERVICES · PRELIMS & MAINS GS PAPER III

Science & Technology for UPSC

From biotechnology and nuclear power to space, defence, AI and quantum: the complete UPSC syllabus, updated to October 2026.

Compiled by Arvind KrS

29 chapters • 8 units • 319 PYQs 2011–2026 • 143 original diagrams



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Science & Technology for UPSC

Notes for UPSC Prelims and Mains GS Paper III

2027 Edition · Compiled October 2026 · Compiled by Arvind KrS

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UNIT I | 2 CHAPTERS

Science, Technology and India

Science and technology - developments and their applications and effects in everyday life; achievements of Indians in science & technology; indigenization of technology and developing new technology.

CHAPTERS

01 India's Science and Technology Ecosystem: Institutions, Policy and Funding 6

02 Achievements of Indians in Science and Technology and Indigenisation of Technology 20

TOPICS COVERED IN THIS UNIT

01 **India's Science and Technology Ecosystem: Institutions, Policy and Funding**

Why Science and Technology Matter · Science in the Constitution and Government · The Institutional Map · Science Policies Since 1958 · Spending and Research Indicators · Anusandhan National Research Foundation (ANRF) · The RDI Scheme and Deep-Tech Funding · Schemes and National Missions · The Innovation Ecosystem · Science Awards and National Days · Problems and the Way Forward

02 **Achievements of Indians in Science and Technology and Indigenisation of Technology**

Science in Ancient and Medieval India · Pioneers of the Colonial Era · Nobel Laureates and Global Honours · Builders of Post-1947 Science · Women in Indian Science · Milestones Since Independence · Indigenisation: Meaning and Methods · Technology Denial and Self-Reliance · Make in India and Atmanirbhar Bharat · Frugal Innovation and Deep Tech · Challenges and the Way Forward

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SCIENCE & TECHNOLOGY
PRELIMS · GS PAPER III

India's Science and Technology Ecosystem: Institutions, Policy and Funding

In November 2025 India opened a ₹1 lakh crore fund to lend money to private companies for research, something unthinkable when science was paid for and run almost entirely by the government. Official data released in 2026 show that the private sector now spends more on research than the government does. Behind India's famous labs, rockets and vaccines lies a less visible system of departments, policies, funding bodies and missions that decides what gets researched and who pays for it.

SYLLABUS

PRELIMS General Science; Current events of national and international importance

MAINS · GS PAPER III Science and Technology - developments and their applications and effects in everyday life; indigenization of technology and developing new technology

CONTENTS

01 Why Science and Technology Matter
02 Science in the Constitution and Government
03 The Institutional Map
04 Science Policies Since 1958
05 Spending and Research Indicators
06 Anusandhan National Research Foundation (ANRF)
07 The RDI Scheme and Deep-Tech Funding
08 Schemes and National Missions
09 The Innovation Ecosystem
10 Science Awards and National Days
11 Problems and the Way Forward
12 Previous Year Questions

This chapter covers:

- science in the Constitution and the government departments, councils and advisers that run Indian science;

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- India's science and technology policies from 1958 to the draft STIP of 2020;
- how much India spends on research and what the main indicators (researchers, papers, patents, innovation rank) show;
- the Anusandhan National Research Foundation, the RDI Scheme and other ways research is now funded;
- national missions, the innovation ecosystem, science awards and days, and the problems that remain.

Achievements of Indian scientists and the indigenisation of technology follow in Chapter 2. Each field (biotechnology, nuclear, space, defence, ICT) has its own unit later in the book.

01 Why Science and Technology Matter

Science is the organised search for knowledge about how nature works. **Technology** applies that knowledge to make tools, processes and services. **Innovation** carries an idea through to a product or practice that people actually use. Policy documents now speak of the three together as **STI** (science, technology and innovation), because a discovery that never leaves the lab does little for a country.

For a developing country the case for science is practical. India grew enough food after the Green Revolution of the 1960s because of new seeds, fertilisers and irrigation. Its pharmaceutical industry makes affordable medicines for much of the world. Space technology gives weather forecasts, disaster warnings and maps of crops and forests, and nuclear power and defence research protect strategic autonomy. More recently, digital public infrastructure such as Aadhaar and UPI has reached hundreds of millions of people. The Mains syllabus phrase *"applications and effects in everyday life"* points to exactly this link between laboratory work and daily life.

Science also has a wider purpose. A society that reasons from evidence is harder to mislead, quicker to adopt better practices and better at weighing risks such as those of new vaccines, genetic technologies or artificial intelligence. Jawaharlal Nehru called this outlook **scientific temper**, and the Constitution later adopted the term.

02 Science in the Constitution and Government

Constitutional Provisions

- **Article 51A(h)**, a Fundamental Duty added by the **42nd Amendment (1976)**, asks every citizen "to develop the scientific temper, humanism and the spirit of inquiry and reform".
- **Union List, Entry 66**: coordination and determination of standards in institutions for higher education or research and scientific and technical institutions. **Entries 63–65** place institutions of national importance and central research bodies with the Union.
- **Concurrent List, Entry 25**: education, including technical and medical education, so the states also run universities and research institutions.
- **Article 48A** (environment) and **Article 47** (public health and nutrition) depend heavily on science.

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Who Advises the Government

The **Principal Scientific Adviser (PSA)** to the Government of India gives independent advice to the Prime Minister and the Cabinet. The post was created in **1999**, and its first holder was A. P. J. Abdul Kalam. The PSA chairs the **Prime Minister's Science, Technology and Innovation Advisory Council (PM-STIAC)**, set up in **2018**. PM-STIAC identifies national science missions and coordinates them across ministries. **NITI Aayog** runs the **Atal Innovation Mission** and advises on technology policy. Ministries also have scientific advisory committees of their own.

03 The Institutional Map

Indian science is run by many departments. The strategic departments, Atomic Energy and Space, report directly to the Prime Minister, through the Atomic Energy Commission and the Space Commission. Most civilian research is under the Ministry of Science and Technology. Other ministries keep their own research councils for health, agriculture, defence, earth sciences and electronics.

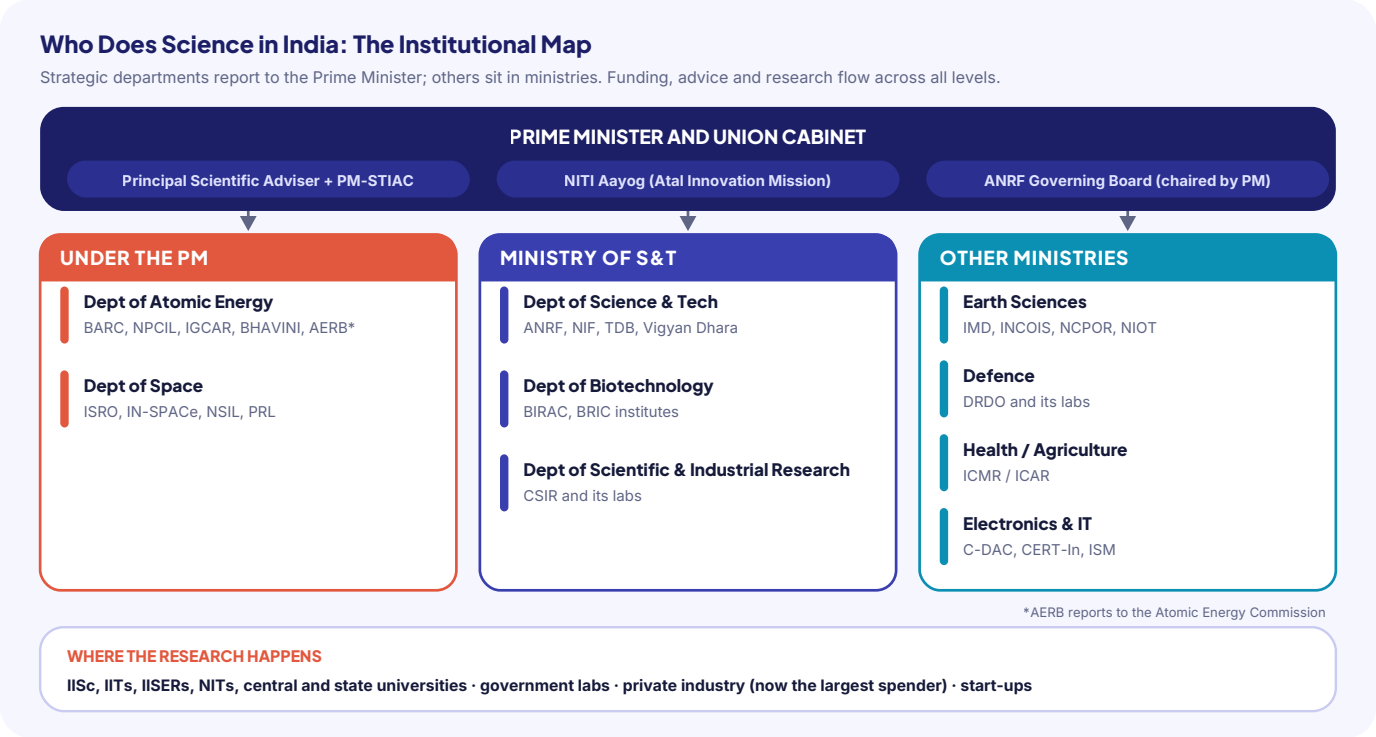


Fig. 1.1 The main departments, councils and research bodies, and where they sit in government.

BODY	SET UP	WHAT IT DOES
Department of Science and Technology (DST)	1971	Nodal department for S&T policy; funds research, fellowships (INSPIRE), technology missions; administrative home of ANRF

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BODY	SET UP	WHAT IT DOES
Department of Biotechnology (DBT)	1986	Biotechnology research and industry; BIRAC for start-ups; BRIC (Biotechnology Research and Innovation Council) institutes
CSIR, under DSIR	1942 (CSIR); 1985 (DSIR)	Network of about 37 national laboratories, from chemicals and drugs to aerospace and food
Department of Atomic Energy (DAE)	1954 (Atomic Energy Commission 1948)	Nuclear power, research reactors, BARC, nuclear medicine; under the Prime Minister
Department of Space (DoS)	1972 (ISRO 1969)	ISRO, IN-SPACe, NSIL; under the Prime Minister
Ministry of Earth Sciences (MoES)	2006	IMD, INCOIS, NCPOR, NIOT; weather, oceans, polar research, Deep Ocean Mission
DRDO	1958	Defence research and development, about 40 laboratories
ICMR / ICAR	1911 / 1929	Biomedical and agricultural research councils

Research also happens in the **Indian Institute of Science** (Bengaluru, **1909**), the IITs, the seven **IISERs**, central and state universities, autonomous institutes such as TIFR, and, more and more, in private industry. Universities train most of the country's researchers. Yet a large share of public research money still goes to government laboratories, and critics see this split between teaching and research as a weakness of the Indian system.

