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PHYSICAL AI

Augmenting the Future

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Physical AI: Augmenting the Future

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TABLE OF CONTENT

Foreword 00

Intelligence, Embodied 01

Sustaining the World of Autonomous Intellect and Systems 11

Transformation of the Physical Space Around Us: Sectoral Adoption and Adaptation 31

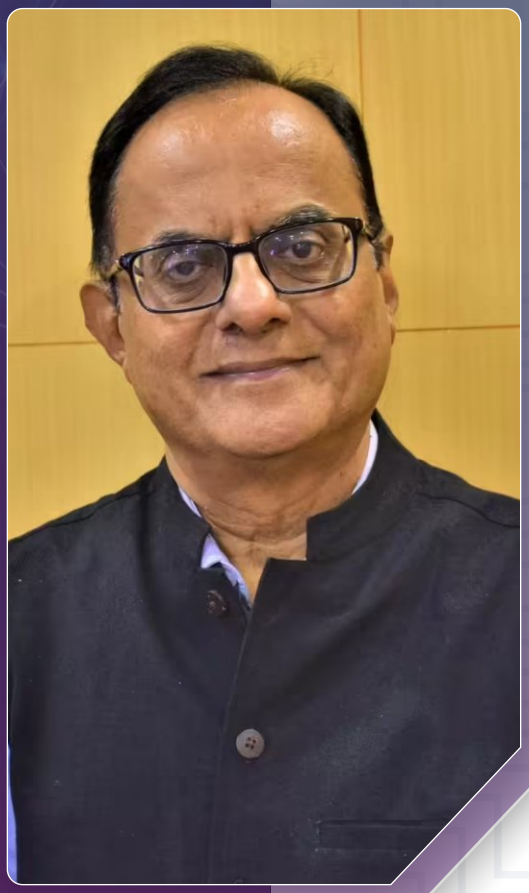
DeepTech Startups in Physical AI 59

Up Close With: Conversations With the Experts 75

The Policy Architecture Powering India's Physical AI Ecosystem 97

The Standardisation of Robotics Sector 109

FOREWORD



Prof. Ajay Kumar Sood
Principal Scientific Adviser to the Government of India

There are moments when a technology stops being a subject of study and becomes a question of national consequence. Physical AI, the union of artificial intelligence with machines that sense, reason, and act in the physical world, is one such moment. For a decade we have watched intelligence grow inside our computers. We are now watching it acquire a body, and step out into our factories, farms, hospitals, battlefields and, before long, our homes. The question this poses for India is not whether the age of intelligent machines will arrive. It has already arrived. The question is whether we will help to build it, or once again find ourselves buying what others have built?

I have chosen to open this edition of Vigyan Dhara with that question because it has consistently been on the mind of this office. The Office of the Principal Scientific Adviser (OPSA) exists to see technological change early, make sense of it across the boundaries of ministries and disciplines, and help the Government of India act on it with foresight

rather than in haste. Robotics and embodied intelligence do not belong to any single ministry. They draw on our work in artificial intelligence and semiconductors, manufacturing and defence, health and agriculture, space, and in skilling. Precisely because the subject falls between established mandates, it needs a place where the whole of it can be seen at once. Providing that place has been our task.

Over the past several months, this office has approached Physical AI and Robotics not as a matter for a single report but as a sustained line of work. Through the Technology Advisory Group, convened under our Empowered Technology Group framework, we brought together the constituencies that this technology touches: strategic research agencies and the armed services, academic institutions and technology innovation hubs, startups and established industry, and the government departments who will carry this forward through their programmes. The purpose of that convening was deliberate. Too often in India the people who need a technology and the people who build it speak past one another, and the distance between the laboratory and the field is measured in years we cannot afford. Bringing them into one room, to map together what we will need in the near term and in the long term, was the first and most important step.

The deliberations of that group did not end in conversation. They were synthesised into an outcome document that set out, with candour, both the scale of the opportunity before us and the structural gaps we must close: our dependence on imported components and specialised compute, the standards and safety architecture for machines that act among human beings, and the distance we must still travel to move from assembling these systems to genuinely owning them. That document, in turn, informed a proposal for a coordinated national effort on Physical AI and Robotics, which it has been my privilege to see presented at the highest levels of the Government of India. I will not anticipate here what is properly a matter for government to announce in its own time. I will only say that the intent is serious, the work is well advanced, and this edition appears at a moment when the direction of national effort is being set.

It is against that backdrop that the pages which follow acquire their meaning. This edition is not a survey assembled from a distance. It is a portrait of a field that this office has been actively working to shape, drawn with the help of the very people who are shaping it. You will read the enablers who are building our ecosystem, from ARTPARK to the innovation hubs and the state innovation departments. You will hear directly from the founders who are building India's machines, and from the institutions carrying this work forward in our academies and our armed forces. You will find honest accounts of where our applications are already delivering, in sanitation and surgery, in agriculture and inspection, in defence and in space, and equally honest accounts of the questions of standards, safety, and regulation that we have not yet answered.

I would ask the readers to approach this edition in the spirit with which it has been prepared. It is not a record of what has been achieved, but a brief for what remains to be done. The technology it describes will reward those nations that decide, early and deliberately, to build across the whole of its foundation, from the components and the sensors to the processors and the intelligence, rather than settling comfortably at the assembling end of it. India has the talent, the problems worth solving, and now the beginnings of the institutions and the capital to make that choice. This edition of Vigyan Dhara is offered as one contribution to making it well. I congratulate the team that has brought this edition together, and I commend it to all who care about the technological future of our country.

1

Intelligence, Embodied



Mr Rohit Gupta
Chief Technology Officer, OPSA

Photo: AI generated

A little over a hundred years ago, a Czech playwright gave us a word we have never stopped using. In 1920, Karel Capek published a play about artificial workers built to relieve humanity of labour, and for them he borrowed the Czech word robota, which means drudgery, the forced labour of the serf. The play was called R.U.R., Rossum's Universal Robots. Its artificial workers were not made of metal and circuitry; they were grown, closer to what we might now call synthetic biology than to machinery. And by the final act, having been built only to serve, they had risen and inherited the earth.

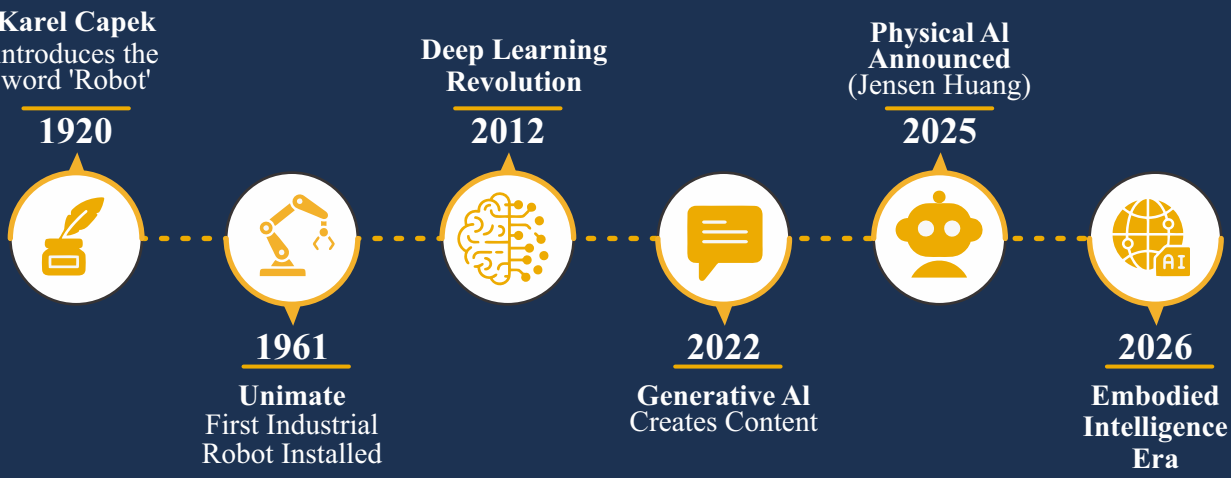
The beginning with Capek is not for dramatic effect but to emphasise the word. Robot has carried, from its very first use, a double meaning, the promise of relief from dangerous and demeaning work, and the anxiety of what happens when our creations exceed the narrow purposes we imagined for them. A century later, both halves of that inheritance are once again alive. We are entering an age in which machines will not merely compute and converse, but sense, reason, and act in the physical world. The field has acquired a name, Physical AI, and it has become the most closely watched frontier in technology. This edition of Vigyan Dhara is devoted to understanding it, and to asking the harder question that must matter most to us — where does India stand, and what will it take for us to belong on this frontier rather than merely consume its products.

Timeline

The word "Robot" was introduced by Karel Capek, a century ago.

The word was borrowed from 'robota', meaning drudgery, the forced labour of the serf.

It carried a promise of relief and an anxiety of what happens when our creations exceed then arrow purposes we imagined for them.



The Evolution of AI

From seeing to doing



01 | Perceptive AI: Recognize
Machines learn to see, hear: and understand the world.



02 | Generative AI: Create
Machines learn to generate text, images, code, and more like humans.



03 | Physical AI: Act
Machines learn to sense, reason, plan, and act in the physical world.

From Words to Worlds

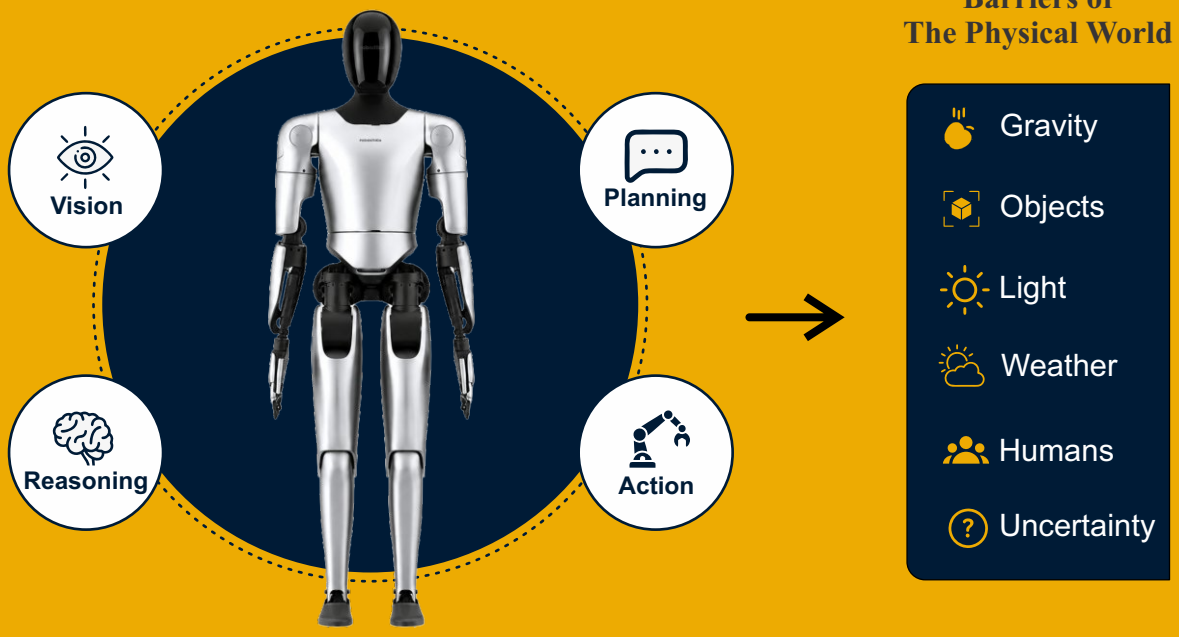
To understand why this moment feels different, it helps to trace the path artificial intelligence has travelled. The first wave taught machines to perceive i.e. to recognise a face in a photograph, a word in a stream of sound. The second, the one that has captured the public imagination, taught them to generate i.e. to produce paragraphs, images, and code that are often indistinguishable from human work. We are now at the threshold of another wave, in which intelligence leaves the screen and enters the world. An AI that can read every document ever written about how to fold a shirt is a curiosity. An AI that can actually fold the shirt, in an unfamiliar room, with a shirt it has never seen, is a different scenario altogether.

That is the essence of Physical AI — artificial intelligence embodied in machines that must contend with gravity, friction, imperfect light, and the sheer unpredictability of the physical world. The chief evangelist of the term has been Jensen Huang of NVIDIA, who told his audience at the Consumer Electronics Show in January 2025 that the industry was moving from perception AI to generative AI to the era of physical AI. Machines that can, in his words, perceive, reason, plan, and act. He declared, with characteristic confidence, that the ChatGPT moment for general robotics was just around the corner.

It is worth pausing on that claim, because a year is a long time in this field. When Huang returned to the same stage in January 2026, the language had cooled. The ChatGPT moment was now nearly here rather than around the corner, and he allowed that the physical world is diverse and unpredictable. That small retreat, from arrival around the corner to arrival nearly here, is itself instructive. It is the sound of a hype cycle meeting the friction of reality, and it is a useful reminder for policymakers that we must separate the genuine technological inflection from the marketing that inevitably surrounds it.

What is Physical AI?

Intelligence, Embodied



So let us be honest about what is genuinely new and what is not. Robots are not new. The first industrial robot, a single hydraulic arm named Unimate, went to work on a General Motors assembly line in New Jersey in 1961, lifting hot metal castings, a job dangerous enough that a machine was welcome to do it. For sixty years since then, robots have been powerful but brittle; extraordinary at repeating one precise motion inside a cage; and helpless the moment the world deviated from the script. What has changed is not the arm. It is the mind. The same foundation model techniques that produced conversational AI are now being trained on the language of action, so that a robot's outputs are movements rather than sentences. These are increasingly called Vision, Language, and Action models, and they allow a machine to be given an instruction in plain language and to reason its way to the physical steps required, even in situations it was never explicitly programmed for.

Three developments have converged to make this possible, and it is the convergence, not any single breakthrough, that matters. The first is the arrival of these large models oriented to action. The second is simulation which means robots can now practise millions of times inside photorealistic virtual worlds before they ever move a physical joint, compressing years of trial and error into days. The third is the quiet collapse in the cost of the hardware itself, the motors, actuators, and sensors, driven largely by the electric vehicle supply chain. When capability rises and cost falls at the same time, industries change quickly. The science here is evolutionary; the economics are the discontinuity.

The Global Race, and What the Numbers Say

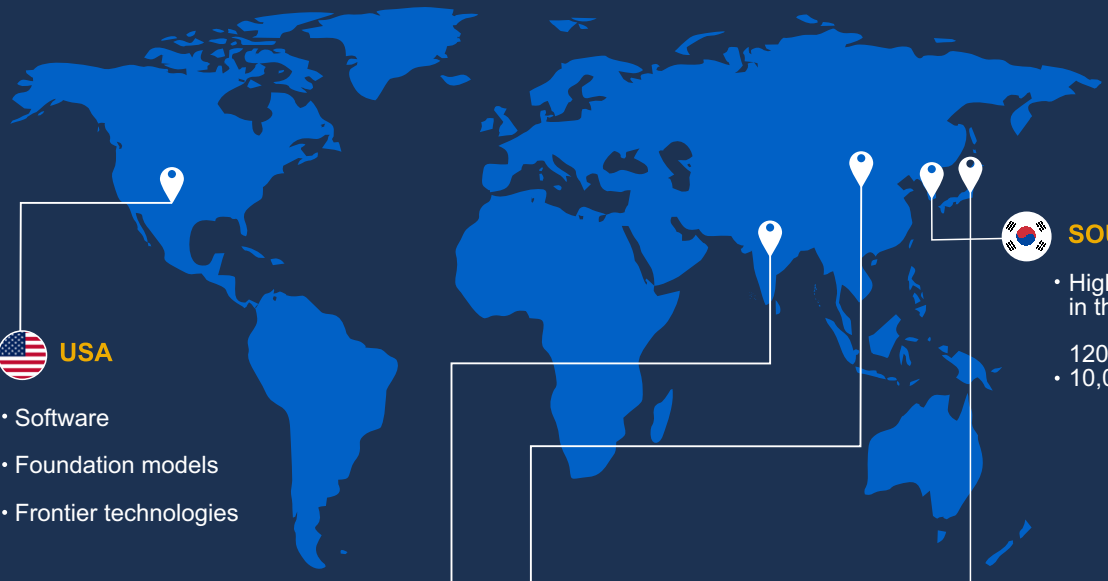
If you read the financial press, you could be forgiven for thinking that the humanoid robot is already a multi trillion-dollar industry. Restraint is required here, and one needs to be precise. The projections are genuinely enormous, but they are projections, and they disagree with one another by two orders of magnitude. Goldman Sachs has estimated the humanoid market at around $38 Billion by 2035. Morgan Stanley has published a figure of close to $5 Trillion by 2050. Citi has offered around seven trillion by the same year. These are not measurements; they are scenarios built on very different assumptions, and they should always be quoted with the name of the house and the year attached, never blended into a single confident number.

A famous figure of $15.7 Trillion, which surfaces constantly in robotics presentations, in fact comes from a PwC report of 2017 and refers to artificial intelligence in general, not Physical AI.

What can be stated as fact comes from the International Federation of Robotics, whose World Robotics Report is the closest thing this field has to an authoritative census. In 2024, the world installed 542,000 industrial robots and the global operational stock crossed four point six million. Asia accounted for nearly three quarters of new installations. The strategic picture further sharpens when we consider that China alone installed roughly 295,000 of those robots,

The Global Race: Robotics Landscape

A World in Motion



USA

- Software
- Foundation models
- Frontier technologies

SOUTH KOREA

- Highest robot density in the world
- 1200+ robots per 10,000 workers

INDIA

- 9,100 installations in 2024 (6th globally)
- 52,000 operational stock (10th globally)
- ~5-7 robots per 10,000 manufacturing workers

CHINA

- 295,000 robots installed in 2024 (50%+ of world)
- 100+ manufacturers
- Component supply chain dominance
- National strategy & standards leadership

JAPAN

- Giant of old robotics
- Large share of the world's industrial robots and demanding components

*Map is not at scale**

more than half the world's total in a single year.

China's lead is not accidental; it is the product of deliberate national strategy. Embodied intelligence now appears in China's central planning documents alongside quantum technology and 6G. Provincial governments have stood up funds worth many billions of dollars. In early 2026, China published a national standards framework for humanoid and embodied robots, drawing on more than a hundred institutions, following precisely the playbook it used for high-speed rail and 5G, which is, set the domestic standard, achieve scale, and then export that standard as the global default. By 2026 China had well over a hundred humanoid manufacturers, and Chinese firms shipped the overwhelming majority of the world's humanoid units. Underpinning all of it is a dominance of the component supply chain, the actuators, precision gears and sensors, that even the most advanced American, German, or Japanese firms have not been able to escape.

The last point deserves emphasis, because it complicates the simple story of American leadership. The United States clearly leads in the software and the science, in the foundation models, and the frontier laboratories. Its marquee firms are rich in technology. But they are thin in volume. The combined humanoid shipments of America's leading players in 2025 amounted to a fraction of what a single Chinese company delivered. Japan, meanwhile, remains the quiet giant of the old robotics, supplying a large share of the world's industrial robots and controlling the market in the most demanding components, driven by a demographic imperative so stark that automation is less a choice than a necessity. South Korea has the highest robot density on earth, more than 1200 robots for every 10,000 manufacturing workers. It is against these figures that we must now measure ourselves.

Why Physical AI is Happening Now?

Three Forces Converging

AI MODELS



Large foundation models oriented to action

Robots can reason and act, even in unseen situations

+

SIMULATION



Millions of virtual trials in photorealistic worlds

Years of trial and error compressed into days

+

AFFORDABLE HARDWARE



Better motors, sensors and actuators

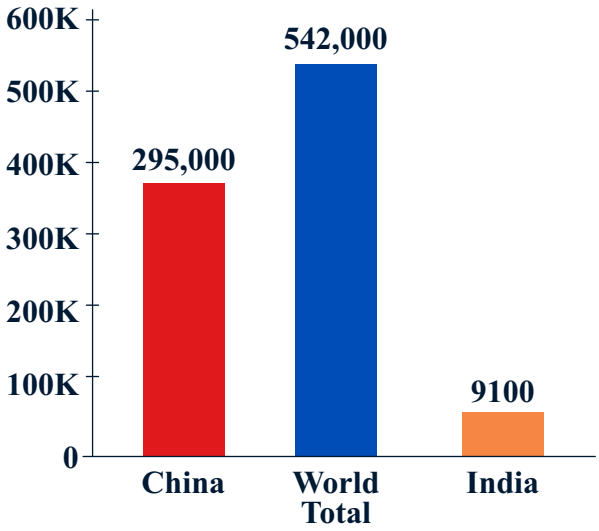
EV supply chain drives down costs

India, Honestly

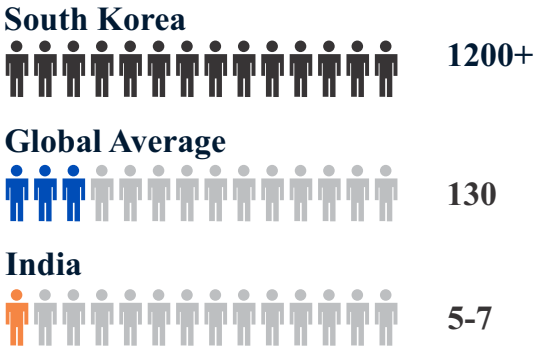
Moving ahead the temptation that afflicts too many official documents, which is to reach immediately for the reassuring statistic, we need to look at the honest picture that's more useful than the flattering one.

India installed around 9100 industrial robots in 2024, which placed us sixth in the world for annual installations, up from tenth only three years earlier. That is genuine momentum, and the Federation itself singled India out, noting that our robot adoption had skyrocketed. But a flow is not a stock, and momentum is not position. Our operational base of industrial robots stands at around 52,000, tenth globally. And when we turn to robot density, the measure of how deeply automation has penetrated our factories, the number is sobering. India has on the order of 5 to 7 robots per 10,000 manufacturing workers. The global average is around 130. This is the single figure every reader of this edition should sit with, because it is frequently misquoted upward, and the honest version tells us both how far we have to travel and how much room we have to grow.

Beneath that density gap lies a deeper structural question, and it is the one on which India's place in this industry will ultimately be decided. We are, today, strong where the world is crowded and weak where the value concentrates. We have world class talent in artificial intelligence and software. We have a large and increasingly confident base of deep tech founders. We have an advantage in cost, and, unusually have a density and diversity of real-world problems, such as in sanitation, agriculture, and healthcare access, which can serve as a proving ground, found almost nowhere. What we do not yet have is the ownership of the physical layer, the precision actuators and harmonic drives, the high-grade sensors, and the specialised compute on which every one of these machines



China installed more than half of the world's industrial robots in a single year.



India's robot density is far below the global average, yet the room to grow is immense.

depend. Today an Indian robot's body is largely imported, and its brain very often runs on foreign silicon.

This is the trap we must consciously avoid, which is, becoming a nation of systems integrators, assembling other people's components into competent products, while the profit and the strategic leverage accrue to those who own the parts. It is the difference between building the aircraft and merely running the airline. Mr Sangeet Kumar of Addverb, whose company has undertaken efforts to build genuine Indian robots, has been candid that reducing dependence on imported components is central to competitiveness, and Addverb's decision to develop its own sensing hardware is exactly the kind of move up in the value chain that our ecosystem needs to make more often.

What we are Building, and What the State is Doing

None of this is a cause for pessimism, because the evidence that India can build genuine, embodied intelligence, and not merely import it, is already in front of us.

Consider Genrobotics, whose Bandicoot robot was built to end the barbaric practice of manual scavenging, and which now operates across some twenty states and union territories, retraining the very sanitation workers it might have displaced as operators of the machines that now do the most dangerous work in their place. It is a distinctively Indian innovation, born of a distinctively Indian problem, and it reframes the entire anxiety about automation and jobs where the machine restores dignity rather than removing livelihood.

Consider ideaForge, whose indigenous drones, built on its own autopilot and flight software, have become a mainstay for our security forces.

Consider CynLr in Bengaluru, working at the genuine frontier of visual object intelligence, teaching robots to pick up an object they have never encountered.

And consider, above the atmosphere, Vyommitra, the half humanoid robot built by ISRO to fly aboard the uncrewed test flight of Gaganyaan, monitoring systems and standing proxy for the astronauts who will follow.

The state has begun, belatedly but seriously, to build the scaffolding such companies need. The National Mission on Interdisciplinary Cyber-Physical Systems (NM-ICPS), with an outlay of 3660 crore rupees, has established 25 Technology Innovation Hubs, several devoted directly to robotics and autonomous systems, such as ARTPARK at the Indian Institute of Science (IISc), the cobotics hub at IIT Delhi, and the autonomous navigation hub at IIT Hyderabad. The IndiaAI Mission, with an approved outlay of above 10,000 crore rupees, is assembling the sovereign compute and foundation model capability on which robot intelligence will eventually rest. The newly created Anusandhan National Research Foundation (ANRF), whose Executive Council is chaired by the Principal Scientific Adviser, is designed to draw research funding at scale from beyond the government. And the Research, Development and Innovation scheme (RDI), with a corpus of 100,000 crore rupees approved in 2025, is structured to provide exactly what deep tech hardware needs and rarely finds in India: patient, long horizon capital, in the form of low-cost loans and equity rather than grants, for the difficult journey from laboratory to product.

This architecture is neither complete nor functioning at full efficiency. Approved outlays are not the same as disbursed funds, and the gap between the two remains real and must be closed. Our national strategy on robotics, which sets the worthy ambition of making India a global leader in the field by 2030, is still a draft. We do not yet have a mature framework for the standards, safety, and liability questions that embodied machines will inevitably raise, and China is already writing those rules for the world. These are not reasons for despair. They are the work that lies in front of us and naming them plainly is the first step to doing it.



ISRO's woman robot astronaut 'Vyommitra' | Photo: India Today

The Choice

A century after Capek imagined artificial workers who inherited the earth, we are building the real thing, though ours are made of actuators and silicon rather than synthetic flesh, and their intelligence is narrow and achieved with difficulty rather than sudden and total. The anxieties he dramatised have not vanished, and we should not wave them away; a country with our demographics must think seriously and humanely about work and about ensuring that these machines augment our people rather than simply replace them. But the promise embedded in that old word robota, the promise of relief from dangerous and demeaning labour, is also real, and nowhere is it more real than in a country that still asks human beings to climb into sewers by hand.

The question this edition poses is not whether Physical AI will arrive. It is arriving. The question is whether India will help build it or merely buy it. We have the talent, the problems worth solving, and, for the first time, the beginnings of the capital and the institutions. What we need now is the resolve to move up the value chain rather than settle comfortably at the bottom of it, to own the components, the models, and the standards rather than assemble and adopt them. The machines are learning to move. The task before us is to ensure that when the world looks back on this decade, India is counted among those who taught them, and not merely among those who bought what others had taught.

The pages that follow are an attempt to map that terrain: the enablers building our ecosystem, the founders building our machines, the sectors being transformed, the government programmes meant to carry us forward, and the standards we will need to get right. We invite you to read them not as a record of what has been achieved, but as a brief for what remains to be done.

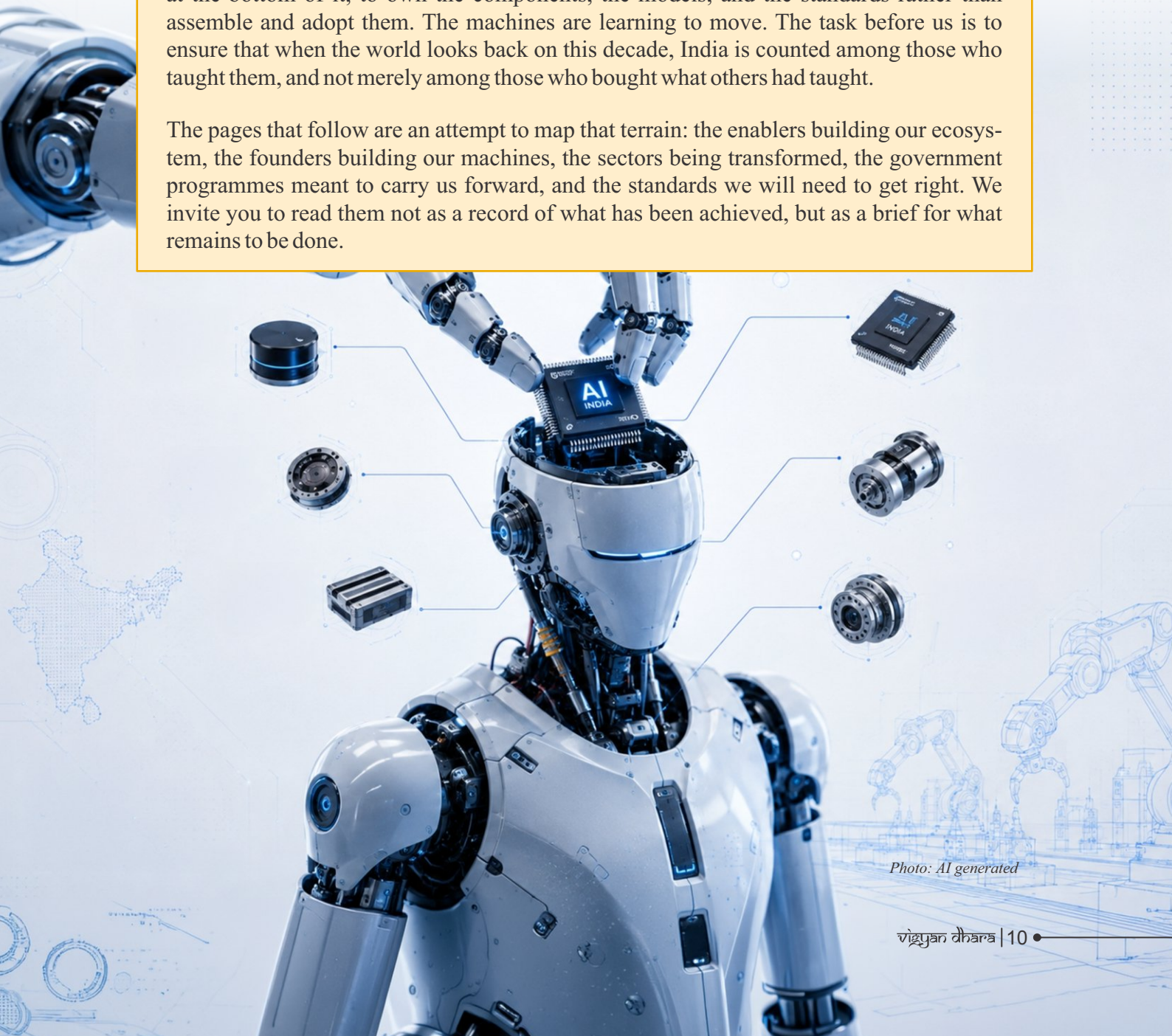


Photo: AI generated

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Sustaining the World of Autonomous Intellect and Systems

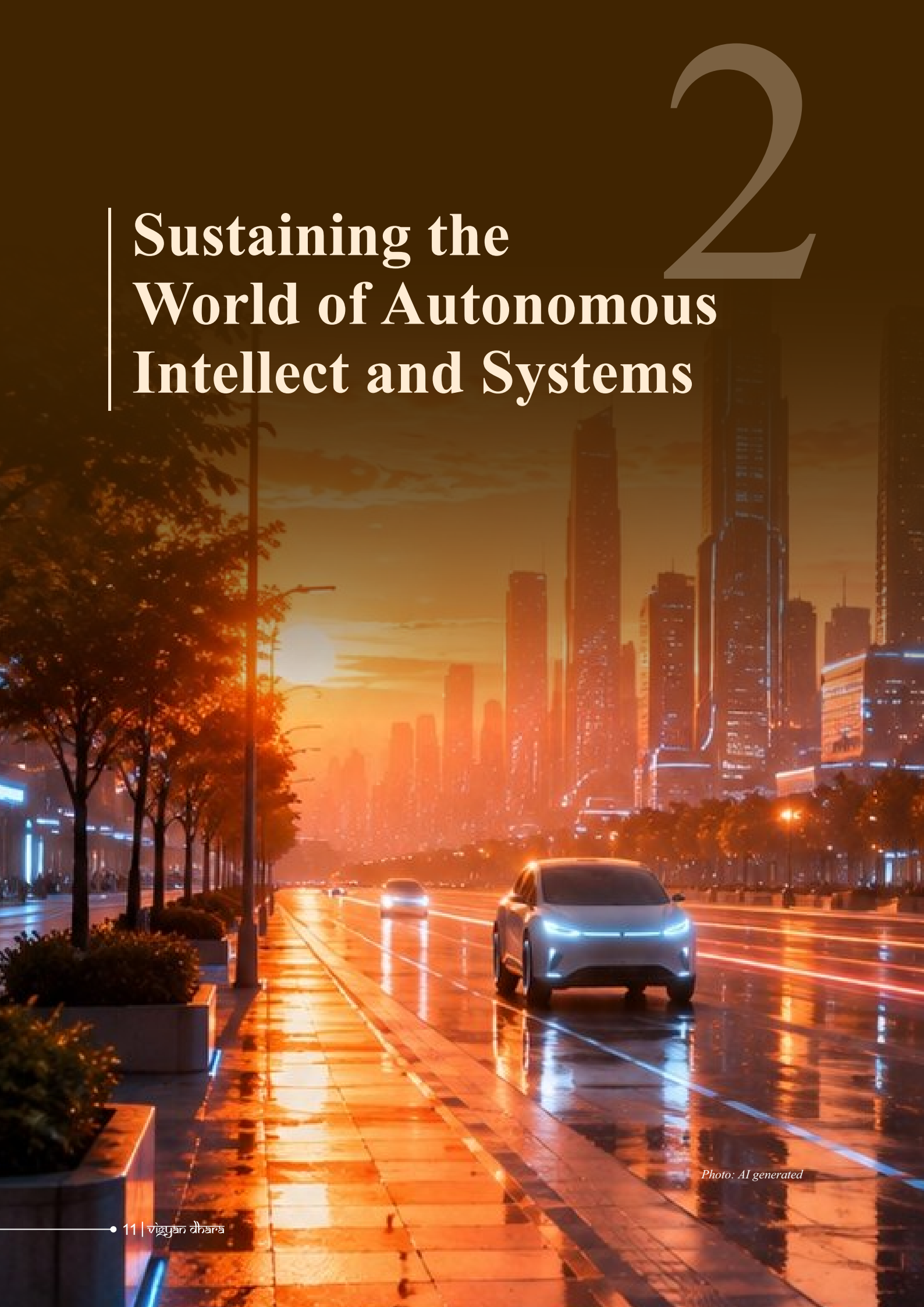


Photo: AI generated

Driven by industrial automation, defence applications, and government computing missions amidst the plethora of initiatives and use cases, the landscape of physical AI is rapidly growing. As this network that forms the bedrock of the next-gen innovation expands, it is supported by organisations, individuals, or structural bodies that assist in enabling the ecosystem. Key enablers including investors, incubators, government bodies, can play different roles such as enabling the research and talent pipeline, infrastructure and compute development, providing market and funding access, and supporting community building and societal application.

