IMC 25

ROBOTICS

A Foundational Understanding of Robotics

zamun.

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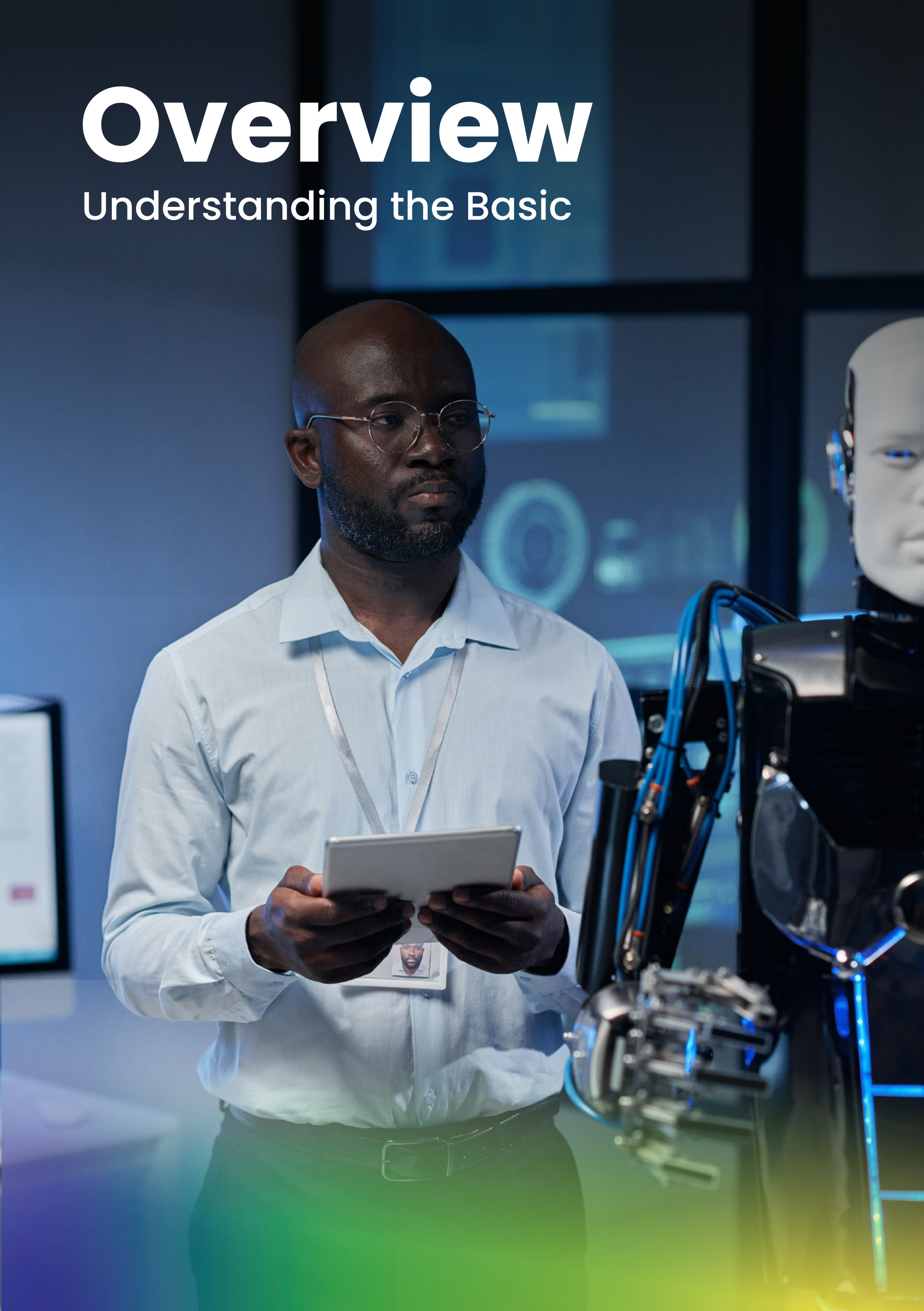
Future **Builders!**

You’re stepping into a world where machines think, learn, and evolve.
On this journey, we’ll break down the core building blocks of robotics and trace the path from early mechanical marvels to today’s age of intelligent autonomy.
We’ll dive into the 2025 Global Robotics Market from industrial giants and defense systems to healthcare bots, consumer helpers, and smart agricultural solutions.
Then, we’ll shift focus to India’s growing robotics frontier and spotlight the visionary leaders and innovators shaping what comes next.
So buckle up! because the future isn’t just happening. You’re here to build it.

Overview

Understanding the Basic



What is Robotics?

Definition and Scope

Robotics is the interdisciplinary science (Mech, Elec, CS, AI) of designing and operating autonomous machines. A robot's core components are its Mechanical Structure (physical framework/actuators), Sensors (perception via cameras/LiDAR), Controllers (microprocessors for input/output), and Software & Algorithms (the AI decision-making brain)

Categories of Robots

Category	Examples	Typical Applications
Industrial Robots	FANUC M-20iA, ABB YuMi	Welding, pick-and-place, CNC automation
Service Robots	iRobot Roomba, SoftBank's Pepper	Cleaning, retail customer interaction
Medical Robots	Da Vinci Surgical System	Minimally invasive surgery, diagnostics
Humanoid Robots	Boston Dynamics' Atlas, Tesla Optimus	Research, public interaction
Mobile Robots (AMRs)	Warehouse AGVs, drone swarms	Logistics, agriculture, surveillance

Robots are no longer confined to controlled environments. In 2025, robots interact with humans, navigate unpredictable spaces, and respond intelligently to verbal and visual cues.

Evolution of Robotics

From Mechanization to Autonomy

Understanding this trajectory contextualizes current trends and underscores The evolution of robotics has paralleled the evolution of human labor—from mechanization of repetitive tasks to intelligent assistance and now, full autonomy. the foundational innovations of the present.

01.

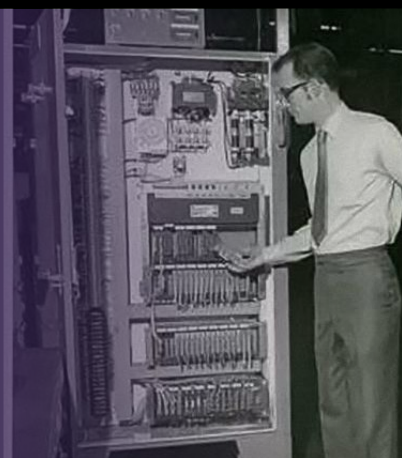
Mechanized Origins (1950s–1980s)

- 1954: The Unimate robot arm, used in GM's assembly lines, marked the inception of industrial robotics.
- 1973: KUKA develops the world's first six-axis articulated robot.