04 Science Policies Since 1958

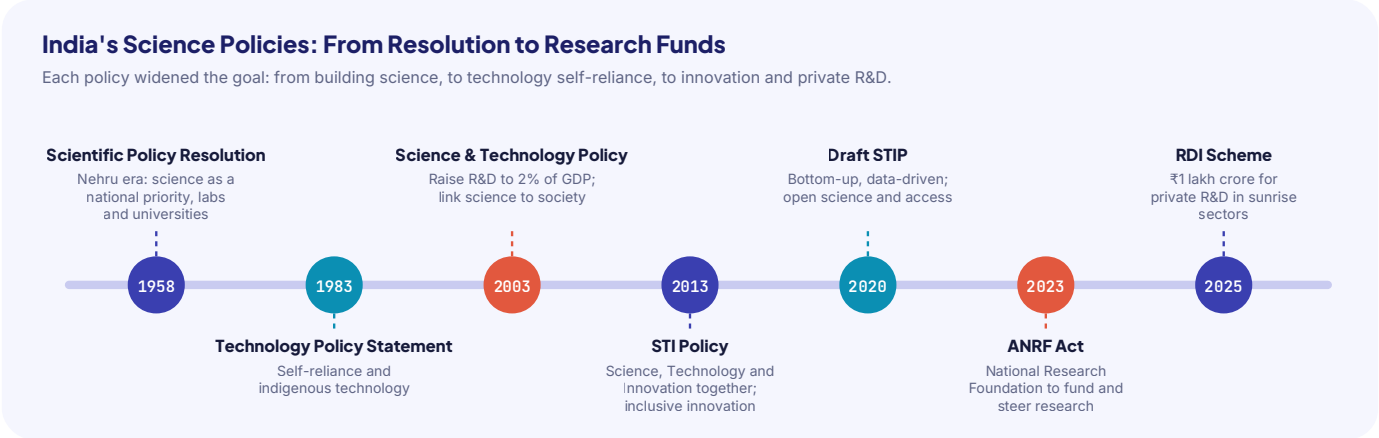


Fig. 1.2 Milestones in India's science policy. Each statement widened the aim, from building scientific capacity to private-sector innovation.

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Scientific Policy Resolution, 1958

Parliament adopted the **Scientific Policy Resolution** in **1958**. It committed the state to "foster, promote and sustain" science and scientific research, to train scientists in large numbers and to give them a respected place in national life. Under it the country built its laboratories, the IITs and the atomic and space programmes.

Technology Policy Statement, 1983

By the 1980s the gap between laboratory and factory was obvious. The **Technology Policy Statement** stressed **technological self-reliance**, the development of indigenous technology, and the efficient absorption and adaptation of imported technology. It also asked for technology to serve the poor and to conserve energy and resources.

Science and Technology Policy, 2003

Coming after liberalisation, this policy brought science and technology into a single document. It set the long-quoted target of raising research spending to 2 per cent of GDP. It called for more private investment, better intellectual property management and stronger links between universities and industry.

Science, Technology and Innovation Policy, 2013

The **STI Policy 2013** was the first to put *innovation* at the centre, and it was launched in the "Decade of Innovation" (2010–20). It aimed to place India among the top five scientific powers, sought private R&D partnerships and spoke of **inclusive innovation**, meaning affordable solutions for people at the bottom of the income pyramid.

Draft Science, Technology and Innovation Policy (STIP), 2020

The draft **STIP** was released in December 2020 after nationwide consultation. Unlike earlier policies it was written "bottom-up", with inputs from thousands of experts and citizens. Its main ideas were:

- an **open science** framework, including the idea that later became One Nation One Subscription;
- a national STI observatory to hold research data, and a dedicated **STI finance** mechanism;
- doubling researchers and research spending every five years, with a larger share from the private sector;
- equity and inclusion in STEM for women, rural students and marginalised groups;
- **"strategic technology development"** in areas such as semiconductors, quantum technology and AI.

05 Spending and Research Indicators

The Department of Science and Technology publishes **Research and Development Statistics**. The **2025-26** edition, released in mid-2026, shows that India's **Gross Expenditure on R&D (GERD)** reached a record **₹2.45 lakh crore** in **2023-24**. This was about **0.84 per cent of GDP**, up from 0.82 per cent the year before and roughly three times the ₹79,356 crore spent in 2013-14. For the first time, the private sector as a whole (₹1.27 lakh crore) outspent government (₹1.18 lakh crore), although government is still the largest single funder, ahead of private industry alone (about 45 per cent).

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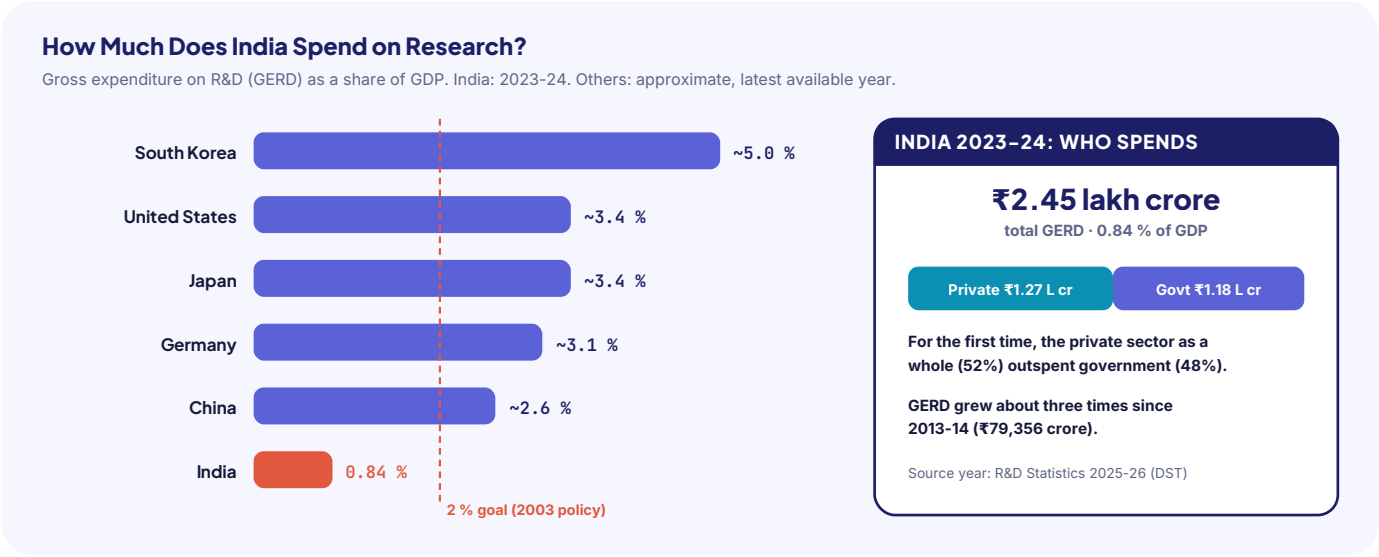


Fig. 1.3 India's research spending compared with leading research nations, and who spends it within India.

Even so, the share of GDP remains far below the 2 per cent target set in 2003. Countries that lead in technology spend between **2.5 and 5 per cent**: China about 2.6 per cent, the United States and Japan about 3.4 per cent, and South Korea about 5 per cent. India's private spending is also concentrated in a few sectors: transport (mainly automobiles), pharmaceuticals, biotechnology and IT.

INDICATOR	WHERE INDIA STANDS (LATEST)
R&D spending	₹2.45 lakh crore, 0.84% of GDP (2023-24); private sector now the larger spender
Researchers	About 354 full-time-equivalent researchers per million people (2023-24), far below the several thousand per million in advanced economies; women are about 29 per cent
Scientific publications	3rd in the world by number of papers, after China and the United States
Patents	About 1.1 lakh applications filed in 2024-25, 62 per cent of them by Indian residents; India is the sixth-largest patent office in the world
Global Innovation Index (WIPO)	**38th** of 139 economies in 2026 (as in 2025), up from 81st in 2015 and 46th in 2021; first among lower-middle-income economies
Start-ups	The third-largest start-up ecosystem in the world, with well over a lakh government-recognised start-ups

COMMON CONFUSION: GERD, PUBLICATIONS AND QUALITY

A high rank in the number of papers does **not** mean a high rank in impact. Indian papers are cited less often, on average, than those of leading research nations, and predatory journals have been a

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problem. In the same way, a rise in patent *filings* is not a rise in *grants* or commercial use. Read every indicator together with what it measures.

06 Anusandhan National Research Foundation (ANRF)

The **Anusandhan National Research Foundation Act, 2023** set up a single apex body to fund, coordinate and promote research across the natural sciences, engineering, medicine, agriculture, social sciences and humanities. The foundation started work in **2024**. It was modelled partly on the US National Science Foundation, and the idea came from the **National Education Policy 2020**, which wanted research to reach universities beyond a few elite institutions.

- **Structure:** a **Governing Board chaired by the Prime Minister**, with the Ministers of Science and Technology and of Education as vice-presidents. The Executive Council is chaired by the Principal Scientific Adviser. The **Department of Science and Technology** is the administrative department.
- **Merger:** the **Science and Engineering Research Board (SERB)**, set up by a 2008 Act, was repealed and folded into ANRF.
- **Money:** about **₹50,000 crore** over five years (2023-28). Some ₹14,000 crore comes from government and the larger part is meant to come from industry, philanthropy and other non-government sources.
- **Programmes: PAIR** (Partnerships for Accelerated Innovation and Research) pairs top institutions with state universities in a hub-and-spoke model. **MAHA** (Mission for Advancement in High-impact Areas) funds mission-mode research, starting with electric mobility. ANRF also runs early-career and prime-ministerial research fellowships.
- **Custodian of the RDI fund:** the RDI Scheme's money sits in a Special Purpose Fund inside ANRF (see below).