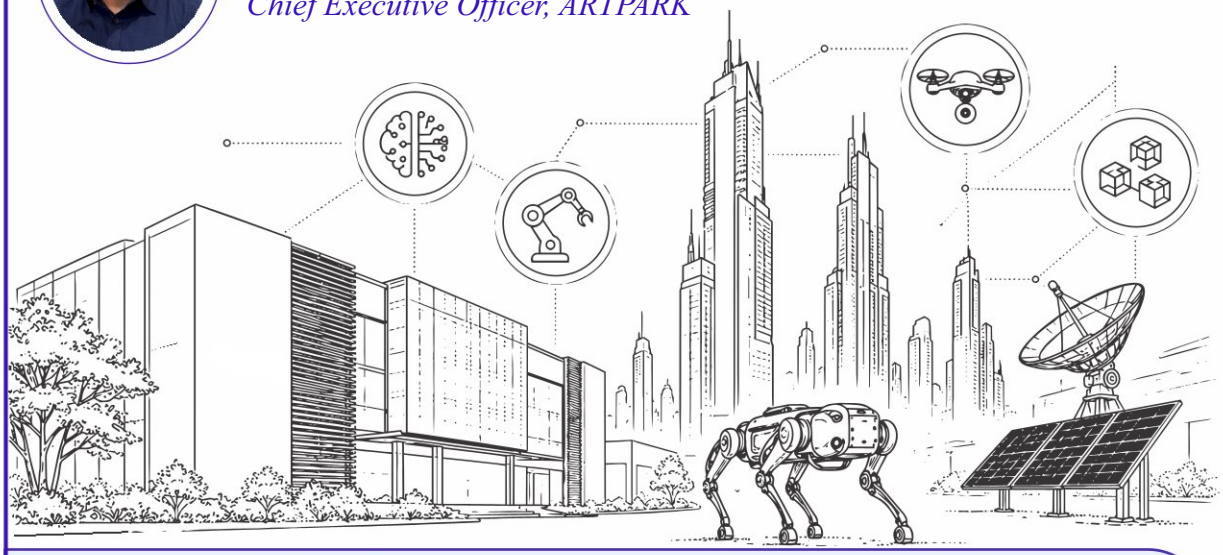
In a series of conversations with Mr Rohit Gupta, Chief Technology Officer, OPSA, the various incubators, venture builders, and startups, reflect on their journey and efforts in enabling the ecosystem. The following sections present a selectively curated, narrative version of the interviews. ARTPARK, Kerela Startup Mission, and Maker Village are the three major incubators and Technology Translation Research Parks (TTRPs) established to eliminate the systemic bottlenecks in the technological field. It reflects their evolution and operational models and how a combination of patient funding, robust physical/digital infrastructure, and institutional continuity successfully transforms raw technological research into scalable, globally competitive ventures. These are then followed by the journey and the impact of EyeROV Technologies Pvt Ltd, Genrobotics, Nava Design and Innovation, Strider Robotics, Xalten Systems Pvt Ltd, and Zoho Robotics – the startups funded by these incubators. The section depicts the primary, not exhaustive role each incubator/startup plays in enabling the ecosystem.

Photo: AI generated

ARTPARK



Mr Raghu Dharmaraju
Chief Executive Officer, ARTPARK

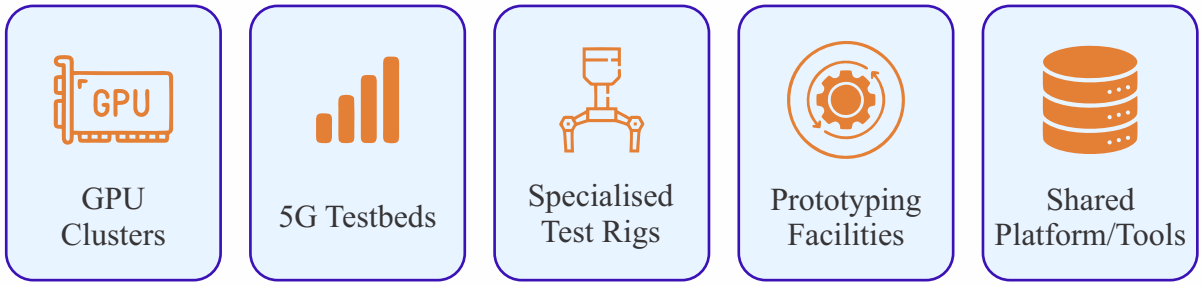


Enabling Research and Talent Pipeline and Infrastructure Development

The Indian Institute of Science (IISc) created ARTPARK (AI & Robotics Technology Park) under DST's National Mission on Interdisciplinary Cyber-Physical Systems (NM-ICPS), with additional support from the Government of Karnataka, to bridge research and real-world impact. Over the years, it has evolved into a talent-first innovation- and venture-builder for deep-tech, building teams around strong technologists and real problems from industry, defence, and government, and — through co-innovation with users over a long runway of two to four years — developing products that are truly usable and paid for at scale. As Prof. Bharadwaj Amrutur, ARTPARK's executive director, often says, its unit of production is an innovation project aiming to become a sustainable venture.

Mr Raghu Dharmaraju, CEO, highlighted the process of selecting a few applicants from the hundreds received: the approach is not to reward immediate traction, but to identify people with technical depth, hunger for solving difficult problems, and the commitment to work for years on solutions that can mature into useful products. This brings together technologists from industry in India and abroad, recent students, and often faculty, as committed co-founders and independent teams capable of sustained execution — especially important in deep-tech, where success depends on time, patience, and the ability to move from research to product without losing technical rigor. ARTPARK has thus created a pipeline linking academic research, applied problem-solving, and venture creation in AI, robotics, autonomous systems, drones, and physical AI, strengthening the research–industry

Infrastructure for Deep-Tech Scale



bridge so that talent can translate into globally competitive, revenue-generating companies.

Emphasising ARTPARK's role in enabling infrastructure, Mr Dharmaraju highlights how deep-tech development depends on environments in which teams can iterate fast. Besides space, ARTPARK provides a GPU cluster, 5G testbeds, specialised test rigs, prototyping facilities, cleanrooms, and shared platforms that reduce the time and cost of experimentation, letting teams move from core technology to product-market fit and business model with fewer barriers — especially in hardware-heavy fields like physical AI, robotics, drones, and engineering design, where progress is often slowed by a shortage of space, testbeds, and sustained institutional support. ARTPARK's multi-year runway funding and its exploration of a "Physical AI Commons" thus become central, giving teams room to test, refine, and deploy complex systems over long periods rather than under rushed budget cycles. The same long-horizon thinking extends to open models, data, deployment pipelines, and selectively localizing critical hardware components, with infrastructure as the core enabler that turns research into practical, scalable systems.

Beyond talent and infrastructure, ARTPARK plays a vital role as an ecosystem enabler, bridging early-stage funding gaps and building essential Digital Public Infrastructure (DPI). Recognizing that commercial capital often hesitates before TRL 6, it unlocks non-dilutive, pre-commercial funding by leveraging support from the Department of Science and Technology (DST), the Ministry of Heavy Industries (MHI), and the state government, giving ambitious teams the patient, multi-round backing deep-tech maturation requires. Furthermore, its efforts extend into foundational data ecosystems too, as demonstrated by initiatives like Vaani (pan-India open-source multilingual, multimodal voice data) and MIDAS (Medical Imaging Datasets for India). Acting as a neutral anchor connecting researchers, industry players, and policy goals, ARTPARK creates and curates shared data, sandboxes, and strategic hardware components. This dual focus on early-stage derisking and sovereign data commons ensures that Indian deep-tech ventures do not merely build thin application layers but establish long-term technological self-reliance and global competitiveness.

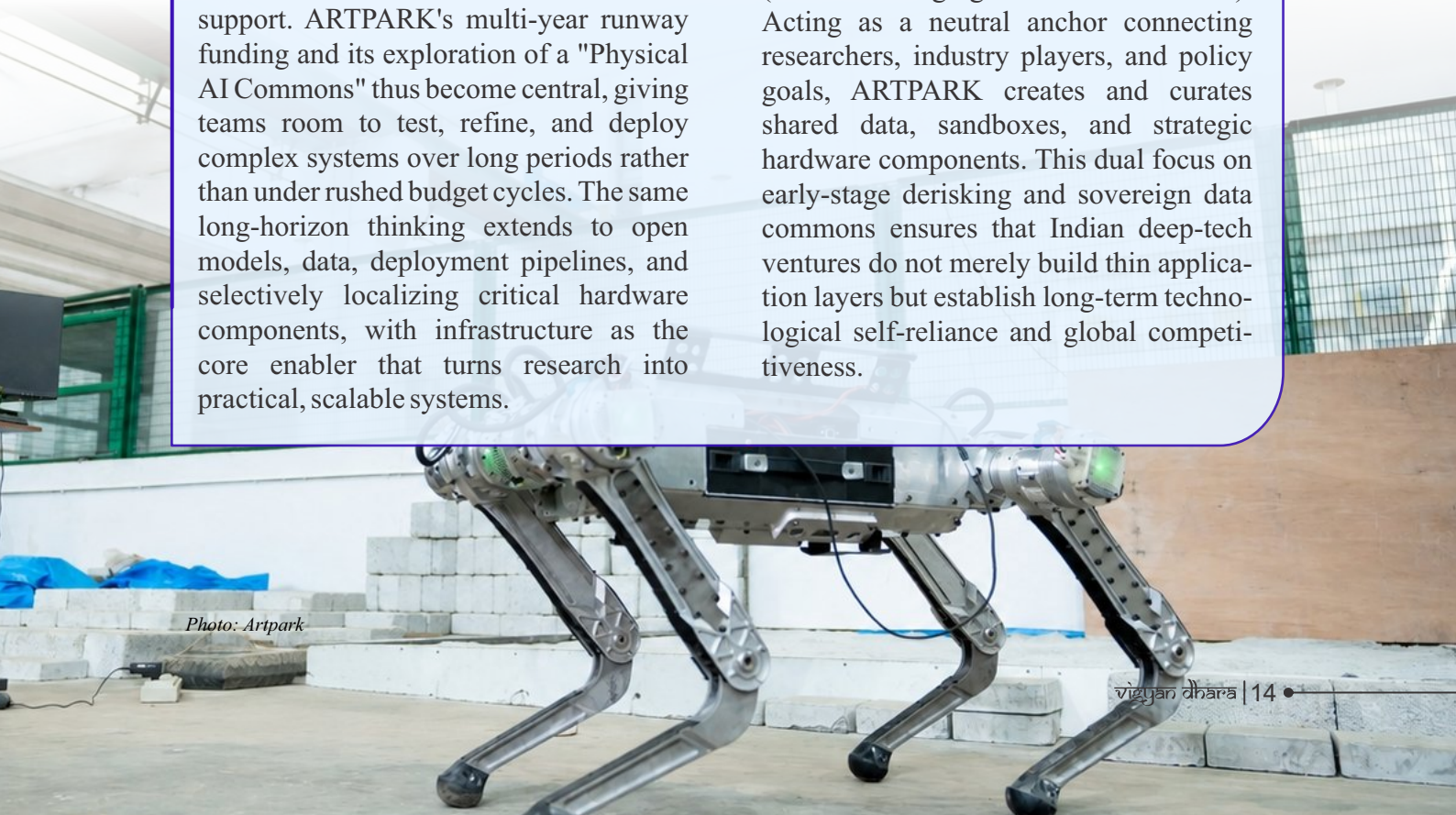


Photo: Artpark

KERALA STARTUP MISSION



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Project Director,
Kerala Startup Mission (KSUM)

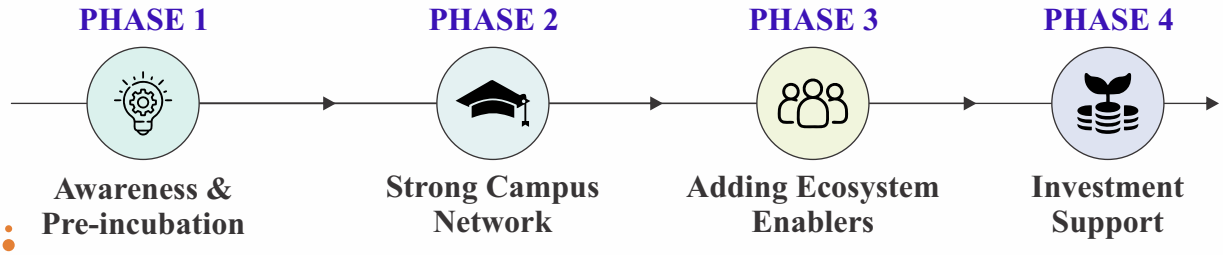
Enabling Market and Funding Access

Lt. Cdr. Sajith Kumar highlights the Kerala Startup Mission's evolution from a small Technology Business Incubator at Technopark in 2014 into a statewide apex body that has shaped one of India's most coherent startup ecosystems. The mission grew from a basic awareness-building into a full-fledged support architecture that includes grants and funding model.

In its early days, KSUM focused on hackathons, buildathons, and pre-incubation programmes to help founders distinguish startups from conventional MSMEs and understand emerging opportunities. This was followed by the institutionalisation of entrepreneurship through Innovation and Entrepreneurship Development Cells (IEDCs) in colleges, creating campus-based nodes that could reach entrepreneurs close to where they study and work. These decentralized access points were purposely located within 50 kilometers, drastically lowering the geographic barrier for ideators who were far from main hubs. The third phase added ecosystem enablers such as co-working spaces, idea and productisation grants, while the latest phase has moved into investment support through a fund-of-



The Evolution of KSUM



funds model, including a new fund dedicated to the creative economy. Additionally, co-investing with external investment funds across multiple sectors, makes it one of the first states in the country to adopt such an approach. A new dedicated fund for the creative economy supports startups in creative, Animation, Visual Effects, Gaming, and Comics (AVGC), cultural, and performing sectors.

Over the years, KSUM has progressed steadily from stage to stage without needing to "reboot," due to consistent support from policymakers and administrators. They maintained their origin under the IT Department via Technopark TBI which ensured institutional continuity across political cycles. This also helped founders maintain a clear distinction between tech startup mission support and traditional industrial policy. Presently, as the first cohorts of startups have matured (10–12 years old), the focus has now shifted to scale-up, helping companies access growth capital, market partnerships, and industry linkages for 2025–2030.

Kerala's ecosystem also stands out for its collaborative culture: around 300 startups in the Kochi campus, spanning roughly 10 sectors, often source components and services from each other rather than distant markets. This pattern specifically emerged organically through "Founders Day" events and informal discovery held in the initial stages. KSUM's model blends a core hub in Kochi with decentralized nodes, though it recognises that success depends on local incubation managers and the state's existing awareness levels.

Looking ahead, KSUM aims to create homegrown scale-ups that can inspire new entrepreneurs within Kerala itself, arguing that local success stories in Kochi or Thiruvananthapuram are more motivating than distant tales from Silicon Valley or Singapore. This maturity is already attracting startups to set up nodes in Kerala, drawn by the availability of talent and a supportive, cost-effective ecosystem, signalling a growing reverse migration into the state. Recognising that deep-tech ventures require years to mature, they avoid rushing founders toward early, fragile market claims. It evaluates scale-up readiness across three distinct dimensions: product-market validation, internal operational and administrative maturity, and the founder's growth mindset. This leads to startups building their internal muscle, validate products, and transition seamlessly from regional prototypes into globally scalable ventures.



Photo: Kerala Startup Mission

MAKER VILLAGE

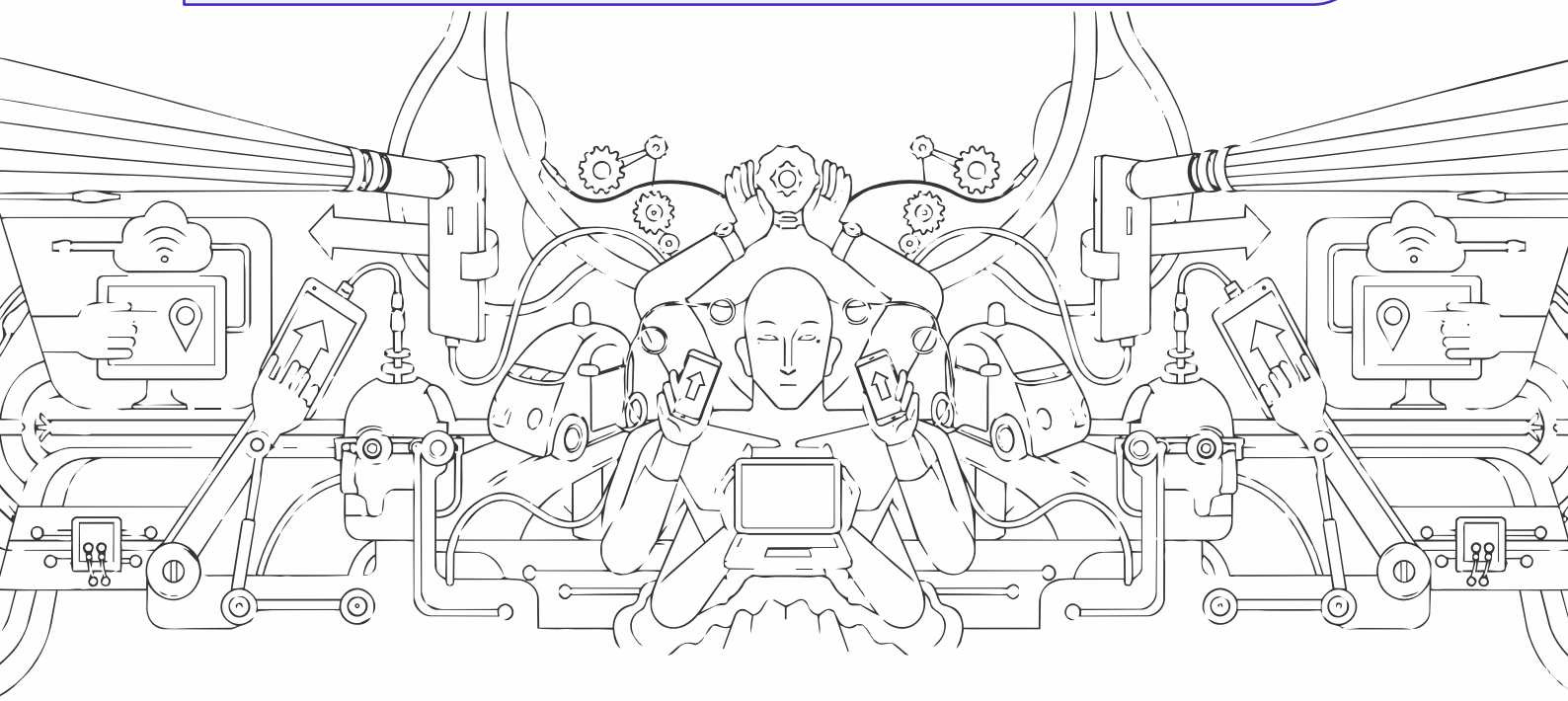


Prof. Alex James
Director, Indian Institute of Information Technology and Management; Professor, AI hardware and Controller of Examinations, Digital University Kerala

Enabling Research and Talent Pipeline and Infrastructure and Compute Development

The evolution of Maker Village in Kerala reflects a transformative journey in building India's hardware startup ecosystem. Grounded in Very Large Scale Integration (VLSI) and AI hardware expertise, the institution's concept grew out of early initiatives like local IoT labs, student-led efforts like Startup Village, and national frameworks like the Electronics System Design and Manufacturing (ESDM) policy. Formally launched around 2017 with support from IIITMK (now Digital University Kerala), MeitY, and the Kerala Startup Mission, Maker Village was created to fill a critical national void: providing dedicated incubation tailored specifically to physical product manufacturing rather than software.

Unlike software ventures that scale rapidly, hardware development demands an extended runway. Recognising that a standard 1.5-year software incubation period is insufficient for physical products, Maker Village established a structured three-tier, five-year incubation model. This framework guides startups from initial ideation and prototyping to product refinement and ultimate commercialisation. Over time, admission criteria evolved from simply nurturing early



ecosystem activity to evaluating deep intellectual property, genuine indigenisation, and strategic relevance across domain-agnostic electronics domains.

Prof. James recounts how Maker Village offers a sincere, technically grounded talent pool with a growing influx of PhDs and experienced researchers returning to translate intellectual property into commercial products. He remarked on how success stories like Xalten demonstrate the way local hardware startups can build complex capabilities such as desktop-level PCB assembly units and specialised instrumentation, thus, reducing dependency on foreign imports. However, hardware founders face distinct systemic hurdles. Technical teams often lack initial business and marketing expertise, early-stage seed funding (typically ₹10–20 lakhs) remains low by global standards, and capital-intensive infrastructure requires substantial long-term investment.

To combat high turnover among technical staff managing expensive lab infrastructure, Maker Village also partnered with private operators and startups through revenue-sharing Expressions of Interest (EOIs) to run facilities smoothly and sustainably. During the COVID-19 pandemic, the facility demonstrated its adaptability by maintaining open labs and guiding robotics and instrumentation startups to pivot toward producing vital medical hardware, PPE kits, and masks.

Prof James opines that financial sustainability for hardware incubators requires a multi-faceted revenue and equity strategy. While Maker Village initially operated on a zero-equity basis to encourage early participation, it later transitioned to taking a modest "patient equity" stake of 1% to 3% during IP-heavy product development phases. Operational revenue is further sustained through commercial lab utilisation, specialised training programs, state utility subsidies, multi-agency partnerships (including MeitY, MSME, the Indian Navy, and Cochin Shipyard), and high returns from revolving grants and early equity investments.

He believes that measuring an incubator's viability solely through rental income or rapid self-sustainability is unfeasible, particularly in tier-2 regions where workspace charges must remain low to protect early-stage founders. Instead, the public value of an incubator lies in macro-economic impact such as in job creation, regional economic development, and domestic technology building. The Maker Village model offers a clear blueprint to foster deep-tech ecosystems. Successful replication requires strong alignment between state and central governments, proactive financial planning to navigate funding delays, and a dedicated state nodal agency like the Kerala Startup Mission. This allows the incubator to focus entirely on its core mandate: enabling technical innovation, supporting hardware founders, and driving national self-reliance.



Photo: Maker Village

EyeROV™



Mr Johns T. Mathai
Co-founder and CEO



Autonomous Underwater ROVs

EyeROV is a marine robotics startup that builds advanced underwater drones and AI-powered inspection platforms. It provides autonomous solutions to safely inspect critical infrastructure such as dams, bridges, and ships while reducing human risk. The company serves defence and commercial clients globally. Backed by institutional funding from prominent investors, they continue to expand their technological front globally across West Asia and Europe, cementing their role as a key leader in the international marine robotics domain.

Operations in
Kochi, Kerala; International operations in the Gulf Cooperation Council (GCC), Europe, South and East Asia

Incubator
Maker Village

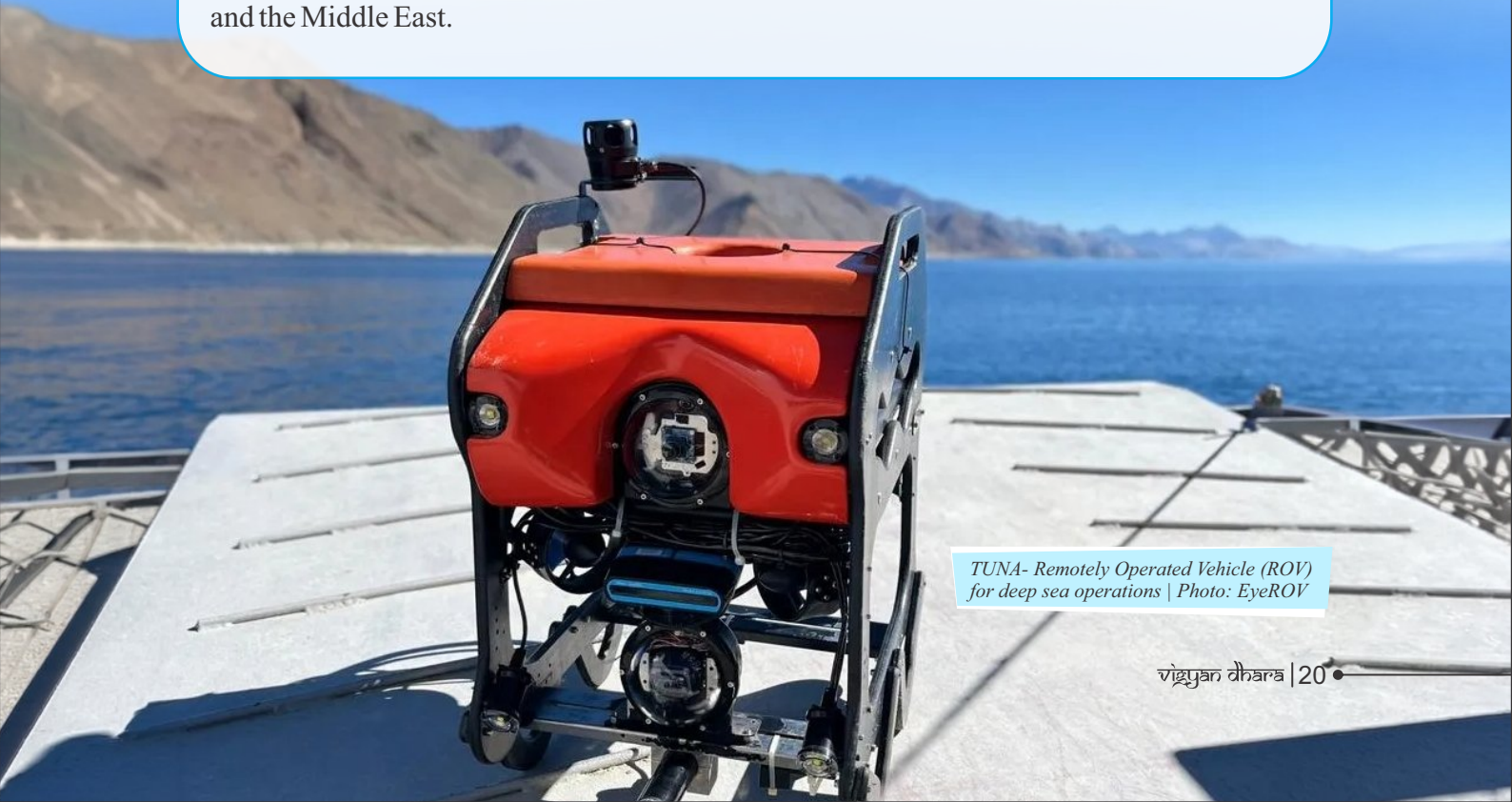
Milestones Achieved
150+ completed projects; 800+ field days; 2,500+ ROV inspection hours; and 12+ products delivered

Patents
5 granted patents

Enabling Community Building and Societal Application

Founded in 2017 to address India's critical need for indigenous underwater robotics, EyeROV has scaled from a small startup into a nearly 100-member defence technology enterprise. Leveraging early support from incubation hubs like Maker Village, state grants from KSUM, central programs like DST's NIDI PRAYAS and iDEX, and equity from Gas Authority of India Limited (GAIL), the firm developed its flagship platforms: the "Tuna" ROV for shallow structural inspections and the heavy-duty "Trout" ROV for offshore energy operations and naval missions. To fulfil broader Underwater Domain Awareness (UDA) needs across India's 7,500 km coastline, the company expanded into survey-grade Unmanned Surface Vehicles (USVs) for bathymetric mapping, high-speed 25–30 knot kamikaze surface craft, and Autonomous Underwater Vehicles (AUVs). Looking forward, the company is targeting mine countermeasures, Extra-Large AUVs (XLAUVs) for long-duration oceanic missions, and international defence markets across Southeast Asia, Europe, and the Middle East.

Despite strong tailwinds from asymmetric warfare trends and rising global interest in deep tech, scaling hardware operations presents distinct structural challenges. Hardware ventures require patient capital due to seven-to-ten-year maturation cycles, yet private venture capital remains cautious without consistent contract visibility. Furthermore, executing massive procurement orders introduces severe cash-flow constraints because government entities typically pay post-delivery while requiring high bank guarantee margins for advances. To resolve these bottlenecks, the company advocates for expanding credit guarantee limits (such as Credit Guarantee Fund Trust for Micro and Small Enterprises (CGTMSE) and Credit Guarantee Scheme for Startups (CGSS)), establishing dedicated testing clusters, implementing milestone-based payments, and incentivising local manufacturing for critical supply chain components like specialised motors and sonar sensors to ensure full national self-reliance.

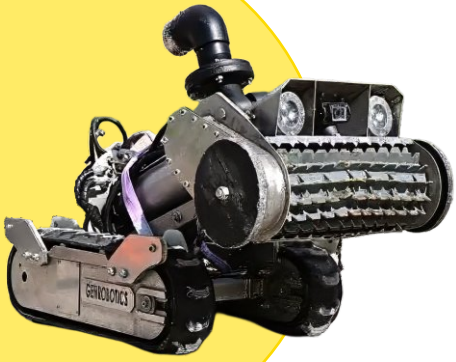


TUNA- Remotely Operated Vehicle (ROV) for deep sea operations | Photo: EyeROV

GENROBOTICS



Mr Vimal Govind K.K.
Co-founder and CEO



Willboar, advanced heavy-duty robot rover

Genrobotics is an Indian deep-tech robotics startup, pioneering Physical AI solutions that combine robotics, artificial intelligence, computer vision, and autonomous sensing technologies to solve critical infrastructure and human safety challenges. The company develops intelligent robotic systems that improves safety, efficiency, and operational outcomes across sanitation, healthcare, industrial, and emerging defence sectors. Their technology has become a benchmark for mechanised sanitation and is deployed by municipalities, government agencies, and urban local bodies across India.

Operations in
Thiruvananthapuram (Trivandrum), Kerala; 300 robotic systems across 19 states and 3 Union Territories in India; International operations in the UAE and South Africa

Incubator
Kerala Startup Mission

Characteristics
Robotic scavengers to clean manholes and sewer networks without needing human assistance

Patents
27 patent applications and 9 granted patents

Enabling Community Building and Societal Application

Co-founded by Vimal Govind and his college batchmates, Genrobotics originated from early research on exoskeleton suits inspired by military heavy-lifting applications. However, a tragic local manhole accident prompted a critical pivot toward ending manual scavenging. This led to the development of Bandicoot, a semi-autonomous robot designed to eliminate human entry into hazardous, gas-filled manholes. Over time, the company expanded its suite to address the full sanitation cycle for automated waste processing, sewage pumping station maintenance, and clearing choked canals. These technologies combine computer vision, AI, pneumatic-hydraulic actuation, and specialised material engineering to operate in corrosive, confined spaces, handling high payloads exceeding 100 kg.

