GS Paper II – International Relations **Date: 03.07.26**

Free Indo-Pacific a priority for India and Japan: Modi

During first visit to India as PM, Takaichi says both countries are 'perfectly aligned' and stresses the need for 'strategic cooperation'; both sides sealed 129 MoUs on technology, investment and AI

Saurabh Trivedi
Kallol Bhattacherjee
NEW DELHI

A "free and rules-based Indo-Pacific" is a common priority for India and Japan, Prime Minister Narendra Modi said on Thursday while welcoming his Japanese counterpart, Sanae Takaichi. Mr. Modi said India and Japan would jointly develop technologies that would help in maintaining maritime security and "regional peace".

"India and Japan are among the biggest economies of the world. A free, prosperous and rules-based Indo-Pacific is our shared priority. We will jointly pave the way for peace, stability and progress for the entire region," Mr. Modi said.

Boosting ties: Prime Minister Narendra Modi with his Japanese counterpart Sanae Takaichi in New Delhi. SHIV KUMAR PUSHPAKAR

"In the field of defence, India and Japan have done the first agreement for co-development of projects. This agreement on naval radio antenna will open a new chapter of defence technology partnership. Now, we will jointly develop such technologies that will help in maintaining regional peace, maritime security, and strengthen rules-based order," Mr. Modi added.

Ms. Takaichi, who arrived in New Delhi on July 1 for her first visit to India as Prime Minister, renewed her call for an updated free and open Indo-Pacific (FOIP) and emphasised the need for "strategic cooperation". She said the two countries were "perfectly aligned".

Mr. Modi and Ms. Takaichi attended an economic session in which Indian and Japanese companies sealed 129 memoranda of understanding on technology, investment, and artificial intelligence.

According to a document shared by the External Affairs Ministry, Japan is on track to invest $1 trillion across States, including Haryana, Odisha, Maharashtra, Gujarat, and those in the northeastern region.

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GS Paper II – Social Security

NIMHANS opens 'database' to aid research on sleep disorders among stroke patients

Afshan Yasmeen
BENGALURU

A team of researchers from NIMHANS, Bengaluru, and the International Institute of Information Technology (IIIT), Hyderabad, has developed the first open-access Asian database of overnight sleep studies in patients with ischemic stroke.

The database, which has been made publicly available, is expected to support research on sleep disorders in stroke survivors and help improve post-stroke care.

The dataset, named iSLEEPS (Polysomnography Dataset for Sleep Analysis in Ischemic Stroke Patients), has been published in the Nature Portfolio journal *Scientific Data*. It comprises 100 overnight polysomnography (PSG) recordings collected at the NIMHANS between September 2018 and December 2021.

The database comprises 100 overnight polysomnography (PSG) recordings collected at the NIMHANS. SUDHAKARA JAIN

Each recording includes manually scored sleep stages, respiratory events, oxygen desaturation episodes, periodic limb movements and clinical information, all annotated, according to the American Academy of Sleep Medicine's 2017 guidelines.

Srijithesh P.R., professor of neurology at NIMHANS and one of the corresponding authors of the study, told *The Hindu* that the project was conceived to address a major gap in sleep medicine research. "Sleep-disordered breathing is extremely common after ischemic stroke, but researchers have had very limited access to large, well-annotated datasets from stroke patients... We wanted to create a high-quality resource that researchers across the world can use," he said.

"Sleep... plays an important role in brain repair, memory consolidation and functional recovery after stroke. If sleep disorders... are not recognised and treated, they can adversely affect rehabilitation and even increase the risk of recurrent stroke," he said.

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GS Paper II – Polity

The right to a fair trial at the crossroads

Gautam Bhatia
Delhi-based lawyer

As proceedings in the 2020 Delhi Riots cases show, endless imprisonment without trial raises urgent questions about liberty and justice

When, earlier this year, the Supreme Court of India denied bail to Umar Khalid and Sharjeel Imam in the 2020 Delhi Riots cases (while granting bail to five other individuals in the same case), one key question that arose was this: "how long is too long" for people to be kept in jail without being found guilty of an offence? At the time of the Court's judgment, Umar Khalid and Sharjeel Imam had spent more than five years in jail without trial; at the time of writing, that period is approaching six years.