07 The RDI Scheme and Deep-Tech Funding

Private companies, especially start-ups, often cannot fund risky, long-gestation research. Banks rarely lend against an untested technology. The **Research, Development and Innovation (RDI) Scheme**, approved by the Union Cabinet on **1 July 2025** with a corpus of **₹1 lakh crore**, tries to fill this gap. It was formally launched in **November 2025** at the **Emerging Science, Technology and Innovation Conclave (ESTIC)** in New Delhi.

- **Purpose:** encourage private-sector R&D in **sunrise and strategic sectors**, finance projects at **higher technology readiness levels**, help acquire critical technologies, and set up a **Deep-Tech Fund of Funds**.
- **Two tiers:** a **Special Purpose Fund** within ANRF holds the money (tier 1). It passes money to **second-level fund managers**, such as development finance institutions and alternative investment funds, which pick and finance projects (tier 2).
- **Form of support:** mainly long-term concessional loans at low or nil interest. Equity is possible for start-ups. Grants are **not** the main tool.

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- **Governance:** strategic direction from the ANRF Governing Board (chaired by the PM); guidelines from ANRF's Executive Council; approvals and reviews by an **Empowered Group of Secretaries** under the Cabinet Secretary. **DST is the nodal department.**

From Idea to Market: Technology Readiness Levels and Who Funds Each Step

TRL 1 is a basic principle observed; TRL 9 is a proven system in real use. Funding gaps in the middle are called the 'valley of death'.

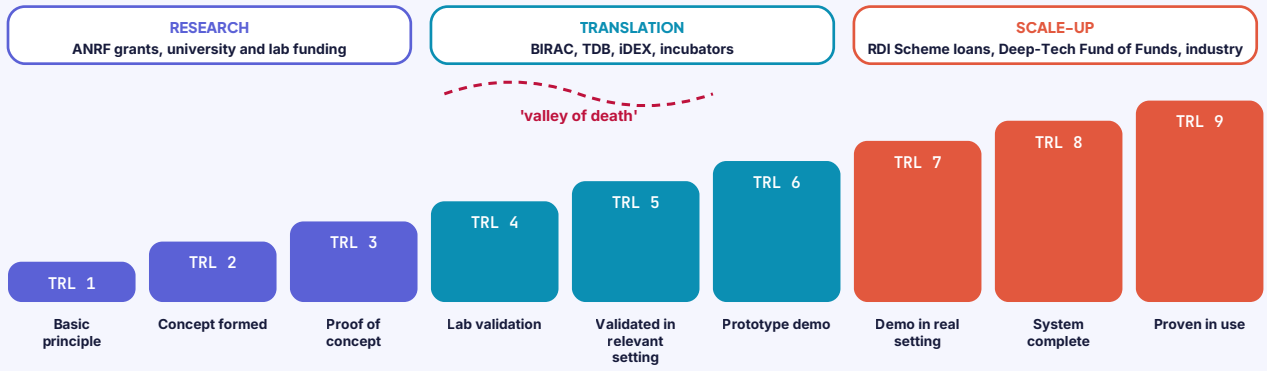


Fig. 1.4 Technology Readiness Levels (TRL 1–9) and the kind of funding that supports each stage. The RDI Scheme targets the later, costlier stages.

CONCEPT: TECHNOLOGY READINESS LEVEL

The **TRL scale** was developed by NASA and is now used worldwide. It measures how mature a technology is, from **TRL 1** (basic principle observed) to **TRL 9** (system proven in actual operation). Universities work mostly at TRL 1–3 and industry at TRL 7–9. Between them lies the **"valley of death"**, where many promising ideas die for lack of money to build and test prototypes.

Other channels for funding innovation include the **Technology Development Board** (loans and equity for commercialising Indian technology), **BIRAC** (biotech start-ups), **iDEX** (defence innovation; see Chapter 18), the **Fund of Funds for Start-ups** run by SIDBI and sector missions with their own money. The **Union Budget 2026-27** added a ₹10,000 crore **Biopharma SHAKTI** programme for biologics and biosimilars, a ₹20,000 crore scheme for **carbon capture, utilisation and storage**, and **India Semiconductor Mission 2.0**. It also proposed new and upgraded astronomy facilities, among them a National Large Solar Telescope and a National Large Optical-Infrared Telescope.

08 Schemes and National Missions

Schemes for People and Access

- **Vigyan Dhara** (approved 2024): DST's three umbrella schemes (institutional and human capacity building, research and development, and innovation and technology deployment) merged into one, with about **₹10,579 crore** for 2021-22 to 2025-26.
- **INSPIRE** (Innovation in Science Pursuit for Inspired Research, 2008): scholarships and fellowships to draw talented students into science. Its **INSPIRE-MANAK** component rewards school students' ideas.

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- **One Nation One Subscription (ONOS)**: approved in November 2024 with about **₹6,000 crore** for 2025–2027. A single national subscription gives every government higher-education and research institution access to some 13,000 journals from about 30 international publishers. **INFLIBNET**, an inter-university centre of the UGC, runs it.
- **WISE-KIRAN** and related DST programmes support women scientists, including those returning after a career break.

National Technology Missions

Since the late 2010s the government has organised much of its research spending into **missions**. Each has a clear goal, a deadline and a dedicated budget. They are covered in their own chapters.

MISSION	NODAL BODY	AIM (SEE CHAPTER)
National Supercomputing Mission (2015)	DST, MeitY	Build PARAM supercomputers in India (Ch. 21)
National Mission on Interdisciplinary Cyber-Physical Systems (2018)	DST	Technology Innovation Hubs for AI, robotics, IoT
Deep Ocean Mission (2021)	MoES	Deep-sea exploration, manned submersible, minerals
India Semiconductor Mission (2021)	MeitY	Chip fabs, packaging, design (Ch. 21)
National Green Hydrogen Mission (2023)	MNRE	Green hydrogen production and use (Ch. 27)
National Quantum Mission (2023)	DST	Quantum computers, communication, sensors (Ch. 24)
IndiaAI Mission (2024)	MeitY	AI compute, models and datasets (Ch. 23)
BioE3 Policy (2024)	DBT	Biomanufacturing (Ch. 5)
Mission Mausam (2024)	MoES	Better weather and climate forecasting
Nuclear Energy Mission (2025)	DAE	Small modular reactors, 100 GW by 2047 (Ch. 10)

Deep Ocean Mission and Samudrayaan

The **Deep Ocean Mission** of the **Ministry of Earth Sciences** (approved in June **2021**, about ₹4,077 crore for five years) supports India's **Blue Economy**. It has six components:

- deep-sea mining technology and a **manned submersible**;
- ocean climate-change advisory services;

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- exploration and conservation of deep-sea biodiversity;
- deep-ocean survey for minerals such as polymetallic nodules;
- energy and freshwater from the ocean;
- an advanced marine station for ocean biology.



Fig. 1.5 The ocean research vessel Sagar Nidhi, used for deep-sea surveys and trials.

Its flagship project is **Samudrayaan**, built around **Matsya-6000**, a submersible designed by the **National Institute of Ocean Technology (NIOT), Chennai**. It will carry three people to 6,000 metres in a titanium-alloy crew sphere, with about 12 hours of normal endurance and up to 96 hours of emergency life support. Only a handful of countries, including the United States, Russia, France, Japan and China, have crewed vehicles for such depths. In August 2025 two Indian aquanauts trained by diving to about 4,000 and over 5,000 metres in the Atlantic aboard the French submersible *Nautile*. Matsya-6000 completed crewed harbour wet tests in early 2025 and was being prepared in 2026 for crewed trials, first in shallow water and then to about 500 metres, before full-depth dives.

09 The Innovation Ecosystem

- **Atal Innovation Mission (AIM)**, set up in **2016** under **NITI Aayog**: **Atal Tinkering Labs** in schools, Atal Incubation Centres and challenges. AIM 2.0 runs until March 2028, and the 2025-26 Budget promised 50,000 more tinkering labs in government schools over five years.
- **National Innovation Foundation–India (NIF)**: an autonomous body of the **Department of Science and Technology**, set up in 2000 and based in Gujarat. It scouts, protects and spreads grassroots innovations and traditional knowledge, building on the Honey Bee Network. It is **not** a programme for elite research collaborations.
- **Smart India Hackathon** (since 2017): a nationwide contest in which students build digital and hardware solutions to problem statements set by ministries, states and industry. It is **not** a smart-cities or digital-payments scheme.
- **Startup India** (2016), the Fund of Funds for Start-ups, incubators in IITs and research parks, and a draft national deep-tech start-up policy all aim to turn research into companies.
- **Technology Innovation Hubs** under the cyber-physical systems mission, and **Technology Business Incubators** funded by DST.

India in International Mega-Science Projects

Some experiments are too big for one country. India shares in several and gains access, skills and contracts for its industry in return.

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PROJECT	WHAT IT IS	INDIA'S ROLE
ITER (France)	Experimental fusion reactor	Full member; supplies the cryostat and other parts (Ch. 9)
CERN (Switzerland)	Particle physics, Large Hadron Collider	Associate member since 2017
LIGO-India (Maharashtra)	Gravitational-wave detector	Being built with the US LIGO Laboratory (Ch. 17)
Square Kilometre Array	Giant radio telescope (South Africa, Australia)	Member of the observatory
Thirty Meter Telescope	Optical-infrared telescope	Partner
FAIR (Germany)	Antiproton and ion research facility	Founding partner

10 Science Awards and National Days

Since 2024 a single set of national science awards, the **Rashtriya Vigyan Puraskar**, has replaced many separate departmental awards. It has four categories:

- **Vigyan Ratna**: lifetime achievement. The first went to the biochemist G. Padmanabhan (2024); the 2025 award went posthumously to the astrophysicist **Jayant Vishnu Narlikar**.
- **Vigyan Shri**: distinguished contributions; **Vigyan Yuva–Shanti Swarup Bhatnagar**: young scientists up to 45 years.
- **Vigyan Team**: teams of three or more. The 2025 award went to CSIR's Aroma Mission team.