02.

Programmable Robotics (1990s–2000s)

- Rise of PLCs and flexible manufacturing systems.
- Expansion of robotics into logistics and electronics.



03.

Cognitive Robotics (2010–2020)

- Integration of vision systems, rudimentary AI, and cloud robotics.
- Introduction of collaborative robots (cobots) to work safely alongside humans.

04.

Intelligent Autonomy (2021–2025)

- Generative AI and LLMs enabling natural language interfaces.
- Robots performing open-ended tasks with multi-modal reasoning (e.g., Tesla Optimus, AI humanoid).

Segmental Breakdown

of the Global Robotics Industry

As the global robotics ecosystem evolves, it is segmenting into nuanced markets based on end use application, each defined by distinct technical, regulatory, and market dynamics.

Industrial Robotics

The most established and capital-intensive segment, serving the automotive and electronics industries. Robots are high-precision, AI-integrated manipulators. The 2025 market is projected at USD 35 Billion, with China and the USA as key markets.

Healthcare Robotics

A rapidly expanding field that includes surgical robots and rehabilitation exoskeletons. Innovations in haptics are improving patient outcomes. The 2025 market is forecasted at USD 13-15 Billion, with growth regulated by strict compliance standards (FDA/CE).

Consumer and Service Robotics

Driven by post-COVID adoption, this segment includes cleaning robots and service kiosks. Its 2025 market is over USD 23 Billion, trending toward integration with voice assistants and emotion AI.

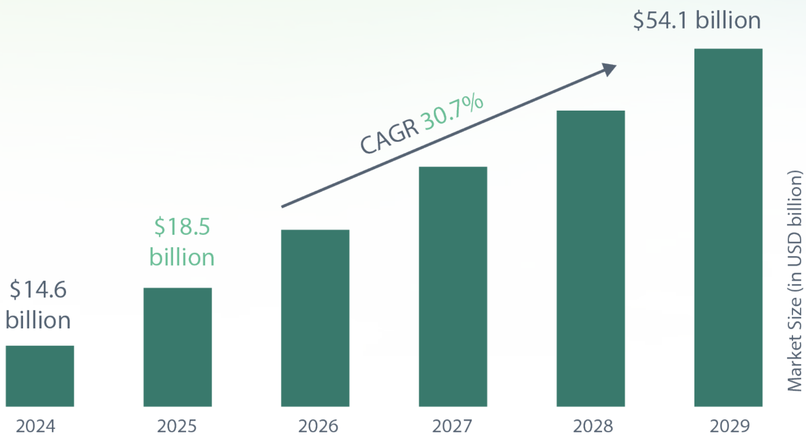
Defense & Aerospace

Focused on resilience and autonomy for reconnaissance and planetary exploration, driven by government modernization programs.

Agricultural Robotics:

Emergent systems critical for precision farming (autonomous tractors, crop drones) and environmental conservation, tied to global food security needs.

Consumer Robotics Global Market Report 2025



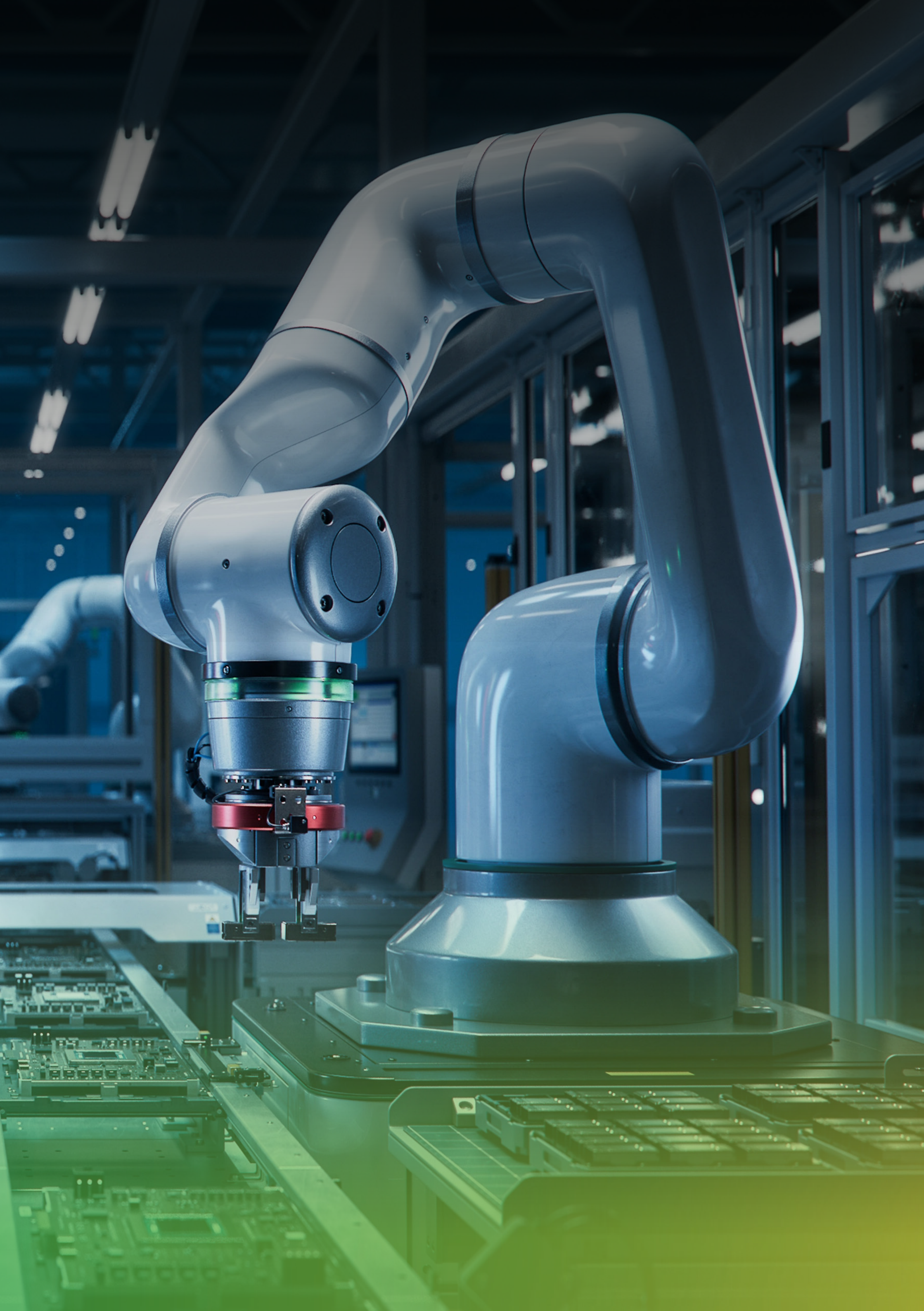
Source: researchandmarket

This chart shows the Consumer Robotics global market outlook (2024–2029), projecting rapid growth from $14.6B in 2024 to $54.17B in 2029 at a striking CAGR of 30.7%, driven by increasing adoption in households and personal applications.