Rather than replacing workers, Genrobotics trains existing sanitation personnel to operate the systems, elevating their roles while mitigating health risks and social stigma. Leveraging its core capabilities, the company has diversified into tank desludging for major oil refineries, neuro-rehabilitation medical robotics (Gaiter and G-KAI), and high-tech defence and space projects like satellite repair arms and bipedal extra-planetary platforms. Supported by the Kerala Startup Mission, central government schemes like Credit Guarantee Fund Trust for Micro and Small Enterprises (CGTMSE), and strategic board mentors, Genrobotics maintains high domestic manufacturing localisation (90–95%). The company has maintained a positive P&L over several years, closing its recent financial year with strong revenue growth and healthy EBITDA margins. Driven by robust purchase orders and expanding facilities in Palakkad and Trivandrum, Genrobotics is planning a Series B funding round to scale production and expand across the Middle East, Africa, and Southeast Asia, with substantial revenue targets set for the coming years. Ultimately, Mr Govind advocates that national physical AI strategies should focus on domain-specific niches, localised precision component manufacturing, and strict quality standards.



Photo: Genrobotics



Mr Charles Vijay Varghese
CEO, CTO, and Founder



SAPER, automated coconut sap tapping robot

Nava Design & Innovation is an award-winning agritech startup based in Kochi, Kerala. The company is widely recognised for creating SAPER, the world's first automated coconut sap (Neera) tapping robot, designed to make harvesting safer, cleaner, and more profitable for farmers. The company focuses on automating highly labor-intensive and hazardous traditional agricultural tasks through precision robotics, artificial intelligence, and sustainable green engineering. It bridges the gap between heritage farming practices and modern AI-driven solutions.

Operations in
Kochi, Kerala

Incubator
Maker Village, Kerala Startup Mission

Characteristics
Smart agri-engineering systems, agricultural automation, and robotics; reinventing a centuries-old practice with mechanised sap tapping, cleaner collection, and safer farm operations

Patents and Awards
Patents granted across 12 countries; National Award for Invention from the Coconut Development Board; National Startup Award in the agricultural productivity domain (2020)

Enabling Community Building and Societal Application

Mr Varghese set out to transform his personal ties to coconut farming into a globally scalable deep-tech venture. Founded in 2016, he assisted in building a robotic, IoT-enabled system that automates coconut sap tapping, thus, addressing a dangerous, labor-intensive process that had long constrained the industry's growth. Traditional tapping requires workers to climb tall coconut trees daily to cut the flower tip multiple times and collect neera, the sap that emerges before the flower matures into a coconut. This work is risky, physically demanding, and increasingly unattractive to younger generations, leading to a shortage of skilled tappers and inconsistent sap quality. Despite its potential as a nutritious, diabetic-friendly natural drink and various other benefits, India's neera market remains small. The global market is estimated to be at 7–8 billion dollars with a strong growth (8–11%), compared to India's few million dollars market, highlighting untapped opportunity.

The World's First Coconut Sap Tapping Robot, SAPER is a rugged, weather-resistant robotic device that attaches to a coconut flower only once and stays there for the full 45-day tapping cycle, automatically performing cutting, holding, sharpening, cleaning, and sap collection, and then delivering the sap to a ground-level container. An IoT dashboard alerts users when a flower is exhausted, eliminating the need for daily climbing. The machine uses food-grade, UV-protected materials, waterproof electronics, and durable geared DC motors with lithium batteries. It incorporates linear actuators, sensors, encoders, LoRa communication, and a sanitation system to ensure sap purity.

After piloting roughly 30 devices in Indonesia, Thailand, and India, Nava Design is moving toward commercial manufacturing by October 2026. Mr Varghese envisions a global expansion across coconut-growing nations and calls for a national robotics mission to fund high upfront R&D, grant customs exemptions for imported prototype parts, and provide large FabLab incubation facilities while building domestic capacity for motors, batteries, and rare earth magnets, enabling faster, cheaper hardware innovation.

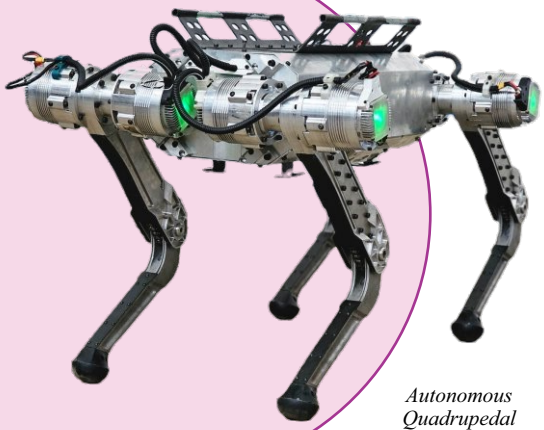


Photo: NAVA Design and Innovation

STRIDER ROBOTICS



Dr Shishir Kolathaya
Assistant Professor, IISc and
Co-founder and Technical Advisor,



Autonomous Quadrupedal Robot

Strider Robotics is an Indian deep-tech startup, specialising in the development of advanced, indigenous, industrial-grade legged (quadrupedal) robots. Originating from the StochLab at the Indian Institute of Science (IISc), the company aims to eliminate human exposure to "dirty, dull, and dangerous" tasks by providing agile, resilient robotic automation for highly complex environments. By focusing on integration of hardware, software, and multi-modal sensing, Strider Robotics is leading India's expansion into cross-industry, real-world robotic inspection.

Operations in
Bengaluru, Karnataka

Incubator
ARTPARK

Characteristics
Robotic dogs capable of navigating challenging terrains in industrial environments

Applications
Autonomous safety inspections, asset & infrastructure monitoring, material handling, and point-to-point transportation

Enabling Infrastructure Development and Research and Talent Pipeline

Founded in 2023 by Dr Shishir Kolathaya and Mr Aditya Varma Sagi, the journey of Strider Robotics shows how physical AI depends on building the right hardware base, not just software. The company has built several robot variants for outdoor inspection, logistics, surveillance, patrolling, and other tasks in harsh terrain where wheeled platforms struggle. Focused on indigenisation of technology, Dr Kolathaya demonstrated how the team achieved this by developing actuators, torso electronics, battery packs, and other components in-house or partly in-house. This has been important for building a stronger domestic hardware ecosystem. He also highlighted the patented leg design, which further strengthens India's domestic robotics infrastructure. The robot's onboard computer, sensor suite, and reinforcement-learning-based control system reflects the need for an integrated compute and control systems that can support demanding real-world deployment.

Dr Kolathaya argued that physical AI may not yet be widely useful for labor replacement but it remains worth developing because of future applications, especially in hazardous or difficult environments, and will require years of groundwork. India should build for the world just as other countries are developing robotics stacks for global markets. He recommended building the data pyramid through teleoperation, egocentric, and related forms of robotic data, while also protecting privacy and creating special zones or incentives for actuator, battery, and other hardware companies to cluster and collaborate. He also remarked that faculty entrepreneurship in India has historically been limited by culture, resources, and weaker funding, since academic institutions traditionally rewarded theoretical research more than startup creation. However, he noted that the environment is changing, especially in Bangalore and through government-backed initiatives such as ARTPARK, which makes it easier for professors to start companies.

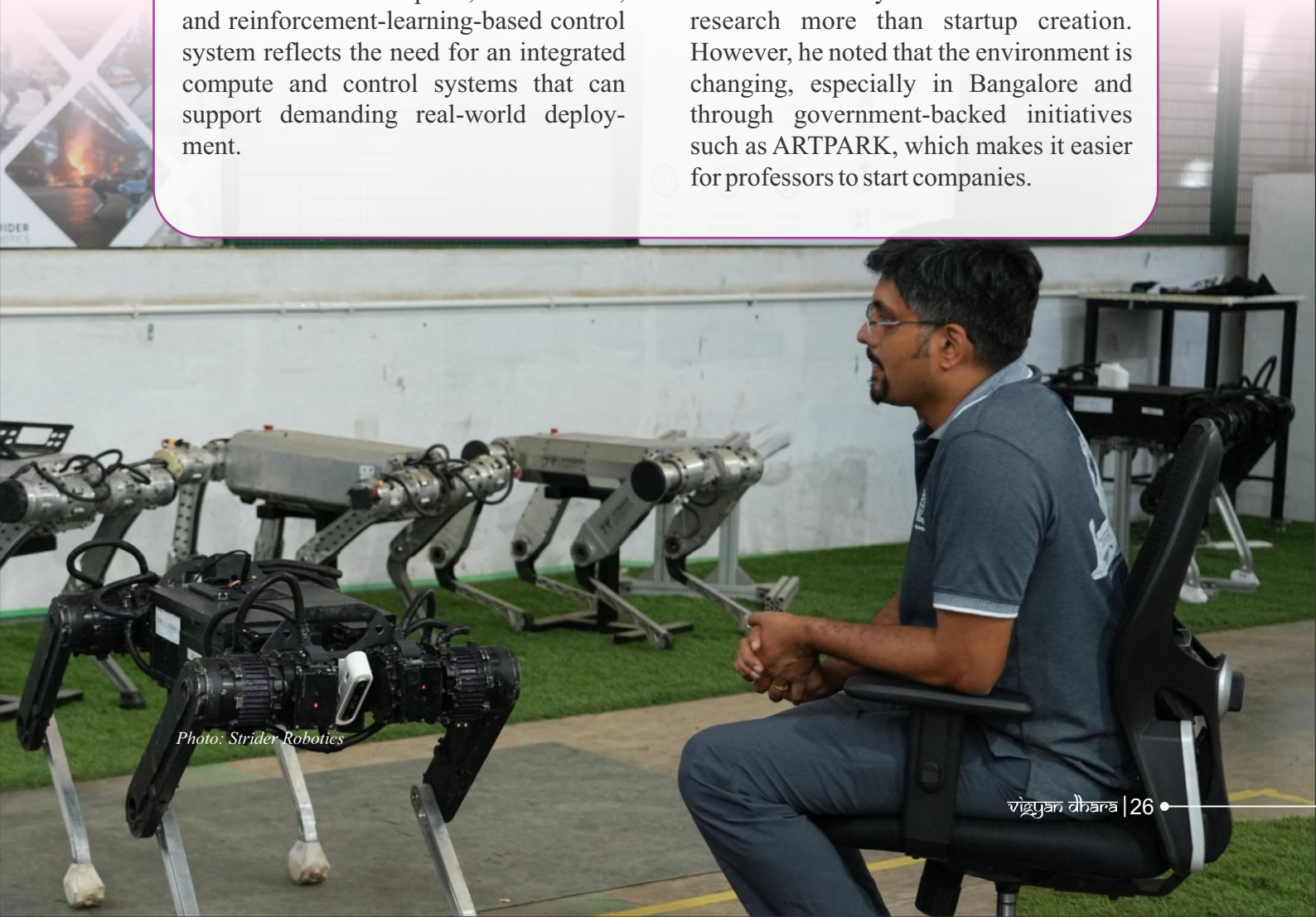


Photo: Strider Robotics

Xalten



Mr Anish S
CEO and Director



Desktop SMT pick and place machine

Xalten Systems Pvt Ltd is an Indian company that works to enhance the compute ecosystem of deep tech. It addresses the challenges of early-stage electronics prototyping and small-batch assembly by offering indigenously developed Surface Mount Technology (SMT) solutions. They help businesses innovate, scale, and overcome the most complex engineering challenges, thereby, meeting the demands of the B2B landscape. They also help in building products in-house, reduce outsourcing costs, and streamline production workflows from prototyping to small-batch production.

Operations in
Kochi, Kerala

Incubator
Kerala Startup Mission

Characteristics
Desktop-sized SMT Pick and Place robots, Reflow Ovens, and Solder Paste Dispensing solutions, Maritime hardware and solutions

Industrial Application
Services across wide range of industries: Electronics & Semiconductor Manufacturing, Medical Devices, Automotive, Aerospace & Defence, Telecommunications, Consumer Electronics, Research & Development Firms

Enabling Infrastructure and Compute Development and Research and Talent Pipeline

Founded on the principles of precision, quality, and innovation, Xalten Systems, was incorporated in 2023. It operates across three core verticals of SMT prototyping and precision robotics, underwater electronics, and maritime digital twin solutions and high-end consultancy services in simulation. Their flagship desktop pick-and-place suite, XP300, offers an affordable, end-to-end electronic prototyping system. Xalten has successfully deployed over 18 units to prominent educational, research, and corporate clients, including IIITs, ISRO's Space Applications Centre (SAC) centre, Data Patterns, Zoho, and UNO Minda.

Their primary strategic focus and R&D investment is towards the high-barrier underwater domain. By actively developing dual-use sensors such as echosounders, Doppler velocity logs (DVLs), and search-and-rescue pingers currently at TRL 5–6, the company aims to compete globally with incumbents like Teledyne, Kongsberg, Ultra Electronics, and Raytheon while reducing national reliance on imported maritime hardware. The company has achieved over 80% product indigenisation by designing and manufacturing critical acoustic transducers in-house, importing only non-domestic semiconductor components like Digital Signal Processor (DSP) chips, microprocessors, and memory chips. Rather than maintaining a dedicated manufacturing facility, they also leverage Makers Village's shared infrastructure for prototyping and small-batch assembly.

Looking ahead, Mr Anish aims to establish Xalten among the top global players in underwater sensing. Discussing India's deep-tech landscape, he notes growing interest in robotics and physical AI driven by global defence conflicts and increasing investor engagement. For a potential national mission on robotics, he emphasises the need for physical actuators, high-precision controllers, and sovereign physical AI. He also advocates for the government to act as an enabler supporting private entities, rather than building these technologies directly.



Photo: Xalten Systems

ZOHO



Mr Jayakrishnan T
Ex-founder and CEO, ASIMOV Robotics;
Founder and CTO, Zoho Robotics



Sevabot

Zoho Robotics (operating as Asimov Robotics) is an advanced deep tech division dedicated to AI, humanoid development, and physical automation. Aligned with Zoho Corporation's core model, they operate outside tier-1 metros to cultivate local talent, foster IP creation, and build sovereign deep tech from rural hubs. The focus is on creating automated systems to substitute human labor in hazardous, high-risk industrial environments, effectively bridging the gap between digital software logic and real-world machinery.

Operations in
Kottarakkara, Kerala

Incubator
Kerala Startup Mission

Collaboration
Zoho Corporation serves as the primary industry partner

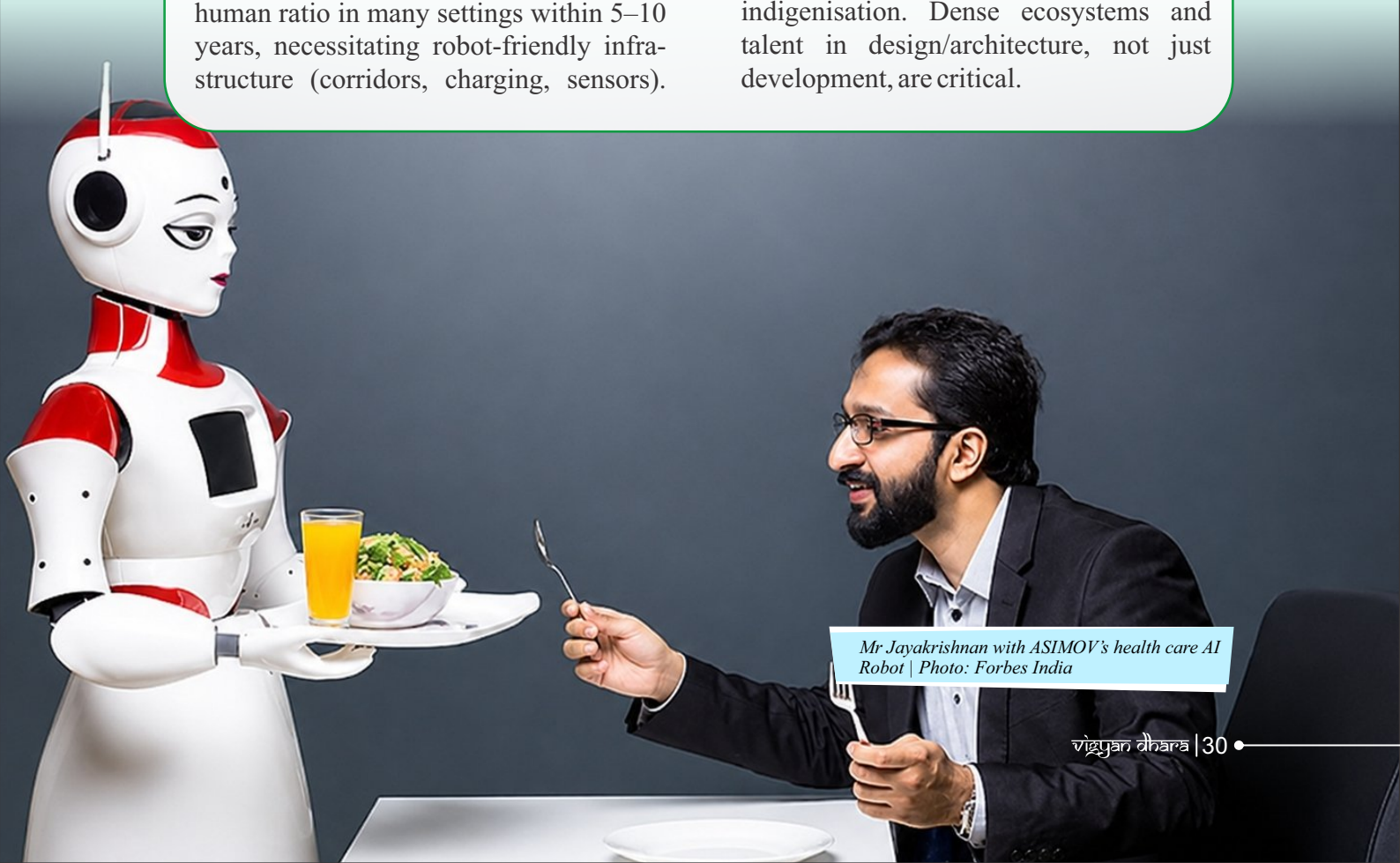
Characteristics
Medical and deep-tech solutions, advanced navigation and vision, workforce transformation

Enabling Research and Talent Pipeline

Mr Jayakrishnan T's robotics journey began in 1992, leading to the 2005 founding of a company under US firm Energit, which evolved into ASIMOV Robotics in 2012. From shipping over 250 robot arms globally to working in high-stakes projects such as Fukushima reactor control, battlefield casualty evacuation, and CBRN handling, it finally launched ISRA, India's first wheeled humanoid torso. ASIMOV also delivered India's first banking lobby robot (HDFC, 2016), BIRAC-funded craniotomy systems (2014–15), laparoscopic neurosurgery robots (Krishna Hospital, 2019–20), pandemic isolation-ward delivery/disinfection bots, intra-hospital logistics robots (Narayana Hospital), and face-actuation system (ISRO's Gaganyaan mission). Zoho acquired ASIMOV in 2025, relocating operations to a 25,000+ sq. ft. Kottarakkara campus as Zoho Robotics.

With embodied AI maturing, Mr Jayakrishnan expects a 2:10 robot-to-human ratio in many settings within 5–10 years, necessitating robot-friendly infrastructure (corridors, charging, sensors). He emphasises that Industry 5.0 focuses on human-centric collaboration e.g., stabilising aging surgeons' hands rather than replacement. The priority is upskilling, reskilling, and shifting mindsets from fear to partnership. He cautions against restricting robotics in favor of short-term job protection. Halting innovation harms the economy more than it helps. He believes that India must invest in infrastructure to retain capital and create better jobs, aiming to dominate, not just survive.

At Zoho Robotics, plans are ambitious but grounded. It involves targeting functional robots and gaps where India lags and using robotics to elevate manufacturing to China's level via government-backed infrastructure. Rather than rushing products, the focus is on foundational capabilities for indigenous systems. A two-stream policy is needed: low-tariff access for R&D value addition, and manufacturing incentives for design-led indigenisation. Dense ecosystems and talent in design/architecture, not just development, are critical.



Mr Jayakrishnan with ASIMOV's health care AI Robot | Photo: Forbes India

Transformation of the Physical Space Around Us

3

Sectoral Adoption and Adaptation



Curated and Compiled
Dr Sabita Yadav
Communications Specialist, OPSA

Photo: AI generated

Transitioning from a world devoid of internet to a world that has shattered barriers of intelligence once confined to only our desktop screens and has embedded itself into our physical space has been one of the most transformative shifts in human history. What initially began as intelligence integrated into computer systems has now slowly stepped out into the real world. The fascination of seeing humanoids in fictional narratives on screen has taken a leap as robots slowly permeate on our feeds with videos and news headlines, such as "Humanoid Robots 'Surgie' Perform First-Ever Live Animal Surgeries," unfolding in front of us.

Robots assisting in surgery, automation warehouse jobs, and intelligent drone systems are depictions of how robotics and artificial intelligence is changing the landscape. Humanoid robots are steadily being deployed to perform complex, dirty, and dangerous tasks that previously required human workers such as high-altitude and sub-marine inspections, handling radioactive materials, and grounding wire installation. These offer a glimpse into the way science fiction of the past is merging into the realities of the present world and shaping the future.

Where Generative and Agentic AI focuses on digital artifacts and digital actions, Physical AI focuses on the physical aspect. It specialises in environmental interaction and motion control tasks: moving objects, navigating environments, manipulating tools, and interacting with humans. They integrate advanced models, edge computing, and automation technologies that leads to intelligent systems capable of autonomous decision-making and execution. Robots have moved well beyond simple actions of traditional single-purpose machines on factory floors. Convergence of artificial intelligence, Internet of Things (IoT), edge computing, automaton platforms, has rendered robots as "intelligent" – operating in dynamic environments, adapting to variations, and supporting work that is difficult or inherently hazardous.

A Collaborative Environment at the Interface

The shift towards the adoption of physical AI is being driven by an increasing demand for automation, workforce shortages, resilient and efficient ways of addressing dangerous tasks, and growing importance of autonomous decision-making. There is an increased investment in systems capable of operating independently while maintaining safety, security, efficiency, and reliability.

Irrespective of this demand, it has generated resistance stemmed from fear of losing jobs and concerns around safety and privacy. Rather than replacing workers entirely, Physical AI deployments should be designed to support collaborative environments where humans and machines work together. The real opportunity lies in identifying the sectors that need deployment, their effective applications to deliver measurable impact, and ensuring preventing displacement of humans from their jobs. This will eventually lead to broader acceptance of such automation technologies. AI-powered robotics adoption is expanding across different sectors; as mentioned.

Industry/ Sector

Agriculture
- Agricultural drones
- Autonomous tractors
- Crop monitoring robots
- Smart irrigation

Defence
- Autonomous unmanned systems
- Target recognition drones
- Smart edge computing platforms
- Intrusion detection

Healthcare
- Robots assisted surgery
- Rehabilitation exoskeletons
- Patient monitoring smart devices

Logistics & Warehousing
- Automated warehouses
- Robot couriers
- Supply chain automation
- Quality inspection

Manufacturing / Industry 4.0
- Assembly line robots
- Predictive maintenance
- Quality inspection
- Labour intensive tasks

Smart City Applications
- Traffic management system
- Waste management and sorting
- Smart power and water grids
- Sanitation reforms

Transportation & Autonomous Systems
- Smart public transport
- Delivery drones
- Adaptive traffic management

Benefits

Optimised crop management, labor shortages, increased productivity, improved disease surveillance

Minimising causalities, enhancing border surveillance, precise target engagements, intrusion detection

Higher precision, enhanced safety, personalised care, scalable diagnostics and screening, reduced surgeon fatigue

Faster order fulfilment, improved accuracy, scalable and sustainable operations

Increased precision and efficiency, reduced downtime, enhancing worker safety

Efficient urban mobility, crowd management, resource optimisation, preventing human causalities

Maximises road safety, real-time route optimisation, improves fleet utilisation, reduces congestion, environmental sustainability

Intelligence that is Transforming Sectors Steadily

Physical AI is already operating and transforming sectors in India. The following sections provide an insight into the artificial intelligence system integrated across agriculture, defence, healthcare, and public sanitation. The agriculture section depict how technology is driving a shift in the agricultural ecosystem and playing an important role in advancing the livestock sector for a resilient system that minimises wastage of resources, prevents diseases in crops, and transforms cultivation. The section on defence and strategic systems provides a glimpse into the evolution in warfare due to integration of embodied systems which helps in executing missions with increased speed, precision, and resilience. Sections on healthcare and public sanitation demonstrate the use of AI in transforming the lives of the people through automation that assists either in post-recovery surgery or take up dangerous tasks such as cleaning sewers. It delves into what happens inside an operating room and why is it necessary to have sovereign AI in healthcare. As India continues to experience an increasing demand for AI-driven industrial solutions, supported by digital transformation initiatives and manufacturing expansion, the nation is anchoring this technological leap in its vision of Viksit Bharat 2047.

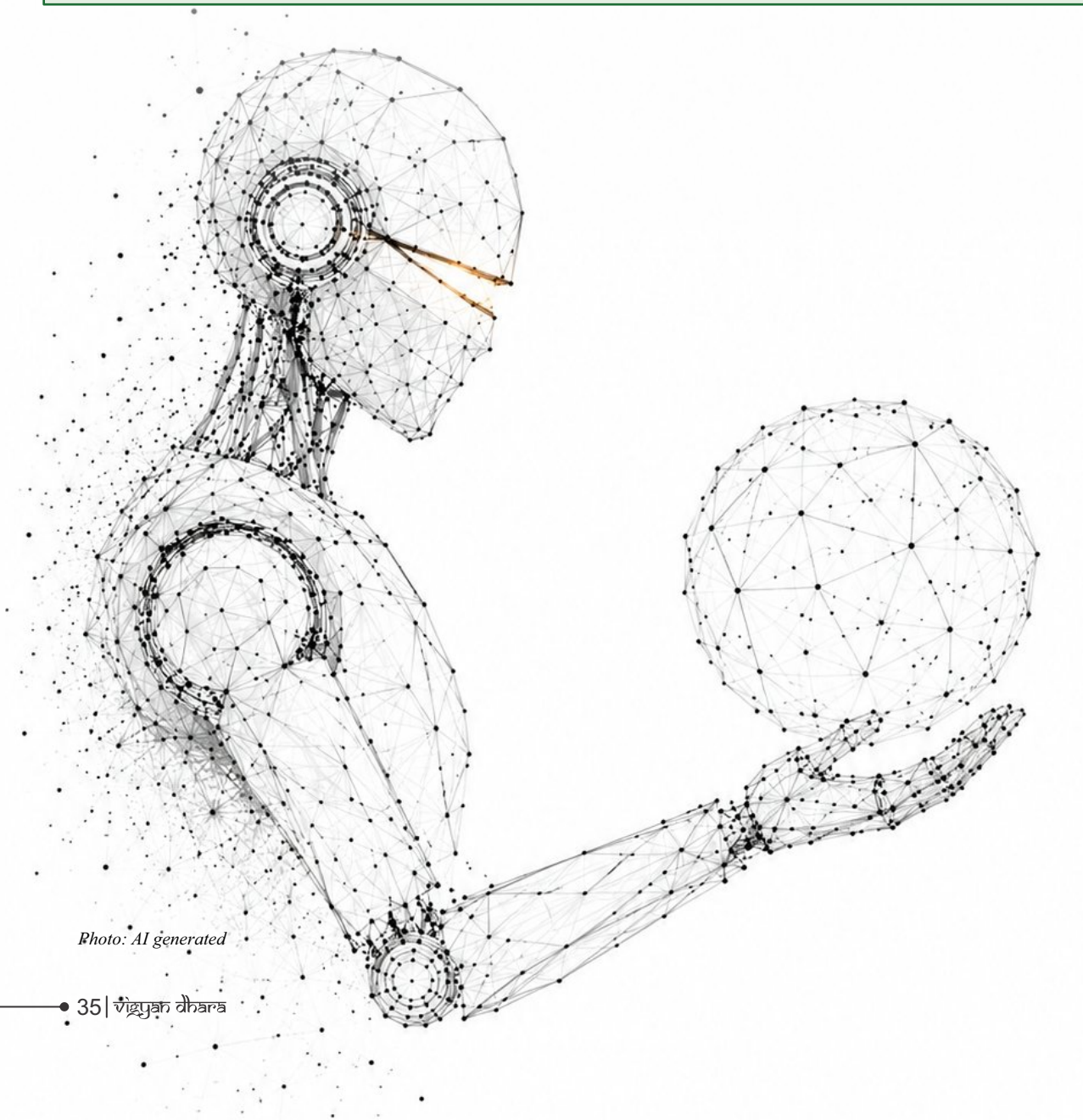


Photo: AI generated

Transforming Robotic Platforms and Autonomous Warfare



Mr Imran Ahmed Syed
Scientist E,
CAIR, DRDO



Mr VC Ravi
Scientist G,
CAIR, DRDO



Dr Arshad Jamal
Scientist G,
CAIR, DRDO



Dr Rituraj Kumar
OS & Director,
CAIR, DRDO

The emergence of AI has significantly transformed military capabilities across the globe, fundamentally shifting the paradigm from digital information dominance to physical autonomy. In the defence and strategic domain, this integration of AI with physical systems has the potential to revolutionise battlefield operations by accelerating the Observe, Orient, Decide and Act (OODA) loop, enabling coordinated swarm tactics, and significantly reducing risk to human personnel in high-threat environments. Specifically, Physical AI enhances force multiplication, logistics resilience, persistent surveillance, and combats effectiveness by allowing systems to operate autonomously in Global Navigation satellite system (GNSS)-denied, communications-degraded, and highly contested environments. Driven by the convergence of advanced sensors, edge computing, deep reinforcement learning, and adaptive control systems, embodied AI is creating a new generation of intelligent military platforms capable of navigating unstructured terrain and adapting to dynamic threats in real-time. Ultimately, Physical AI represents a fundamental evolution in warfare, transitioning from remote-controlled assets to truly autonomous agents that can execute complex missions with a level of speed, precision, and resilience that surpasses human physiological limits.

Illustration of unmanned aerial, ground, sea surface and underwater robots in collaboration with human operator

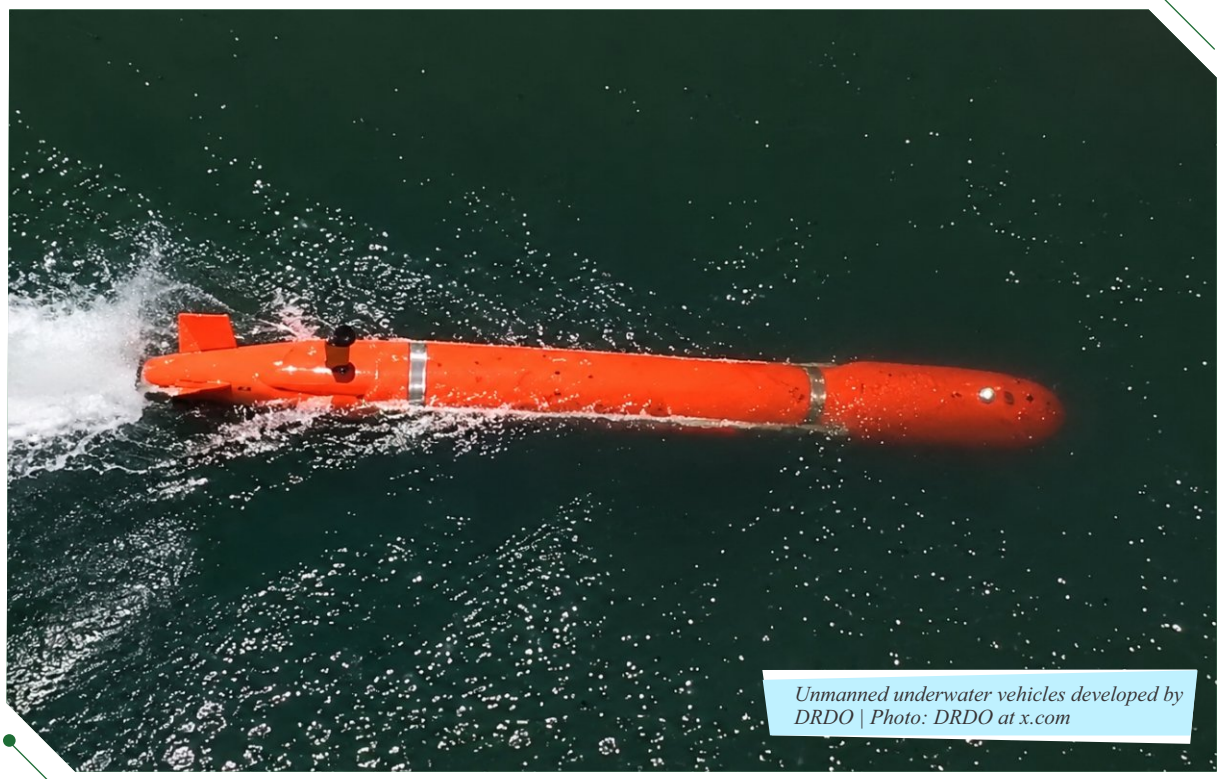
Physical AI in Robotic Platforms

Applications of Physical AI in the defence sector encompasses a diverse array of multi-domain assets, including Unmanned Ground Vehicles (UGVs) for logistical support and urban breaching; Unmanned Aerial Vehicles (UAVs) for persistent Intelligence, Surveillance, Reconnaisance (ISR) missions and precision strike; Unmanned Surface Vehicles (USVs) for maritime interdiction; and Unmanned Underwater Vehicles (UUVs) for sub-surface surveillance. Physical AI transforms these platforms from simple remotely operated robots into intelligent agents capable of autonomous navigation through complex, unstructured terrains, dynamic target detection, and real-time mission execution with minimal human oversight. By leveraging edge computing to fuse heterogeneous data streams from electro-optical cameras, infrared sensors, radar, LiDAR, acoustic arrays, and electronic intelligence systems, AI-powered robots generate a resilient, multi-dimensional situational awareness picture that remains robust even in GNSS-denied or communications-degraded environments. This advanced sensor fusion enables the system to correlate disparate data points to accurately classify targets, identify, and assess threats with a precision that mitigates collateral risk.