DAY	DATE	WHY
National Science Day	28 February	C. V. Raman announced the Raman effect, 1928
National Technology Day	11 May	Pokhran-II nuclear tests (1998), first flight of Hansa aircraft and Trishul test
National Space Day	23 August	Chandrayaan-3 landed near the Moon's south pole, 2023
National Mathematics Day	22 December	Birth anniversary of Srinivasa Ramanujan

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11 Problems and the Way Forward

Persistent Problems

- **Low and narrow spending:** below 1 per cent of GDP, and private R&D concentrated in a few large firms and sectors.
- **Too few researchers:** low pay and uncertain careers. Fellowship payments are often delayed, and many top graduates leave for industry or for research abroad (**brain drain**).
- **Weak university research:** most of the 1,100-plus universities do little research. Heavy teaching loads, old equipment and rigid rules hold them back.
- **Industry–academia gap:** few joint projects and slow technology transfer; the "valley of death" between prototype and product.
- **Bureaucratic processes:** slow procurement of equipment and approvals for grants, and audit fears that discourage risk-taking.
- **Gender gap:** women earn a large share of science degrees but leave research in large numbers as careers progress.
- **Quality concerns:** predatory journals, plagiarism, and low citation impact in some fields.
- **Dependence on imports** for scientific equipment, chips and critical materials.

Way Forward

- Raise GERD towards 2 per cent of GDP, with tax incentives and RDI-type finance to crowd in private money.
- Make ANRF a genuinely autonomous, peer-review-driven funder that reaches state universities.
- Offer secure research careers, timely fellowships and schemes that bring Indian scientists back from abroad.
- Ease rules on buying equipment, hiring and spending grants; judge projects by outcomes, not paperwork.
- Use mission-mode programmes for strategic technologies, but protect curiosity-driven basic research, from which the big breakthroughs usually come.
- Build scientific temper through school science, open data and science communication in Indian languages.

USING THIS CHAPTER IN MAINS

Questions on India's research capacity, university research or innovation need numbers. Quote GERD at about 0.84 per cent of GDP (2023-24), India's 38th place in the Global Innovation Index 2026 and its third place in publications. Name the reforms (ANRF, RDI Scheme, One Nation One Subscription, national missions), then weigh them against the structural problems listed above. Article 51A(h) and the 1958 Resolution make good openings, and NEP 2020's call for research in every university makes a good close.

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Previous Year Questions

Prelims

2026

Which of the following statements with regard to India's Deep Ocean Mission is/are correct ?
1. It was launched by the Ministry of Ports, Shipping and Waterways, Government of India.
2. Matsya-6000 has been designed to carry 3 people for deep sea exploration.
3. Samudrayaan is a project under this mission.
Select the answer using the code given below :

a 1 only | b 2 and 3 only | c 1 and 2 only | d 1, 2 and 3

Answer: (b). The Deep Ocean Mission is run by the Ministry of Earth Sciences, and its Samudrayaan project uses the three-person Matsya-6000 submersible (Section 08).

2019

Atal Innovation Mission is set up under the

a Department of Science and Technology
b Ministry of Labour and Employment
c NITI Aayog
d Ministry of Skill Development and Entrepreneurship

Answer: (c). Atal Innovation Mission was set up in 2016 under NITI Aayog to promote innovation and entrepreneurship (Section 09).

2017

Which of the following statements is/are correct regarding Smart India Hackathon 2017 ?
1. It is a centrally sponsored scheme for developing every city of our country into Smart Cities in a decade.
2. It is an initiative to identify new digital technology innovations for solving the many problems faced by our country.
3. It is a programme aimed at making all the financial transactions in our country completely digital in a decade.
Select the correct answer using the code given below :

a 1 and 3 only | b 2 only | c 3 only | d 2 and 3 only

Answer: (b). Smart India Hackathon is a nationwide initiative inviting students to build digital solutions to problems posed by ministries and industry (Section 09).

2015

Which of the following statements is/are correct regarding National Innovation Foundation–India (NIF)?
1. NIF is an autonomous body of the Department of Science and Technology under the

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Central Government.
2. NIF is an initiative to strengthen the highly advanced scientific research in India's premier scientific institutions in collaboration with highly advanced foreign scientific institutions.
Select the correct answer using the code given below.

a 1 only | b 2 only | c Both 1 and 2 | d Neither 1 nor 2

Answer: (a). NIF is an autonomous body of the Department of Science and Technology that scouts and supports grassroots innovations, not elite research collaborations (Section 09).

Mains

2020 — GS III · 10 MARKS

How is science interwoven deeply with our lives? What are the striking changes in agriculture triggered off by the science-based technologies?

Approach: Show science in everyday life through health, communication, energy and transport. Describe agricultural changes: high-yielding varieties, fertilisers, irrigation and mechanisation, Bt cotton, remote sensing, precision farming and digital markets. Mention side effects such as soil decline and suggest sustainable science-based farming (Section 01).

2014 — GS III · 12.5 MARKS

Scientific research in Indian universities is declining, because a career in science is not as attractive as are business professions, engineering or administration, and the universities are becoming consumer-oriented. Critically comment.

Approach: Begin with indicators: low R&D spending (about 0.84% of GDP), few researchers per million and modest citation impact. Examine causes: weak pay and career paths, poor funding and facilities, focus on degrees and placements, and brain drain; also note counter-trends such as IISERs, INSPIRE and ANRF. Conclude with reforms in funding, autonomy and industry–academia links (Sections 05 and 11).

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UNIT IV | 6 CHAPTERS

Space Technology

Awareness in the field of Space: orbits and satellites, launch vehicles, India's missions, space reforms and applications, global missions and the universe.

CHAPTERS

12	Space Science Basics: Orbits, Satellites and Frequency Bands	186
13	Launch Vehicles and Space Propulsion	202
14	India's Space Programme: Milestones and Missions	216
15	Space Sector Reforms, Applications and Governance	231
16	Global Space Missions and Exploration	248
17	The Universe: Stars, Black Holes and Cosmic Phenomena	263

TOPICS COVERED IN THIS UNIT

12 **Space Science Basics: Orbits, Satellites and Frequency Bands**
Why Satellites Stay Up · Describing an Orbit · Orbits by Altitude · Polar, Sun-Synchronous and Molniya · Lagrange Points and Deep Space · Satellites: Parts, Sizes and Types · How Satellites See the Earth · Frequency Bands and Satellite Links · Satellite Navigation and GNSS · NavIC and GAGAN · Space Weather and Satellites

13 **Launch Vehicles and Space Propulsion**
How a Rocket Works · Rocket Propellants · Cryogenic Technology in India · From Sounding Rockets to SLV · PSLV: The Workhorse · GSLV and LVM3 · SSLV and Private Launchers · Reusable and Air-Breathing Vehicles · Launch Pads and Spaceports · Next-Generation Launchers

14 **India's Space Programme: Milestones and Missions**
Beginnings: INCOSPAR to Aryabhata · Operational Satellite Fleets · Chandrayaan-1 and Chandrayaan-2 · Chandrayaan-3 · The Next Moon Missions · Mars and Venus · Space Observatories · NISAR and SpaDeX · Human Spaceflight · Space Station and Goals for 2047

15 **Space Sector Reforms, Applications and Governance**
Opening the Space Sector · Indian Space Policy 2023 · IN-SPACe, NSIL and Antrix · FDI, Funding and the Space Economy · Private Space Industry · Remote Sensing and Applications · Satellite Communication and Internet · Space Debris and Situational Awareness · Space Law and Global Governance · Space Security: ASAT and Defence · Challenges and the Way Forward

16 **Global Space Missions and Exploration**
The New Space Age · Space Telescopes · NASA's Artemis Programme · The Race to the Moon · Exploring Mars · The Sun and Earth Observation · Inner Planets and Small Bodies · Giant Planets and Beyond · Space Stations: ISS and Tiangong · Private Spaceflight and Tourism · Issues and the Way Forward

17 **The Universe: Stars, Black Holes and Cosmic Phenomena**
The Universe: Origin and Scale · How Stars Are Born and Live · How Stars Die · Black Holes · Gravitational Waves · Dark Matter and Dark Energy · Neutrinos and Cosmic Rays · The Sun and Space Weather · Comets, Asteroids and Meteors · Exoplanets and Cosmic Puzzles · Observatories: India and the World

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SCIENCE & TECHNOLOGY
PRELIMS · GS PAPER III

14

India's Space Programme: Milestones and Missions

On 15 July 2025 Group Captain Shubhanshu Shukla splashed down off California after 18 days aboard the International Space Station, the first Indian to visit it and only the second Indian in space after Rakesh Sharma in 1984. His flight came between India's landing near the Moon's south pole in 2023 and the first uncrewed flight of its own crew capsule, Gaganyaan, still awaited in October 2026. Six decades after the first rocket rose from a fishing village in Kerala, India's space programme is moving from satellites for development to exploration and human spaceflight.

SYLLABUS

PRELIMS General Science; Current events of national and international importance

MAINS · GS PAPER III Science and Technology - developments and their applications and effects in everyday life; Achievements of Indians in science & technology; Awareness in the fields of IT, Space, Computers, robotics, nano-technology, bio-technology

CONTENTS

01 Beginnings: INCOSPAR to Aryabhata
02 Operational Satellite Fleets
03 Chandrayaan-1 and Chandrayaan-2
04 Chandrayaan-3
05 The Next Moon Missions
06 Mars and Venus
07 Space Observatories
08 NISAR and SpaDeX
09 Human Spaceflight
10 Space Station and Goals for 2047
11 Previous Year Questions

This chapter covers:

- the history of India's space programme, from INCOSPAR and Aryabhata to today;
- India's operational satellite fleets and recent launches and losses;
- Chandrayaan-1, 2 and 3, and the planned Chandrayaan-4 and 5;
- the Mars Orbiter Mission, the Venus mission and the space observatories AstroSat, XPoSat and Aditya-L1;

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- NISAR, SpaDeX, Gaganyaan, Axiom-4 and the Bharatiya Antariksh Station.

Orbits and satellites are explained in Chapter 12 and launch vehicles in Chapter 13; space reforms, applications and space law follow in Chapter 15, and other countries' missions in Chapter 16.