Bail, delay, and rights

In its own prior judgments, the Court had noted that an extended delay in trial would trigger an accused's right to personal liberty under Article 21. Thus, even though the Unlawful Activities (Prevention) Act (UAPA) has strict requirements for delay, these statutory restrictions could not override the constitutional (and indeed, human) right to personal liberty.

However, in denying bail to Umar Khalid and Sharjeel Imam, another Bench of the Court noted that a delay in the trial could not create an iron-clad right to bail, but would have to be weighed against other factors such as the gravity of the offence and which of the parties was "responsible" for the delay. With respect, these observations appear to miss the point. Issues such as the gravity of an offence are factors used to determine, in the first instance, whether or not a case for bail is made out. To then invoke the gravity of the offence–which, at the stage of bail, is only an allegation made by the state – to override the question of delay essentially creates a sliding scale under which certain individuals can be kept in jail for decades simply because they have been "accused" of grave offences.

Indeed, this has happened: people accused under the UAPA have been kept in jail for more than two decades before eventually being acquitted, with the best years of their lives robbed from them. Indeed, the very fact that this has happened on more than one occasion ought to have given the Court pause.

Nor does the argument that the accused themselves might be responsible for delaying the trial hold any water. Whatever applications an accused (or, for that matter, the state) may make, ultimately it is the judge who controls the courtroom and the pace of the trial, and it is the judge upon whom the ultimate responsibility rests to ensure that trials are completed within a reasonable timeframe.

Indeed, it was clear that the Court itself recognised some of these issues when, in a rare move, another two-judge Bench recently openly criticised the Delhi Riots bail rejection as being contrary to established precedent and reiterated the fundamental principle that, under a Constitution committed to the rule of law, individuals cannot be incarcerated indefinitely without a trial.

In response, and in another case, the Delhi Riots Bench "referred" this question to the Chief Justice to constitute a larger Bench to resolve. With respect, the very fact that the Supreme Court is effectively debating whether people who have spent more than half a decade in jail (the amount of time that another famous political prisoner, Captain Alfred Dreyfus, did) should or should not be released, is a cause for consternation.

Bail and legal inconsistency

In the meantime, at the level of the trial court and the High Courts, conflict and inconsistency in judicial decisions continue to persist. Recently, the High Court of Delhi (correctly) granted bail to the Kashmiri human rights activist, Khurram Parvez, who had been incarcerated for more than four years without trial. This length of time in prison without trial weighed heavily with the High Court in deciding to grant bail. What is curious, however, is that the judge who (correctly) granted Khurram Parvez bail had denied bail in the Delhi Riots cases the previous year, when the accused in that case had already spent more than four years in jail. Nor is this the only instance of the same judge speaking with different judicial voices: in the Delhi Riots cases themselves, on the same underlying facts, the same judge delivered opposing bail judgments a year apart.

It is trite to say that no case is identical to the other. On an issue as basic as pre-trial incarceration, repeated inconsistencies across cases and courts undermine the rule of law and, ultimately, damage the cause of fundamental rights and individual liberty. These questions assume particular significance because laws such as the UAPA, in particular, have an undeniably political character, and it has been demonstrated across the world that states are only too happy to interpret these laws in a way that blurs the line between political dissent and what the law defines as "terrorism". Recent attempts in the United Kingdom and the United States around dissent linked to Israel's genocide in Palestine are examples of this.

What the judiciary must ensure

In such a context, it becomes particularly important for the judiciary to ensure that such laws are not weaponised. While legal interpretation is subjective, one thing is – and should be – crystal clear: that the state cannot keep people behind bars for years without trial. It makes a mockery of having a system based on the rule of law, and one that – to use the old adage – entrenches the process as the punishment.

It is unclear whether – or when – the Court's larger Bench will opine on the issue. In the meantime, however, there remain contentious UAPA cases, where individuals continue to be imprisoned without trial, and their time spent in custody continues to increase with no resolution in sight. Indeed, one such case is that of Umar Khalid and Sharjeel Imam, the last two individuals among the accused student activists who remain in custody in the "Delhi Riots cases". After the denial of bail by the Supreme Court, the case is once again coming up before the trial court this week; in the meantime, five years in prison have turned into six, and the cost – both to the lives of the imprisoned individuals and to the rule of law – has continued to become steeper.