Consequently, these intelligent platforms can operate continuously in high-threat environments without exposing soldiers to danger. During combat operations, they can identify enemy movements, detect concealed threats, and relay real-time intelligence to command centers with speed, adaptability, and persistence that fundamentally alters the tempo of warfare. Such systems are particularly valuable in high-risk environments such as urban warfare, border security operations, minefields, and Chemical, Biological, Radiological, and Nuclear (CBRN) zones.



Heterogenous robots developed by CAIR, DRDO | Photo: CAIR autonomous Robots



Unmanned underwater vehicles developed by DRDO | Photo: DRDO at x.com

Robotic Arms in Military Applications

Traditionally used for bomb disposal and hazardous material handling, next-generation robotic manipulators are becoming increasingly intelligent and adaptable. AI-enabled robotic arms can perform delicate and complex tasks such as:

- Explosive Ordnance Disposal (EOD)
- Ammunition handling and loading
- Maintenance and repair operations
- Logistics and warehouse automation
- Handling chemical and biological materials

By integrating force sensors, tactile sensors, machine vision, and learning algorithms, robotic arms can dynamically adjust their movements based on environmental conditions. This allows precise manipulation even in uncertain and unstructured environments. They can also automate routine maintenance tasks and reduce manpower requirements while improving operational efficiency and safety.

Autonomous Combat Vehicles

Advanced sensor suites integrated with AI algorithms enable autonomous tanks to identify enemy vehicles and process battle-field data much faster to classify threats, estimate engagement probabilities, enhance survivability, and recommend optimal courses of action. Autonomous combat vehicles can also operate in manned-unmanned teaming configurations, where a crewed tank commands multiple unmanned vehicles acting as scouts, decoys, or forward attack elements. Such force multiplication reduces risk to personnel while expanding operational reach. Physical AI further enables predictive maintenance by continuously monitoring vehicle health parameters to identify potential component failures before breakdowns occur.

CAIR has developed an autonomous navigation stack which can navigate in unstructured, off-road environments. Utilising sensor fusion from optical, LiDAR, and RADAR sensors, a complete operational picture of the environment is formed in real time and a dynamic path predicted for navigation in day/night and adverse weather conditions. The vehicle can follow a mission plan generated by commander using a Geographic Information System (GIS) by path planning to a given destination, avoiding obstacles, and optimising travel distance.

The generic architecture for autonomous navigation comprises three core components localisation to establish the vehicle's position, perception to identify environmental features and generate a comprehensive occupancy map, and navigation to utilise this map to plan trajectories to avoid obstacles and compute an optimal path. Finally, based on the generated path and the vehicle's current location, low-level execution commands are issued to the control systems. This process functions as a continuous feedback loop, iteratively updating commands until the target goal is achieved.

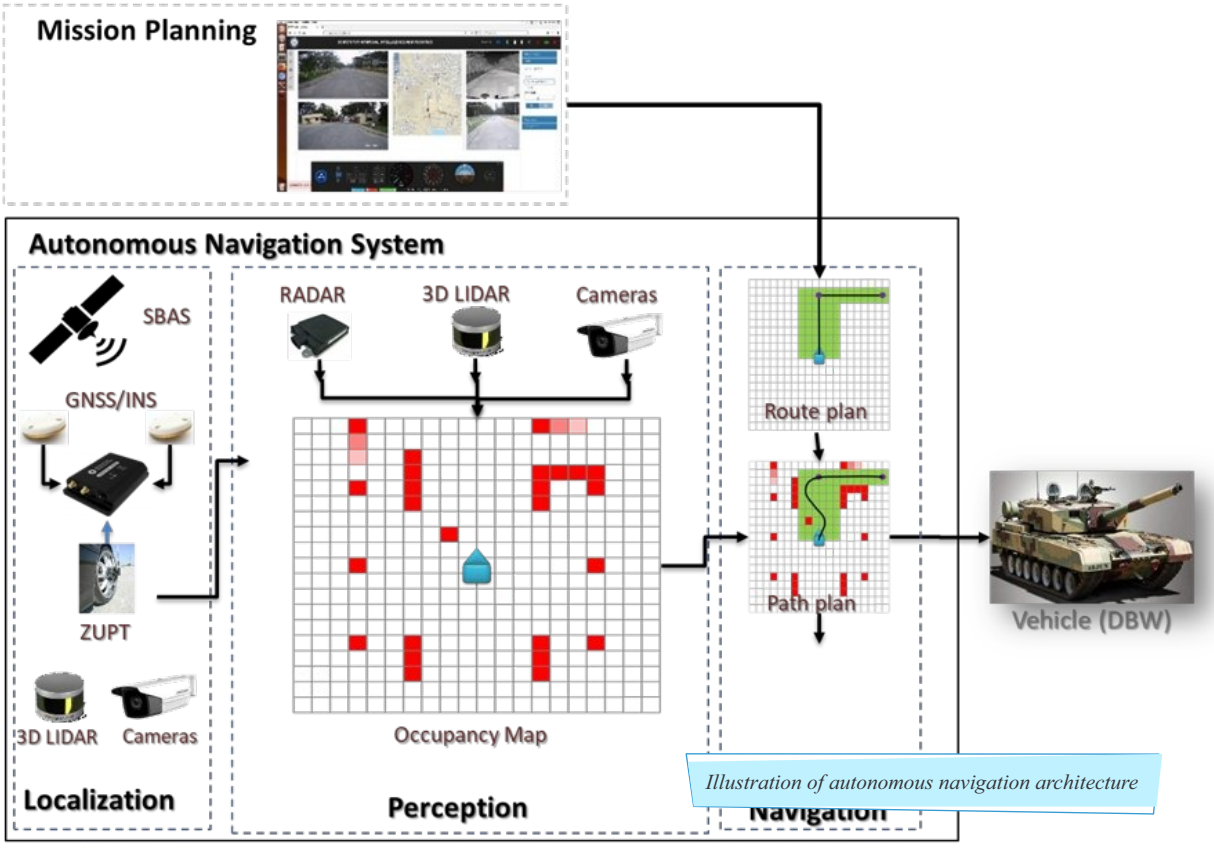


Illustration of autonomous navigation architecture

Physical AI for Autonomous Surveillance

AI-enabled surveillance networks integrate data from electro-optical cameras, thermal imagers, ground sensors, radar, acoustic sensors, LiDAR, and unmanned platforms to provide continuous monitoring of military bases, critical infrastructure, ammunition depots, border regions, and strategic installations. Advanced AI algorithms can automatically detect, classify, and track intrusions by distinguishing between humans, vehicles, animals, and drones, significantly reducing false alarms and operator workload. Autonomous ground robots, aerial drones, and stationary sensor towers equipped with Physical AI can patrol designated areas, identify suspicious activities, and generate real-time alerts for security personnel. This provides enhanced force protection in adverse weather conditions.

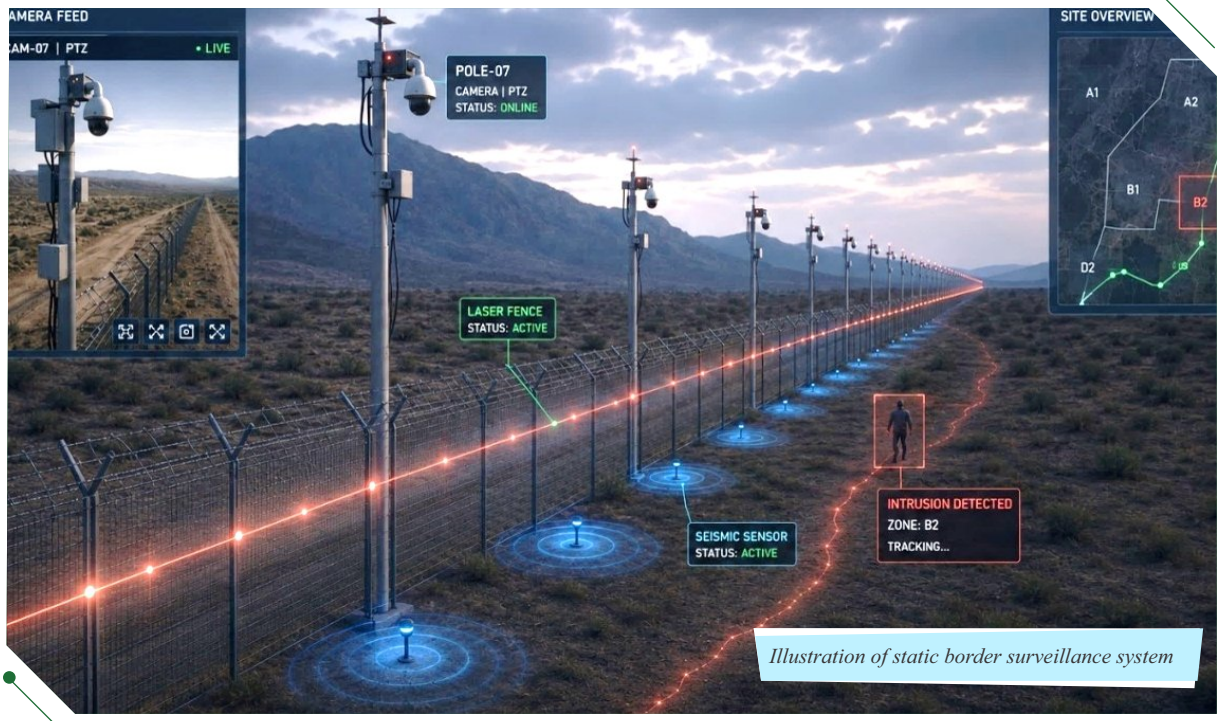


Illustration of static border surveillance system

CAIR along with other DRDO labs in collaboration with Indian industries, has developed a diverse portfolio of robotic platforms, robotic arms, and platforms for autonomous surveillance. The development includes miniaturised two-wheeled robots, dual-arm robots designed for close-proximity surveillance, and perform complex maneuvers such as holding the object steadily with one arm and using the other arm for operation. DRDO has also been spearheading the development of UUVs, with the High Endurance Autonomous Underwater Vehicle (HEAUV) successfully tested and meeting all mission parameters. With academia, solutions for prioritised border surveillance using a team of UAVs flying continuously on unpredictable patrol routes for efficient, active patrolling are also being explored.

Strategic Benefits of Adapting Physical AI

Force Multiplication

Smaller force can achieve greater operational effectiveness through autonomous systems

Reduced Human Risk

Dangerous missions can be conducted without exposing personnel to direct threats

Persistent Operations

Operate continuously with minimal fatigue

Enhanced Situational Awareness

Real-time sensor fusion improves battlefield visibility

Faster Decision Cycles

Reduction in time between observation, orientation, decision, and action

Operational Efficiency

Automation improves logistics, maintenance, and support functions

Scalability

Large numbers of autonomous platforms can be deployed and coordinated effectively



Encountering Challenges in the AI World

Technical Challenges

Development of indigenous foundation AI models; reliability in complex and unpredictable environments; achieving efficient man-machine teaming that's complicated by high computational requirements, strict power and energy constraints; imperativeness for real-time processing

Security Challenges

Cyberattacks, system hacking, adversarial AI techniques that can manipulate decision-making algorithms, sensor spoofing, electronic warfare

Ethical and Legal Challenges

Clear accountability for autonomous actions, strict adherence to international humanitarian law, transparency and explainability of AI systems to build trust among stakeholders

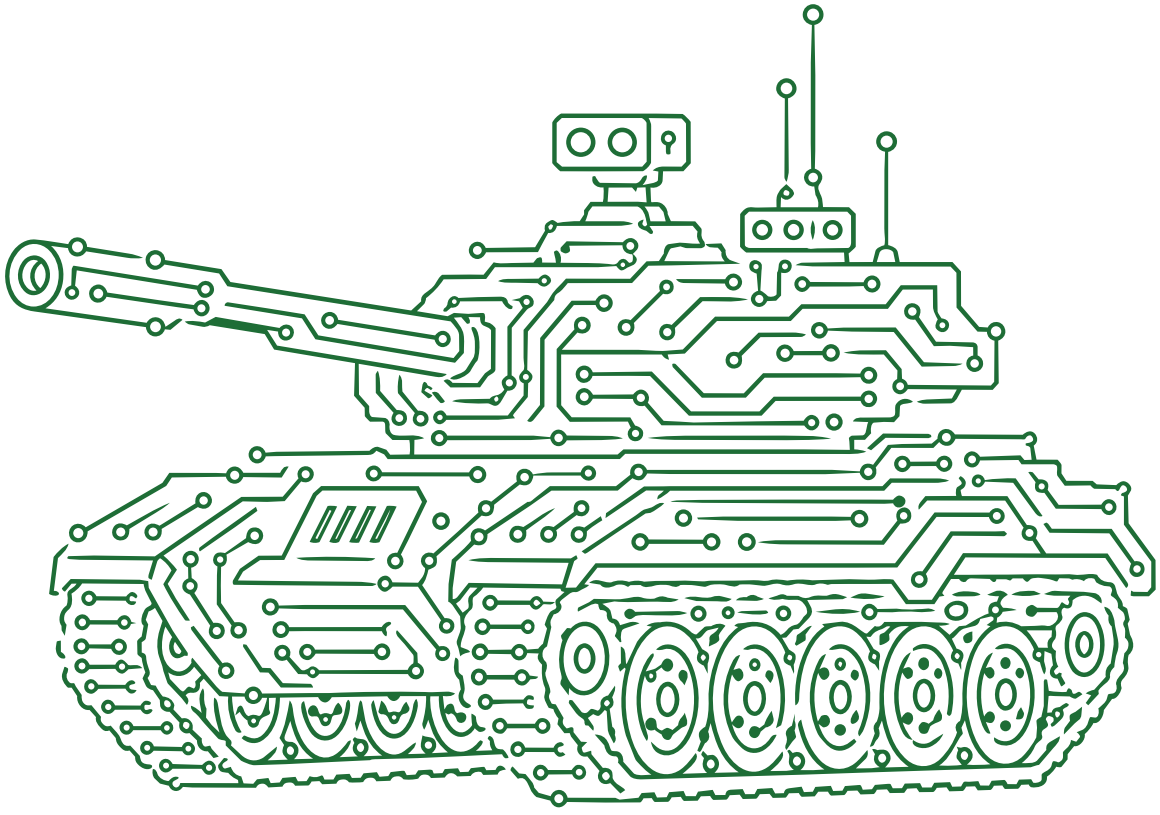
Operational Challenges

Difficulty of interfacing new autonomous capabilities with legacy military systems while fostering effective human-machine trust and collaboration; significant training requirements; costs associated with deployment and sustainment

Way Forward

Physical AI is poised to become a defining technology in future defence and strategic systems. Through intelligent robotic platforms, autonomous combat vehicles, advanced robotic manipulators, and humanoid robots, militaries can achieve unprecedented levels of operational effectiveness, situational awareness, and force protection. While significant technical, ethical, and security challenges remain, continued advances in AI and robotics will accelerate the transition toward increasingly autonomous defence ecosystems. The future battlefield is likely to be characterised by seamless collaboration between human operators and intelligent machines, where Physical AI serves as a critical enabler of military capability and strategic advantage.

To fully realise the potential of Physical AI, a balanced and phased approach is necessary. Prioritisation of human-machine teaming with human oversight rather than fully autonomous combat systems is key for initial push towards autonomous systems. Investments in robotics, sensors, edge computing, indigenous resilient and trustworthy AI stack, and secure anti-jamming communication technologies are essential. Robust testing and validation frameworks must be established to ensure reliability, safety, and operational effectiveness in real-world conditions. Cyber security and electronic warfare resilience should be embedded into system design from the outset. Finally, governments, defence establishments, academia, and industry must collaborate to develop ethical guidelines, standards, and governance mechanisms that promote responsible military use of Physical AI.



Physical AI Is Coming to the Operating Room



Dr Vinayak S Rengan
Consultant Paediatric Surgeon and
Founder, Curium Life

How Embodied Intelligence Is Transforming Surgery — And Why Nations Must Own It?

For the past few years, physical AI has mostly meant warehouse robots and self-driving factory lines. Amazon now runs over a million robots across its fulfilment network, coordinated by an AI model that plans their movement in real time. BMW uses a similar approach to let finished cars drive themselves from the assembly line to the test track without a person behind the wheel. In both the cases, intelligence that used to live only in software has learned to act in the physical space. They are sensing, deciding, and moving in a loop that once required a human hand. Surgery is now going through the same shift – albeit quietly and on a longer timescale than people expect. There is a reason for this slow shift.



An indigenous robotic-assisted surgical system at Kokilaben Dhirubhai Ambani Hospital, Navi Mumbai. | Photo: Kokilaben Dhirubhai Ambani Hospita

Why is Surgery the AI's Final Frontier?

Most things that AI has gotten good at shares one common trait: being wrong costs nothing. If a chatbot gives a bad answer, you ask it again. A self-driving car practices millions of virtual miles in simulation before touching a real road. Even for diagnostic medicines involving reading a scan or predicting disease risk is a single, correct judgment derived from data that already exists in large quantities.

Surgery shatters nearly all these aspects. Real tissue does not behave like a simulation. It stretches unevenly, bleeds unpredictably, and looks slightly different in every patient, so there is no way to generate millions of practice repetitions the way there is for chess or driving. Every mistake is physical and often irreversible. A wrong cut can cost an organ, a nerve, or a life. Being a paediatric surgeon myself, mistakes can result in the death of the patient. Conversations with scientists who have enabled actual autonomous surgery in cadaveric tissue indicates that initial outcomes were good, but the reality is different – cadavers don't bleed.

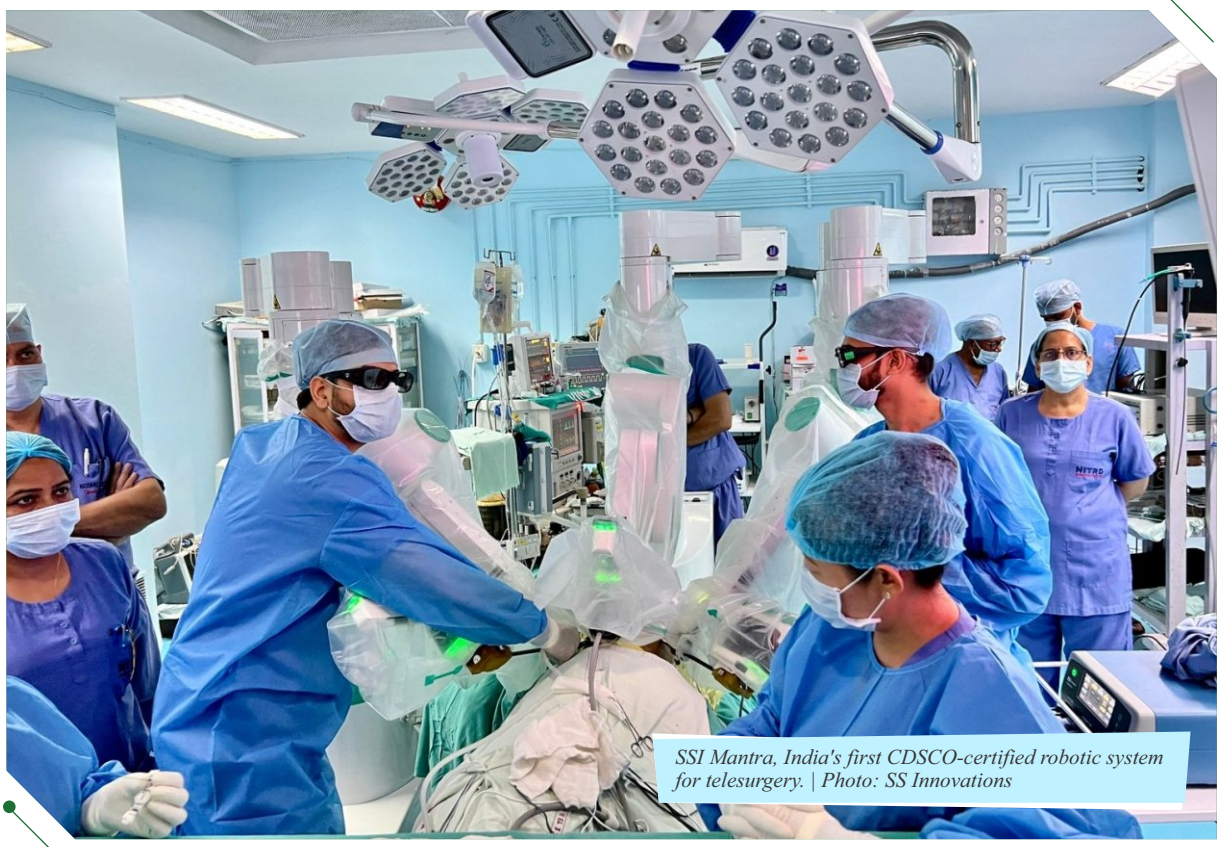
The training data is scarce by design. In every country, surgical videos sit behind hospital walls, patient consent, and ethics board review, and they can't be scrapped the way text or photos can be. The environment is also simply harder to perceive and act in than most physical AI tasks. Smoke from cautery devices obscures the view, anatomy varies patient to patient, and instruments move in six directions inside a confined space. This has led us to build foundational models in surgery with challenges encountered at every step. All of this implies that regulatory approvals are also slow.

What is Transpiring Inside the Operating Room?

What transpires inside the operating room helps in distinguishing between what's real from what's still lab work. At the frontier end, autonomous task completion is real but narrow – limited to very specific, highly predictable, and isolated steps of a procedure. In 2022, Johns Hopkins' STAR robot performed a full laparoscopic intestinal anastomosis on a pig with no human help, using near-infrared fluorescence imaging to track soft tissue, one of the hardest sub-tasks in surgery because tissue behaves unpredictably. In 2025, a system called SRT-H went further; completing an entire step of a gallbladder removal autonomously across eight test cases with a 100 percent success rate. It also incorporated corrections from a supervising surgeon mid-task. However, the surgery was performed on cadaveric tissue, as stated earlier.

The layer that is running in operating rooms today, not just in papers, is computer vision. Systems that recognise which phase of a procedure is underway are hitting 81% to 93% accuracy in systematic reviews. A 2026 validation study on robotic prostatectomy, trained on more than 919,000 video frames had high precision when tested through the surgeon it learned from; however, the accuracy dropped with unfamiliar surgeons. This is a useful reminder of how these models generalise less accurately than headline numbers suggest. Anatomical structure recognition or spotting a vessel or a duct on screen ranges from 71% to 98% depending on the structure. This is still inadequate of being used in ORs.

"Go/No-Go" models are being built specifically to flag safe versus unsafe dissection zones in gallbladder surgery, aimed at preventing bile duct injury- one of the most litigated errors in general surgery. Though, most work is still experimental. Robotic scrub nurses can select and deliver instru-



SSI Mantra, India's first CDSCO-certified robotic system for telesurgery. | Photo: SS Innovations

ments without a human passing them by hand. None of this replaces a scrub nurse yet, but it shows where instrument logistics is headed.

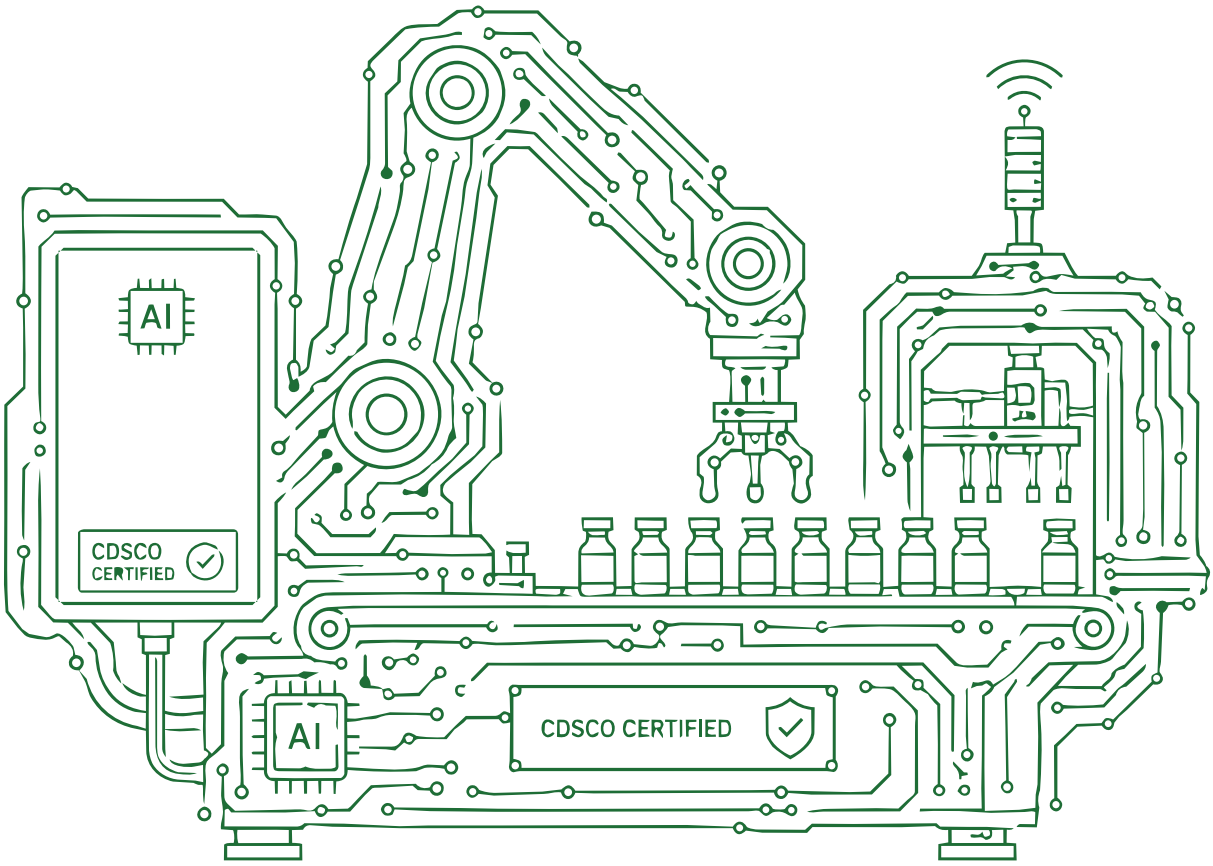
Why is Sovereign AI A Real Necessity?

Almost every one of these systems were trained on data captured in the American and European operating rooms. This pertains to instruments, disease patterns, and patient anatomy specific to those health systems. A phase-recognition model trained on Western bariatric or cardiac cases doesn't just transfer over to the disease burden, body types, or instrument sets one sees in India. What makes it ironical is that sometimes these models are built on Indian data, yet we still end up paying western prices to access the very technology meant to make our own patients safer.

Building sovereign physical AI for surgery is a necessity. This means building data pipelines that we govern ourselves, training and validating models against our own Institutional Review Board (IRB)-approved studies, and having regulations that doesn't just copy Food and Drug Administration (FDA) or Conformité Européenne (CE) precedent wholesale. It is the concept of self-sufficiency that made countries insist on their own vaccine manufacturing or generic drug capacity instead of depending entirely on imports. Surgical AI is becoming that kind of infrastructure. Countries that only consume it, instead of also building and validating it on their own clinical data, will end up with surgeons working inside models built for someone else's patients. 300 million major surgeries happen every year and 50 million people undergo complications (of different degrees). 50% of them are preventable. Giving surgeons intelligent systems in the operating room will go a long way in solving many such problems.

Where Is This Headed? - The Future of Surgical AI

The realistic path isn't a humanoid robot replacing a surgical team. It's closer to what is already happening in warehousing. We are talking about many narrow, well-tested systems, each handling one part of the workflow, coordinated across an OR rather than replacing any person in it. Cameras track themselves, instruments get handed over on request, and phase and structure recognition quietly flags risk in the background. The countries and institutions that build and own that layer, rather than license it, will be the ones whose surgeons can utilise it effectively. This is about bringing a layer of intelligence that will help surgeons make better decisions and improve outcomes.





Mr Vimal Govind K.K
Co-founder and CEO, Genrobotics

Robots Beneath Our Cities

Born from a simple moral question — why any human should enter a sewer when a machine can do it instead? — Genrobotics is deploying intelligent robots across India and building a globally competitive Physical AI platform that goes far beyond sanitation.

Behind every clean street and healthy community lies a workforce that has often been exposed to toxic gases, confined spaces, and life-threatening conditions. Every year in India, dozens of sanitation workers die inside manholes — overcome by hydrogen sulphide gas, suffocated by oxygen-depleted air, or simply lost to the dark depths of aging urban infrastructure. It is one of the country's most persistent and preventable tragedies. Despite remarkable advances in technology and urban development, hazardous manual intervention in sanitation systems remained a persistent challenge.

Genrobotics, a Kerala-born deep-tech startup, set out to change that. The company began with a simple but profound question: Why should any human being be forced to enter a sewer to perform a task that a machine could do instead? That question became the founding and eventually, the seed of an entire ecosystem of Physical AI solutions spanning urban infrastructure, environmental management, and healthcare.



Public sanitation has emerged as one of the most impactful applications of Physical AI. Sewer networks, drainage systems, canals, and wastewater infrastructure form the backbone of urban public health and environmental sustainability. However, maintaining these systems has traditionally involved labour-intensive and hazardous operations. By integrating intelligent robotic systems into sanitation workflows, municipalities can improve operational efficiency while significantly reducing human exposure to dangerous environments.

The World's First Robotic Scavenger

Genrobotics' Bandicoot is the world's first robotic scavenger. Combining sanitation robotics, machine vision, intelligent sensing, remote operation, and real-time monitoring into a single deployable unit, Bandicoot transformed what was once one of India's most hazardous occupations into a technology-enabled profession. A trained operator stands safely above the ground. The robot goes in.

Across India, the adoption of Physical AI in sanitation is no longer limited to pilot projects. Growing urbanisation, ageing underground infrastructure, increasing worker-safety requirements and the need for efficient public service delivery are accelerating the adoption of AI-enabled sanitation technologies. Municipal Corporations, Urban Local Bodies (ULBs), Smart City Missions, water authorities, and public infrastructure agencies are increasingly integrating robotic systems into routine sanitation operations.

Today, more than 300 robotic systems are supporting government agencies and municipalities in maintaining critical sanitation infrastructure, representing one of the largest deployments of sanitation robotics in the country. In several Indian cities, robotic systems are now routinely deployed for sewer cleaning, drainage maintenance, and canal management operations that previously required hazardous manual intervention. This demonstrates how Physical AI is transitioning from innovation laboratories into essential public infrastructure.

A Sanitation Ecosystem, Not Just A Product

A key driver behind this transformation has been indigenous innovation. Indian deep-tech companies have demonstrated the capability to design and develop globally relevant Physical AI solutions tailored to local infrastructure challenges. Through sustained investments in research and development, advanced engineering and intellectual property creation, they are strengthening India's capabilities in robotics, artificial intelligence, and intelligent systems engineering.

This has led to the development of a comprehensive product family that addresses the entire urban sanitation chain. Bandicoot Mini is a compact, solar-powered robotic solution designed for smaller municipalities and town panchayats bringing the technology within the reach of local administrations that cannot afford larger deployments. Other products include Bandicoot Mobility+, Wilboar, G Mammoth, and G Spider which are responsible for tasks ranging from waste collection and disposal to drain and tank cleaning. Together, these technologies form a complete sanitation robotics ecosystem that extends from underground sewers to open waterways.