Fellow innovators!

We’ve covered the Definition and Core Components of Robotics, tracing its Evolution from simple mechanization to today’s intelligent autonomy, and segmented the 2025 global market into Industrial, Healthcare, Consumer, Defense, and Agricultural applications.

Market Sizing and Trends



Robotics in 2025

A Global Snapshot

Industry Overview

Market is estimated at

$83.6 B

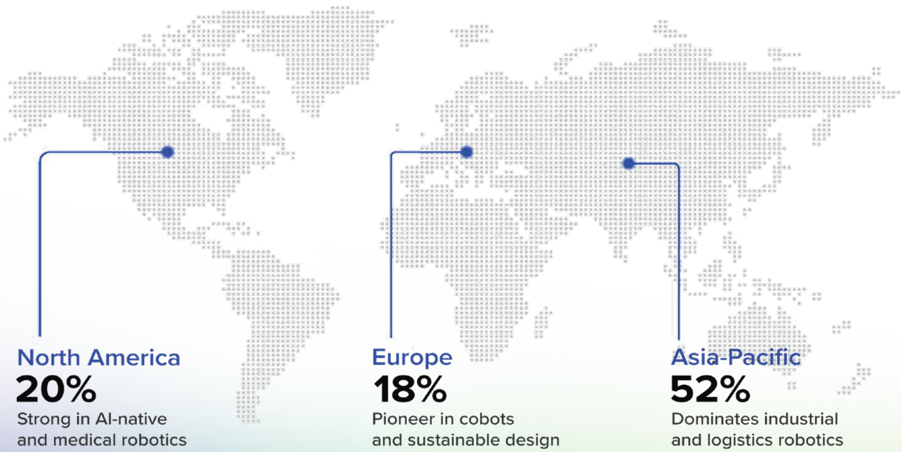
in 2025

(Sources: Statista and Market Research Future.)

Growing at approximately 12.3% CAGR since 2020.

The demand for robotics continues to surge as nations and industries prioritize automation, resilience, and digital transformation in the post-pandemic economy.

Regional Market Share



Rest of World
10%
Focused growth in agriculture and security

Key Market Drivers

Labor Shortages and Post-Pandemic Resilience

Industries facing chronic labor shortageWs—especially in logistics, manufacturing, and eldercare—are increasingly turning to robotics to sustain operations and improve productivity.

AI Integration and Intelligent Automation

Robotics in 2025 is no longer limited to repetitive mechanical tasks. With the integration of large language models (LLMs), computer vision, and edge computing, modern robots exhibit adaptive behavior and contextual awareness.

Surge in Healthcare and Service Applications

The aging population in developed countries, coupled with rising demand for minimally invasive procedures, is driving adoption of surgical and assistive robots globally.

Market Composition by Sector (2025 Projection)

Sector	Key Use Cases	Market Share (%)
Industrial	Assembly, welding, packaging	42%
Service & Consumer	Cleaning, hospitality, domestic use	28%
Healthcare	Surgical robotics, rehabilitation	16%
Defense & Space	Surveillance, UAVs, space rovers	10%
Agriculture & Others	Harvesting, livestock mana gement	4%

Regional Market Trends

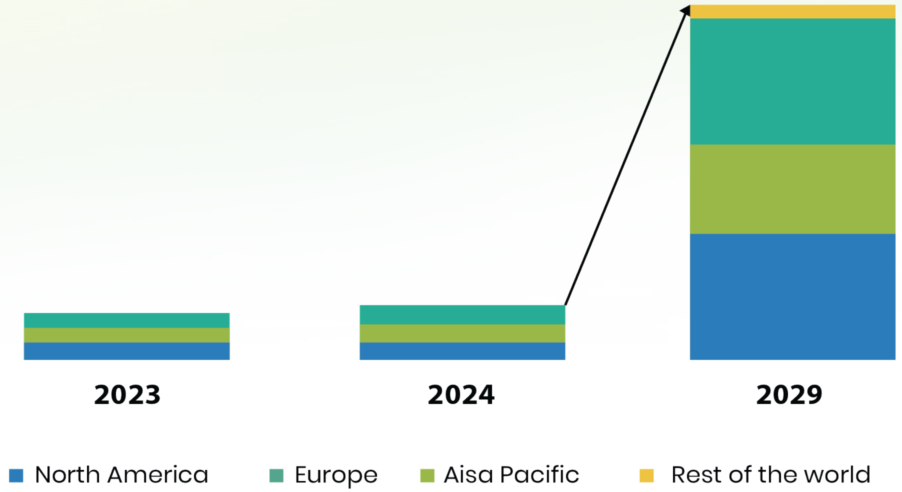
- China alone accounts for over 35% of global industrial robot installations (IFR, 2024).
- Europe's regulatory rigor has promoted development of ethical and sustainable robotic systems.
- The U.S. continues to lead in innovation, particularly in AI-integrated and humanoid systems.