Ultimately, therefore, this issue is both about individual human lives and about our commitment as a society to human and democratic values. As these cases continue to arise, the courts will once again have an opportunity to reaffirm these values, whether in individual bail cases before trial courts or when it comes to laying down the law before the Court. It is to be hoped that this happens, and that the cycle of endless imprisonment without trial is broken.

GS Paper II – Governance

A shot at life, Mandsaur's model for HPV vaccination

Aditi Garg

Collector and District Magistrate, Mandsaur, Madhya Pradesh

This district in Madhya Pradesh has demonstrated effective grassroots strategies for HPV vaccination delivery

The birth of Savita (name changed) in Mandsaur district, Madhya Pradesh, 14 years ago was a moment of celebration for her family. The Banchhada community she was born into – a denotified tribe in Madhya Pradesh traditionally associated with sex work – welcomes the birth of girls, who are often viewed as future breadwinners. Yet, when a team of human papillomavirus (HPV) vaccinators recently approached Savita's family, they were apprehensive. "Will she be able to work?" they asked candidly, worried about the vaccine's future impact.

Their hesitation was neither unexpected nor isolated. Although cervical cancer is the second most common cancer among Indian women, preventive health-care initiatives often grapple with low levels of awareness and social stigma. Cervical cancer vaccination faces a distinct set of challenges – low cultural sensitivity around sexual health and gender bias, coupled with vaccine hesitancy – making it a pressing public health concern.

In light of this, the Government of India launched a nationwide cervical cancer campaign on February 28, 2026, providing free HPV vaccinations to 1.15 crore girls aged 14-15 years. India bears a quarter of the global cervical cancer burden, reporting over 1.2 lakh new cases and 80,000 deaths annually. Since nearly 95% of cases are caused by high-risk HPV strains, vaccination offers a significant preventive breakthrough.

From data to coverage

To implement the programme effectively and inclusively, the Mandsaur district administration adopted a data-driven, decentralised and adaptive strategy. For exhaustive coverage, the most vulnerable and often overlooked populations were targeted first.

Girls from difficult-to-reach communities – Banchhadas, nomadic tribes, urban slums, and school dropouts – became the starting point. These "missed populations" are at greater risk of falling off the radar of government service delivery.

At the grassroots, the challenge is often not vaccine hesitancy but data invisibility. Leveraging multiple government databases – Rashtriya Bal Swasthya Karyakram (RBSK), SAMAGRA MP (a citizen-centric social security platform by the Government of Madhya Pradesh) and Ladli Laxmi Yojana hyper-localised target lists were created. Fragmented records were transformed into actionable intelligence. Door-to-door surveys and tracking through SAMAGRA IDs ensured that eligible girls did not fall through statistical gaps. School and anganwadi enrolment gaps over the years were meticulously analysed to prepare village-level Master Line Lists. Rapid identification of 'low-coverage/high-resistance' areas enabled coordinated micro-planning. Mapping vulnerable groups geographically also enabled customising communication strategies, tailored to cultural sensitivities.

Reducing barriers through 'nudges'

Behavioural insights played a pivotal role in grassroots' saturation. The district relied on the "Nudge Approach" that helped design an environment where vaccination became the default choice. This helped in effectively breaking down grassroots barriers such as reluctance, inertia, social discomfort. Health-care workers informed families that their daughters were 'due for vaccination', rather than asking them to choose to vaccinate. Families who refused vaccinations received repeated counselling visits by health-care teams. Schools and local bodies arranged transportation to eliminate logistical barriers, simplifying access.

Misinformation hoaxes and myths around vaccine-induced infertility resulted in initial resistance. To counter rumours, the administration launched targeted awareness campaigns involving Gen-Z influencers and youth icons. National-level athletes, young doctors, students, religious leaders and media personalities voluntarily joined the effort to promote vaccination and dispel misconceptions.