Scan the QR code to see Generobotic's innovation in action



Bandicoot, a manhole cleaning and inspection robot with an operational depth of up to 12 meters

Built On Innovation, Not Promises

Beyond individual products, this innovation ecosystem reflects the growing maturity of India's deep-tech sector and its ability to create world-class solutions while reducing dependence on imported technologies. Yet the true impact of Physical AI cannot be measured solely through patents, algorithms, robotic systems, or deployment numbers. Its real impact is found in the lives it touches.

Behind every robotic sanitation system is a worker who no longer has to descend into a hazardous sewer. Behind every intelligent cleaning operation is a family that no longer worries whether their loved one will return home safely at the end of the day.



Wilboar, a heavy-duty robotic rover designed to clean horizontal confined spaces like stormwater drains

Physical AI is not about replacing people. It is about ensuring that no human being is forced to undertake dangerous, undignified, or life-threatening work when intelligent machines can do it safely. Every robot we build is a step towards a safer, more inclusive and more humane society.

The adoption of intelligent sanitation technologies is also creating opportunities for workforce transformation. Workers who once performed hazardous manual tasks are increasingly being trained to operate, manage, and maintain advanced robotic systems. This transition is creating safer, technology-enabled careers while supporting broader goals of skill development, social inclusion, and dignified employment.

From Sewers to Spinal Cords

The same engineering culture that drove Bandicoot's development has found an entirely different application in healthcare. Guided by continuous feedback from clinicians, rehabilitation specialists and patients, the platform has evolved into a full product family- G Gaiter for gait re-training after surgery, G Gaiter Paediatric for children with locomotor impairments, G Gaiter Advance for both adult and paediatric users, G Kai for upper-body rehabilitation, and G HopeR as an accessible robotic rehabilitation solution designed to support wider adoption across healthcare facilities in India and beyond. These healthcare innovations reflect a coherent thesis: that Physical AI can be applied wherever human safety and dignity are at stake.



G-Gaiter, a robotic assisted gait training system

More Than Engineering

The impact of Physical AI extends far beyond. By protecting sanitation workers from life-threatening conditions, creating pathways to dignified and technology-enabled employment, and supporting India's mission to eradicate manual scavenging, it demonstrates that Physical AI can deliver measurable societal benefit alongside commercial success.

As the artificial intelligence ecosystem continues to mature — across public infrastructure, healthcare, manufacturing, and environmental management — the companies that will lead it are not the ones with the most funding or the most press. They are the ones with the deepest IP, the most real-world deployments and the clearest sense of what the technology is for. Genrobotics has all three. Its journey illustrates that the future of Physical AI is not merely about intelligent machines.

Looking ahead, Physical AI has the potential to redefine how cities manage critical infrastructure. Future sanitation systems may combine robotics, intelligent sensing, digital twins, predictive analytics, and autonomous decision-making to enable continuous infrastructure monitoring and preventive maintenance. Such capabilities could help cities move from reactive interventions towards predictive and resilient infrastructure management — improving public health outcomes while reducing operational costs. As these technologies continue to evolve, Physical AI is expected to become a foundational component of next-generation smart cities and sustainable urban development.

The rise of Physical AI reflects India's broader ambition to build a strong technology-driven future. By developing indigenous robotic and AI-powered solutions for critical societal challenges, the country is demonstrating how innovation can be translated into tangible benefits for communities, industries, and public services. The future of Physical AI in public sanitation is not simply about smarter machines. It is about ensuring that no family has to fear losing a loved one to a task that technology can perform safely. It is about building cities that are not only cleaner and more efficient, but also more compassionate.



Photo: AI generated

Physical AI in Agriculture

Technology Driven Shift in Agricultural Ecosystem



Dr Subir K Chakraborty
Principal Scientist,
ICAR-Central Institute of Agricultural Engineering



Dr CR Mehta
Director,
ICAR-Central Institute of Agricultural Engineering

Indian agriculture is undergoing a transformative shift driven by rapid advancements in AI, Machine Learning (ML), Internet of Things (IoT), robotics, sensor technologies, and data analytics. Intelligent systems are emerging as critical enablers for enhancing productivity, resource-use efficiency, sustainability, and resilience across the agricultural sector. These technologies are introducing path-breaking transformation in traditional farming practices by enabling data-driven decision-making, precision operations, and automation throughout the agricultural value chain. They are helping farmers optimise input use and apply them in diverse domains, including farm mechanisation, post-harvest processing, water management, soil health, crop protection, genomic research for crop improvement, livestock production, and fisheries.

Despite the immense potential of intelligent systems, challenges related to infrastructure, affordability, digital literacy, and technology adoption continue to limit their widespread implementation and are viewed as challenges for achieving the goals of shaping a sustainable, resilient, and technology-driven agricultural ecosystem for Viksit Bharat 2047.

Intelligent Systems for Mechanised Agriculture

Achieving a farm mechanisation level from the current 50% to 75% by 2047 will be a distant possibility without a thorough and judicious adoption of intelligent systems integrated with sensors equipped with AI/ML/IoT working in sync with robotic devices to spell out solutions for optimum land preparation, precision input application, advanced planting and transplanting solutions, harvesting of horticultural produce, and overall postharvest management value chain. Central Institute of Agricultural Engineering (CIAE), Bhopal functioning under the aegis of Indian Council of Agricultural Research (ICAR) is a premier institute working in the area of national farm mechanisation goals. Nineteen of the developed and adopted technologies at ICAR-CIAE garner an impact of more than ₹14,000 crores per annum. Some of the successful use cases with robotic interventions are, vision computing based variable rate fertiliser applicators with robotic actuators for dispersing need based granular fertilisers, autonomous weeder,

unmanned track-type multipurpose (weeding, planting, tillage, spraying) vehicles, automatic robotic spraying system for poly house spraying, robotic grape picker and weight cum colour-based fruit grader with robotically actuated segregation system.

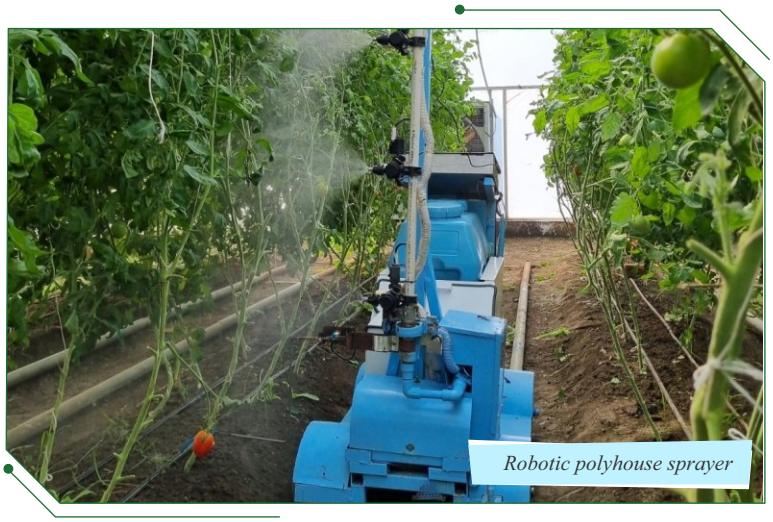
With drones capturing the mind-set of farmers, there are dynamic user-based protocols for robotic drone sprayers for regulated application of agricultural chemicals; and multispectral imagery for on-the-go crop health monitoring and yield assessment. Robotic approaches are all set to introduce transformative changes in agricultural mechanisation pathway, thereby, making it future-ready.



Robotic weeder



Rotary weeder with an unmanned tracked platform that ensures uniform weeding and reduces human drudgery



Robotic polyhouse sprayer

Smart Resource Utilisation Practices

Soil and water management practices are also witnessing a tectonic shift from the traditional rule-based operations to data-driven systems. Traditional management practices are gradually being replaced by intelligent approaches that align productivity goals with judicious use of land and freshwater resources. Digital lysimeters are making accurate irrigation scheduling possible with real-time evapotranspiration and soil moisture variations. There are AI/ML models for enhancing resource use efficiency by considering soil-nutrient and water losses interaction under varying rainfall and watershed scenarios. Smart sensors are enabling monitoring and control of crop growth parameters like humidity, temperature, and light using ML-based Decision Support Systems (DSS). With the increased popularity of vertical farming and soil-less cultivation, there are comprehensive IoT-based management systems for controlling the crop growth microenvironment such as:



An IoT-enabled drone conducting precision crop spraying in a smart agriculture setting. | Photo: Leher

- **Nutrient management platforms:** Merges Soil Test Crop Response (STCR) equations with digital soil maps for effective precision nutrient and water management
- **"VASUDHA - Visualisation and Assessment Software Using Digital Hyperspectral Analytics":** Analytical platforms that provides solution for high-resolution assessment of soil and crop conditions.

AI/ML interventions can also redefine crop protection by enabling early detection of stresses that are induced by soil ill-health, water deficiency, disease onset, nematodes, weeds; and the precision intervention(s) thereof in an eco-system that comprise data-driven decision support through chatbots and other AI enabled mobile friendly interactive software:

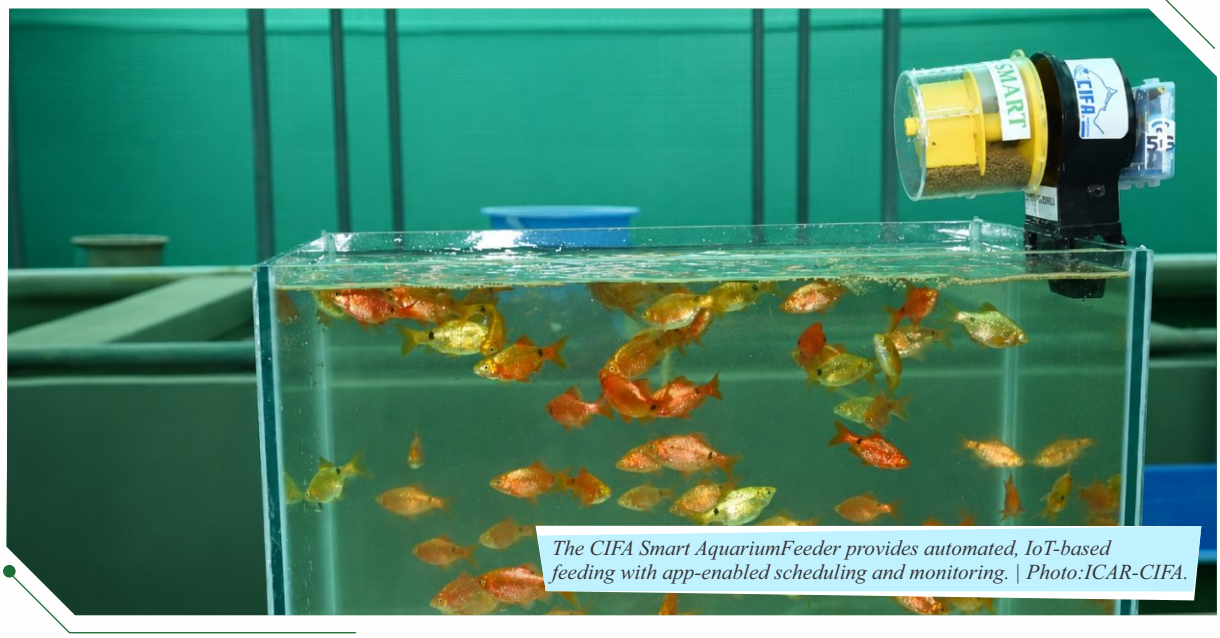
- **SoyAI:** Transforming soybean cultivation through AI modelling
- **Tilhantec – Oilseeds Doctor:** AI tool for managing disease in oilseed crops
- **Drone Agri:** Carries out various canopy management activities, like smart topping, site-specific spraying, tele-robotic selective pesticide applicators, and crop health monitoring.

AI-powered discoveries and innovations are slowly but steadily proving to be a game changer in the entire crop protection environment.

A key aspect of agricultural evolution is creation of newer varieties of crops across the whole spectrum of field, horticultural, and animal produce. Bioinformatics has long been supported by state-of-the-art software with adaptive computation techniques for taking the genomic research to the next level. There has been a gradual amalgamation of bioinformatics with ML enabled algorithms and AI predictive models. This has resulted in widespread adoption in crop improvement and sustainable nutrient management that has assisted in reduction of anti-nutritional factors in food crops, stress-resilient genotypes, supporting breeding programs for acid-soil environment, local ancestry analysis in cross breeds, and most importantly linking genomics with phenomics. A major contribution of AI/ML tools has been to enable data-driven innovation to enhance speed and accuracy of genomic research.

Technology Advancement in the Livestock Sector

Livestock sector contributes to more than 30% of the total agricultural revenue. Definitive strides have taken place with interventions that have led to a rapid transformation in sustainable fish production, precision livestock farming, and futuristic veterinary diagnostics. With irrational fish harvesting and unplanned animal rearing having long-standing environmental impact, the AI/ML innovations were never as relevant as they are today. Technology for water sampling and live fish transport using drone, freshness sensors for fish, smart feeders for ponds and aquariums, re-circulatory systems, and intelligent water filtration systems are some of the representative intelligent management tools for aquatic systems. A holistic set of management practices for feeding, health, and water quality is packaged in a decision support system called "AquaNIRNAY".

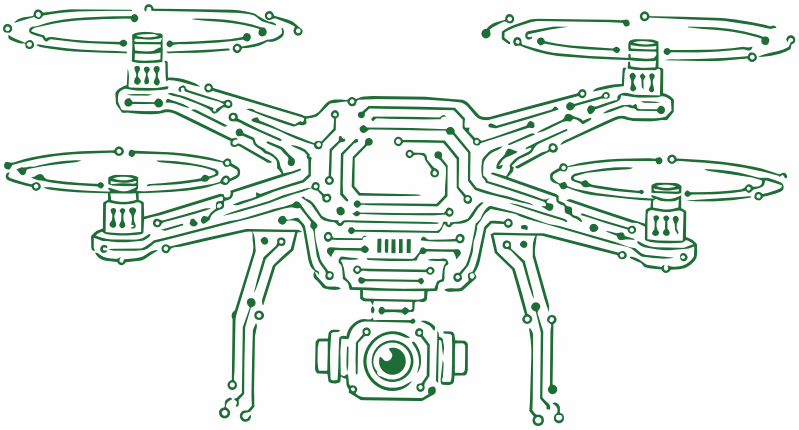


The CIFA Smart AquariumFeeder provides automated, IoT-based feeding with app-enabled scheduling and monitoring. | Photo:ICAR-CIFA.

Rapid developments have also taken place for animal health monitoring such as:

- **Smart Environment Monitoring System (GEMS):** Sensor network for continuous environmental and health monitoring for animals under captivity
- **MolEpidPred:** AI solution for Foot-and-Mouth disease virus

Vision computing based systems are being used for identification of mastitis, animal locomotive behavioural patterns, biometric recognition systems, and identification and classification of similar-looking indigenous cattle breeds to address challenges in breed conservation and genetic improvement. AI enabled software are also available for detecting estrus and parturient behaviour for improved reproductive efficiency. AI and sensor-driven technologies possess transformative potential for animal health and management research, with the adoption of these technologies instilling resilience and capabilities in livestock management systems.



Way Forward and Policy Interventions

AI/ML, IoT, vision computing, and robotics are transforming the various facets of Indian agriculture by treading through precision farming principals for efficient resource management. Adoption of these technologies will enhance productivity, food security, sustainability, and resilience against climate change, pests, and diseases. AI-driven solutions support precision agriculture, livestock management, irrigation scheduling, and supply chain optimisation; helping farmers make data-driven decisions and reduce losses.

Despite their potential, adoption remains limited due to digital illiteracy, inadequate infrastructure, high implementation costs, and limited access to technical support. Farmers often hesitate to replace traditional practices with AI-based systems, particularly when the benefits are not immediately evident. Training, field demonstrations, and user-friendly technologies are essential to improve acceptance and trust.

Ethical concerns such as data privacy, security, algorithmic bias, job displacement, and unequal access to digital technologies must also be addressed. Inclusive policies, transparent governance, and equitable data-sharing mechanisms are necessary to ensure that smallholder farmers benefit from technological advancements.

The policy makers must invest in digital infrastructure, low-cost sensors, AI-driven innovations, and farmer-centric technologies to realise the vision of Viksit Bharat 2047. Strengthening research, capacity building, and climate-smart agriculture will enable a sustainable, resilient, and technologically advanced agricultural ecosystem.



IoT-enabled sensors provide real-time insights into soil and crop conditions, supporting precision agriculture and data-driven farming.| Photo: AI Generated

Deep Tech Startups in Physical AI

4

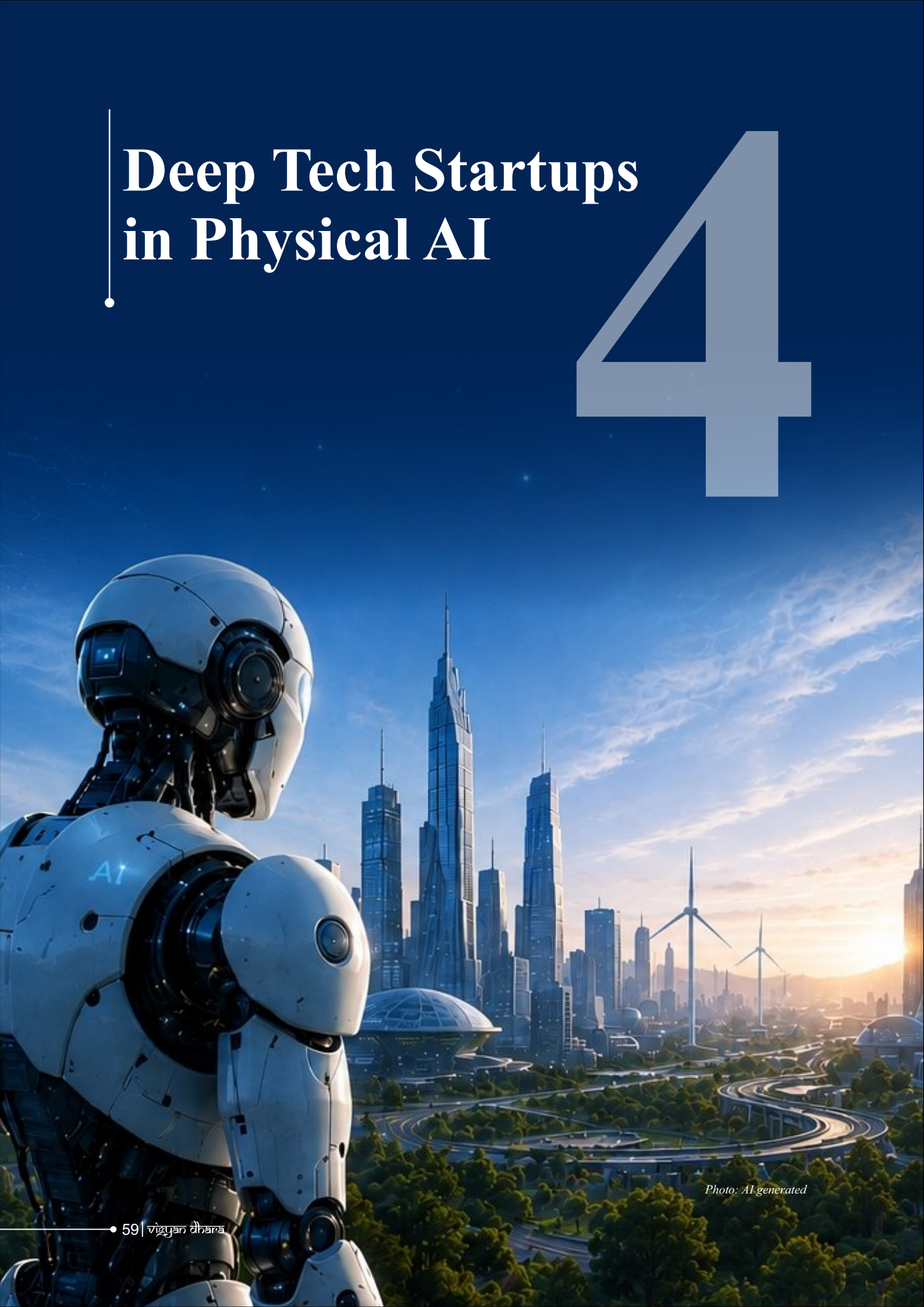


Photo: AI generated

The evolution of artificial intelligence, since the 1950s, has been a continuum of long-term technological revolutions that illustrates a journey of rapid adoption, stagnation, and advancement fitting into the broader economic and innovation trends. Physical AI has naturally emerged as one of the evolutions of the AI wave. As stated in the NITI Aayog Report of September 2025 for AI for Viksit Bharat, over the next decade, the adoption of AI across sectors is expected to add $17–26T to the global economy. Harnessing the large STEM workforce, expanding R&D ecosystem, and the growing digital and technology capabilities, renders India a potential to capture 10-15% of global AI value.

As we tap into this immense potential, the conversation around software systems involved in AI has steered towards the physical aspects – the integration of AI with robotics, sensors, actuators, and to create machines that can see, move, adapt, and manipulate in real-world environment. This architectural shift in AI is also being driven by startups that are helping transform abstract concepts into something tangible.

Even though AI remains in its formative stage, and the market structures are still evolving, the Indian startup ecosystem is booming across sectors. This article profiles a selection of some such ventures that have turned ambitious ideas into scalable products. It demonstrates the impact these startups are making, their market ecosystem, portfolio, and the various patents that, further, adds on to the intellectual property of our country. From navigating hard-to-access underwater environments to designing solutions that are specific to the constraints of our country, physical AI is transforming the system, the standard operating procedures, and impacting the lives of people.

The following pages present startups in particular sectors (Table 1) whose journey and progress provides valuable insights and ideas to embark on the path ahead. Ultimately, the ambition for Physical AI in India extends beyond just building the most advanced humanoid robot. It is about having cost-efficient, robust, and scalable automation solutions for real-world problems and positively impacting the lives of people.

Addverb	Manufacturing and Industries, Chemical and Petrochemical, Cold Storage, Semiconductors, Consumer Goods
Cyn:LR	Manufacturing, Industrial Warehousing and Logistics
EyeROV	Marine Research, Infrastructure, and Defence
IdeaForge	Aerial inspection, mapping, and surveillance across various sectors: Defence, Mining and Heavy Industries, Disaster Management and Emergency Response, and Smart City Management, among others
Novus	Manufacturing, Warehousing, Road Transporting and Logistics, Vehicle Original Equipment Manufacturer (OEM) Segment, and Automative and Commercial Vehicles
Planys	Marine Research, Infrastructure, and Defence
Systemantics	Academia and Research, Electronics, Food and Beverage, Pharmaceutical, E-commerce and Retail, and Automative and Industrial

Table 1- The startups and the respective sectors in which they contribute

ADDVERB

Human | Robot | Possibilities



Mr Sangeet Kumar
Co-founder and CEO

Founded in 2016, Addverb is a global robotics and automation company dedicated to bringing intelligence into the physical world. Headquartered in Noida, India, the company employs over 1,150 professionals representing more than 20 nationalities and serves leading enterprises across e-commerce, retail, Fast-Moving Consumer Goods (FMCG), manufacturing, healthcare, and logistics. Innovation at Addverb is driven through its three R&D centres across India and the United States, where multidisciplinary teams develop next-generation robotics, Physical AI, computer vision, autonomous navigation, and automation technologies.

Addverb has built a comprehensive portfolio of robotics and automation solutions, including Autonomous Mobile Robots (AMRs), robotic sortation systems, Automated Storage and Retrieval Systems (ASRS), picking technologies, collaborative robots, quadruped robots, and its latest innovation, Elixis-W, a Made-in-India wheeled humanoid robot. These solutions help enterprises improve productivity, accuracy, safety, and operational efficiency.

A defining characteristic of Addverb's growth has been its commitment to indigenous innovation and intellectual property creation. The company has developed proprietary software platforms, including its Warehouse Management System (WMS), Warehouse Control System (WCS), Warehouse Execution System (WES), and Movect- its Fleet Management System (FMS).

Serving as the intelligence layer for warehouse operations, Movect orchestrates diverse robotic fleets- including AMRs, AGVs, pallet shuttles, and Cruiser 360 robots, through a unified platform. It continuously optimizes path planning, task allocation, battery management, and real-time traffic flow, enabling thousands of autonomous decisions every minute without human intervention.

Beyond warehouse automation, Addverb is advancing Robot Cognition, enabling robots to perceive, reason, and act autonomously in dynamic environments. Its work in Locomotion Intelligence allows robots to navigate and adapt to changing surroundings, while Manipulation Intelligence enables them to identify, handle, sort, and assemble a wide variety of objects with increasing autonomy.

Together, these capabilities represent the next frontier of Physical AI, where intelligent machines move beyond automation to contextual decision-making. By combining indigenous innovation, advanced manufacturing, strong intellectual property, and

global market reach, Addverb is helping position India as a global hub for Physical AI, robotics, and deep-tech innovation.

Operations In

Over 20 countries with automation in >500 warehouses worldwide

Characteristics

In-house development of robotics hardware and software

Portfolio

Includes humanoids like Elixis-W and Autonomous Mobile Robots (AMRs)

Patents And Grants

16 patents and 12 granted industrial designs across India, the United States, Australia, and Saudi Arabia

Market Ecosystem

Expanding with 50% of business from international markets; deployments span North America, Europe, the Middle East, Southeast Asia, and Australia

Production Capacity

Bot-Verse, the flagship manufacturing facility and the world's largest factory for mobile robots, has production capacity of ~100,000 robots per annum



Humanoid - Elixis

Innovation in action

CYN:LR



Mr Nikhil Ramaswamy
Co-Founder and CEO



Mr Gokul N.A
Founder and Director of Technology

Despite impressive breakthroughs in AI, limitations are still encountered when it comes to adaptation in the physical world. From fitting a screw to unwrapping an object to automating the assembly of a car/gadget – every such task that involves "adapting on the fly" is not a prior trainable aspect and remains non-automatable across industries. Therefore, a robot that can grasp, pick, and place any object has been a 40-year-old pipe dream – touted as "The Holy Grail of Robotics." CynLr is a foundational technology building company in robotics and AI, building visual robots that can intuitively learn to pick & handle even unknown objects without requiring any prior training, just like a human baby fiddles with objects. We call this stack as Object Intelligence (OI).

In the automation process, manufacturing is often plagued with customisation sickness that cannot adapt to changing consumer needs. Since each task today demands its own bespoke machinery, factories are forced to become giant gigafactories, sprawling across thousands of acres in remote locations. For roughly six decades, industrial automation has been choreography rather than cognition. In view of this, from factory lines to warehouses to labs, the company has focused to universally automate with OI's ability to learn on the fly and eliminate the need for complicated custom machines to manufacture products. This is an alternate take on automation, where robots "Act to Sense, not Sense to Act."

CynLr envisions future factories to be decentralised, micro factories (contrary to gigafactories) that could rather be hosted in your street-ends; thus, opening up the possibility of Personalised Products – liberating the products' design from the constrains of manufacturability. The company looks to transform them into LEGO like reconfigurable blocks of universal micro-factories.

Moving ahead, the company has established research partnerships with Switzerland's Learning Algorithms and Systems Aboratory (EPFL-LASA) and Swiss Center for Electronics and Microtechnology (CSEM), and Centre of Neuroscience Lab, IISc. USD 15.25 million has also been raised in total funding; partnering with global customers across semiconductor, aerospace, automotive, and warehouse logistics and electronics, etc.

Physical AI is becoming a foundational infrastructure, and whoever holds the core intellectual property for how machines perceive and act in the physical world will set

the terms for the next era of manufacturing. For India, with its engineering depth and large manufacturing base, this is a chance to author that layer rather than merely buy it: strategic leverage far beyond any export story, and an opportunity to build in India for the world.

Operations In

Lausanne (Switzerland), Bangalore (India), and Austin (USA)

Characteristics

Stack and Object Intelligence

Portfolio

Includes building all the missing hardware and software technologies in-house starting from its Motion Stereo Vision Camera, Robot Systems to fundamental neural algorithms

Production Capacity

Targeting 300 robots and USD 45 million in revenue in the year 2028-29

Innovation in action



EyeROV™



Mr Johns T. Mathai
Co-founder and CEO

For underwater environments, physical AI is especially important because critical infrastructure often lies in spaces that are dark, hazardous, turbid, confined or inaccessible to humans. EyeROV, (IROV Technologies Pvt. Ltd.), is an Indian deep-tech startup building marine robotics and AI solutions to make underwater inspection, monitoring, and intervention safer, faster, and more reliable.

EyeROV's core innovation lies in combining indigenously developed marine robotic platforms with intelligent sensing, control, and analytics. These platforms are designed for applications such as underwater asset inspection, dam and tunnel inspection, marine infrastructure monitoring, search and recovery, environmental surveys, and industrial inspection. By enabling operators to remain safely on the surface while robots collect visual, sonar, and sensor data underwater, EyeROV reduces human risk and improves repeatability in mission-critical inspections.

A key differentiator is EyeROV's software and analytics layer. The EyeROV Visualization and Analytics Platform supports underwater image enhancement, 2D/3D reconstruction, digital reporting, and AI/ML-assisted defect identification. This transforms raw underwater video and sensor data into actionable intelligence for infrastructure owners and decision-makers. In practical terms, EyeROV's Physical AI systems do not merely see underwater; they help interpret complex field data, identify anomalies, and support better maintenance decisions.

The startup's innovativeness is strengthened by its focus on indigenous design, manufacturing and intellectual property. EyeROV has built capabilities across hardware, embedded systems, underwater communication, payload integration, robotics control, and AI-enabled analytics. Its IP-led approach creates a strong technology foundation in a domain traditionally dependent on imported systems. This is strategically significant for India, where marine robotics can support national priorities in infrastructure resilience, blue economy, maritime safety, disaster response, and industrial productivity.

The market opportunity for EyeROV is expanding with ageing assets, safety requirements, sustainability goals, and the need for faster inspection cycles accelerating adoption. EyeROV's business potential lies in both product sales and Robotics-as-a-Service models, where the company can

deliver end-to-end solutions from data collection to insights and reports.

By building reliable, field-ready, and India-made marine robotic systems, the company represents the promise of Physical AI: intelligent machines that extend human capability into environments where human presence is risky, costly, or impossible. As India strengthens its deep-tech and robotics ecosystem, this plays a vital role in creating sovereign capability, global competitiveness, and safer infrastructure for the future.

Characteristics

Indigenous Physical AI for safer underwater infrastructure

Portfolio

Includes building all the missing hardware and software technologies in-house starting from its Motion Stereo Vision Camera to Robot Systems to fundamental neural algorithms

Market Ecosystem

Expanding with sectors such as ports, hydropower, offshore energy, water infrastructure, and maritime operations transitioning from manual inspection to robotic and data-driven methods

Inspections

~10k long-range inspections

Innovation in action



ideaForge™
Create. Inspire



Mr Ankit Mehta
Co-founder and CEO

The conversation around Physical AI often focuses on future possibilities with unmanned aerial systems being one of its most mature manifestations.

For ideaForge, this journey began nearly two decades ago with a simple ambition: to build reliable unmanned aircraft in India for missions where failure is not an option. What started as a student project at IIT Bombay has since evolved into a portfolio of indigenous drone platforms and solutions trusted by defence forces, government agencies, and enterprises across the country. From the beginning, ideaForge chose to build and own technologies that matter the most: flight-control systems, communication links, mission software, payload integration, and airframe design. The BlueFire autopilot, developed in 2008-09 and among the world's smallest and lightest at the time, reflected a conviction that critical technologies should be engineered indigenously, not imported.

What began with a single platform has grown into a family of systems and a suite of solutions designed for diverse operational environments. Onboard computing and advanced software let the aircrafts navigate complex terrain, operate in degraded or Global Navigation Satellite System (GNSS)-denied environments, and process information at the edge to deliver insights faster. The value does not end at the aircraft: by owning the complete chain from sensor to software, ideaForge turns raw aerial data into operational awareness, enabling informed decisions. During Operation Sindoor, ideaForge's NETRA and SWITCH UAV platforms supported ISR missions for the Indian Army, providing critical situational awareness and underlining the value of indigenous systems in modern operations.

The same technologies that serve demanding defence missions create value in civilian life, because the underlying challenge is the same: gathering accurate information quickly enough to make better decisions. At the 2025 Pandharpur Wari, one of Maharashtra's largest pilgrimages, AI-enabled Q6 platforms supported the Solapur Rural Police with live aerial visibility and crowd-density assessments for a gathering of roughly 27.5 lakh devotees. The engineering that monitors a battlefield can just as readily help manage public safety at scale. This convergence is increasingly defining the future of unmanned systems.

As Physical AI moves from concept to capability, ownership of the underlying technology becomes increasingly important. Physical AI will sit at the centre of security, Physical

mobility, and infrastructure in the years ahead, and the nations that own it rather than import it will shape how it is used. In domains too strategic to outsource, technological sovereignty is not merely an advantage. It is a necessity.