HUMANOID ROBOT MARKET

Market Size, Market Dynamics & Ecosystem

CAGR, 2024-2029

45.5%

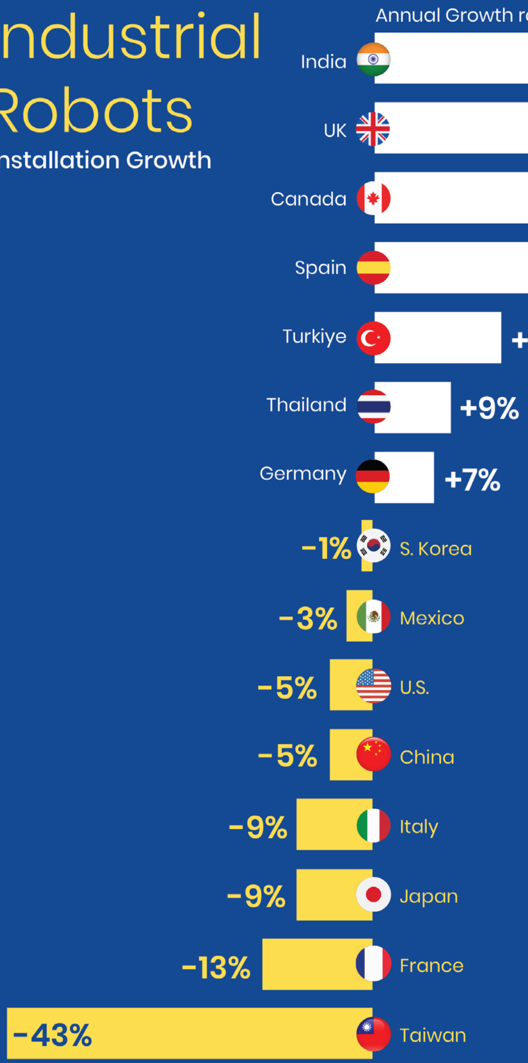


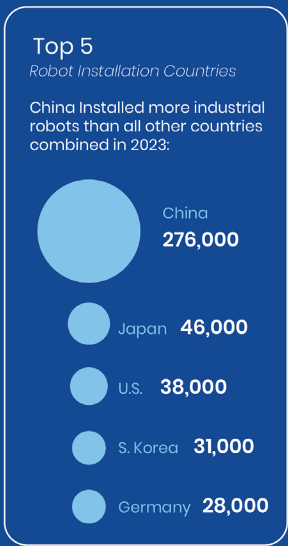
MARKET SIZE (USD BILLION)

Source: MarketsandMarkets, accessed: 21.10.2024

Industrial Robots

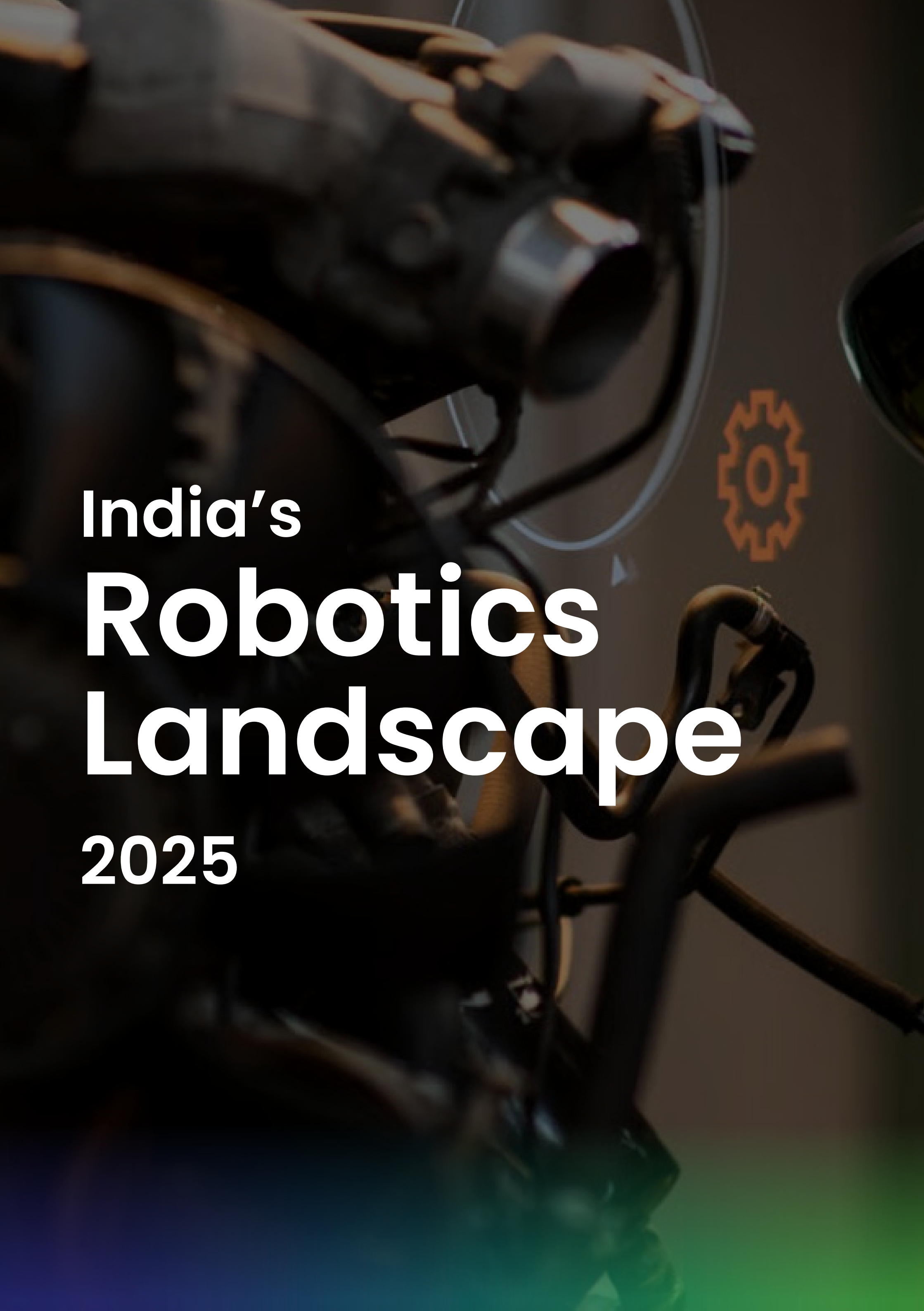
Installation Growth





Source: International Federation of Robotics, Artificial Intelligence Index Report 2025

This chart shows industrial robot installation growth in 2023, with India (+59%), the UK (+51%), and Canada (+37%) leading in growth rates, while Taiwan (-43%) and France (-13%) saw sharp declines; despite slower growth, China dominates installations with 276,000 units, exceeding the combined total of all other top countries.



India’s Robotics Landscape 2025

India's robotics industry is estimated to reach ₹6,300 crore (~$750 million) in 2025, with an expected CAGR of over 15%. While still nascent compared to global giants, the ecosystem is maturing rapidly through startup innovation, academic research, and government-backed manufacturing incentives.

Policy and Institutional Support

- PLI Schemes: Robotics-related hardware is covered under India's broader electronics PLI framework.
- SAMARTH Udyog Bharat 4.0: Focused on modernizing MSMEs using automation and robotics.
- AI Strategy (NITI Aayog): Promotes AI and robotics in agriculture, healthcare, and governance.

Key Domestic Players

Startup	Focus Area
Asimov Robotics	Education and service robots
Addverb Technologies	Warehouse automation, AGVs (now under Reliance)
Sastra Robotics	Industrial testing and QA bots
CynLr	Object manipulation and visual AI
Gridbots	Defense robotics, nuclear inspection

Academic and Skilling Ecosystem

IIT Madras: Hosts the Centre for Innovation in Robotics and Automation (CIRA).
IISc Bangalore & IIT Bombay: Leading research in soft robotics, prosthetics, and AI planning.
T-Works, Hyderabad: Hardware incubator supporting robotics startups.
ATL Labs + AICTE Curriculum: Robotics now formally included in secondary and engineering education. on the basics,

Profitability and Value Chains

The 2025 robotics value chain is a complex structure involving three tiers critical for understanding profitability and strategic advantage.