Social norms and peer networks served as powerful "behavioural nudges". Local events publicly felicitated vaccinated families and recognised vaccinated girls as peer champions. Gram panchayat and ward-level data sharing sparked both collaboration and competition. Recognition was given to both top performers and the most improved. "Digital nudges" and red-flag reminders for frontline workers enhanced monitoring and accountability.

At the cutting-edge implementation level, resistance often manifests as delay, doubt, and discomfort rather than outright refusal. Vaccinations were conducted exclusively under medical supervision at visible health-care facilities, normalising the practice of adolescent girls' vaccination. Experiences of women affected by cervical cancer were shared to create emotional resonance and encourage informed decision-making. Counselling sessions reduced stigma and replaced distrust with dialogue.

Strategy to impact

The HPV campaign was further integrated with on-going health-care programmes. Routine immunisation days, antenatal care clinics and the Pradhan Mantri Surakshit Matritva Abhiyan sessions were used to promote HPV awareness and conduct vaccination drives. When women accessed one service, they became more receptive to another, creating avenues for 'bundling' of health-care service delivery.

The results were significant. In less than 40 days, Mandsaur achieved 100% of its vaccination target – 493 vaccination sessions were conducted through 12 permanent and 27 temporary vaccination sites across the district. Girls who met the criteria, from 893 villages and 190 urban wards, were mobilised, moving from planning on paper to protecting the population.

The magnitude of India's health-care challenge must be met with the measure of its grassroots' actions. Policy design must bridge the yawning gap between intended outcomes and empirical ground realities. Behavioural and systemic "nudges" in implementation can leverage the human tendency to opt for preset choices. Dovetailing health-care data and grassroots innovations tailored to regional realities can bridge the last mile and deliver the final dose.

By moving from coverage to care, from data to impact, Mandsaur turned a formidable public health challenge into a collective mass movement. The district's inclusive vaccination campaign demonstrated how a simple shot in the arm can truly become a fair shot at life.

GS Paper III – Science & Technology

SC sets aside NCLT order for relying on AI-crafted case law

Aaratrika Bhaumik
NEW DELHI

Observing that the use of non-existent or AI-generated hallucinated judicial precedents is "catastrophic" to the judicial process, the Supreme Court on Thursday set aside an order of the National Company Law Tribunal (NCLT) after finding that it relied on fictitious AI-generated case law.

A Bench comprising Justices P.S. Narasimha and Alok Aradhe underscored that courts must adopt a "zero-tolerance" approach towards the reliance on AI-generated precedents without independent verification as it "contaminates" the very "lifeblood of judicial determination".

"Even if an iota of fake or hallucinated material enters the decision-making process, it would violate the sanctity of adjudication. It is absolutely necessary to maintain integrity in decision-making, and we reiterate and declare zero tolerance for the Bar as well as the Bench to cite, refer to, or rely on such material," the Bench said.

> Even if an iota of fake or hallucinated material enters the decision-making process, it would violate the sanctity of adjudication
>
> SUPREME COURT BENCH

It cautioned against AI-generated hallucinations quietly permeating legal practice, warning that reliance on fictitious precedents "subverts the rule of law". While acknowledging that "increased workloads of modern life" have compelled lawyers and judges to adapt to AI to improve efficiency, it underlined that meaningful human oversight must remain integral to every stage of the adjudicatory process.

"For us, i.e., for those in the province of adjudication and determination of disputes, this by-product of AI, i.e., the production of fake, non-existent, and hallucinated material and its utilisation as precedents in law, is like the release of methyl isocyanate in the province of law and justice: invisible, insidious, and catastrophic by the time anyone notices," it said.

The Supreme Court called for a "deeper collaboration" between the Bar and the Bench on AI and urged the Bar Council of India to frame norms to address the issue of AI-generated precedents.

The Bench noted that the process had already begun with the court publishing the Draft Regulations for Use of Artificial Intelligence in Courts, 2026, for public consultation.

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GS Paper III – Science & Technology

Vikram-1, India's first-ever privately developed orbital rocket, gears up for launch

The Hindu Bureau
BENGALURU

India's first privately developed orbital-class rocket is all set for its maiden launch.