01 Beginnings: INCOSPAR to Aryabhata

Indian space science has deep roots. In the 1920s S. K. Mitra probed the ionosphere with radio waves in Calcutta, and C. V. Raman and Meghnad Saha laid foundations in physics. The organised programme began with **Vikram Sarabhai**, who saw early that satellites could bring education, communication and weather forecasts to a poor country faster than ground networks could. As he put it, India had to be second to none in applying advanced technologies to the real problems of man and society.

- **1962:** the **Indian National Committee for Space Research (INCOSPAR)** was set up under the Department of Atomic Energy, led by Sarabhai, with the encouragement of Homi Bhabha.
- **1963:** the first sounding rocket rose from the **Thumba Equatorial Rocket Launching Station**, near the magnetic equator. The rocket parts were famously carried on bicycles, and a church served as the office. TERLS was dedicated to the United Nations in 1968.
- **15 August 1969:** the **Indian Space Research Organisation (ISRO)** replaced INCOSPAR.
- **1972:** the **Space Commission** and the **Department of Space** were created, and ISRO was placed under the department, which reports directly to the Prime Minister. Satish Dhawan, chairman from 1972 to 1984, shaped the programme after Sarabhai's death in 1971.

ISRO's Main Centres

CENTRE	PLACE	ROLE
Vikram Sarabhai Space Centre (VSSC)	Thiruvananthapuram	Lead centre for launch vehicles
U R Rao Satellite Centre (URSC)	Bengaluru	Designs and builds satellites
Satish Dhawan Space Centre (SDSC SHAR)	Sriharikota	Launch base
Liquid Propulsion Systems Centre (LPSC)	Valiamala and Bengaluru	Liquid and cryogenic engines and stages
Space Applications Centre (SAC)	Ahmedabad	Payloads and applications; atomic clocks
National Remote Sensing Centre (NRSC)	Hyderabad	Receives and processes satellite images
Human Space Flight Centre (HSFC)	Bengaluru	Gaganyaan and future crewed missions

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Learning by Doing: 1975–1990

India's first satellite, **Aryabhata**, a 360 kg scientific satellite, was launched by a Soviet rocket on **19 April 1975**. The **Satellite Instructional Television Experiment (SITE)** of 1975–76 used an American satellite, ATS-6, to beam educational programmes to some 2,400 villages, one of the largest social experiments of its kind. Its lessons led to the use of satellites for distance education and rural development, and later to EDUSAT (2004), a satellite built only for education. The Bhaskara satellites (1979, 1981) tested Earth observation, and **APPLE** (1981), carried to its test site on a bullock cart, was India's first experimental communication satellite. SLV-3 placed Rohini in orbit in 1980 (Chapter 13). In April 1984 Squadron Leader **Rakesh Sharma** flew to the Soviet Salyut-7 station aboard Soyuz T-11, becoming the first Indian in space.

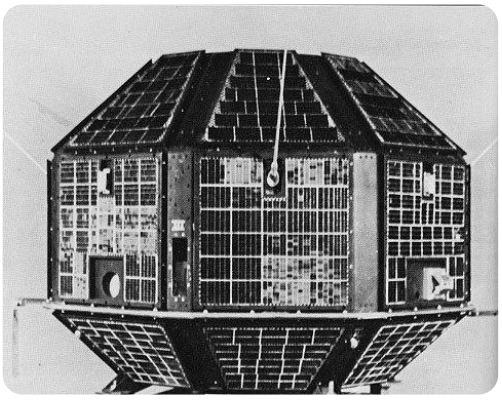


Fig. 14.1 Aryabhata, India's first satellite, launched by a Soviet rocket in April 1975.

Six Phases of India's Space Programme

From sounding rockets to a planned space station: each phase built on the capabilities of the one before.

1962–74 Foundations	1975–89 Experiments	1990–2007 Operational systems	2008–19 Exploration	2020–26 New frontiers	2027–47 Goals for 2047
INCOSPAR (1962), TERLS (1963), ISRO (1969), Department of Space (1972)	Aryabhata (1975), SITE TV for villages, Bhaskara, SLV-3 (1980), APPLE, Rakesh Sharma (1984)	INSAT and IRS fleets; PSLV (1994) and GSLV (2001); EDUSAT	Chandrayaan-1, Mangalyaan, NavIC, AstroSat, 104-satellite launch, Chandrayaan-2	Sector opened to industry; Chandrayaan-3, Aditya-L1, XPoSat, SpaDeX, Axiom-4, NISAR	Gaganyaan crew, Chandrayaan-4, Venus orbiter, BAS by 2035, Indian on the Moon by 2040

Fig. 14.2 The six phases of India's space programme, from its foundations to the goals set for 2047.

02 Operational Satellite Fleets

From the 1980s ISRO built two great operational systems. The **Indian National Satellite (INSAT)** system, which began working with INSAT-1B in 1983, combined telecommunication, television broadcasting and weather observation, and became one of the largest domestic satellite systems in the Asia-Pacific. The **Indian Remote Sensing (IRS)** system began with IRS-1A in 1988 and grew into one of the largest civilian Earth-observation constellations in the world, serving agriculture, water, forests, cities and disasters. With PSLV from 1994 and GSLV from 2001, India could launch most of these satellites itself (Chapter 13).

Recent Satellites, 2022–2026

Since 2020 new Earth-observation satellites carry an **EOS** number and communication satellites a **CMS** number. Among them are the radar satellite **EOS-04** (RISAT-1A, 2022), the ocean satellite EOS-06 (Oceansat-3, 2022), EOS-07 and EOS-08 on the small SSLV, and the weather satellite **INSAT-3DS** (2024). **GSAT-N2** (2024) brought Ka-band broadband for aircraft and remote areas, and **CMS-03 (GSAT-7R)**, a 4,410 kg naval communication satellite launched by LVM3 in November 2025, replaced the older GSAT-7. But 2025–26 also brought painful losses of strategic satellites: **NVS-02** of NavIC was stranded in its transfer orbit

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(January 2025), the radar satellite **EOS-09** was lost on PSLV-C61 (May 2025) and the hyperspectral **EOS-N1** on PSLV-C62 (January 2026). The run of bad luck ended on 4 September 2026, when GSLV-F17 launched **EOS-05 (GISAT-1A)**, India's first Earth-imaging satellite designed to watch the country continuously from geosynchronous orbit, replacing GISAT-1, lost in a GSLV failure in 2021.

YEAR	MILESTONE
1975	Aryabhata, first Indian satellite (Soviet launch); SITE begins
1980	SLV-3 places Rohini RS-1 in orbit from Sriharikota
1983 / 1988	INSAT-1B starts the INSAT era; IRS-1A starts the IRS era
1994	First successful PSLV flight
2008	Chandrayaan-1 reaches the Moon
2014	Mangalyaan enters Mars orbit; Indian cryogenic stage flies
2016–18	NavIC constellation completed; 104 satellites on one PSLV (2017)
2023	Chandrayaan-3 lands near the lunar south pole; Aditya-L1 launched
2025	SpaDeX docking; Axiom-4 crew flight; NISAR launched; 100th launch from Sriharikota
2026	PSLV-C62 failure; first private orbital launch (Vikram-1); EOS-05 (GISAT-1A)

03 Chandrayaan-1 and Chandrayaan-2

Chandrayaan-1 (2008)

Chandrayaan-1, India's first mission beyond Earth orbit, was launched by PSLV-C11 on **22 October 2008**. The 1,380 kg orbiter circled the Moon at 100 km with 11 instruments, five Indian and six from NASA, ESA and Bulgaria. On 14 November 2008 its **Moon Impact Probe**, carrying the Indian flag, struck the surface near the south pole. The mission's best-known result came from NASA's **Moon Mineralogy Mapper (M3)** and India's instruments together: clear evidence of water and hydroxyl molecules spread across the lunar surface, especially near the poles. It also mapped minerals and found signs of buried lava tubes. Contact was lost in August 2009, after about 10 months of a planned two years.

Chandrayaan-1's data kept yielding results long after the mission. Its radar found signs of water ice in permanently shadowed polar craters, and in 2020 scientists reported, from its images, traces of **haematite**, a form of rust, near the lunar poles, puzzling because rusting needs oxygen and water. The mission also showed that India could navigate a spacecraft to another world for a fraction of the usual cost.

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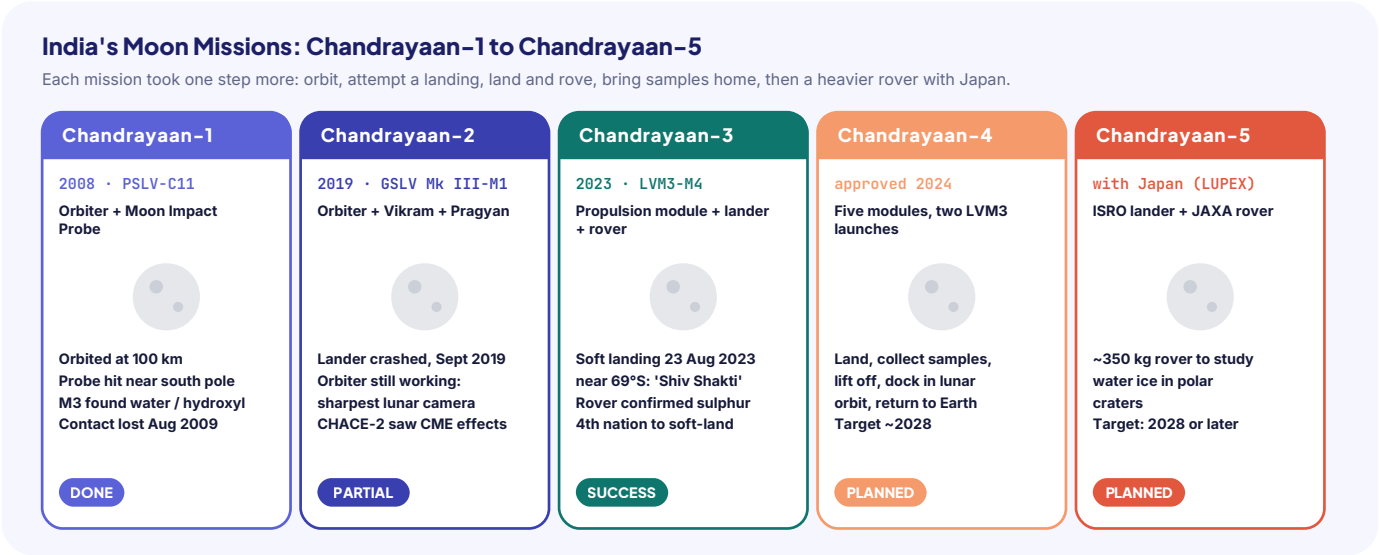


Fig. 14.3 India's Moon missions: what each carried, what it achieved and what is planned next.