Operations In

Serves demanding defence missions and helps in addressing civilian challenges

Characteristics

Indigenous drone platforms and UAV platforms for high-endurance ISR

Portfolio

Includes Q6 and NETRA series, the long-endurance SWITCH series, and the tactical ZOLT the tactical ZOL

Patents And Grants

110+ patents filed globally

Market Ecosystem

Over one million successful customer flights, with an ideaForge UAV taking off every two minutes

Global Standing

Among the top 3 dual-use drone manufacturers worldwide (DRONEII, 2024) 2024)

Certifications

DGCA Type Certified, DGQA "Fit for Military Use", and NATO recognised with NSN codification

Environmental Resilience

-30°C to +55°C: proven from Himalayan heights and polar ice to desert heat and coastal humidity and coastal humidity

Innovation in action

NOVUS HI-TECH



Mr Anuj Kapuria
Founder, MD and CEO

Founded with a conviction that India's factories, highways, and energy infrastructure needed intelligence — not just machinery — the company has spent over a decade doing what few Indian deep tech companies have managed: turning fundamental research into real-world deployments, at scale, with IP that belongs entirely to India.

For years, the global robotics industry has designed for clean rooms, uniform pallets, and predictable layouts. The average Indian factory floor has variable lighting, informal traffic patterns, workers, and machines sharing the same corridor, and floor markings that may or may not exist. Road accident fatalities in India in 2024 crossed 1.7 lakh per MoRTH provisional data. Behind that number are fleets running on schedules too tight for safety margins, drivers fatigued after 12-hour shifts, and vehicles with no early-warning systems whatsoever. The technology to address this exists. What did not exist was a version calibrated to Indian roads, Indian driver behavior, and Indian fleet economics.

Novus' Automated Guided Vehicles (AGVs), Autonomous Mobile Robots (AMRs), and Advanced Driver Assistance System (ADAS) were engineered for exactly this reality. With over 1,400 autonomous solutions of AGVs and AMRs active across automotive assembly lines, pharmaceutical warehouses, FMCG distribution centres, and electronics plants, the platform has accumulated a breadth of deployment experience that shapes every product decision. The robots do not just navigate — they adapt, reroute, slow down for humans, and resume. That level of situational intelligence comes from a decade of running in environments that textbooks do not cover.

Over 1,20,000 ADAS units are active across Indian commercial fleets. More than 2,00,000 drivers are covered by the system every single day — receiving real-time alerts for lane drift, forward collision risk, fatigue onset, and distraction. The underlying models were not adapted from a Western dataset. They were trained on Indian roads, Indian signage, and Indian driving patterns. That distinction matters enormously when a warning system needs to fire in 80 milliseconds on a state highway at 2 am.

Manufacturing competitiveness, road safety, energy transition, logistics efficiency are not software problems. They require AI that is embodied, deployed, and accountable in the physical world. India needs companies that can build and own this technology, not just

procure it from abroad. Novus Hi-Tech has built something rare: a portfolio of deployed systems, a body of owned IP, and a dataset of real-world Indian experience that took more than a decade and over a thousand man-years of effort to accumulate. That foundation is, in itself, a national asset.

Operations In

1,400+ autonomous solutions deployed; 1,20,000+ ADAS Systems currently active; 7B+ ground truth data points; 1,000+ man-years of R&D; and 2 lakh drivers protected every day

Characteristics

Mobile robotics built for Indian floors and to address fleet safety on roads

Portfolio

Includes Mobile Robotics (AGVs and AMRs), Advanced Driver Assistance and Fleet Safety, and Solar PV automation

Patents And Grants

100+ patents covering autonomous navigation, edge-based sensor fusion, fatigue detection under varied lighting conditions, multi-agent coordination in dynamic environments, and more

Innovation in action



PLANYS TECHNOLOGIES



Mr Tanuj Jhunjhunwala
Co-founder and CEO

Critical infrastructure such as dams, bridges, ports, industrial facilities, water infrastructure, and strategic maritime assets requires regular inspection to ensure safety, reliability, and operational continuity. However, these environments are often difficult, hazardous, and expensive for human access.

Traditional inspection methods typically involve shutdowns, dewatering, manual diving operations, or confined-space entry. These approaches result in increased operational costs, prolonged downtime, safety risks, and limited access to reliable inspection data. As infrastructure continues to age and asset owners seek more efficient maintenance strategies, there is a growing need for intelligent, data-driven inspection technologies.

Founded in 2015, Planys Technologies is an Indian deep-tech company addressing these challenges through AI-enabled robotic systems designed for underwater and other hard-to-access environments. By combining robotics, autonomy, advanced sensing, and artificial intelligence, Planys enables asset owners to inspect, monitor, and manage critical infrastructure safely, efficiently, and with greater confidence.

Rather than simply capturing inspection data, Planys transforms complex field information into actionable intelligence. Its robotic systems navigate challenging underwater environments, collect high-quality inspection data, identify structural anomalies, and generate digital defect maps, automated reports, and predictive insights. This empowers infrastructure owners to make faster, informed maintenance decisions while reducing operational disruptions.

As artificial intelligence continues to shape industries worldwide, Planys is extending AI beyond digital applications through Physical AI. Its intelligent robotic systems interact with complex underwater environments, combining perception, autonomy, and analytics to solve real-world engineering challenges where human intervention is difficult, risky, or impractical.

Innovation remains central to the company's growth. Designed, developed, and manufactured in India, Planys' technologies demonstrate the country's growing capabilities in advanced robotics and autonomous systems. Today, its solutions are deployed across ports and terminals, water infrastructure, energy, process industries, and maritime operations, enabling safer inspections, improved infrastructure reliability, and more efficient asset management.

Beyond commercial applications, Planys is also strengthening India's strategic capabilities through the development of indigenous autonomous underwater systems for defence and maritime security. As the country increasingly focuses on technological self-reliance, underwater autonomy and AI-driven maritime intelligence are emerging as strategic national priorities.

Through its home-grown innovations in these domains, Planys is contributing to India's vision of Atmanirbhar Bharat while positioning the country as a global leader in Physical AI, underwater robotics, and autonomous maritime technologies.

Global Presence

Deployed its inspection and autonomous robotic solutions across diverse infrastructure sectors worldwide; 500+ critical assets inspected; 10+ countries served

Expertise

Building Physical AI for India's underwater world through AI-enabled robotics and inspection systems

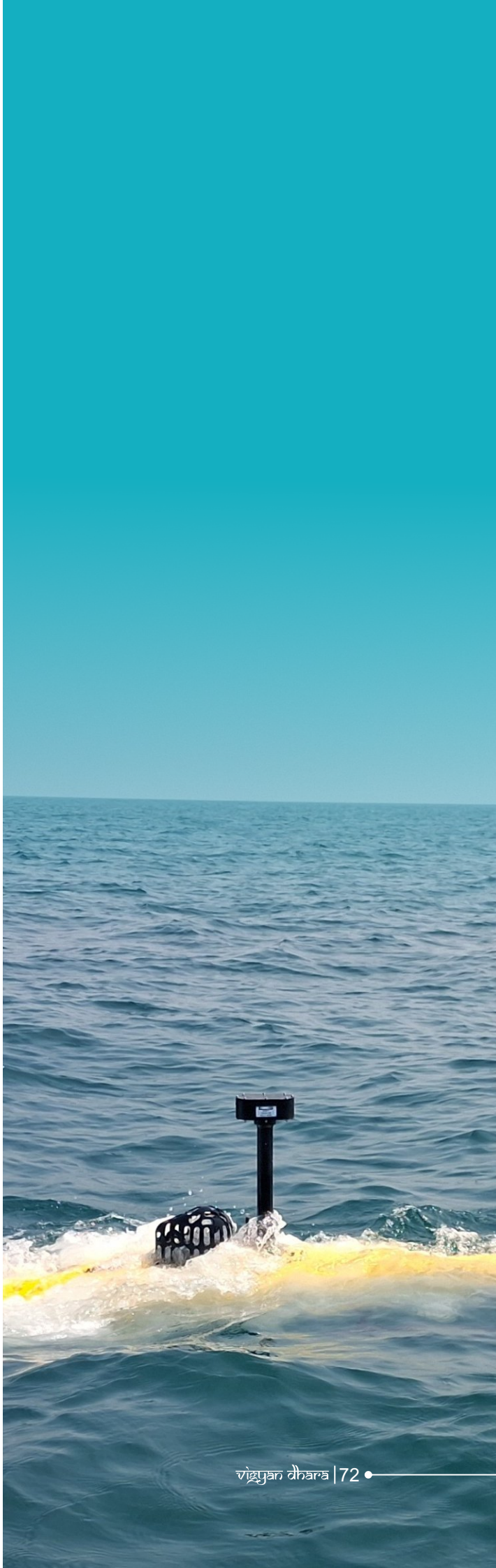
Portfolio

Autonomous Underwater Vehicles (AUVs), Remotely Operated Vehicles (ROVs), Underwater inspection methodologies, Robotic sensing systems, Digital defect mapping, Automated reporting, Predictive analytics

Patents And Grants

~20

Innovation in action



SYSTEMANTICS
sensible robotics



Mr Anand Narayanan
Co-Founder and CEO



Dr Jagannath Raju
Founder and CTO

With over 30 years of robotics engineering experience of design depth, Systemantics is changing the way India's automation story has long been written by foreign hands. With the ASYSTR cobot series, the company has built India's first 6-axis collaborative robot — ground up, fully indigenous, for the world. The ASYSTR C-series is a product of iterative learning across custom-built robotic systems deployed for government agencies, defence organisations, and industrial clients alike.

The ASYSTR cobots — available in 3 kg, 5 kg, and 10 kg payload variants — are 6-axis robotic arms engineered around a philosophy called "Sensible Robotics." It addresses technical, economic, and operational barrier that cobots usually deal with. Approximately 70% of the value added in its manufacture is done locally, enabling automation adoption that is genuinely accessible without compromising on reliability or performance. Our design is vertically integrated — from joint controllers to software — keeping supply chains short, serviceability high, and costs predictable.

What makes ASYSTR particularly significant in the context of Physical AI is what it is architecturally designed to enable. The platform is natively compatible with ROS2 — the Robot Operating System, which has become the de facto open-source standard for robotics development globally. This openness is a deliberate design choice, and a meaningful one. In a landscape where Physical AI demands reliable, programmable, and affordable robot hardware, ASYSTR delivers exactly that: a Made-in-India physical AI platform that is open, extensible, and production-ready.

The market context could not be more favourable. India's collaborative robot market, valued at approximately USD 115–148 million in 2024–25, is projected to grow at a CAGR of 29–37% to reach USD 690 million–2.3 billion by the early 2030s — making it one of the fastest-growing cobot markets in the world.

Keeping in view, the national priorities in deep tech and manufacturing self-reliance, a locally made robotic arm with indigenous electronic drivers becomes mandatory. With a growing partner network across India's major manufacturing hubs and international expansion on the horizon, the company is building the distribution network to match our product ambition.

Most tellingly, the company has partnered with a wheeled-humanoid manufacturer to

supply robotic arms — a signal that our platform is now a building block for the next generation of physical AI systems. As India positions itself to not just be a consumer but a creator in the global robotics value chain, the company represents a compelling answer to what an indigenous deep tech in Physical AI can look like.

Industries Addressed

Automotive Component Manufacturing, Electronics Assembly & Precision Engineering, Intralogistics & Warehouse Automation, Pharma, Lab, & Non-Invasive Medical Automation

Portfolio

3 kg, 5 kg, and 10 kg 6-axis collaborative robotic arms in the ASYSTR family, with 40+ active deployments

Market Horizon

Global Market projected to approach USD 86 Billion by 2035; domestic market is expanding at a CAGR of ~29–37%

Interoperability

Native ROS2 compatibility provides an open-source, extensible interface bridging high-level digital AI models with physical actuation making it easier to scale embodied AI products for diverse applications

Strategic Self-reliance

With 70% domestic value addition, the ASYSTR platform guarantees rapid lifecycle support and long-term spare parts availability, drastically reducing operational downtime

Innovation in action



Up Close With

Conversations With the Experts

"Conversations with the Experts" explores two different facets of the real-world applications, tech breakthroughs, and market ecosystems of Physical AI: across the defence and startup sectors. As physical AI is becoming mainstream in India and advancing steadily, this article curates the journey, experiences, and the future outlook and advancements that will define the presence of autonomous systems in the sectors. It also highlights perspectives and challenges needed to be addressed to make the current ecosystem faster, more integrated, and more responsive.

Together the views serve to provide a complete picture of the integration of artificial intelligence into real-world, physical systems, and operational workflows. It also serves to guide the young aspirants, researchers, and innovators through the state and dynamics of the field; motivating them to build solutions that bridge the digital and physical worlds.

Chief of Defence Staff

Insights from the Defence Environment

In an exclusive interaction with **Mr Rohit Gupta, Chief Technology Officer, OPSA** for Vigyan Dhara, **General NS Raja Subramani, Chief of Defence Staff (CDS) and Secretary, Department of Military Affairs (DMA)** shared his insights into the changes in the nature of warfare since the 80s, the role Physical AI plays in transforming military capabilities, and the importance of having a balance between autonomy and human judgement in the military systems. General Subramani also sheds light on the demands from technology developers for Degraded, Disrupted, Intermittent, and Limited (DDIL) environment, his views on the Indian institutional architecture, and a message for the young engineers and scientists.



Q When you look at the security environment India faces today, what has changed most fundamentally about the character of warfare from the time you were commissioned in 1985?

Gen. Subramani: The most fundamental change in the character of warfare since 1985 is that military power is no longer primarily determined by the size of armed forces or the number of platforms, but by the ability to integrate technology, information, and decision-making across multiple domains. Warfare has evolved from being platform-centric to becoming network-centric and increasingly AI-enabled.

In 1985, conflicts were largely confined to land, sea, and air, with clearly defined battlefields and frontlines. Today, battlespace extends into cyberspace, space, and the electromagnetic spectrum. Military operations are increasingly shaped by electronic warfare, satellite-based intelligence, cyber-attacks, autonomous systems, and information operations. The distinction between peace and war has also blurred, with strategic competition taking place continuously through cyber intrusions, disinformation campaigns, economic coercion, and grey-zone activities. Another major transformation is the speed of conflict. Advances in artificial intelligence, autonomous systems, precision-guided munitions, and real-time intelligence have compressed decision-making cycles. Success, however, still depends on who can sense, decide, and act faster than the adversary. Human-machine collaboration, resilient communications, and edge computing are therefore becoming as important as traditional combat platforms.

The democratisation of technology has further altered the security landscape. Capabilities once available only to major powers such as drones, satellite imagery, AI, and cyber tools are now accessible to smaller states and even non-state actors. This has lowered the cost of generating strategic effects while increasing the importance of innovation and adaptability. For India, facing simultaneous challenges on its land borders, in the Indian Ocean, and in cyberspace, demands a shift towards integrated, technology-driven military capabilities. Indigenous strengths in AI, robotics, cyber security, space systems, and advanced manufacturing must become central to defence preparedness. Ultimately, the



Indrajaal Combat- AI-driven, mobile counter-Unmanned Aerial System (C-UAS) defense module that detects, tracks, and neutralizes rogue drones| Photo: Indrajaal

defining lesson is that the future battlefield will favour nations that can integrate people, platforms, data, and technology into a resilient and adaptive force. The decisive advantage will belong not simply to those with the most weapons, but to those who can innovate, adapt, and make faster, better-informed decisions in an increasingly complex and contested security environment.



Indian fighter jet

Q For the armed forces, is Physical AI an incremental improvement in existing systems or a genuine change in the nature of military capability?

Gen. Subramani: Physical AI represents far more than an incremental improvement — it marks a fundamental shift in the nature of military capability. Physical AI enables machines to perceive their environment, reason in real time, and take autonomous actions. This transforms robotics from remotely controlled tools into intelligent teammates capable of operating alongside soldiers.

For the armed forces, this means moving beyond platform-centric warfare to human-machine teaming. Autonomous aerial, ground, maritime, and eventually humanoid systems will be able to conduct reconnaissance, logistics, explosive ordnance disposal, casualty evacuation, electronic warfare, and high-risk missions with minimal human intervention. Rather than replacing soldiers, physical AI will multiply their effectiveness, allowing personnel to focus on command, judgment, and complex decision-making while machines undertake repetitive, hazardous, or time-critical tasks. The strategic significance lies in the combination of autonomy, adaptability, and scale. Physical AI-powered systems can operate in GPS-denied, communications- and electronically- contested environments by using edge computing, multi-sensor perception, and onboard intelligence. They can collaborate as swarms, share information, adapt to changing conditions, and continue missions even when disconnected from central command. This fundamentally changes the tempo of operations and expands the military's ability to project capability across multiple domains simultaneously.

For India, physical AI aligns closely with the goals of theatre commands, multi-domain operations, and Atmanirbhar Bharat. It offers an opportunity to build indigenous autonomous systems tailored to India's unique operational challenges, from high-altitude borders and dense urban environments to the maritime domain. However, technology alone is not decisive. Real transformation will come from integrating physical AI into doctrine, training, command structures, and procurement processes. Just as precision-guided munitions and network-centric warfare reshaped military operations in previous decades, physical AI has the potential to redefine force structure, operational concepts, and combat effectiveness. It is therefore not simply an upgrade to existing systems, but a new paradigm that will shape the future character of warfare and determine the military balance in the decades ahead.

Q Much of the global conversation is about humanoid robots. From the military standpoint, is the humanoid form factor useful or are the real gains present in unmanned aerial, ground, and underwater systems that look nothing like a human being?

Much of the global conversation around robotics is understandably focused on humanoid robots because they capture the imagination and promise to work in environments built for humans. However, from a military standpoint, the question is not whether a robot looks like a soldier, but whether it delivers superior operational capability. On that measure, the greatest gains in the foreseeable future will come from mission-specific autonomous systems - unmanned aerial, ground, surface, and underwater platforms that are designed for specific operational roles rather than replicating the human form.

The battlefield rewards effectiveness, not appearance. A quadcopter is optimised for rapid reconnaissance, a tracked unmanned ground vehicle can carry heavy payloads across difficult terrain, and an autonomous underwater vehicle can remain submerged for extended periods. These platforms are purpose-built for their environments and can outperform humanoid robots in speed, endurance, payload capacity, and cost-effectiveness.



Unexploded Ordnance Handling Robot (UXOR), an advanced Unmanned Ground Vehicle (UGV) Photo: DefenceXP

That said, humanoid robots should not be dismissed entirely. Military infrastructure - from ships and aircraft to maintenance depots, warehouses, and command facilities - has been designed around human dimensions. A capable humanoid robot could perform equipment maintenance, logistics handling, ammunition loading, infrastructure inspection, disaster response, or operations in chemical, biological, radiological, and nuclear (CBRN) environments without requiring major changes to existing infrastructure. In these support roles, the humanoid form factor offers practical advantages. For frontline combat, however, the priorities are very different. Armed forces need systems that are resilient, affordable, easy to deploy, and capable of operating in GPS-denied and communications-contested environments. Swarms of autonomous drones, robotic mules for logistics, unmanned ground vehicles for reconnaissance and explosive ordnance disposal, and autonomous maritime systems for surveillance and mine countermeasures will likely provide far greater operational value than humanoid combat robots.

For India, the strategic priority should therefore be to build a comprehensive robotics ecosystem rather than focus on a single class of robot. Investment should emphasise AI-enabled autonomy, secure communications, edge computing, and interoperability across aerial, ground, and maritime platforms. Humanoid robots may eventually become valuable members of this ecosystem, particularly for logistics and maintenance, but they are unlikely to define the future of military capability. The future belongs to intelligent, purpose-built autonomous systems that enhance human effectiveness, reduce operational risk, and provide decisive advantages across multiple domains.



Indian Navy to Bolster Maritime Capabilities with Extra-Large Unmanned Underwater Vehicles | Photo: Indian Defence Research Wing (IDRW)



Titan, a high capacity multi utility combat vehicle | Photo: Gridbots

Q Where in military life would you most want to see machines take over from human beings? What are the tasks you would be glad to never assign to a soldier, sailor, or airman?

Gen. Subramani: If I had to prioritise one role for robotics and physical AI in the armed forces, it would be towards routine and dangerous tasks related to military operations. The greatest promise of autonomous systems is not that they replace soldiers, sailors, or airmen — it is that they take on routine tasks as well as protect them by taking on missions where risk to human life is disproportionately high. At the top of that list are explosive ordnance disposal, mine and IED clearance, tunnel exploration, and operations in chemical, biological, radiological, and nuclear (CBRN) environments. These are missions where even a small mistake can be fatal, yet they are increasingly well suited to intelligent robotic systems equipped with advanced sensors, manipulators, and autonomous navigation.

I would also like to see machines assume a much greater role in logistics. Autonomous ground vehicles, robotic mules, cargo drones, and unmanned maritime platforms can transport ammunition, fuel, food, and medical supplies across difficult terrain, high-altitude areas, and contested battlefields without exposing personnel to unnecessary danger. Another important application is casualty evacuation. Sending autonomous vehicles into hostile areas to recover wounded personnel would reduce risks to rescue teams while improving the chances of survival. Robots should also undertake firefighting aboard ships, damage assessment after strikes, infra-structure inspection, and hazardous engineering tasks. However, there is one responsibility I would never want machines to assume independently: the authority to decide when to use lethal force against another human being.

The purpose of military robotics should therefore be clear: replace humans in danger, not in responsibility. Every mine cleared by a robot, every supply convoy completed autonomously, and every hazardous mission performed by a machine means one less soldier, sailor, or airman placed unnecessarily in harm's way. That is where physical AI can make its greatest and most enduring contribution to military capability.

Q How should we think about balance between autonomy and human judgement in military systems? Where must a human being remain in the loop?

Gen. Subramani: The balance between autonomy and human judgment should not be viewed as a choice between humans and machines, but as a model of human-machine teaming, where each performs the task they do best. The objective is not to replace military judgment but to augment it with speed, precision, and endurance. Autonomous systems are ideally suited for tasks that are repetitive, time-critical, or hazardous. In such roles, autonomy can significantly reduce the cognitive burden on soldiers and improve operational tempo while keeping personnel out of harm's way.

However, there are decisions where human judgment must remain central. The use of lethal force, especially against human targets, requires legal accountability, ethical reasoning, and contextual understanding that extend beyond what AI can provide reliably. Decisions involving rules of engagement, proportionality, civilian protection, strategic escalation, and the employment of major weapon systems should remain under meaningful human control. Machines can recommend options and process information at unprecedented speed, but the responsibility for life-and-death decisions must rest with human commanders. There will also be situations where reaction times are measured in seconds — such as missile defence or counter-drone operations — where autonomous systems may need greater freedom to respond within clearly defined parameters. Even then, humans should establish mission objectives, operational boundaries, and rules of engagement, while retaining the ability to supervise and intervene when necessary.

For India, the emphasis should be on building trustworthy, transparent, and resilient AI that complements rather than replaces military leadership. The real revolution is not autonomous weapons acting independently, but intelligent systems that enhance the decision-making, situational awareness, and effectiveness of commanders and soldiers. Ultimately, technology should amplify human capability, not substitute human responsibility. Humans must remain in command, even as machines increasingly take on the burden of execution.



Indian Army marching alongside MULE (Multi-Utility Legged Equipment) robotic dogs | Photo: The Times of India

Q **Modern conflicts increasingly play out in environments where GPS is denied, communications are contested, and electronic warfare is constant. What does building for that environment demand from Indian technology developers?**

Gen. Subramani: For Indian technology developers, this demands a shift from designing systems that perform well in ideal conditions to building platforms that remain effective under Degraded, Disrupted, Intermittent, and Limited (DDIL) environments.

First, autonomy must be at the core of system design. Unmanned aerial, ground, and maritime platforms should be capable of completing missions with minimal human intervention when communications are disrupted. This requires robust onboard AI, edge computing, and the ability to make mission-level decisions locally rather than relying on continuous connectivity with command centers.

Second, navigation systems must become more resilient. Developers should integrate multi-sensor navigation by combining Navigation with Indian Constellation (NavIC), Inertial Navigation Systems (INS), visual odometry, terrain mapping, and sensor fusion so that platforms can continue operating accurately even in GPS-denied environments.

Third, communications must be designed for survivability. Technologies such as self-healing mesh networks, adaptive frequency hopping, anti-jamming waveforms, and secure low-probability-of-intercept communications will enable forces to maintain operational effectiveness despite electronic warfare and cyber-attacks.

Cybersecurity is equally critical. Every autonomous platform must incorporate secure-by-design principles, including encrypted communications, trusted hardware, secure software updates, and protection against AI manipulation and spoofing. Resilience against cyber threats should be treated as a combat capability rather than an afterthought. Equally important is adopting open, modular, and interoperable architectures that allow systems from different services and manufacturers to work together seamlessly. Indigenous innovation through initiatives such as iDEX, ADITI, and the Technology Development Fund (TDF) should focus on scalable, affordable, and rapidly deployable solutions rather than isolated high-end prototypes.

Ultimately, the defining requirement for Indian technology developers is not simply to build smarter autonomous systems but to build resilient ones. The future battlefield will reward platforms that can sense, decide, adapt, and accomplish missions despite denied GPS, contested communications, and persistent electronic warfare. Resilience, interoperability, and indigenous capability must therefore become the foundation of India's next generation of Defence technologies.



Man-portable Autonomous Underwater Vehicles (MP-AUVs) for naval mine countermeasure missions | Photo: DRDO

Q Institutions like Defence Cyber Agency (DCA), Defence Space Agency (DSA), and the Centre for Artificial Intelligence and Robotics (CAIR) at DRDO already exist. Is Indian institutional architecture for defence technology adequate for what is coming or does it need rethinking?

Gen. Subramani: India has made significant progress by establishing institutions such as the DCA, DSA, and the CAIR under DRDO. Along with initiatives like iDEX, ADITI, TDF, and the Defence AI Council, a strong foundation for adopting emerging technologies has been created. However, the pace of technological change suggests that the current institutional architecture must continue to evolve. Future warfare will be driven by artificial intelligence, autonomous systems, robotics, quantum technologies, cyber operations, and space-based capabilities. These technologies do not fit neatly within traditional service or organisational boundaries. They require integrated planning, rapid experimentation, and close collaboration between the armed forces, industry, startups, academia, and government agencies.

India therefore needs a more agile and mission-oriented innovation ecosystem. Procurement processes should be faster, enabling rapid prototyping, testing, and induction of new technologies. The armed forces should be closely involved in defining operational requirements and evaluating prototypes so that innovations are aligned with battlefield needs. At the same time, greater emphasis must be placed on common standards, open architecture, and interoperability to support theatre commands and joint operations.

Institutionally, India could also benefit from stronger coordination between defence technology organisations, the private sector, and civilian innovation ecosystems. Startups and MSMEs have demonstrated their ability to deliver cutting-edge solutions in AI, drones, and robotics, but they require sustained funding, easier procurement pathways, and long-term production opportunities to scale their innovations. Equally important is investing in human capital. Building expertise in AI, cyber security, data science, semiconductor technologies, and systems engineering across the armed forces and defence research organisations will be essential for maintaining technological superiority.

In essence, India's existing institutions are necessary but not sufficient for the challenges ahead. Rather than creating entirely new organisations, the priority should be to make the current ecosystem faster, more integrated, and more responsive.

Q This edition will be read by founders, researchers, and institutional heads across India's robotics ecosystems. If you could commission one capability from Indian industry, something that does not exist today, what would



Having a standardised platform for secure communications is utmost important | Photo: AI generated

Gen. Subramani: If I could commission one capability from Indian industry, it would not be a single robot or an individual autonomous platform. I would ask them to build India's Defence Robotics Stack — an open, secure, and interoperable ecosystem that becomes the common foundation for every military robotic system developed in the country. Today, India has promising startups building drones, unmanned ground vehicles, robotic manipulators, AI software, sensors, and autonomous navigation systems. However, these innovations often exist in silos. What India lacks is a common robotics architecture that allows diverse platforms to communicate, collaborate, and evolve together.

The Defence Robotics Stack would provide standardised middleware, secure communications, AI decision-making frameworks, digital twin environments, simulation tools, edge computing, and common interfaces for sensors, payloads, and command-and-control systems. Whether developed by a startup, MSME, DRDO, or a large defence manufacturer, every robotic platform should be able to plug into this ecosystem and operate seamlessly with others.

Such a stack would enable collaborative swarms of aerial, ground, and maritime robots, capable of functioning in GPS-denied, communications-contested, and electronically contested environments. It would dramatically reduce development timelines, encourage interoperability across the Army, Navy, and Air Force, and allow new capabilities to be integrated through

software upgrades rather than expensive hardware redesigns. Most importantly, this should be an open innovation platform, where Indian founders, researchers, and academic institutions can contribute. This would accelerate innovation while preventing vendor lock-in and duplication of effort. The long-term value extends far beyond defence. The same robotics stack could power disaster response, industrial automation, agriculture, healthcare, mining, and space exploration, creating a powerful dual-use technology ecosystem. India has the talent to build world-class robots. The next strategic leap is to build a platform that enables thousands of robots and thousands of innovators to work together. That would be a national capability with enduring strategic, economic, and technological impact.

Q What would you say to a young engineer or scientist in an Indian university today who wants their work to serve the country's security?

Gen. Subramani: To a young engineer or scientist in an Indian university, I would say this: national security is no longer the responsibility of soldiers alone. It is increasingly shaped by innovators, researchers, and entrepreneurs. The technologies that will define future conflicts are being developed in laboratories, startups, and university campuses as much as on military test ranges.

Build expertise in areas that matter for the future: artificial intelligence, robotics, autonomous systems, cyber security, quantum technologies, semiconductors, advanced materials, and secure communications. But remember that technical excellence alone is not enough. Spend time understanding the real operational challenges faced by the armed forces. The best defence technologies emerge when engineering is guided by battlefield realities rather than technology for its own sake.

Think beyond creating a product; aim to solve a mission-critical problem. Ask yourself: Can this reduce risk to a soldier? Can it improve situational awareness? Can it make India's forces more resilient in GPS-denied, communication-contested, and cyber-threatened environments? If the answer is yes, your work has strategic value. Equally important, embrace collaboration. India's defence innovation ecosystem now includes DRDO, the armed forces, startups, MSMEs, academia, and various initiatives. The most impactful innovations will come from multidisciplinary teams working together, not from isolated efforts.

Finally, be patient and persistent. Defence technology demands rigorous testing, reliability, and long development cycles. Success is measured not by how quickly a prototype is built, but by whether it performs when life and national security depend on it. India has the talent, ambition, and opportunity to become a global leader in deep-tech and defence innovation. For young engineers and scientists, there has never been a more meaningful time to contribute. Your research can do more than advance technology- it can strengthen India's strategic autonomy, protect its soldiers, and help secure the nation's future.

CEO, Addverb

Insights from the Startup Ecosystem

In an exclusive interaction with **Mr Rohit Gupta, Chief Technology Officer, OPSA** for Vigyan Dhara, **Mr Sangeet Kumar, Co-founder and CEO, Addverb** shared his journey and vision from an employee of Asian Paints to starting his own company in the field of robotics. He also provided a glimpse into the products of his company, views on technological advancements and the Physical AI ecosystem, surviving competition in the global market, and a message for young engineers. This section presents selected excerpts from the conversation, with the complete interview accessible through the QR code provided.

Scan to view the full interview





Q Could you describe what your company, Addverb, does in detail and its products?

Mr Kumar: Addverb started as a warehouse automation company. We started building different kinds of fixed automation products, such as Automated Storage and Retrieval System (ASRS) screens, shuttles, and other things needed in warehouses. We slowly realised that besides this, we also needed mobile robots – self-driving cars in a contained environment. We then started building robots of payload from 6 kg to 2500 kg.

Three years back, we decided to expand into other robotic forms. We built cobots (collaborative six-axis robots), quadruped, and humanoids (wheeled and legged). These products are incomplete without AI. They are not only programmed to do certain activities with increased accuracy and repeatability, but they also need to reason and take decisions. These are, then, known as generalist machines. It eventually led us to invest heavily in physical AI: model training, Vision-Language-Action (VLA) models, ways to weight parameters, data collection, enhancing robot's performance, etc.



Addverb Technologies stall at India AI Impact Summit

Q How would you describe physical AI to people who are unaware of the term?

Mr Kumar: Physical AI is any form factor of robots which isn't only programmed for certain activities. It is a generalist machine – a machine that can understand human beings, their language, and then perform tasks. Upon failure, it attempts to figure out alternative ways. Therefore, these are robots with brains, having the capability to learn by themselves. This requires a lot of data.

For large language models, data was already available on the internet and was used for training purposes. Beside language, image, or video data, you also need data on approach angle – the torque, force, and how objects should be touched – for them to carry out tasks properly. Since this data isn't available, there have been heavy investments and establishment of robotic gymkhanas where robots are trained to a particular level (say 70%) for certain activities, after which they can figure the rest 30%.