Upstream (Components)

Suppliers of hardware (sensors, actuators, semiconductors) face modest margins due to competition, though their innovations are crucial.

Midstream (Integrators/OEMs)

Companies like FANUC and ABB integrate hardware, software, and AI. This tier commands the highest gross margins (35–55%) via brand and IP.

Downstream (Services)

Deployment, maintenance, and software licensing form lucrative, recurring revenue streams under the Robotics-as-a-Service (RaaS) model.

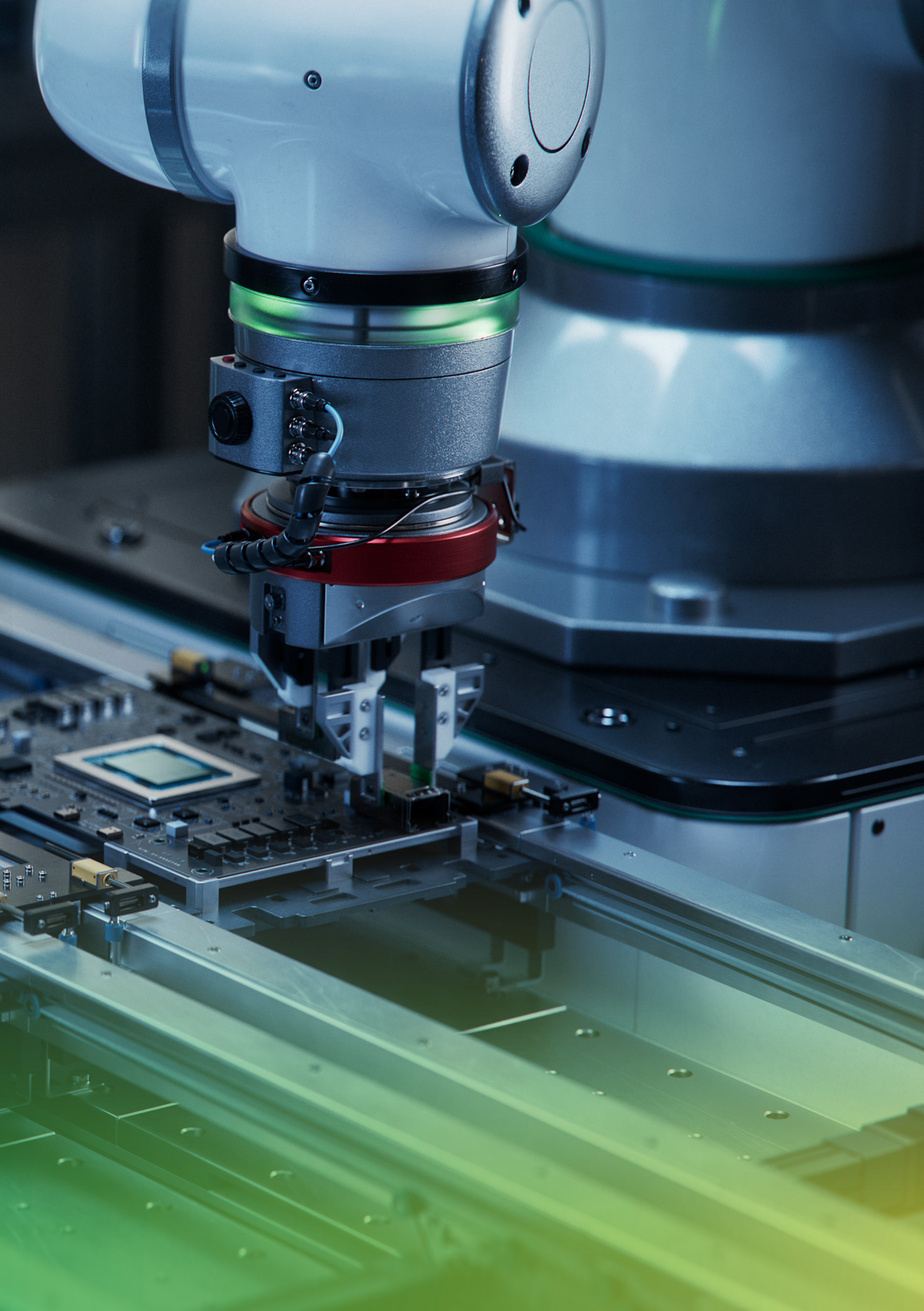
Emerging Profit Pools

- **AI and Analytics:** Selling analytics platforms that optimize robot fleet performance
- **Simulation and Digital Twins**: Licensing of environments like NVIDIA Isaac Sim or Unity Robotics Hub
- **Domain-Specific Solutions**: Turnkey systems tailored for healthcare, mining, or hospitality

Hi Peeps! Till now we’ve covered the Global Robotics Market Sizing (currently USD 83.6 Billion), its key Drivers (labor shortages and AI integration), and its Composition by sector. We then explored India’s Robotics Landscape and finally detailed the Profitability and Value Chains from component suppliers to RaaS models.

But who are the real value builders? Guess, we’ll have to find it out ourselves.

Key Players and Leaders



Global Market Leaders

2025

The robotics landscape in 2025 is shaped by a mix of industrial automation giants, AI-centric startups, and medical device pioneers.

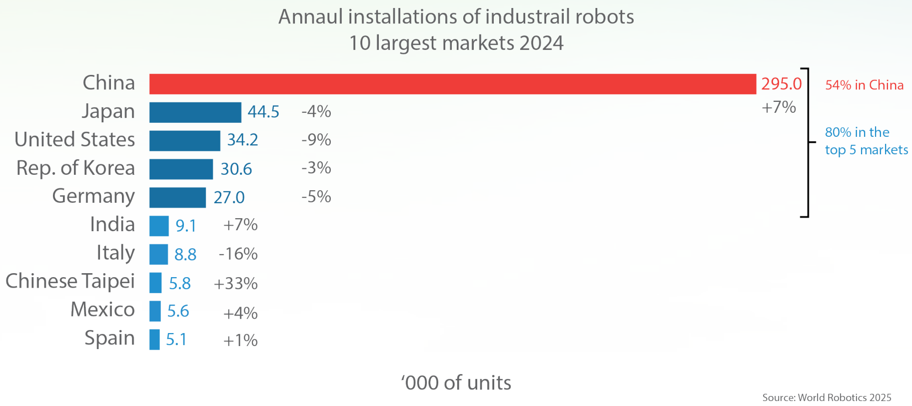
Company	Country	Specialization
Boston Dynamics	USA	Advanced mobility, humanoid robots (Atlas)
ABB Robotics	Switzerland	Collaborative industrial robots (YuMi)
FANUC Corporation	Japan	CNC and factory automation systems
KUKA AG	Germany	Automotive and precision manufacturing
iRobot Corporation	USA	Home robotics (vacuuming, mopping)
Intuitive Surgical	USA	Medical robotics (Da Vinci system)

Promising Emerging Players

- **Agility Robotics (USA):** Specializes in bipedal bots for logistics.
- **Figure AI (USA):** Integrating LLMs with humanoid robotics.
- **Unitree Robotics (China):** Affordable quadruped bots for research and surveillance.