Chandrayaan-2 (2019)

Chandrayaan-2, launched by GSLV Mk III-M1 (now LVM3) on **22 July 2019**, was India's first attempt to land. It had an orbiter, the **Vikram** lander (named after Vikram Sarabhai) and the **Pragyan** rover. On 7 September 2019 Vikram lost its way in the final descent and crashed; the impact site was later named "Tiranga Point". The orbiter, however, has worked for years. Its **Orbiter High Resolution Camera** takes the sharpest pictures of the Moon from orbit (about 25 cm), its dual-frequency radar maps ice in shadowed craters, its X-ray instruments map elements and watch solar flares, and its **CHACE-2** instrument in 2024 recorded the first direct evidence of a solar coronal mass ejection swelling the Moon's thin atmosphere.

04 Chandrayaan-3

Chandrayaan-3 was built to finish what Chandrayaan-2 began: a **safe soft landing** and a roving mission. It had no orbiter of its own, relying on Chandrayaan-2's orbiter for back-up communication. Its three modules, with a combined mass of about 3,900 kg, were launched by **LVM3-M4** from Sriharikota on **14 July 2023**. After a series of orbit-raising burns around Earth, the craft entered lunar orbit on 5 August and the lander separated on 17 August.

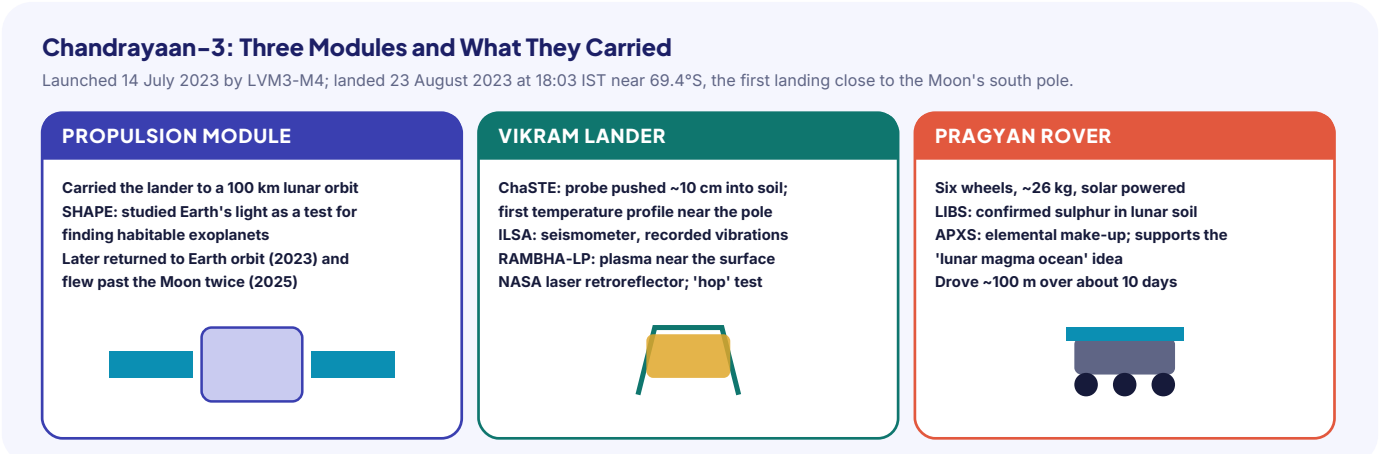


Fig. 14.4 The propulsion module, Vikram lander and Pragyan rover of Chandrayaan-3, and their main instruments and findings.

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On **23 August 2023** at 18:03 IST, Vikram touched down at about 69.4°S, the first landing close to the Moon's south pole. India became the fourth country to soft-land on the Moon, after the Soviet Union, the United States and China; Japan followed in January 2024 with SLIM. The landing site was named **"Shiv Shakti Point"**, and 23 August is now celebrated as **National Space Day**. The lander had been redesigned after the 2019 failure, with stronger legs, more fuel, a larger landing zone, more sensors and software able to cope with failures.

The descent itself was the hardest part. From about 30 km up, Vikram had to slow from some 1.7 km/s to near zero in under 20 minutes, guided by a laser Doppler velocimeter, altimeters and hazard-detection cameras that picked a safe spot on their own; no command from Earth could arrive quickly enough. The whole mission cost roughly ₹600 crore, far less than comparable missions of other countries.

Through one lunar day (about 14 Earth days) the instruments worked as planned. Pragyan's laser instrument confirmed **sulphur** in the soil and measured aluminium, calcium, iron and other elements, and its X-ray spectrometer found a composition that supports the idea that the young Moon was covered by a **magma ocean**. The lander's **ChaSTE** probe recorded how temperature changes with depth in the top 10 cm of polar soil, and its seismometer recorded vibrations. Before the mission ended, Vikram even fired its engines to "hop" about 40 cm and land again, a test for future sample-return missions. The propulsion module was later brought back to Earth orbit, and in November 2025 it drifted back into the Moon's sphere of influence and made two lunar flybys, giving ISRO valuable tracking experience.



Fig. 14.5 The Vikram lander on the Moon, photographed by the Pragyan rover's navigation camera from about 15 metres, 30 August 2023.

CONCEPT: THE VIRTUAL LAUNCH CONTROL CENTRE

For Chandrayaan-3, ISRO for the first time used a **Virtual Launch Control Centre** at the Vikram Sarabhai Space Centre (VSSC), Thiruvananthapuram, linked in real time to the launch centre at Sriharikota. The engineers who designed LVM3 could watch the rocket's data from their own centre during the countdown and flight, check systems and support the launch decision without travelling to the launch site. The approach spreads expertise across centres and is being extended to other missions.

COMMON CONFUSION: SOUTH POLE VS FAR SIDE

Chandrayaan-3 was the first mission to land **near the lunar south pole**, on the side of the Moon facing Earth. It was **not** the first to land on the **far side**: China's Chang'e-4 did that in 2019, and Chang'e-6 brought far-side samples home in 2024. The south pole matters because craters there never see sunlight and may hold water ice, a resource for drinking water, oxygen and rocket fuel.

Chandrayaan-3's success came weeks after Russia's Luna-25 crashed while aiming for the same region, and it placed India in the front rank of the new race to the lunar south pole, where NASA's Artemis programme and

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China's planned research station also plan to go. It showed that a mid-sized space agency could land precisely on a hostile, cratered terrain with a modest budget, and it strengthened India's hand in partnerships such as LUPEX with Japan.

05 The Next Moon Missions

Chandrayaan-4, approved by the Union Cabinet in **September 2024** at a cost of about ₹2,104 crore, will try to bring lunar soil back to Earth. It is far more complex than any earlier Indian mission: five modules will be launched on two LVM3 rockets and joined in orbit. A lander will set down near the south pole and collect samples; an ascender will lift them back into lunar orbit and dock with a transfer module; and a re-entry capsule will bring them to Earth. Its docking steps rely on the technology proved by SpaDeX. ISRO's chairman put the launch at about 2028. Only the United States, the Soviet Union and China have so far returned lunar samples.

Chandrayaan-5, approved in March 2025, is a joint mission with Japan's space agency JAXA, also called the **Lunar Polar Exploration Mission (LUPEX)**. ISRO will build the lander and JAXA will launch it on its H3 rocket and provide a rover of about 350 kg, more than ten times heavier than Pragyan, to study water ice in the polar regions. It is planned for 2028 or later. These missions lead towards the national goal of landing an Indian on the Moon by **2040**.

06 Mars and Venus

The **Mars Orbiter Mission (MOM)**, popularly called **Mangalyaan**, was launched by PSLV-C25 on **5 November 2013**. Because PSLV could not send it directly to Mars, the 1,337 kg craft raised its orbit around Earth in six burns before leaving for Mars. It entered Mars orbit on **24 September 2014**. India thereby became the **fourth space agency** to reach Mars, after the Soviet space programme, NASA and the European Space Agency, the first Asian country to do so, and the first to succeed on its maiden attempt. The mission cost about ₹450 crore, less than many Hollywood films.

MOM was mainly a technology demonstration: deep-space navigation, autonomy and communication across up to 400 million km. Its five instruments, including a Mars Colour Camera, a methane sensor and the MENCA analyser of the upper atmosphere, returned global images of Mars and its moon Phobos. Designed for six months, it worked for almost eight years until contact was lost in 2022. A Mars lander mission is now being studied.

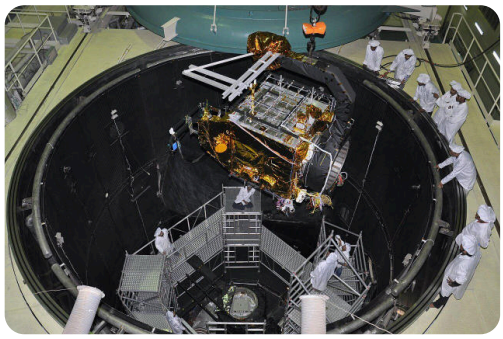


Fig. 14.6 The Mars Orbiter spacecraft being lowered into a space-simulation chamber for thermal-vacuum tests before launch.

MOM's success on the first attempt is still remarkable: about half of all missions to Mars have failed. The United Arab Emirates' Hope orbiter matched the feat in 2021, but it was launched on a Japanese rocket. MOM's MENCA instrument also measured the Martian exosphere, and its long life let scientists follow seasonal changes and dust storms.