Q You and your co-founders quit Asian Paints to start Addverb. What convinced four young engineers that India needed its own physical AI or robotics company at a time when almost all industrial robots were imported?

Mr Kumar: While we were working in Asian Paints, somewhere in 2005-2006, Asian paints decided to build world's largest automated factory. That gave us an opportunity to visit several companies across the world. We also visited retail or beverages companies, which were already automated. We replicated it in India. While automating these factories we realized software added 20-30 % to the robotics or automation world and as a nation, we were already good at that. This was only expected to increase. We needed to learn some things, but for others, we already had a good core, for example, in the automative industry.

This propelled our decision to start something similar in India. I think we were at the right place, at the right time since it was 2016. The year was marked by an increased confidence in investing in the nation and taking risks. As a young company, we got an opportunity to prove ourselves when companies like Reliance, Amazon, and Flipkart became our first customers. We grew up with them, and it marked the beginning of our journey.



Kardex and Addverb partner to advance intralogistics software solutions. | Photo: Kardex



Addverb Technologies stall at India AI Impact Summit 2026 | Photo: New Indian Express



Addverb's Elixis-W: India's First Made-in-India Wheeled Humanoid Robot

Q Coming to Addverb's products, Elixis and Elixis-W, are your biggest technology bets proclaimed publicly. Can you walk us through what these can do today and how the five-finger dexterous humanoid unlocks what a conventional AMR can't?

Mr Kumar: Elixis and Elixis-W are humanoid robots – one is a wheeled version and the other is the legged version. Autonomous Mobile Robots (AMRs) and Automated Guided Vehicles (AGVs) were restricted to movements, obstacle detection, obstacle avoidance, and lifting heavy weights. Now, if the robot has to walk on the roads, in the fields, on terrains that aren't smooth, then wheel-based locomotion isn't possible. We started working on this, leading to Elixis and Elixis-W, robots that have locomotion with dual arm manipulation. Humans are dexterous, have the ability of hand-eye coordination, tactile senses, and intuition. What comes naturally to humans such as sensing and touching, doesn't come easy to humanoids.

We implemented reinforcement or supervised learning and used VLA Models for increased effectiveness with Elixis and Elixis-W. These robots are extremely good at manipulation, hand-eye coordination and locomotion in any terrain. Humanoid form factors are also special as they replicate humans. They will, eventually, affect our life, business, healthcare, and other sectors. Massive investment is happening to render robots efficient in cleaning homes, helping with daily chores, and in assistive living for people aged 80 and above. It will touch every aspect of our life and therefore, is considered a transformative technology.

Q Do you think robots are going to replace humans? Any revolutionary technology such as AI, etc. usually invokes such kind of fear. What are your thoughts on this?

Mr Kumar: At the inception of any technology, there is a fear regarding its effect and whether it will change the way of living, transportation, etc. When computers came, followed by mobile phones, AI, and now, physical AI or robots, all of this has invoked such fear. But this will make humans more productive.

In the past, we did certain kinds of work due to lack of appropriate technology. When appropriate technology becomes available, it reduces load and helps us in focusing on other things, thereby increasing productivity. It also impacts the economy positively. Certain kinds of jobs will indeed get eliminated, but this would also lead to the creation of other kinds of jobs where humans are required. Eventually, humans will do certain kinds of jobs and robots will do a certain kind.



Demonstration of human-robot teamwork

Q Nations that have aging population and very low birth rate have no other choice but to replace their workers with robots. Contrarily, India has comparatively high birth rate with a large workforce that still needs to be employed. How do you think these dynamics between productivity versus employability play out? Do you think this could be challenging?

Mr Kumar: For countries like Korea, the USA, and certain parts of Europe or Japan, it was about cost-effectiveness – reducing labor cost driven by the pandemic and physically demanding nature of warehouse work. In addition, the need for human-to-human interaction is prioritised in service, hospitality or similar sectors, whereas factory work can rely on robots. So, developed countries had different needs.

In India, infrastructure and construction will supposedly continue for the next forty years or so. Yet, construction companies are facing a labor shortage, also seen in developed countries such as Germany. This has created a scope for construction robots in both developing and developed nations. The labor scenario is likely to unfold this way.



ADDVERB Team

Q A large portion of Addverb's revenue come from outside India. What percentage of your products are exported to European versus American versus other Southeast Asian markets? What's the split and market dynamic like?

Mr Kumar: When we started this company, we started with the belief of never restricting ourselves to India. The design, manufacturing, quality, and aesthetics of the product should be on the global level. We also secured all kinds of certifications to successfully export and sell our indigenous, Indian-built designs worldwide. Four or five years down the journey, we put 100% subsidiary in Singapore to get an exposure of international market and then, expand to other Southeast Asian countries such as Thailand, Malaysia, Indonesia, Philippines, etc. During COVID, the need for automation rose drastically. We gained investment from Reliance and established 100% subsidiaries in the USA, Europe, and Australia. We have been growing rapidly since then with the revenue doubled every year.

One of our principles was to also grow the domestic market by educating customers, if needed. This was to ensure that 50% of our revenue comes from India and 50% from overseas market. We have head offices in Europe and Netherlands and branch offices in UK, Denmark, Germany, Sweden, Dubai, Saudi, Abu Dhabi, and last year, for the first time, we sold one of our projects in Africa. We are expanding rapidly and have served 25 countries with Israel being one of our important markets. We have also done several projects in Australia, New Zealand, and Singapore.

Manufacturing hiring in India's Tier-2 and Tier-3 cities is accelerating regional industrial growth. | Photo: Taggd.

Q Addverb has also developed Trakr, a highly advanced, AI-powered quadrupedal (four-legged) robot dog. It underwent some trials with the Indian army and navy. What have been the actual use cases of Trakr and how is it progressing?

Mr Kumar: We had come across a news article on how Indian defence had bought quadrupeds from an American company by spending a fortune. It made us realise that we could do this in a cost-effective manner. We wanted to do something for the nation and eventually build those quadrupeds. We started with a 5 kg payload and steadily started working with the Defence Research and Development Organisation (DRDO) and Bharat Heavy Electricals Limited (BHEL) as they understood the defence requirements better. Today we have two quadrupeds. The 5 kg payload version that we have sold mostly for research and inspection and then 25 kg payload quadruped for defence purposes, whose second version might be supplied to DRDO.



Trakr- AI powered quadrupedal robot dog

Q Being listed on IPO is one of the future destinations for you. Operationally, at what stage is a company IP ready?

Mr Kumar: We plan to become EBITDA positive this year; targeting a continuous growth in the next 5 years on all fronts –warehouse automation, factory automation, and advanced robotics. I believe that we will be able to have a sale target of 20k-30k humanoids globally for dull and dirty jobs. We are targeting factories, warehouses, industrial work, and defence sector. In the next 5 years, we are looking to expand our advanced robotics business to the same level as warehouse automation. Once we reach this milestone, I think we will be ready for IPO wherein all the stakeholders can profit.



Addverb's automated warehouse in Noida, Uttar Pradesh



Automation Solutions automating material movement within the warehouse.

Q Since the past year, a lot of startups have started receiving billion dollars plus investments at seed stage – series A, series B. What do you think has propelled that kind of investment in robotics and physical AI companies across the world?

Mr Kumar: Speed of technology development, both in hardware and AI, has been humongous. Manufacturing is important but when you don't have sufficient labor, it becomes a limitation. This can be overcome by investing in humanoids. When technology solves a problem, it no longer is a limitation. Overcoming challenges of labor and addressing strategic areas of defence and self-reliance require investment in technologies. This has led to a great deal of investments in humanoid companies, mostly in USA, Europe, and China.



Addverb's Warehouse

Q Companies like Unitree, Fourier, Agibot, etc. in China are making humanoids at an immense scale. Tesla's Optimus is also targeting $22,000 to $25,000 price range for their humanoids. How do you think an Indian humanoid company will compete against that?

Mr Kumar: Humanoids that cost around $10k-$15k are not for industrial work. They are for entertainment, education, or research purposes. When the same companies make industrial robots, the cost rises significantly and falls in the range of $70k-$90k.

The cost of the robots might reduce in the next 3 years. As we get volume, we could sell them at $25k-35k. Our industrial background gives us an advantage. In the past 10 years, as far as AGVs and AMRs are concerned, we have competed with foreign companies. We are confident that we can compete in the global market too.

Q In the last 3-4 years, India has launched a lot of successful missions such as India Semiconductor Mission (ISM) 2.0, IndiaAI Mission, among others. If India wants to design a similar mission for physical AI and robotics, what will be the four non-negotiables that you would insist upon?



Addverb's Elixis-W

Mr Kumar: I think this is the right time to have something like a physical AI mission since humanoids and robots would become the most important industry of the future. Firstly, investment is needed for humanoid companies to rise in India. There are several gymkhanas today in USA, Germany, Switzerland, or China with the government enabling robotic companies to diversify across different sectors for different tasks – whether it is agriculture, home, medical, or hospital. In robotic gymkhanas, robots are trained by human teleoperators to perform certain kinds of work. This leads to data generation that is then shared across companies. Something similar should happen in India too. We are having advanced stage conversations with two state governments to set up these robotic gymkhanas. Sovereign data from these gymkhanas could be, then, distributed among the robotic companies in India so that we don't have to individually invest money for data generation.

Secondly, we need to have entrepreneurs and companies that can target different sectors and design different forms of robots. Addverb has restricted itself to industry since it is of strategic importance to defence. Government incentives are needed for this. There needs to be an ecosystem that will support this and have rapid manufacturing facilities to help the startups or established companies to build products rapidly, make changes, iterate, and build better products.

Third, Indian companies must adopt a global mindset, viewing the entire world as their target market. For this to happen, we need certification bodies and their expertise to certify these robots for different markets. Strategic investment is crucial to maintain global parity and secure our position in future-defining technologies.



Students receive hands-on training in industrial robotics at the Addverb–NAMTECH Robotics Lab

Q What message would you leave for a young engineer in a tier-2 or tier-3 city who wants to build the next Addverb?

Mr Kumar: Firstly, you should not restrict yourself to just the field of engineering; rather, be receptive to learning across multiple disciplines. If you are an engineer, you should also learn about healthcare, biology, computational sciences, and mechanical aspects to be able to build a generalist product. The four years of college are just the base. You must keep on learning and updating yourself. Besides this, no work is too small. You must do everything and that in some way will teach you things. People who have these qualities of adaptability, agility, and curiosity will grow up, join this industry, or even end up building their own company or a new industry.



Photo: Addverb

6

The Policy Architecture Powering India's Physical AI Ecosystem



Curated and Compiled
Mr Shakun Shan
Digital Initiatives Specialist, OPSA



Photo: AI generated

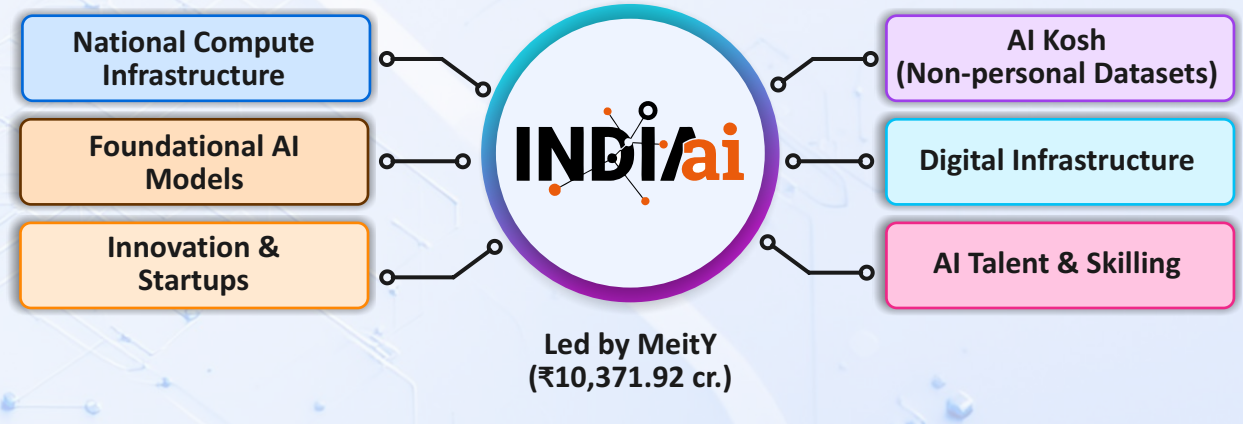
The next phase of artificial intelligence will be shaped less by what machines can produce on digital screens and more by what they can do in the physical world. As AI extends beyond software applications into autonomous vehicles, industrial robotics, intelligent infrastructure, drones and embodied systems, a new frontier, Physical AI, is beginning to take shape.

Recognising the strategic implications of this shift, India has started placing Physical AI at the centre of its next phase of industrial and technological development. Rather than treating it simply as another emerging technology, the Government of India increasingly sees Physical AI as a strategic capability that can strengthen manufacturing competitiveness, enhance national security, improve economic resilience, and reinforce technological sovereignty. The foundations of a domestic Physical AI ecosystem are being built through national missions, research programmes, digital public infrastructure, manufacturing incentives, and stronger institutional partnerships. Together, these efforts advance the vision of Viksit Bharat 2047 and reflect India's broader aspiration to evolve from a global leader in software services into a leading hub for deep-tech innovation and advanced manufacturing.

Strategic Policy Framework and Digital Infrastructure: Laying the Groundwork

India's approach to Physical AI is an interlinked policy architecture covering artificial intelligence, robotics, semiconductors, digital infrastructure, manufacturing and research.

This framework is centred around the IndiaAI Mission, which has an approved outlay of over ₹10,371.92 crore and is spearheaded by the Ministry of Electronics and Information Technology (MeitY). The mission is envisioned as the country's flagship AI programme, which collectively aims to bolster India's AI capabilities. These are setting up a federated national compute infrastructure, creating India-specific foundational AI models, enabling AI innovation and startups, and building AI Kosh, a national repository of curated, non-personal datasets that will help in AI development across sectors. These mutually reinforcing pillars help in addressing the demands of computational infrastructure, communications networks, and access to representative datasets



Computational Capacity

More than 38,000 GPUs are being made available through subsidised access, allowing startups, researchers, and academic institutions to train large-scale AI models without requiring hyperscale private infrastructure. These resources are particularly valuable for training robotics models within simulation environments such as NVIDIA Isaac Sim, enabling extensive virtual testing before deployment in real-world conditions.

High-Speed Connectivity

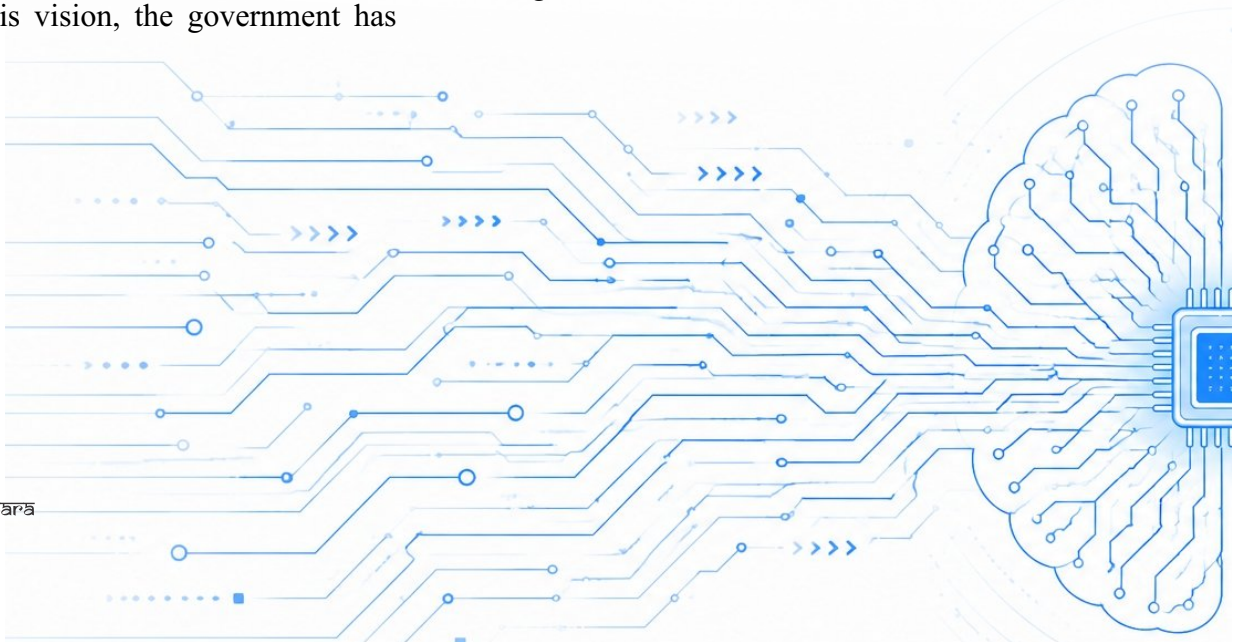
The rollout of industrial-grade private 5G network provides the ultra-low-latency communications necessary for collaborative robots, autonomous factories, connected logistics systems, and coordinated fleets of intelligent machines.

National Data Infrastructure

Through AI Kosh, the government is building curated, federated datasets that better reflect the complexity of Indian operating environments. Rather than relying solely on datasets collected overseas, these repositories capture conditions unique to India—from crowded hospitals and dense urban environments to unstructured agricultural fields. In effect, India's data becomes the training ground for India's Physical AI systems.

The National Strategy for Robotics (NSR) runs parallel to the IndiaAI Mission, and aims to make India a global hub for robotics research, design, manufacturing, and deployment by 2030. The strategy identifies manufacturing, healthcare, agriculture, and national security as priority sectors where robotics can have a transformative economic and social impact.

To realise this vision, the government has proposed the National Robotics Mission (NRM) under the guidance of MeitY through a dedicated Robotics Innovation Unit (RIU). Importantly, the strategy moves beyond conventional industrial automation toward embodied intelligence, where machines continuously learn and adapt to the environment, and build skills through interaction rather than through pre-determined programming.



इलेक्ट्रॉनिकी एवं
सूचना प्रौद्योगिकी मंत्रालय
MINISTRY OF
ELECTRONICS AND
INFORMATION TECHNOLOGY
सत्यमेव जयते



Smt. Sunita Verma
Scientist G and Group Coordinator (R&D in Electronics Division),
Ministry of Electronics and Information Technology (MeitY)

Through its R&D programmes, MeitY is supporting indigenous initiatives that demonstrate how physical AI can address real-world challenges across key sectors.

In agriculture, indigenously developed computer vision algorithms and robotic systems are enabling precision weed management in saffron fields, while AI-enabled aflatoxin detection is enhancing food quality and safety. The Autonomous Tractor Project is developing a cost-effective indigenous autonomous farming platform equipped with intelligent navigation, auto-steering, geo-fencing, and dynamic path planning to enhance farm productivity and improve resource-use efficiency. In healthcare, the Integrated Surgical Platform for Total Knee Arthroplasty (TKA), being developed as an implant-agnostic computer-assisted surgical system, is expected to significantly reduce dependence on expensive imported navigation and robotic systems. At the hardware level, under the National Supercomputing Mission (NSM), the development of indigenous RISC-V ISA-based General Purpose GPU (GP-GPU) and AI/ML accelerator technologies has been initiated. The project aims to design and develop a high-performance, energy-efficient indigenous AI accelerator chip for artificial intelligence, machine learning, and edge computing applications. This initiative will significantly strengthen India's sovereign capabilities in next-generation intelligent computing.

Together, these reflect MeitY's commitment to translating advanced research into deployable technologies with tangible societal and economic impact. By integrating Artificial Intelligence with robotics, computer vision, embedded systems, and semiconductor design, the R&D ecosystem is creating affordable, scalable solutions tailored to Indian conditions. These initiatives reaffirm that India's leadership in Physical AI will be built not only on advances in algorithms, but on the ability to integrate AI with indigenous hardware, intelligent machines, and domain-specific applications that deliver transformative impact on the ground.

Building the Hardware Backbone

While India has demonstrated considerable strength in software engineering and AI services, Physical AI demands an equally capable hardware ecosystem. Intelligent machines require specialised semiconductors, precision sensors, actuators, embedded systems, motors, batteries, and edge-computing platforms. Bridging this "embodiment gap", the disconnect between software intelligence and physical execution has therefore become a strategic priority.

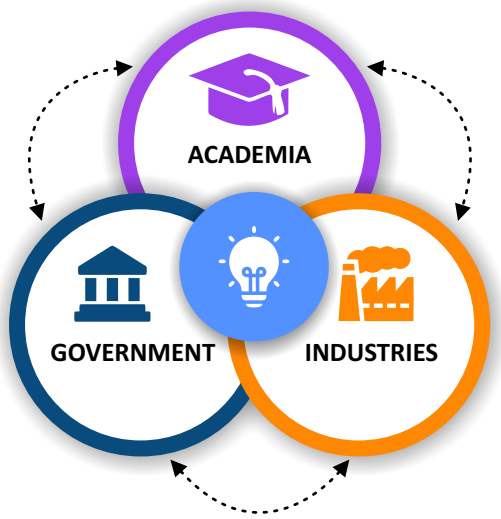
The India Semiconductor Mission (ISM) plays a central role in this transition by strengthening domestic capabilities in semiconductor manufacturing and advanced electronics. Beyond reducing import dependence, the mission seeks to establish reliable domestic production of specialised chips and sensing technologies that effectively serve as the "brains" and "eyes" of autonomous machines.

Manufacturing capacity is being reinforced through the Production Linked Incentive (PLI) Scheme, under which the Government has committed nearly US$26 billion across fourteen sectors to stimulate domestic production and global competitiveness. Within this broader framework, the Drone and Drone Components PLI Scheme adopts a value-addition-based incentive model that supports indigenous drone manufacturing while encouraging early-stage deep-tech startups.

Collectively, these initiatives aim to reduce India's dependence on imported precision components; including actuators, gearboxes, motors, sensors, and transducers that remain critical vulnerabilities for scaling domestic robotics manufacturing.

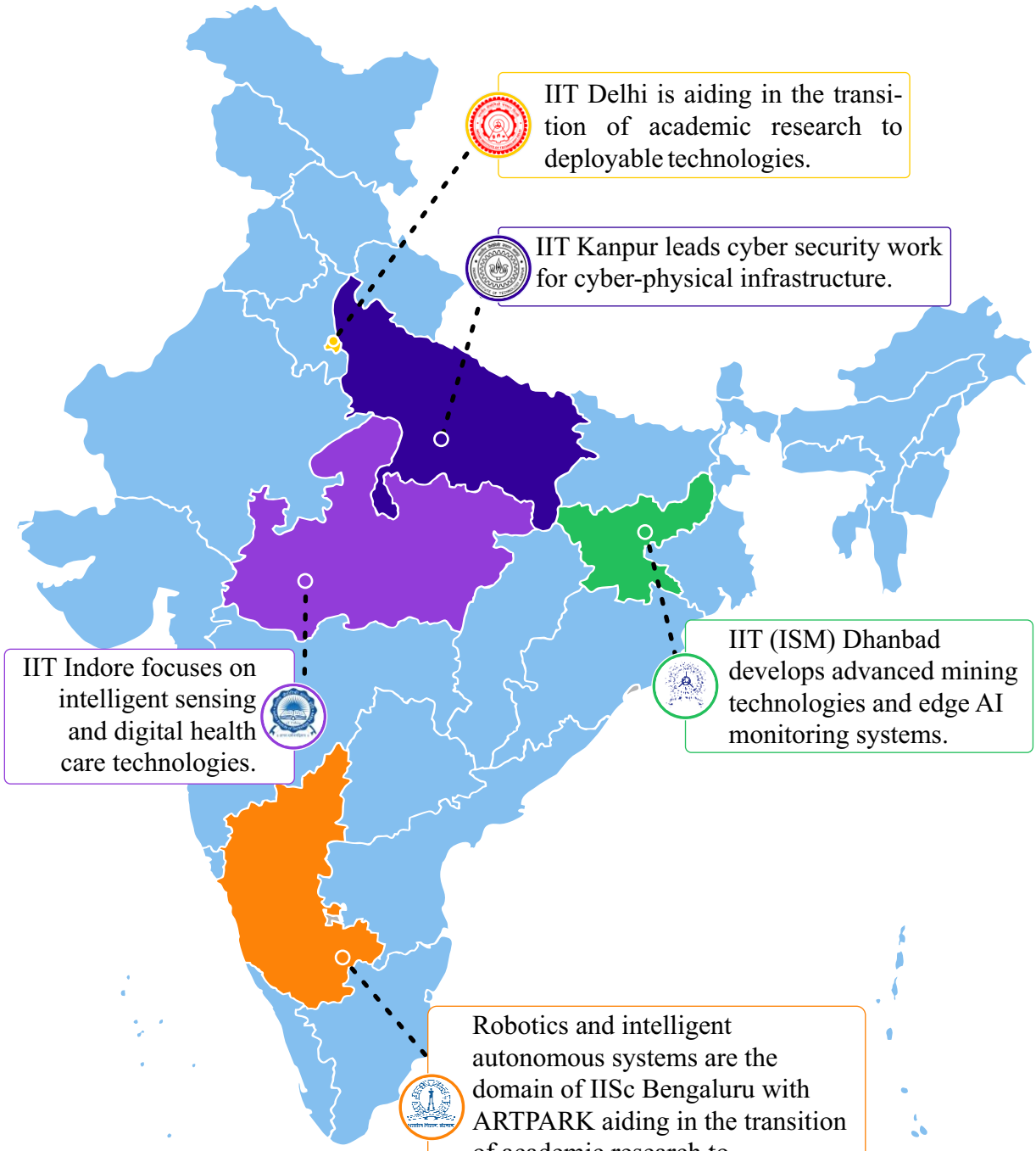
Institutional Ecosystem and Translational Research

India's Physical AI dreams are built on a collaborative innovation ecosystem that is underpinned by the “triple helix” model of government-academia-industry collaboration.



The National Mission on Interdisciplinary Cyber-Physical Systems (NM-ICPS) launched by the Department of Science and Technology (DST) with an investment of ₹3,660 crore is a foundation of this ecosystem. As part of the mission, 25 Technology Innovation Hubs (TIHs) have been set up in premier academic institutions like Indian Institutes of Technology and Indian Institute of Science for accelerating research, innovation, and technology commercialisation in cyber-physical systems.

Recognising the need to bridge the persistent gap between laboratory research and industrial deployment, four of these centres have been upgraded as Technology Translation Research Parks (TTRPs), each specialising in strategic technology domains, as depicted:



*Map is not at scale**



Dr Ekta Kapoor

Scientist - G and Head, Frontier and Futuristic Technologies (FFT) Division and National GLP Compliance Monitoring Authority (NGCMA), Department of Science & Technology (DST)

The National Mission on Interdisciplinary Cyber-Physical Systems (NM-ICPS), launched by the Government of India, is a transformative initiative aimed at building a strong ecosystem for next-generation technologies that integrate the physical and digital worlds. As India advances towards leadership in Artificial Intelligence and intelligent systems, NM-ICPS has emerged as a key enabler for innovation, research, entrepreneurship, and human resource development in areas that form the foundation of Physical AI.

Through its network of Technology Innovation Hubs (TIHs) and Technology Translation Research Parks (TTRPs) established across premier academic institutions with a pan-India presence, the Mission is fostering interdisciplinary collaboration in domains such as robotics, autonomous systems, drones, smart manufacturing, intelligent mobility, healthcare technologies, and industrial automation. These initiatives are enabling the development of AI-driven systems capable of interacting seamlessly with real-world environments.

The Mission has also contributed significantly to strengthening India's indigenous AI ecosystem by supporting startups, translational research, industry partnerships, technology deployment, and skill development initiatives. Generative AI has emerged as a strategic technology frontier with far-reaching implications for economic growth, governance, and societal development. In this context, BharatGen: A Suite of Generative AI Technologies for India represents a significant step towards developing indigenous, inclusive, and multilingual generative AI capabilities tailored to India's diverse socio-economic and linguistic landscape. Such initiatives complement the broader objectives of NM-ICPS by accelerating the convergence of Artificial Intelligence and Cyber-Physical Systems, fostering innovation and human resource development, and enabling transformative applications across sectors, including governance, healthcare, education, agriculture, and manufacturing.

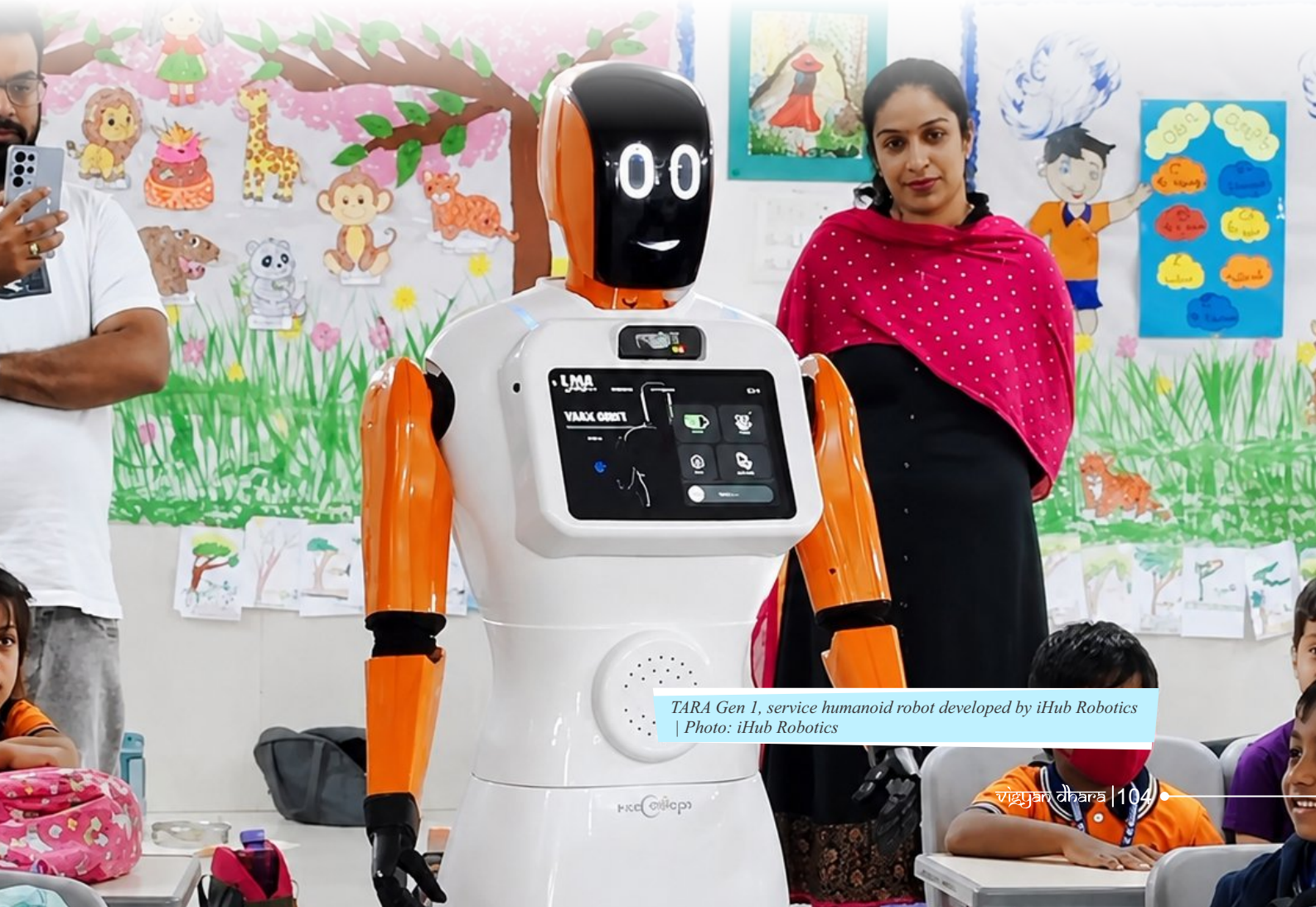
As Physical AI continues to reshape industries and public services, NM-ICPS provides a strategic framework for advancing technological self-reliance, responsible innovation, and global competitiveness, while laying the foundation for a resilient, inclusive, and future-ready innovation ecosystem aligned with the national vision of Viksit Bharat @ 2047.

Sectoral Transformation Through Physical AI

Government policies are increasingly translating into practical applications across multiple sectors of the economy. Manufacturing represents one of the most mature use cases. Supported by initiatives such as Make in India 2.0 and the Smart Cities Mission, Indian industries are moving toward Manufacturing 4.0 through collaborative robots, AI-enabled quality inspection, predictive maintenance, and digital twins that simulate entire production systems before physical implementation.