Regional Strengths

- **Japan:** Robotics innovation leader in industrial and service applications.
- **Germany:** Dominates in high-precision manufacturing robots.
- **USA:** Focused on AI-native robotics and medical tech.
- China: Rapid expansion in warehouse robotics and domestic automation.



Influential People

in the Robotics Industry

The trajectory of Artificial Intelligence has been significantly shaped by a handful of visionaries, scientists, and policy leaders who have expanded both the technical boundaries and the societal imagination of what AI can be.

Daniela Rus

Director of MIT's (CSAIL)

Computer Science and Artificial Intelligence Laboratory

A leader in soft robotics and autonomous mobility. Her work integrates artificial intelligence with novel materials to develop robots that are safer, more adaptable, and capable of functioning in complex environments. Rus's research focuses on creating machines that can work alongside humans seamlessly, in applications ranging from healthcare to urban transport.

Marc Raibert

Founder of Boston Dynamics

A trailblazer in the development of high-mobility robots. He is best known for pioneering work in dynamic legged locomotion, particularly bipedal and quadrupedal movement. His groundbreaking robots—such as BigDog, Spot, and Atlas—have pushed the boundaries of balance, agility, and coordination in robotics, mimicking animal and human motion with remarkable realism.

Angela Schoellig

Affiliated with both ETH Zurich and the University of Toronto

She is known for her research in AI-driven robotics with a focus on safety and human-robot interaction. Her contributions lie in developing learning algorithms that allow robots to operate reliably in dynamic, uncertain environments. By integrating real-time perception and control, her work advances the field of robotics in areas such as autonomous drones, service robots, and collaborative automation.

Tech Influencers and Celebrity Voices

Elon Musk

Co-founder/CEO of Tesla and xAI

He positions “Tesla as an AI robotics company,” focused on the Optimus humanoid robot. He is a primary advocate for robotic autonomy in the consumer sphere, although he also cautions on the societal risks of proliferation.

Brett Adcock

Founder of Figure AI

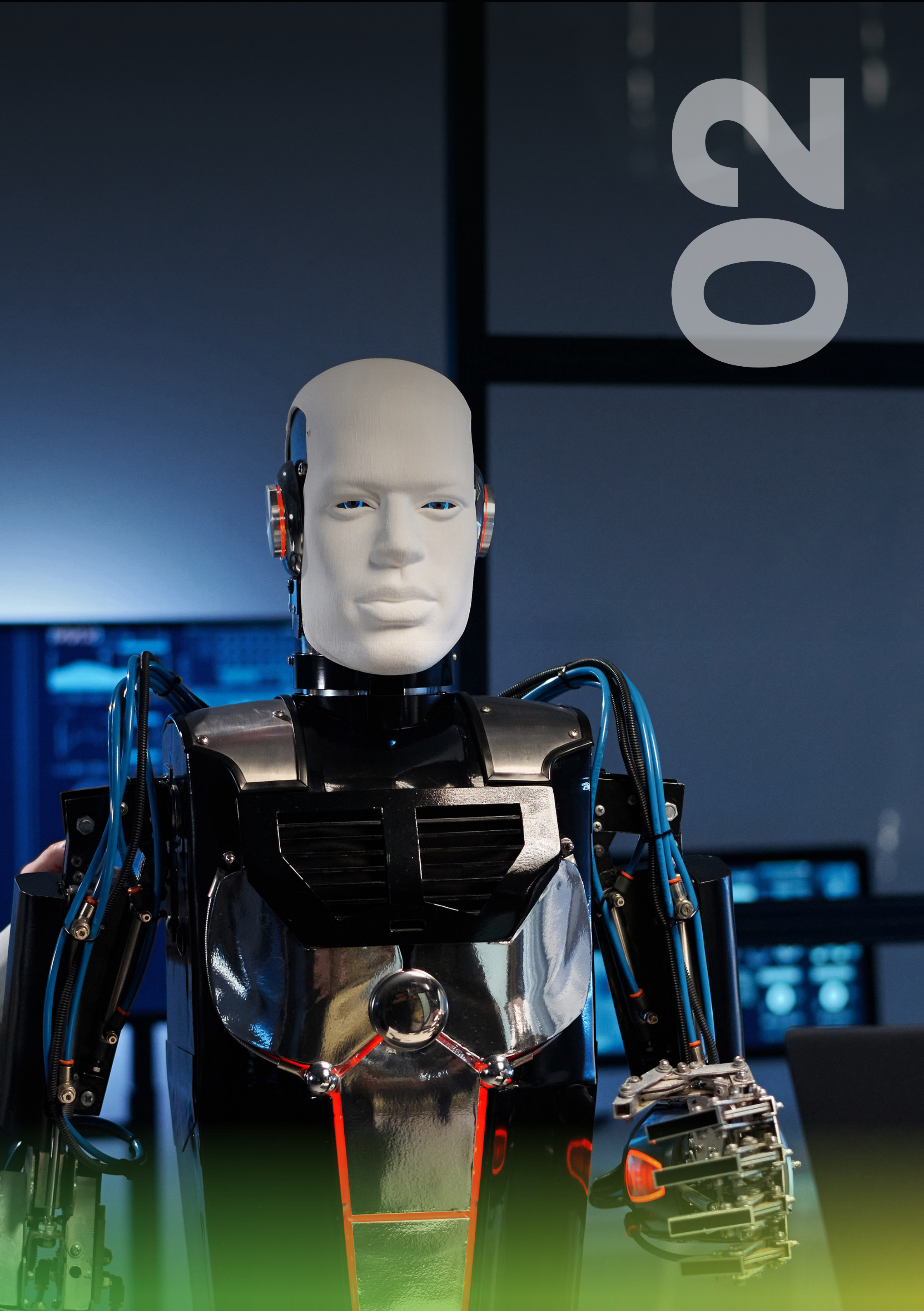
He has successfully focused on building humanoid robots for industrial logistics. His vision is that humanoid robots will soon be “as common as humans,” capable of scalable industrial autonomy.