On Thursday, private space launch company Skyroot Aerospace, based in Hyderabad, announced that the launch window for Vikram-I's first test flight, named Mission Aagaman, is between July 12 and August 4.

It said that Test Flight-1 is targeted for no earlier than July 12, subject to the completion of assembly and testing operations at the launch site at the Satish Dhawan Space Centre in Sriharikota, as well as weather, safety and range clearance. The launch window extends till August 4.

Vikram-1 sits on a launch pad at the Satish Dhawan Space Centre in Sriharikota.

The company said that Mission Aagaman, meaning 'the arrival', marks its second mission following the successful suborbital flight of Vikram-S, the first private rocket to reach space from Indian soil, on November 18, 2022.

It said that this would be a partially commercial flight, with the company planning to commence full commercial flights after one or two successful demonstrations to orbit.

All stages of the Skyroot's Vikram-1 have been successfully integrated and stacked at the launch pad. The mission will gather critical data across propulsion, stage separation, guidance, navigation, control and overall vehicle performance.

GS Paper III – Economy

Unwelcome surge

The buoyancy in GST collections is spurred by imported inflation

India's June GST collections rose 13.9% year-on-year to ₹1.95 lakh crore, driven largely by import IGST, which surged 34.6% compared with June 2025, up from 17.2% growth in May. Domestic GST collections grew by a more modest 6.5%, suggesting that the sharp increase in overall collections owes less to a broad-based improvement in domestic value addition. Some economists have argued that this reflects stronger imports of capital goods and industrial inputs. However, May petroleum products' trade data and Q1 FY27 data on the performance of the eight core industries, point to a rather different explanation. June GST collections reflect economic activity during May. While crude and petroleum products constituted a 54% rise this May (YoY) in merchandise imports by value, the other chunk was gold, which constituted another 34% rise. The surge in gold price, by nearly 60% between last May and this May, suggests hedging during difficult times, rather than broad-based economic activity. To stem gold imports, the government hiked its import duty from 6% to 15% on May 13, which likely added to the May import GST kitty. This period also coincided with the rupee depreciating by almost 6% against the U.S. dollar since late February. This coupled with a spike in freight charges, and a 14.5% rise on non-oil imports in May at elevated global prices mechanically raised the June tax base. This suggests that much of the import GST rise is driven by imported inflation and currency depreciation rather than domestic production growth, indicating an unwelcome increase due to higher prices.

Read alongside the performance of India's eight core industries, which expanded by only about 2.8% in Q1 FY27 compared with around 6% in the corresponding period last year, the domestic economy appears more subdued. Growth has been expectedly weak in crude oil, natural gas, refinery products, fertilizers and electricity. The latest HSBC Manufacturing PMI reading of 54.2 likewise points to steady but moderating factory activity, marking the second-lowest expansion in 13 months. These figures come as India marks nine years of GST as a unified destination-based indirect tax. The government can point to the expansion of the tax base from about 66 lakh taxpayers in 2017 to over 1.65 crore today, reflecting better compliance, greater formalisation, and faster refunds, though input tax credit, litigation and federal balance in revenue sharing issues remain unresolved. GST has strengthened India's indirect tax architecture. Yet, the June numbers are a reminder that a growing share of the recent buoyancy appears to have been underwritten by imported inflation and a depreciating rupee rather than stronger domestic value addition.

GS Paper III – Science & Technology

Can space oncology revolutionise cancer treatment?

Even as the burden of cancer is rising in India, space oncology is a rapidly emerging field, investigating how microgravity and cosmic radiation impact cancer progression and treatment

K. Ganapathy

Cancer is a group of diseases where abnormal cells grow uncontrollably, invading nearby tissues and sometimes spreading to distant organs of the body. In India, an estimated 1.87 million new cases are likely to be diagnosed in 2026, which means 1 in 9 Indians reading this article are at a lifetime risk of developing cancer.

Damage wreaked on the body apart, cancer is one of the most economically disruptive illnesses for families. Every year, ₹3,400 crores is spent on direct and indirect medical costs for cancer: this, however, excludes income loss, debt, asset depletion and caregiver burden.