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Venus Orbiter Mission

The **Venus Orbiter Mission** (often called Shukrayaan) was approved in September 2024 with about ₹1,236 crore. Planned for launch on LVM3 in **March 2028**, it will study Venus's surface and subsurface, its thick, hot atmosphere and its interaction with the Sun. After reaching a large elliptical orbit, it will use **aerobraking**, dipping repeatedly into the upper atmosphere to slow down, to reach a lower science orbit. Venus is similar to Earth in size, and understanding how it became a runaway greenhouse helps us understand our own planet.



Fig. 14.7 The distances reached by India's science missions, from low Earth orbit to Mars.

07 Space Observatories

Earth's atmosphere blocks X-rays, most ultraviolet light and much of the infrared, so many kinds of astronomy can be done only from space. India now has three space observatories.

MISSION	LAUNCH	ORBIT	WHAT IT STUDIES
AstroSat	PSLV-C30, 28 Sept 2015	~650 km, near-equatorial	The sky in ultraviolet, visible, and soft and hard X-rays at the same time
Aditya-L1	PSLV-C57, 2 Sept 2023	Halo orbit round Sun–Earth L1, 1.5 million km	The Sun's corona, flares, CMEs and the solar wind
XPoSat	PSLV-C58, 1 Jan 2024	~650 km	Polarisation of X-rays from black holes, neutron stars and pulsars

AstroSat

AstroSat is India's first dedicated multi-wavelength space observatory. It weighs about **1,513 kg** and orbits at about **650 km**. Its five instruments (the Ultraviolet Imaging Telescope, the Large Area X-ray Proportional Counter, a Soft X-ray Telescope, a Cadmium-Zinc-Telluride Imager and a Scanning Sky Monitor) can observe the same object in several bands at once, which few observatories can. It has studied black-hole binaries, neutron stars and star-forming galaxies, and in 2020 its UV telescope detected far-ultraviolet light from a galaxy some 9.3 billion light-years away. India was **not** the first after the US and Russia to fly such an

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observatory; Europe, Japan and others had done so earlier. Built for five years, AstroSat completed ten years in 2025.

Aditya-L1

Aditya-L1, India's first solar observatory, was launched on **2 September 2023** and placed in a halo orbit around the Sun–Earth **Lagrange point L1** on 6 January 2024 (Chapter 12). From there it watches the Sun without interruption by eclipses. It carries seven instruments. Four look at the Sun: the **Visible Emission Line Coronagraph (VELC)**, built by the Indian Institute of Astrophysics, the **Solar Ultraviolet Imaging Telescope (SUIT)**, built by IUCAA, Pune, and two X-ray spectrometers. Three measure the particles and magnetic fields arriving at L1, among them the ASPEX solar wind experiment of the Physical Research Laboratory. Aditya-L1 has photographed the full Sun in near-ultraviolet light, recorded major flares during the solar maximum of 2024, and, with VELC, pinned down the start time of a coronal mass ejection close to the Sun's surface.

These observations matter beyond science. Storms from the Sun can damage satellites, disturb navigation signals and overload power grids (Chapter 12). Watching the Sun's corona and measuring the solar wind before it reaches Earth gives about an hour's warning of an approaching disturbance, and Aditya-L1's data, shared through ISRO's science archive, add India's own eyes to the international network of solar observatories during the active years of Solar Cycle 25.

XPoSat

The **X-ray Polarimeter Satellite (XPoSat)**, launched on New Year's Day 2024, is the world's second mission dedicated to **X-ray polarimetry**, after NASA's IXPE (2021). It measures the direction in which X-ray light vibrates, which reveals the geometry of magnetic fields and matter around black holes and neutron stars. Its two instruments are POLIX, built by the Raman Research Institute, and XSPECT. The rocket's spent stage was turned into an orbital platform for ten more experiments.

08 NISAR and SpaDeX

NISAR

The **NASA-ISRO Synthetic Aperture Radar (NISAR)** is the first major hardware partnership between the two agencies and, at roughly 1.5 billion dollars, one of the costliest Earth-observation satellites ever built. NASA supplied the **L-band radar**, the 12-metre unfurlable mesh antenna and other parts; ISRO supplied the **S-band radar**, the spacecraft bus and the launch. The 2,392 kg satellite was launched by **GSLV-F16** on **30 July 2025** into a 747 km Sun-synchronous orbit, the first time a GSLV went to such an orbit. Its antenna unfurled in August 2025, and science operations began in November 2025. NISAR maps almost all of Earth's land and ice surfaces every 12 days, day and night and through cloud, detecting ground movements of a centimetre or less. Its free data will help track earthquakes, landslides, glaciers, sea ice, crops, forests, soil moisture and sinking land.

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SpaDeX: India Learns to Dock

Joining two spacecraft in orbit is needed to build space stations, ferry crews, refuel satellites and return samples from the Moon. The **Space Docking Experiment (SpaDeX)** tested this cheaply with two 220 kg satellites, a chaser (SDX01) and a target (SDX02), launched by **PSLV-C60** on **30 December 2024**.

- **16 January 2025:** after careful approaches from kilometres down to three metres, the two satellites docked, making India the fourth country to dock in space, after the US, Russia and China.
- **13 March 2025:** they undocked; on **20–21 April** they docked again and transferred electric power between them.
- The mission used India's own **Bharatiya Docking System**, laser range finders, proximity sensors and a satellite-navigation processor for precise relative positions.

The same rocket carried 24 experiments on its spent stage (POEM-4), including a robotic arm and a plant-growth chamber in which cowpea seeds sprouted in orbit. A second SpaDeX mission is planned to dock satellites in a more demanding elliptical orbit.

Other International Partnerships

ISRO has long worked with other agencies. With France's CNES it built **Megha-Tropiques** (2011) to study tropical rain and **SARAL** (2013) to measure sea level, and the two are building **TRISHNA**, a thermal-infrared satellite to monitor water use and heat stress. In December 2024 PSLV launched ESA's **Proba-3**, whose two satellites fly in precise formation to create artificial solar eclipses. Japan is the partner for Chandrayaan-5 and NASA for NISAR and Axiom-4, and Chandrayaan-3's lander carries a NASA laser reflector. India signed the US-led **Artemis Accords** in 2023 (Chapter 15).

09 Human Spaceflight

Gaganyaan

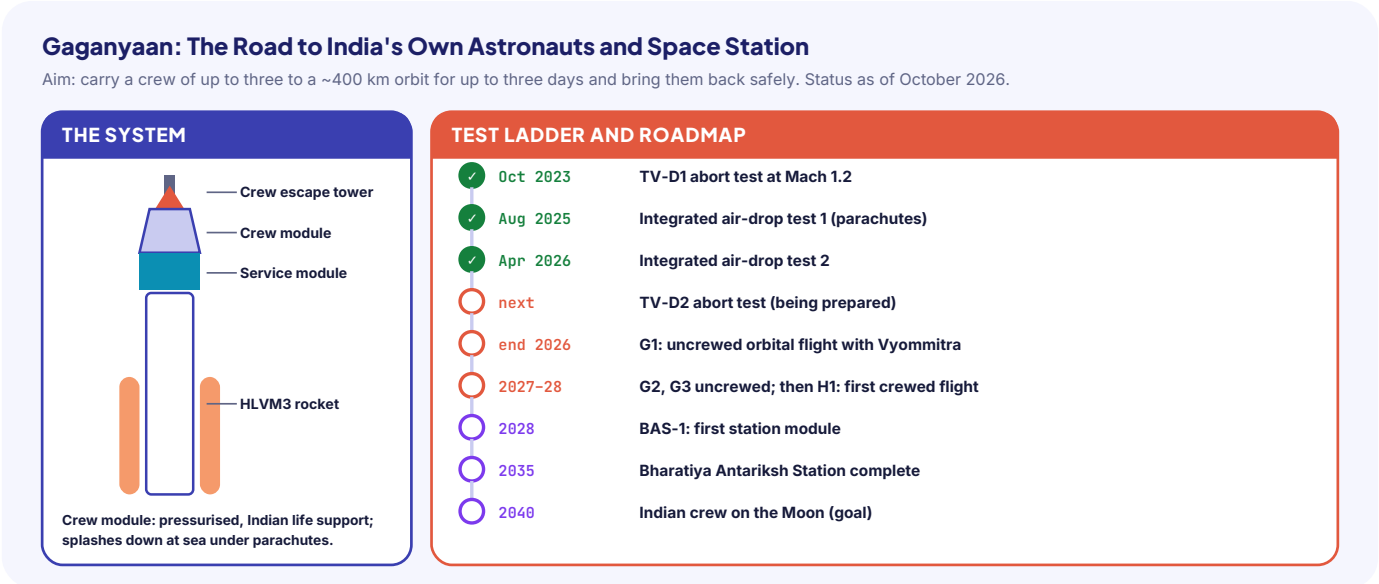


Fig. 14.8 The Gaganyaan system and its test programme. Completed steps are ticked; later dates are targets.

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Gaganyaan, announced on 15 August 2018 and approved in December 2018, aims to show that India can send a crew of up to three to an orbit of about **400 km** for up to three days and bring them back safely. In September 2024 its scope and budget were widened to about **₹20,193 crore** to include the first module of the space station and eight missions in all. A successful crewed flight would make India the fourth country, after the Soviet Union (now Russia), the United States and China, to launch people on its own rocket.

- **Launcher:** the human-rated **HLVM3**, with a crew escape system (Chapter 13).
- **Orbital module:** a pressurised **crew module** with an Indian-built environmental control and life support system, and a **service module** with engines, power and supplies, discarded before re-entry. The crew module re-enters behind a heat shield and splashes down under parachutes.
- **People and partners:** ISRO's **Human Space Flight Centre**, Bengaluru, runs the programme. Four Indian Air Force test pilots, Prasanth Balakrishnan Nair, Ajit Krishnan, Angad Pratap and Shubhanshu Shukla, were named astronaut-designates in February 2024 after training in Russia and India. DRDO laboratories supplied parachute tests, space food and crew-safety systems; the Navy and Coast Guard handle recovery.
- **Testing:** the **TV-D1** abort test (October 2023) proved the crew escape system; integrated air-drop tests from an IAF Chinook in August 2025 and April 2026 proved the parachutes. Thousands of ground tests have qualified the engines, service module and life support.
- **Status (October 2026):** the first uncrewed orbital flight, **G1**, carrying the half-humanoid robot **Vyommitra**, was targeted for the end of 2026, to be followed by two more uncrewed flights (G2, G3); the first crewed flight (H1), once aimed at 2027, was likely to slip to 2028.