Anima Anand Kumar

Caltech Professor and former NVIDIA ML lead

he advances the field through foundational AI research. Her work on interactive in-context learning is critical, enabling robots to generate code and execute complex real-world tasks.

Insights and Thought Leadership


02

Latest Technology Trends

Smart Automation

Smart factories represent the intersection of robotics, IoT, cyber-physical systems, and data analytics—collectively enabling real-time responsiveness, modular production, and predictive control.

Role of Robotics in Smart Manufacturing

- Autonomous Mobile Robots (AMRs) streamline intra-factory logistics.
- Robotic vision systems carry out 100% quality checks at higher throughput than human inspectors.
- AI-optimized cobots reduce downtime via predictive error correction and automated tool calibration.

Implementation in India

- India's Smart Factory Automation market reached ₹27,400 crore ($3.3B) in 2024.
- Leading adopters: Mahindra (automotive), Titan (precision manufacturing), Reliance (warehouse logistics)

Role of Robotics in Smart Manufacturing

- 30% reduction in production downtime
- 18–22% improvement in material handling efficiency
- Energy cost reduction through intelligent load balancing

Sustainability in Robotics

Sustainability is no longer an afterthought—it is an engineering constraint and policy requirement. From materials sourcing to operational efficiency, robotics manufacturers are investing in environmentally responsible innovation.

Green Materials and Manufacturing

- Use of recyclable polymers, low-carbon alloys, and biodegradable substrates in robot design
- Modular designs that enable disassembly and end-of-life material recovery

Energy Efficiency and Lifecycle Optimization

- Solar-assisted robotic systems in agriculture
- AI-enabled idle-time management to reduce unnecessary energy consumption
- Lifecycle assessments using LCA/ISO 14040 standards

Deployment in Sustainability-Critical Domains

- Coastal cleanup robots using autonomous navigation and waste categorization
- Forest surveillance drones for biodiversity monitoring
- Micro-robots for pollution detection in water bodies

Supply Chain Robotics

The COVID-19 pandemic and subsequent geopolitical shifts revealed profound vulnerabilities in global supply chains. In response, robotics is now central to reshaping the logistics and distribution landscape with automation-first strategies.

Warehouse and Fulfilment Automation

- Robotics has drastically reduced dependency on manual picking and packing.
- Autonomous Mobile Robots (AMRs), such as those developed by GreyOrange and Locus Robotics, dynamically navigate warehouses using real-time routing algorithms.
- Robotic sorting systems increase throughput by over 3× in high-demand nodes such as Amazon's fulfillment centres.

Port and Yard Automation

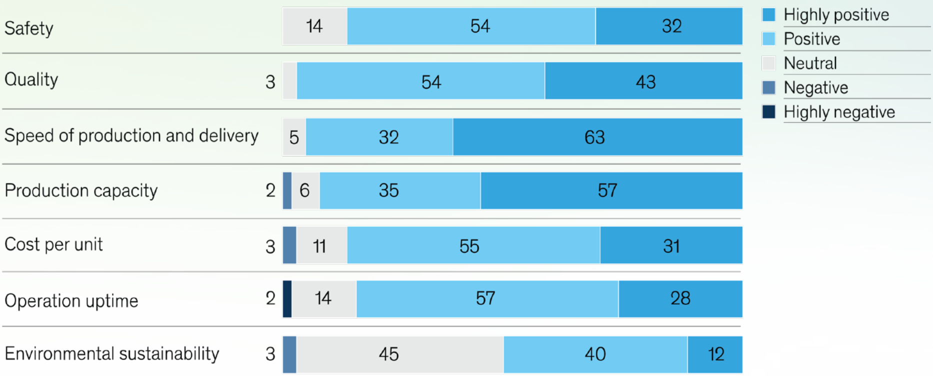
- Ports in Rotterdam and Shanghai now use container-moving robots and AI dispatch systems to optimize berth utilization and reduce dock time.
- Inventory and Risk Management
- AI-enabled robots provide real-time inventory visibility with predictive restocking.
- Robotics supports the implementation of "dark warehouses" that operate 24/7 with no human presence, maximizing uptime and order accuracy.

Reverse Logistics and Circularity

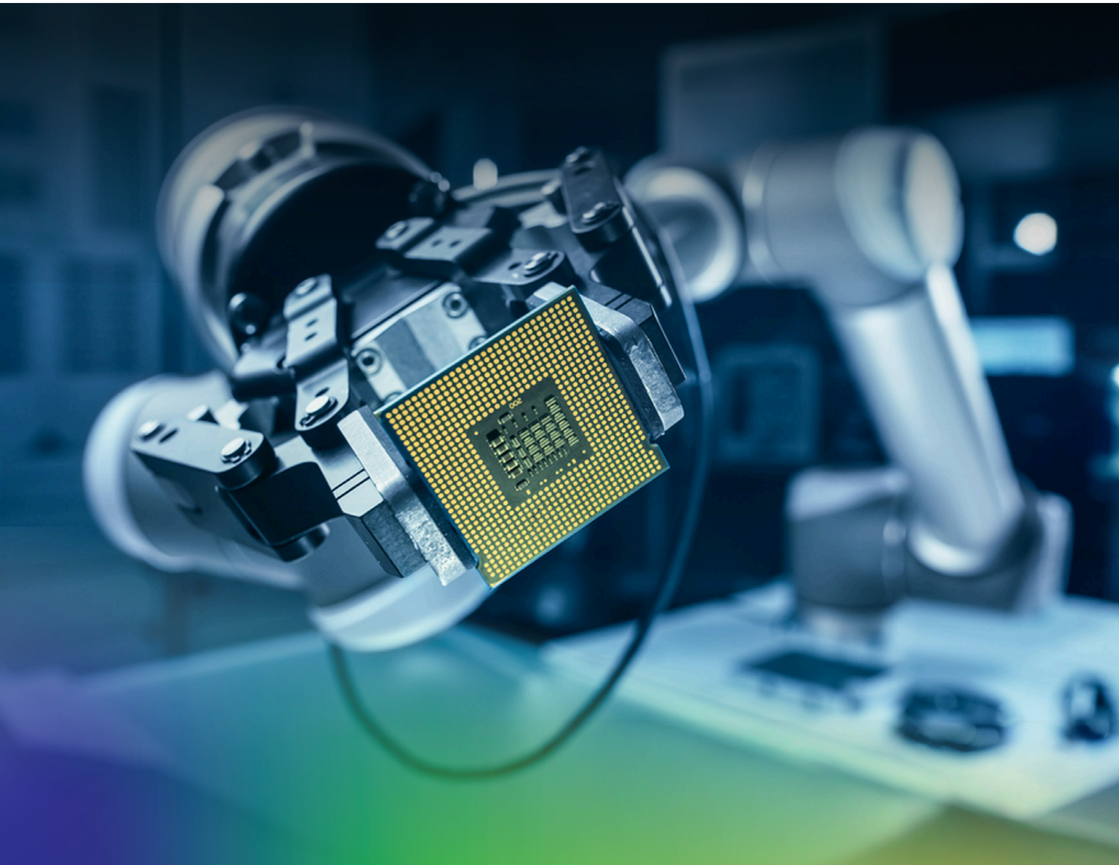
- Robotics aids in automated sorting of returns, product disassembly for refurbishing, and intelligent waste handling—especially for electronics and apparel.