It is no wonder then, that with the burden of cancer rising in India and globally, that it is one of the most widely-studied diseases in the world. And it is this research that has led to the emergence of what could perhaps become a new frontier in cancer treatment: space oncology.

What is space oncology?

Space oncology is a rapidly emerging field, investigating how microgravity and cosmic radiation impact cancer progression and treatment. Space is a natural laboratory for studying cancer biology. Space-based environments are studied to accelerate tumour modelling and drug discovery.

Space oncology has already produced useful, conceptual and technological spin-offs, ranging from 3D cell-culture systems to protein-crystal studies for cancer drug development. This is in addition to refined thinking about radiation risk, tissue response and biomarker discovery.

Why this is useful?

Cancer is biologically diverse. Understanding divergent mechanobiological responses helps identify signalling pathways fundamental to metastasis, tissue invasion and treatment resistance.

Some cell changes that have been identified as a result of microgravity are cytoskeletal reorganisation, altered focal-adhesion signalling, changes in extracellular-matrix interactions and spontaneous formation of multicellular spheroids. Each is relevant to tumour spread and therapeutic response.

When it comes to drugs, researchers have found that microgravity changes the cytoskeleton and spheroid formation of cells, which can help hasten drug discovery and also lead to reduced animal testing for drugs.

As microgravity also allows for more uniform protein crystals and lower-viscosity biologics, this could help develop more stable formulations.

Microgravity also changes the tumour-cell biology that drugs act on, and improves performance of delivery systems such as nanoparticles and 3D formulations. The effects of microgravity on cancer cells, cancer stem cells, and drug response therefore, could help future therapeutic strategies.

International Space Station (ISS) studies have covered real-space and simulated-microgravity experiments across breast, lung, thyroid, prostate, melanoma, glioblastoma and hematologic cancer models. Cancer cells studied in microgravity and exposed to unique radiation environment of space behave differently than in conventional laboratory systems. These differences reveal mechanisms that are otherwise difficult to understand.

Reviews of real-space and simulated microgravity experiments show effects on cell adhesion, migration, proliferation, gene expression and formation of multicellular spheroids.

On microgravity

Microgravity also changes how tiny drug packages (nanoparticles) form. These particles carry chemotherapy directly into the tumours and release it slowly. Microgravity reorganises cancer-cell shapes, membrane behaviour and gene expression. This alters how cells take up drugs. Remove or reduce gravity, and cells experience major changes in fluid behaviour, mechanical loading and cell-to-cell interaction.

For cancer cells, these changes are not trivial. In microgravity, protein crystals and complex biologics form more slowly and uniformly without gravitational sedimentation. Microgravity, therefore, helps produce drug crystals and biologic formulations that are harder to make on Earth.

Breast & GI cancer in outer space

Breast cancer cells show changes in gene expression, morphology, signal transduction and invasive behaviour under microgravity. In a microgravity environment of space, breast cancer cells generally shift toward a less malignant and less aggressive phenotype. Under normal gravity, breast cancer cells attach strongly to their surrounding matrix using focal adhesions. In space, these adhesion points fail to mature, reducing the cells' ability to crawl, migrate, and metastasise. Key proteins that regulate cell cycle checkpoints, specifically cyclin D1 and cyclin B1, are heavily downregulated, pausing the division process and stopping the rapid colony-forming ability of the tumour. Breast cancer spheroids grown in space are more susceptible to specialised therapies.

Gastrointestinal and colorectal cancer, however, react to microgravity by accelerating their disease trajectory and become more aggressive. Reduced expression of drug-resistance genes, increased DNA/RNA damage markers, and reorganisation of the protein, F-actin, make gastric cancer cells more sensitive to the chemotherapy drug, doxorubicin.

Regulations and investments

In 2025, the United States' Food and Drug Administration (FDA) approved a subcutaneous form of an immunotherapy drug, pembrolizumab.

The U.S. space agency, NASA, had developed this through protein crystal growth research performed on the ISS, targeting the ADAR1 gene. These crystals were more uniform and better suited to supporting formulation work for this route of delivery.