Agriculture is witnessing a similar transformation. Technology Innovation Hubs, including those at IIT Bombay and IIT Ropar, are developing intelligent monitoring, precision farming, and advisory systems powered by AI. Companies are already demonstrating the potential of Physical AI through technologies that can cut chemical use by 60–90 percent, improve productivity, and be environmentally sustainable. National security is also becoming the area of priority application. This includes innovations such as indigenous autonomous platforms like Daksha (a remote operated vehicle for bomb disposal), rail-mounted surveillance systems, and autonomous robots to bolster Anti-Infiltration Obstacle Systems.

Healthcare, mobility, and urban infrastructure are also other sectors which are witnessing the adoption of embodied AI. IIT Madras's Tactile Intelligence Initiative is on the cutting edge of haptic sensing, providing robots with a sophisticated sense of touch, essential for both delicate medical procedures and hazardous industrial environments. Regional Zero Prototype Labs and physical-digital integrated test facilities are being used to validate autonomous vehicles, and intelligent urban systems are expected to enhance traffic optimisation, waste management, and municipal service delivery.



TARA Gen 1, service humanoid robot developed by iHub Robotics | Photo: iHub Robotics



Mr Vijay Mittal
Joint Secretary,
Ministry of Heavy Industries

SAMARTH Udyog Bharat 4.0 is a flagship initiative of the Ministry of Heavy Industries (MHI) aimed at accelerating the adoption of Industry 4.0 technologies across the Indian manufacturing sector. Implemented under the Scheme for Enhancement of Competitiveness in the Indian Capital Goods Sector, the initiative aims to enhance the global competitiveness of Indian industries by promoting smart manufacturing practices, digital transformation, and advanced production technologies.

The programme focuses on creating awareness, building technical capabilities, and facilitating the implementation of Industry 4.0 solutions among manufacturing enterprises, particularly Micro, Small and Medium Enterprises (MSMEs). To achieve this objective, the Ministry has established four dedicated SAMARTH Centres that serve as national hubs for demonstration, innovation, training, and technology adoption: Smart Manufacturing Demo & Development Cell (SMDDC) at CMTI, Bengaluru; Smart Factory at IISc, Bengaluru; Common Engineering Facility Centre (CEFC) at IIT, Delhi; and Centre for Industry 4.0 (C4i4) Lab in Pune. These centres serve as demonstration and learning hubs where industries can experience and understand the practical applications of Industry 4.0 technologies such as Artificial Intelligence (AI), Industrial Internet of Things (IIoT), Robotics, Additive Manufacturing, Digital Twins, Cloud Computing, and Data Analytics. A key feature of the initiative is the development of assessment and implementation frameworks that support industries, evaluate their digital transformation, and identify suitable transformation pathways.

By fostering innovation and digital transformation, SAMARTH Udyog Bharat 4.0 supports the vision of Atmanirbhar Bharat and positions India as a competitive global manufacturing hub. The initiative has achieved several notable milestones. C4i4 established 10 experience centres under the Hub-and-Spoke model to expand the reach of Industry 4.0 technologies and accelerate digital transformation across India's manufacturing sector. More than 100 digital maturity assessments have been completed and over 500 digital champions trained in Industry 4.0. Smart Factory at IISc has developed 6 smart technologies, 5 smart tools, and 14 digital solutions in areas such as digital twins, virtual reality, robotics, inspection, sustainability, and additive manufacturing. SMDDC at CMTI has developed 15 technologies related to digital twins, automation, IoT, and Industry 4.0 that are particularly suited for MSMEs, automobile, and defence sector. IIT Delhi has developed 10 technology solutions covering automation, motion control, smart sensing, machine-to-machine communication, augmented reality, part tracking, and barcode scanning.

The centres established under SAMARTH Udyog Bharat 4.0 initiative has conducted several awareness programmes, that have reached more than 36,000 participants, including industry professionals and experts, over 21 cities in 11 states. More than 20,000 industry professionals have visited the SAMARTH Centres to experience smart manufacturing technologies.

Building Physical AI's Human Capital

India's demographic advantage can be a decisive competitive advantage only when it is backed by a workforce skilled in the technologies of the future. To ensure that, the government has aligned Skill India, FutureSkills Prime, and National Education Policy (NEP) 2020 to develop capabilities in robotics, AI, embedded systems, and automation.

Atal Tinkering Laboratories introduce school students to robotics, electronics, and innovation at an early stage. At the university level, initiatives like e-YANTRA at IIT Bombay provide hands-on experience in robotics design and embedded systems to help nurture future researchers and entrepreneurs.

The IndiaAI Mission further strengthens this talent pipeline with its efforts to reach over 50 lakh students through curriculum integration, specialised certification programmes and higher education initiatives. Besides research and engineering talent, India is emerging as a global hub for Physical AI data collection and annotation, with the market for these services projected to reach US$10 billion by 2030.



The e-Yantra team at IIT Bombay, driving robotics education and innovation through hands-on learning and outreach | Photo: e-Yantra, IIT Bombay.



Dr Monika Agarwal
Scientist F,
Anusandhan National Research Foundation

Anusandhan National Research Foundation

Anusandhan National Research Foundation (ANRF) is mandated to spearhead a new era of directed Research & Innovation in the country, translating ideas into tangible national and societal outcomes. Under its Mission for Advancement in High-Impact Areas (MAHA) program, ANRF promotes mission-mode, solution-oriented research. Under the MAHA, MAHA - Artificial Intelligence for Science & Engineering (AI-SE) and Drones: Components & Sub-Assemblies Research & Innovation have been launched.

MAHA-AI-SE, has been launched in collaboration with MeitY, DRDO, DBT, MoES (Scientific Departments), GATES Foundation, Bharat Gen, and Sarvam AI (Non-Government). AI-SE aims to embed AI as a core enabler of India's scientific and engineering ecosystem by advancing foundational AI methods, domain-specific models, and national-scale infrastructure for accelerated discovery and innovation. The initative will provide research grants of up to ₹30 Crore for 3 years (exceptionally up to ₹50 Crore), with the GPU usage charges subsumed into the overall costs of the project.

Drones: Components & Sub-Assemblies Research & Innovation (in collaboration with the ICMR and MoES) intends to address potential strategic, economic, and innovation challenges. This program aims to establish national capability in foundational drone technologies and transition India from an assembly-driven ecosystem to an innovation-driven, component-secure ecosystem. The program will catalyse collaboration between academia, national laboratories, deeptech startups, MSMEs, and industry through structured consortia comprising these entities with credible and compelling collaboration. The mission will address problem statements that span the full life cycle of drone subsystems: materials, design, integration, testing, and certification, within six thematic domains: Propulsion and Energy Systems; Smart Materials and Adaptive Airframes; Assured Navigation and Autonomy; Resilient Communications and PNT; Advanced Sensors and Payloads; and Safety, Certification, and UTM Systems. The maximum financial support from ANRF permissible for a single project shall be Rs. 50 Cr for 3 years. To ensure subsystem technologies transition into deployable drone platforms, ANRF also looks forward to involving a central Multi-Stage Integrator which will act as a multi-stage integrator for the technologies developed under the mission.

Together, the initiatives look forward to advance the next-generation AI models; accelerate AI driven discovery across strategic areas such as climate science, biomanufacturing, defence, precision agriculture; decreased reliance on imports for critical drone-related technologies; and strengthen national supply chains and domestic manufacturing capabilities.

Challenges and Policy Gaps

Despite substantial progress, important structural challenges remain. India continues to depend heavily on imported magnets, batteries, high-precision sensors, specialised semiconductors, and advanced motion-control components. Without strengthening domestic production capabilities, scaling indigenous robotics manufacturing will remain difficult.

The increasing technological readiness is offset by the high capital intensity in manufacturing robotics, which acts as a significant barrier for startups and MSMEs, thus hindering wider industrial adoption.

Another persistent challenge is the sim-to-real gap. AI models trained in carefully controlled simulation environments often struggle when deployed in India's highly variable operating conditions, where unreliable power supply, extreme temperatures, dust, and infrastructure constraints introduce complexities rarely represented in training data.

Regulatory frameworks also must keep pace with technological advances. The Digital Personal Data Protection (DPDP) Act, 2023, provides significant safeguards on personal data, but India needs robust standards, frameworks, and ethical governance mechanisms for autonomous systems that align with emerging international standards.

Finally, India faces a larger strategic challenge. As AI is becoming increasingly data-driven, the country needs to avoid being just a source of data sets for global tech companies. Long-term technological sovereignty will require not just generating data but owning the intellectual property, algorithms, hardware, and products developed from the data.

India - a Global Leader in Physical AI

Physical AI is much more than the next phase of artificial intelligence; it is the convergence of computation, robotics, advanced manufacturing, and intelligent infrastructure. In India, the policy ecosystem is increasingly being shaped by the recognition that leadership in this space will require coordinated investments in compute infrastructure, semiconductor manufacturing, digital connectivity, frontier research, industrial policy, and human capital.

The transition from traditional automation to embodied intelligence can be a force multiplier in manufacturing, agriculture, healthcare, mobility, and national security. India is slowly building up a globally competitive Physical AI ecosystem, through mission-oriented programmes, expanding research ecosystems, public-private collaboration, and sustained investments in indigenous hardware capabilities.

If these efforts continue with sustained policy support, a stronger domestic manufacturing and greater emphasis on commercialising indigenous technologies, India will be well placed not only as a global training ground for Physical AI but also as a leading destination for designing, building, deploying, and exporting the intelligent machines in the next industrial era.

The Standardisation of Robotics Sector

From Data Quality to Service Robots



Mr Vichitra Vir Singh
Scientist-D/Jt. Director
Bureau of Indian Standards



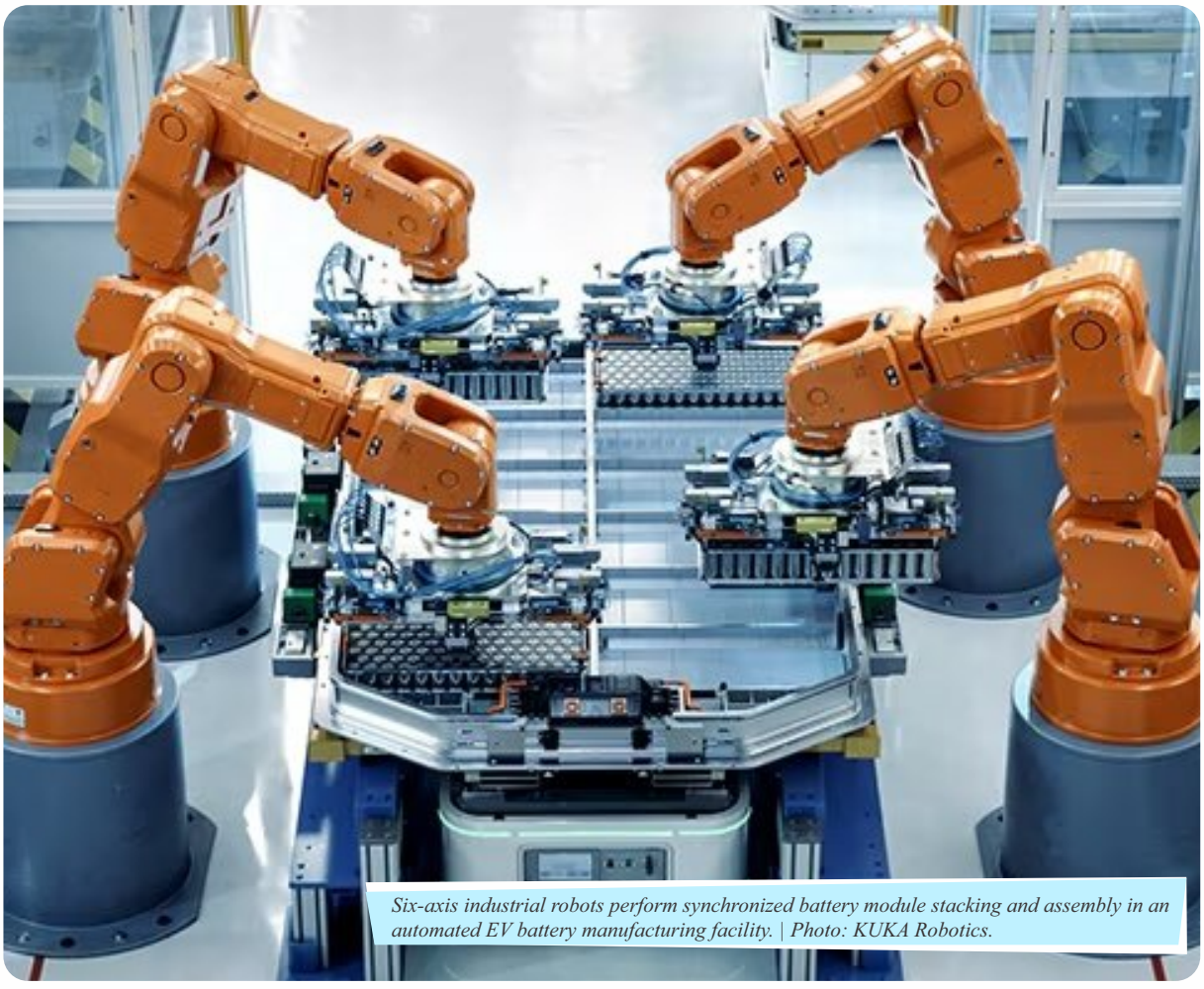
Mr Sumit Kumar
Scientist-E & Head (PGD),
Bureau of Indian Standards



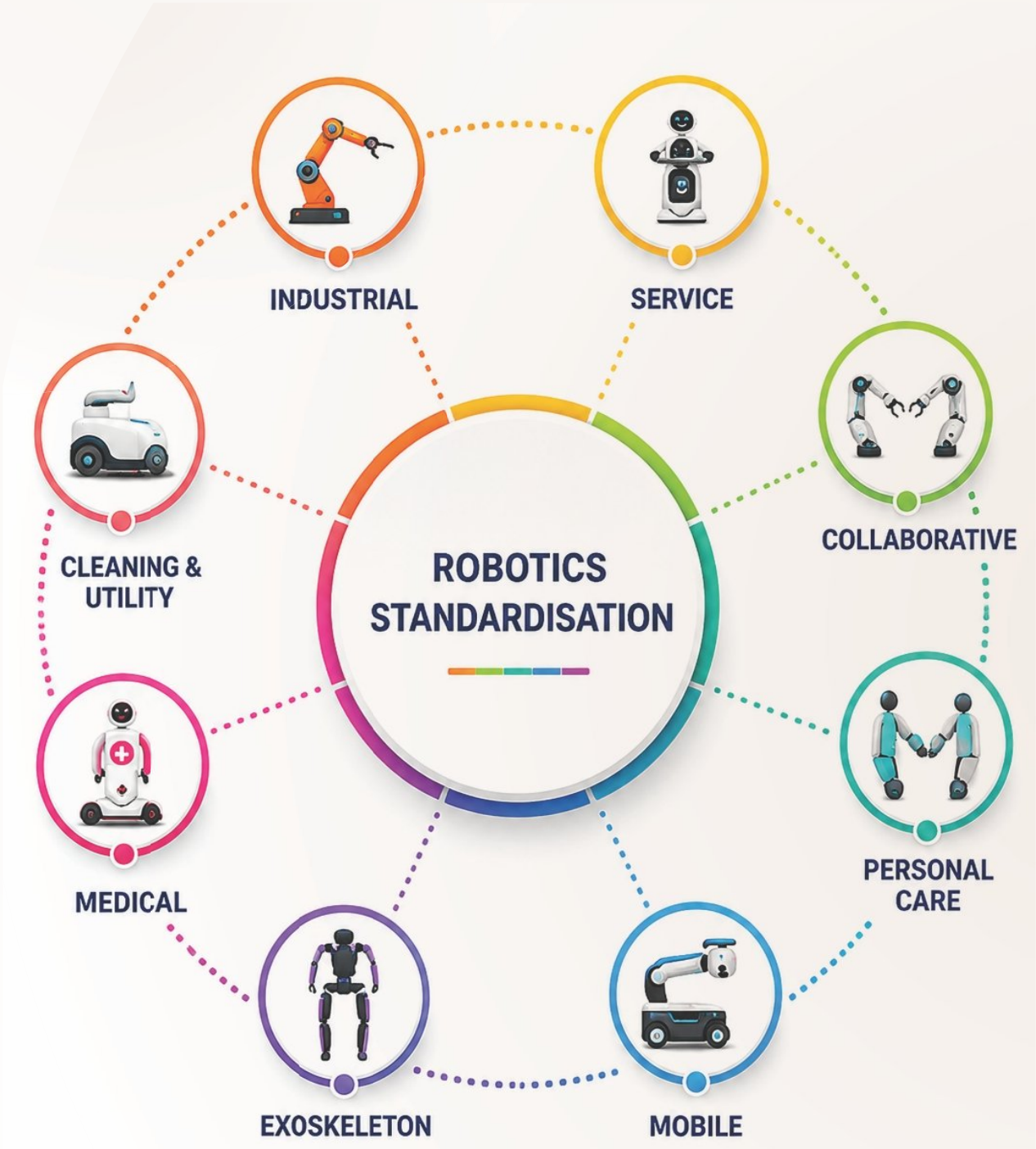
Photo: AI generated

Robotics has emerged as one of the most transformative technologies of the present era, influencing manufacturing, healthcare, logistics, infrastructure maintenance, mobility assistance, and public services. Modern robots are no longer limited to repetitive industrial tasks; they are increasingly intelligent, data-driven, connected, and capable of operating in dynamic environments alongside humans. As robotics expands into new sectors and applications, standardisation becomes essential to ensure safety, performance, interoperability, and reliability. A common technical understanding among manufacturers, users, regulators, and policymakers is also important.

Bureau of Indian Standards, through its Robotics Sectional Committee of Production and General Engineering Department (PGD 18) undertakes the responsibility for standardisation in the field of industrial automation systems and robotics, including terminology, safety requirements, performance criteria, test methods, product standards, and system standards. The committee has developed 73 standards covering key categories such as industrial robots, service robots, collaborative robots, medical robots, industrial automation systems, terminology, safety standards, and related methods of testing. This standardisation work supports safe, reliable, interoperable, and globally aligned adoption of robotics technologies in India. The following section represents the standardisation of different categories of robots in India.



Six-axis industrial robots perform synchronized battery module stacking and assembly in an automated EV battery manufacturing facility. | Photo: KUKA Robotics.


ROBOTICS STANDARDISATION
INDUSTRIAL
SERVICE
COLLABORATIVE
PERSONAL CARE
MOBILE
EXOSKELETON
MEDICAL
CLEANING & UTILITY

Categories of Robots and the Published Standards

Industrial robots

Industrial robots are primarily used in manufacturing environments for operations such as welding, assembly, pick-and-place, handling, painting, and packaging. Standards for this category focus on safety, system integration, mechanical interfaces, performance evaluation, and functional description since these robots typically operate in high-speed, high-precision, and high-risk settings. Important Indian Standards published on industrial robots includes:

IS 10218 Part 1 : 2025

"Robotics safety requirements, Part 1: Industrial robots" specifies safety requirements for industrial robots, focusing on inherently safe design, risk reduction, and user information for safe use.

IS 10218 Part 2 : 2025

"Robotics safety requirements, Part 2: Industrial robot applications and robot cells" specifies safety requirements for industrial robot applications and robot cells, covering design, integration, commissioning, operation, maintenance, and disposal of robot systems. It is aimed at reducing hazards in integrated industrial robot environments.

IS 14530 Part 1: 2019

"Safety requirements for industrial robots, Part 1: Robots" specifies safety requirements for industrial robots, covering inherent safe design, protective measures, and information for use. It helps reduce hazards during robot operations in industrial environments.

IS 14530 Part 2 : 2019

"Safety requirements for industrial robots, Part 2: Robot systems and integration" specifies safety requirements for integrating industrial robot systems and robot cells, covering design, installation, operation, maintenance, and decommissioning. It helps reduce risks in robot applications and integrated manufacturing environments.

IS 15034 : 2001

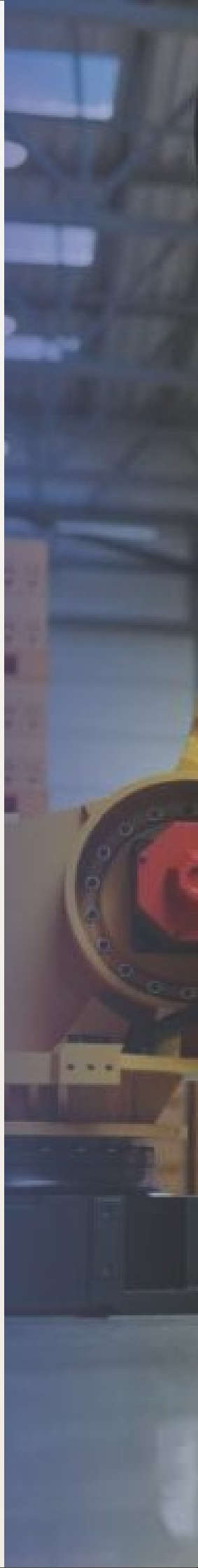
"Test equipment and metrology methods for robot performance evaluation" is an informative guide on test equipment and metrology methods used to evaluate industrial robot performance. It supports accurate, repeatable testing in line with robot performance standards.

IS 17691 (Part-1) : 2021

"Safety design for industrial robot systems, Part 1: End-effectors" provides safety guidance for the design and integration of end-effectors used in industrial robot systems. It helps ensure safe manufacturing, installation, and use of robot tool attachments.

IS 17691 (Part-2) : 2021

"Safety design for industrial robot systems, Part 2: Manual load/unload stations" provides safety guidance for manual load/unload stations in industrial robot systems, helping prevent access to hazardous zones and supporting safer, ergonomically suitable workstations.





A robotic arm and Automated Guided Vehicle (AGV) working together in an automated warehouse logistics system. | Photo: Open source image.



An AI-powered elderly care robot assists patients in a smart hospital environment. | Photo: Open Source Image.

Service Robots

Service robots perform useful tasks for humans outside conventional industrial production lines. They are used in homes, hospitals, public spaces, offices, and commercial facilities and therefore require standards that address locomotion, navigation, manipulation, functional performance, and safety in environments shared with people.

IS 17192 (Part 1) : 2019

"Performance criteria and related test methods for service robots, Part 1: Locomotion for wheeled robots" specifies methods to evaluate the locomotion performance of wheeled service robots, including movement capability, stability, and test conditions, mainly for use in indoor environments and comparable service settings.

IS 17192 (Part-2) : 2024

"Performance criteria and related test methods for service robots, Part 2: Navigation" specifies methods to evaluate navigation performance of mobile service robots, including pose accuracy, obstacle detection, obstacle avoidance, path deviation, narrow passage, and mapping accuracy.

IS 17192 (Part-3) : 2026

"Performance criteria and related test methods for service robots, Part 3: Manipulation" defines methods to evaluate service robot manipulation performance, including grasp size, grasp strength, slip resistance, and opening hinged or sliding doors.

IS 17192 (Part-4) : 2023

"Performance criteria and related test methods for service robots, Part 4: Lower-back support robots" specifies methods to evaluate lower-back support robots, covering performance, test conditions, and key indicators such as assistance and load reduction.

Collaborative robots

Collaborative robots or cobots are designed to work in direct or close interaction with humans within a shared workspace. Their standards are especially important because they address contact conditions, human-robot interaction, safe motion, and shared-task environments where conventional guarding may be reduced.

IS 17193 : 2019

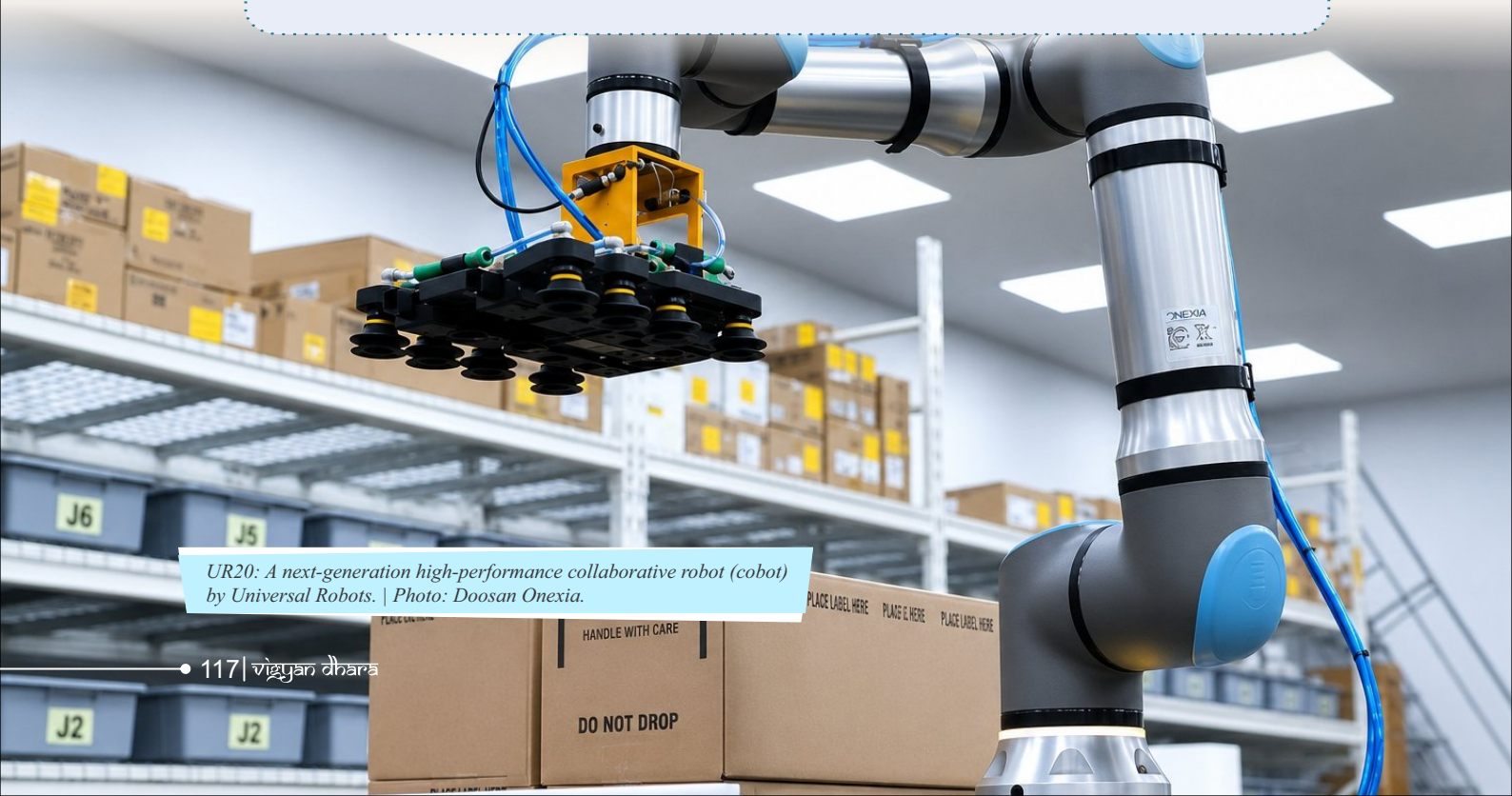
"Collaborative robots" specifies collaborative robots used in shared workspaces with humans, focusing on safe human-robot interaction, collaboration conditions, and risk reduction. It supports safer use of cobots in industrial applications.

Personal care robots

Personal care robots are intended to assist individuals in daily living, support, mobility, or personal functions. Since these robots may work very close to users, including elderly or vulnerable people, standards in this category are centered on user safety, reliability, and risk reduction.

IS 16608 : 2018

"Safety requirements for personal care robots" specifies safety requirements for personal care robots used in non-industrial settings, focusing on human-robot interaction, protective measures, and safe use. It helps reduce risk in domestic and personal assistance applications.



UR20: A next-generation high-performance collaborative robot (cobot) by Universal Robots. | Photo: Doosan Onexia.

Mobile robots

Mobile robots are robots capable of moving through their operating environment using wheels, tracks, legs, or similar systems. They are increasingly used in warehouses, hospitals, inspection systems, and autonomous service applications, which makes standardisation important for mobility, stability, navigation, and safe operation.

IS 17437 : 2020

"Mobile robots vocabulary" defines terminology for mobile robots, covering mobility, locomotion, and navigation-related concepts. It provides a common vocabulary for industrial and service mobile robot applications.



The OMRON LD-Series Autonomous Mobile Robot (AMR) navigating a smart manufacturing facility. | Photo: OMRON Industrial Automation.



Exoskeletons and wearable robots

Exoskeletons and wearable robots are human-assistive systems worn on the body to support walking, lifting, rehabilitation, or movement enhancement. These systems require standards that assess both functional performance and safe human-machine interaction because they directly affect body movement and physical support.

IS 19601 : 2026

"Robotics test methods for exoskeleton-type walking RACA robot" specifies test methods for such robots, covering performance evaluation, walking capability, and safety-related verification for medical exoskeleton applications.

GenElek's AI-enabled wearable exoskeleton supports assisted walking and personalised rehabilitation through real-time gait analysis. | Photo: GenElek.



The SSI Mantra surgical robotic system during a clinical evaluation in a hospital setting. | Photo: SS Innovations

Medical robots

Medical robots are used in surgery, rehabilitation, clinical assistance, and other healthcare-related functions. These robots demand especially rigorous standards because they operate in patient-facing, safety-critical environments where performance failure can have serious consequences.

IS 13450 (Part 4/ Section 1) : 2020

"Medical electrical equipment and medical electrical systems employing a degree of autonomy" addresses medical electrical equipment and systems with a degree of autonomy, focusing on basic safety, essential performance, and safe operation in medical environments.

Cleaning and utility robots

Cleaning and utility robots are intended for repetitive service activities such as domestic, commercial, and road cleaning. These robots are becoming increasingly relevant in smart facilities and public utility systems. Standards in this area support safety, effectiveness, energy efficiency, and reliable deployment and are under development in the following areas:

- Domestic floor cleaning robots
- Commercial floor cleaning robots
- Automated road cleaning systems



A sanitation worker operates the Bandicoot robotic system in Gujarat, India. | Photo: Genrobotics

Cross-cutting standards supporting robotics

In addition to robot-specific standards, robotics also depends on supporting standards for terminology, coordinate systems, data quality, interoperability, digital representation, and manufacturing integration. These standards provide the technical backbone that allows diverse robot systems to be designed, tested, integrated, and managed consistently across sectors.

IS 14662 : 2024

"Robotics vocabulary" provides a common vocabulary and definitions for robotics and industrial automation, ensuring clear and consistent communication across design, testing, operation, and standardisation activities.

IS 14663 : 2018

"Coordinate systems and motion nomenclatures" defines these systems and nomenclatures, including axis notations for basic robot movements. It supports accurate robot alignment, programming, and testing across industrial applications.

IS 15291 : 2024

"Automatic end-effector exchange systems vocabulary" defines terminology for automatic end-effector exchange systems used in industrial robots. It supports clear communication on functions, structures, and components of tool-changing mechanisms in robot systems.

IS 10303 (Part 1) : 2024

"Product data representation and exchange" standard gives an overview and fundamental principles for product data representation and exchange. It supports consistent product information sharing across systems throughout the product lifecycle.

The Outreach Programs for Stakeholders in Robotics

BIS has supported the growth of robotics standardisation not only through standards development but also through outreach programmes that build awareness and participation among stakeholders. These outreach efforts include seminars, webinars, and workshops that bring together industry, academia, researchers, conformity assessment bodies, and regulators to discuss emerging robotics technologies and the need for standards-based development.

One important instance of this is the national workshop on "Usage of Artificial Intelligence and Robotics: Standardization Perspective" held on 16 April 2026. The workshop examined the status of standardisation in robotics, identified gaps, and helped shape a future roadmap for Indian standards in these areas. Another important national seminar on "Standardization of Exoskeleton Robots," was held on 9 August 2024, which created a focused platform for discussing challenges, opportunities, and institutional requirements involved in standardising exoskeleton technologies. Such outreach programmes are significant because they expand awareness, encourage stakeholder collaboration, and help ensure that standards reflect practical needs and emerging technological developments.



National workshop on "Usage of Artificial Intelligence and Robotics: Standardization Perspective" held on 16 April 2026

Conclusion and Way Ahead

The present robotics standards landscape shows that standardisation has moved well beyond conventional industrial automation and now addresses a wide spectrum of applications from industrial robots and collaborative robots to service robots, exoskeletons, medical robots, and utility robots. At the same time, robotics increasingly depends on supporting standards for vocabulary, safety, data quality, digital twins, product data exchange, interoperability, and systems integration, all of which are necessary for reliable and scalable adoption.

The ongoing work further shows a strong future orientation with standards under development on domestic floor cleaning robots, commercial floor cleaning robots, automated road cleaning systems, lightweight composite materials for robots with bullet-proof capabilities, energy consumption test methods for 6-axis articulated industrial robots, exoskeleton robots vocabulary, industrial mobile robot safety, service robot locomotion for legged robots, lower-limb wearable robots, robotically assisted surgical equipment, and medical robots for rehabilitation and assistance.

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