A crewed flight will follow a set profile. HLVM3 will place the orbital module in a low orbit, which the service module will raise to about 400 km. After the mission the service module fires to slow the craft, then separates and burns up; the crew module re-enters, deploys a sequence of drogue and main parachutes and splashes down at sea, where naval ships recover the crew. On G1, **Vyommitra**, a female half-humanoid robot, will monitor the cabin, operate switches and report on the environment as an astronaut would.

The programme has slipped well behind its first target. When announced in 2018, a crewed flight was promised by 2022, India's 75th year of independence. The COVID-19 pandemic disrupted supply chains and training, and ISRO then chose to add more abort and parachute tests rather than take risks with crew safety. Each new subsystem, from the crew module's life support to the Indian-made parachutes, had to be qualified from scratch, since no other country shares such technology freely. The delays are a reminder that human spaceflight is judged by safety, not speed.

> REMEMBER: WHY HUMAN SPACEFLIGHT IS HARD
>
> Unlike a satellite, a crewed craft must keep people alive and bring them home. It needs a **human-rated rocket** with escape options at every stage, a **life-support system** for air, temperature, humidity and waste, protection from radiation, a **heat shield** for re-entry at about 7.8 km/s, reliable parachutes and recovery at sea, and astronaut selection, training and medical care. Each must work first time; there is far less margin for error than in robotic missions.

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Axiom-4 and Shubhanshu Shukla

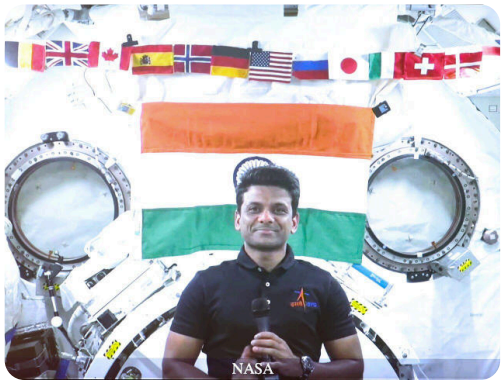


Fig. 14.9 Shubhanshu Shukla aboard the International Space Station during the Axiom-4 mission, June 2025.

While Gaganyaan was being tested, India bought experience abroad. **Axiom Mission 4 (Ax-4)**, a private flight organised by the US company Axiom Space with NASA and SpaceX, was launched on a Falcon 9 rocket in a Crew Dragon capsule on **25 June 2025**. Group Captain **Shubhanshu Shukla** flew as pilot, with a commander from the US and crew members from Poland and Hungary; for India, Poland and Hungary it was the first government-backed human spaceflight in over four decades. The crew spent **18 days on the International Space Station** and returned on 15 July 2025.

Shukla carried out seven ISRO-designed **microgravity experiments** with Indian institutions: on muscle loss, on the sprouting of moong and fenugreek seeds, on tiny tardigrades and on algae and cyanobacteria as future space food, on the growth of crop seeds, and on how astronauts use computer screens in weightlessness. The mission gave ISRO first-hand experience of crew training, mission control, medical support and operations in orbit that will feed directly into Gaganyaan. SpaDeX, by contrast, was a docking demonstration rather than a microgravity research mission.

10 Space Station and Goals for 2047

The **Bharatiya Antariksh Station (BAS)** is India's planned space station. The first module, **BAS-1**, is to be launched around **2028**, and the full station of about five modules completed by **2035**, orbiting at roughly 400–450 km. The first module is expected to weigh about 10 tonnes and to be launched by LVM3; later modules may need the heavier NGLV. A full-scale model of BAS-1 was displayed on National Space Day in August 2025. The station will host Indian crews for longer stays, run microgravity experiments in biology, medicine, materials and Earth observation (ISRO and the Department of Biotechnology have agreed to develop experiments together), and give Indian industry new work. The International Space Station is due to be retired around 2030, and China's Tiangong is already working, so BAS would make India one of very few countries with its own station.

A space station is also a long-term commitment. It must be resupplied with cargo and crews several times a year, which requires a reliable crew vehicle, an uncrewed cargo craft and a high launch rate, and it costs money every year it stays in orbit. That is why BAS is linked so closely to Gaganyaan, SpaDeX-type docking and the Next Generation Launch Vehicle.

In October 2023 the government set out a long-term road map for the space programme up to **2047**: Gaganyaan crew flights, Chandrayaan-4 and 5, the Venus Orbiter, a Mars lander, the **Bharatiya Antariksh Station by 2035**, and an **Indian landing on the Moon by 2040**. The plan reflects how far the programme has come: from a budget measured in a few lakh rupees in the 1960s to an allocation for the Department of Space of about ₹13,700 crore in 2026-27, still only a small fraction of NASA's budget. India's reputation for **frugal engineering** rests on this gap: Mangalyaan and Chandrayaan-3 each cost less than many single satellites built abroad, thanks to low labour costs, reuse of proven designs, fewer prototypes and careful ground testing. These need the Next Generation Launch Vehicle and a much higher launch rate (Chapter 13). Preparation is

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under way on the ground too: in 2024 and 2025 ISRO ran analogue missions in Ladakh, including the HOPE habitat at Tso Kar, where crews lived in isolated, Mars-like conditions to test equipment and human health.

INDIA: STRENGTHS AND GAPS OF THE PROGRAMME

Strengths: low-cost, mission-focused engineering (Mangalyaan, Chandrayaan-3), strong applications (communication, weather, remote sensing, navigation), wide international cooperation and a growing private sector. **Gaps:** a low launch rate, the strategic satellite losses of 2025–26, slow progress in human spaceflight compared with early targets, dependence on imported components such as atomic clocks, and a space budget far smaller than those of the US or China.

USING THIS CHAPTER IN MAINS

For questions on India's space achievements, organise the answer by phase: applications (INSAT, IRS, SITE), launchers, exploration (Chandrayaan, Mangalyaan, Aditya-L1, AstroSat) and human spaceflight (Gaganyaan, Axiom-4, BAS). Link each to development: weather and cyclone warnings, crop and water monitoring, tele-education, navigation and disaster support. For human spaceflight, separate technical hurdles (human-rated rocket, life support, re-entry, escape systems) from logistical ones (training, recovery, cost), and cite progress such as TV-D1, the air-drop tests and Shukla's ISS mission. End with the goals for 2047.

Previous Year Questions

Prelims

2025

Consider the following space missions :
I. Axiom-4
II. SpaDeX
III. Gaganyaan
How many of the space missions given above encourage and support micro-gravity research?

a Only one | **b Only two** | c All the three | d None

Answer: (b). Axiom-4 carried Indian microgravity experiments to the ISS and Gaganyaan is designed to support them, whereas SpaDeX was a docking technology demonstration (Sections 08 and 09).

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2016

With reference to 'Astrosat', the astronomical observatory launched by India, which of the following statements is/are correct?
1. Other than USA and Russia, India is the only country to have launched a similar observatory into space.
2. Astrosat is a 2000 kg satellite placed in an orbit at 1650 km above the surface of the Earth.
Select the correct answer using the code given below.

a 1 only | b 2 only | c Both 1 and 2 | **d Neither 1 nor 2**

Answer: (d). Japan, Europe and others had launched space observatories before India, and AstroSat weighs about 1,513 kg in an orbit about 650 km high (Section 07).

2016

Consider the following statements :
The Mangalyaan launched by ISRO
1. is also called the Mars Orbiter Mission
2. made India the second country to have a spacecraft orbit the Mars after USA
3. made India the only country to be successful in making its spacecraft orbit the Mars in its very first attempt
Which of the statements given above is/are correct?

a 1 only | b 2 and 3 only | **c 1 and 3 only** | d 1, 2 and 3

Answer: (c). Mangalyaan is the Mars Orbiter Mission; India was the fourth space agency (after the Soviet programme, NASA and ESA) to reach Mars, not the second, and the first to succeed on its maiden attempt (Section 06).

Mains

2023

GS III · 15 MARKS

What is the main task of India's third moon mission which could not be achieved in its earlier mission? List the countries that have achieved this task. Introduce the subsystems in the spacecraft launched and explain the role of the 'Virtual Launch Control Centre' at the Vikram Sarabhai Space Centre which contributed to the successful launch from Sriharikota.

Approach: State the main task: a safe soft landing near the lunar south pole, which Chandrayaan-2 missed. List the USSR, USA, China and India as soft-landers. Describe the propulsion module, Vikram lander and Pragyan rover with their payloads, and explain the Virtual Launch Control Centre's role in real-time monitoring and launch decisions (Sections 03 and 04).

2019

GS III · 10 MARKS

What is India's plan to have its own space station and how will it benefit our space programme?

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Approach: Introduce the Bharatiya Antariksh Station plan after Gaganyaan, with the first module targeted around 2028 and full station by 2035. Benefits: microgravity research, long-duration human spaceflight, technology spin-offs, international cooperation and prestige. Note challenges of cost and docking capability, citing SpaDeX (Sections 08 and 10).

2017

GS III · 10 MARKS

India has achieved remarkable successes in unmanned space missions including the Chandrayaan and Mars Orbitter Mission, but has not ventured into manned space missions. What are the main obstacles to launching a manned space mission, both in terms of technology and logistics ? Examine critically.

Approach: Introduce India's robotic successes and the human-spaceflight gap at the time. Technological obstacles: human-rated launcher, crew module, life support, crew escape and re-entry systems. Logistical hurdles: funding, astronaut training, medical support and recovery; conclude with Gaganyaan progress and the opportunities it opens (Section 09).

2016

GS III · 12.5 MARKS

Discuss India’s achievements in the field of Space Science and Technology. How the application of this technology has helped India in its socio-economic development?

Approach: Trace milestones from Aryabhata to PSLV, GSLV, Chandrayaan-1, Mangalyaan, AstroSat, NavIC and record multi-satellite launches. Show socio-economic uses: remote sensing for crops and resources, weather and disaster warning, telemedicine, tele-education, communication and navigation. Conclude with cost-effectiveness and the commercial space opportunity (Sections 01 to 07).

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