Similarly, rebecsinib, became the first space-tested cancer drug to enter clinical trials. Following successful ISS-linked testing it received the FDA 'Investigational New Drug' status. Microgravity-grown tumour organoids helped demonstrate antitumour activity strong enough to support further regulatory progression.

These cases show that space-based research is now a legitimate pathway for drug development, not just a novelty.

This year, United Kingdom regulators and the U.K. Space Agency publicly backed the development of a regulatory pathway in outer space.

The Medicines and Healthcare Products Regulatory Agency (MHRA), the Civil Aviation Authority (CAA), and the Regulatory Innovation Office have streamlined inter-agency bureaucracy. The specific 'dual-regulation' hurdles that previously made space-based pharmacology legally risky for heavy corporate investment were addressed.

This has enabled startups to engineer highly stable, concentrated cancer therapies that patients can self-inject at home instead of hours-long IV infusions. For companies, the costs of setting up a factory are removed; instead they may be able to deploy compact units that operate independently in orbit.

The Indian Space Research Organisation (ISRO), in spite of a modest $13 billion space economy, is the third- largest space-tech power globally and fifth among major government space agencies. Falling launch costs and new commercial platforms are making space oncology and space pharmaceutical manufacturing more realistic. With successful space startups in India the prices may fall further.

Space manufacturing is no longer about research. The picture is clear: the industry is moving from proof-of-concept to commercial production.

The microgravity pharmaceutical manufacturing market valued at $1.5 billion in 2025 is projected to reach $9.8 billion by 2034. Commercial space stations and nano/microsatellites (CubeSats) are now essential platforms for experiments. Small, frequent launches are becoming viable for pharmaceutical payloads.

What the future holds

Over 700 peer reviewed papers, 40 chapters and 12 monographs have already been published in the area of space oncology. At present, space oncology can be encapsulated by the well known saying: 'A journey of a thousand miles begins with the first step.' There is no doubt that humans will exploit outer space in the perpetual quest to solve the cancer conundrum on planet Earth.

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Latest advances: Cancer is biologically diverse. Understanding divergent mechanobiological responses helps identify signalling pathways fundamental to metastasis, tissue invasion and treatment resistance. GETTY IMAGES

When it comes to drugs, researchers have found that microgravity changes the cytoskeleton and spheroid formation of cells, which can help hasten drug discovery and also lead to reduced animal testing for drugs. As microgravity also allows for more uniform protein crystals and lower-viscosity biologics, this could help develop more stable formulations.

THE GIST

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GS Paper III – Economy

Submarine cable project linking India, Malaysia, Singapore unveiled

The Hindu Bureau
HYDERABAD

A consortium comprising Microsoft, Singtel, Tata Communications and AI connectivity platform Lightstorm will build a submarine cable system connecting India, Malaysia and Singapore.

"The facility is designed to cater to the rapidly-growing demand from hyperscalers, GPU infrastructure providers and enterprises running AI training and inference workloads across the India-Southeast Asia corridor," Lightstorm said announcing signing of contracts to launch the building of the cable system. No details of the proposed investment on the project were shared.

Dual landings

I-2SEA, the cable system, would link India's east coast, home to the fastest-growing AI and hyperscaler data centre clusters in Hyderabad and Chennai, directly to Singapore, the region's cloud interconnect and AI hub as well as Malaysia's emerging data centre corridor in Kuala Lumpur. It would have dual landings in India, with the one at Machilipatnam providing shortest subsea access to Hyderabad and

Picture for representational purpose only.

the other at a new diverse landing location in South Chennai.

"The I-2SEA consortium will operate under a joint build agreement. NEC Corporation has been appointed as system supplier and ASEAN Cableship (ACPL) as marine installation partner. The system is now open for capacity commitments," Lightstorm said.

I-2SEA is targeted to be ready-for-service in Q4 2029 and estimated length of the high-capacity cable is 3,600 km from Singapore to Machilipatnam with onward connectivity to Hyderabad.

"It is expected to deliver the fastest transmission on the Singapore/Malaysia-Hyderabad corridor, which is the most strategically critical city pair for AI workloads in the region," the company said.