Automation will have a positive impact on speed, safety, quality, and capacity.

Impact of automation, by type, % of respondents



Source: McKinsey Global Industrial Robotics Survey, 65 senior leaders and executives in automotive; food and beverage; life sciences, healthcare, and pharmaceuticals; logistics and fulfillment; and retail and consumer goods sectors, August 2022



Structural Challenges

Despite its promise, robotics in 2025 faces considerable hurdles—both technical and socio-economic. Recognizing and addressing these challenges is crucial to building a sustainable, inclusive future for automation.

High Capital Costs and Deployment Barriers

- SMEs often face prohibitively high entry costs for industrial robotic systems.
- Customization costs, floor reconfiguration, and long integration timelines are barriers to adoption, especially in traditional sectors like textiles and ceramics.

Technological Bottlenecks

- Power autonomy remains a limitation; mobile robots still require frequent charging or battery swaps.
- Real-time edge AI is limited by current chip efficiency and heat dissipation issues.

Ethical and Legal Grey Areas

- Accountability in autonomous decisions, particularly in surgical or defense applications, remains under-regulated.
- Risk of bias amplification, especially in AI-driven hiring or security bots.
- Workforce Resistance and Perception
- In regions where robotics is linked to job losses, unions and workers have resisted deployments, even when long-term upskilling is proposed.

Mitigation Strategies

To address the barriers identified, industry leaders, policymakers, and academia are increasingly collaborating to implement multifaceted strategies that ensure robotics growth is resilient, ethical, and broadly beneficial.

Democratization of Robotics

- Open-source platforms like ROS2 and open-hardware kits are lowering entry barriers.
- Collaborative ecosystems (e.g., NVIDIA Isaac ROS, Unity Robotics Hub) provide plug-and-play environments for prototyping.
- Policy & Incentive Realignment
- Governments offering depreciation benefits, grants, and import duty relief to encourage robot adoption.
- Dedicated robotics innovation hubs (e.g., India's T-Works, Singapore's A*STAR) provide capital infrastructure for pilot trials.

Industry-Led Skill Acceleration

- Companies like Siemens, ABB, and FANUC offer workforce training bootcamps in partnership with universities and trade schools.
- Certification ladders (e.g., UR Academy for cobot programming) are being scaled globally.

Trust and Ethics Frameworks

- IEEE and ISO now working on robotic ethics design standards.
- Emerging field of Responsible Robotics blends legal, ethical, and technical protocols.

Breakthrough Innovations

Humanoids with Generative AI

- In 2024, Figure AI partnered with OpenAI to embed language models into humanoid robots, allowing contextual conversation and task delegation through natural language.
- Tesla's Optimus Gen-2 displayed real-time walking, object recognition, and manipulation during CES 2025, signaling the feasibility of general-purpose humanoids.

AI-Driven Predictive Maintenance

Companies like ABB have embedded AI in industrial robots for real-time performance analytics, predicting breakdowns with over 90% accuracy, thereby reducing downtime and maintenance costs.

Soft Robotics and Bio-Inspired Design

Inspired by animal and human biomechanics, labs at MIT and ETH Zurich have pioneered soft robots for medical and agricultural applications. These robots offer safer, more flexible interactions with delicate environments.

Green and Sustainable Robotics

Lightweight exoskeletons made with recycled polymers and biodegradable parts have been deployed in pilot programs across Europe, improving both ergonomics and sustainability.

Powering Robotics

Artificial Intelligence and Machine Learning

AI enables adaptive learning and autonomous decision-making. Robots now interpret speech, recognize faces, detect defects, and optimize movements dynamically.

Computer Vision & Sensor Fusion

High-resolution cameras, LiDAR, and haptic sensors provide rich environmental data. Sensor fusion enhances depth perception and movement in unstructured environments.

Edge CXomputing & Real-Time Control

Edge processors allow faster decision-making at the device level, improving safety and performance in high-stakes applications like surgery or autonomous vehicles.

SLAM (Simultaneous Localization and Mapping)

SLAM algorithms enable robots to construct maps and navigate unknown environments, forming the basis of mobile robotics and indoor drones.

Tactile Intelligence & Haptics

Robots with tactile sensors can grip fragile items (like eggs or surgical tissues) with human-like finesse, improving applicability in delicate fields.

Emerging Platforms

- NVIDIA Isaac Sim: Digital twin simulation for robotic training and validation.
- ROS2 (Robot Operating System): The de facto standard for open-source robot development.

Watchlist 2030 Forecasts

What to watch over the next 5 years

Neuro-Robotics

Integration of bio-neural interfaces for prosthetics and cognitive enhancement.

Swarm and Modular Robotics

Collaborative fleets with self-organizing behavior, especially in agriculture, mining, and logistics.

Soft, Deformable Robots

Medical-grade, human–environment-safe materials for interaction zones.

Micro Robotics

Robotics at micro scale for medical, environmental, and embedded industrial tasks.

Ethical & Governance Models

Global standardization in robotic responsibility, redress frameworks, and insurer liability.

Robotics-as-a-Service (RaaS)

Subscription-based deployment models covering supply, maintenance, upgrade, and analytics.

National Robotics Champions

Domestic systems integrating semiconductor chain, advanced materials, and IP creation

Expected Impact

Robotics is projected to add an additional $50–70 billion to India's GDP by 2030, through automation-led industry transformation, employment creation, and export potential.

Annual installations of industrial robots - India

Source: World Robotics 2024


WARNING
PRESSURE

People, till now we've covered Smart Factories and Automation, emphasizing robotics' role in logistics and quality checks. We then looked at Sustainability in Robotics Design, how robotics ensures Supply Chain Resilience, and explored the key Challenges and Breakthrough Innovations driving the field forward.

So, what happens when this tech interacts with other technologies. Let us dive in to look at those wonders.

Interactions with Other Tech

Electronics Manufacturing Services and Robotics

The convergence of robotics and the EMS sector has transformed contract manufacturing from a labor-intensive process into a highly automated, intelligent value chain. Robotics enables EMS firms to meet increasing demands for precision, agility, and scalability, especially in the production of high-density electronics.

Evolution of EMS with Robotics

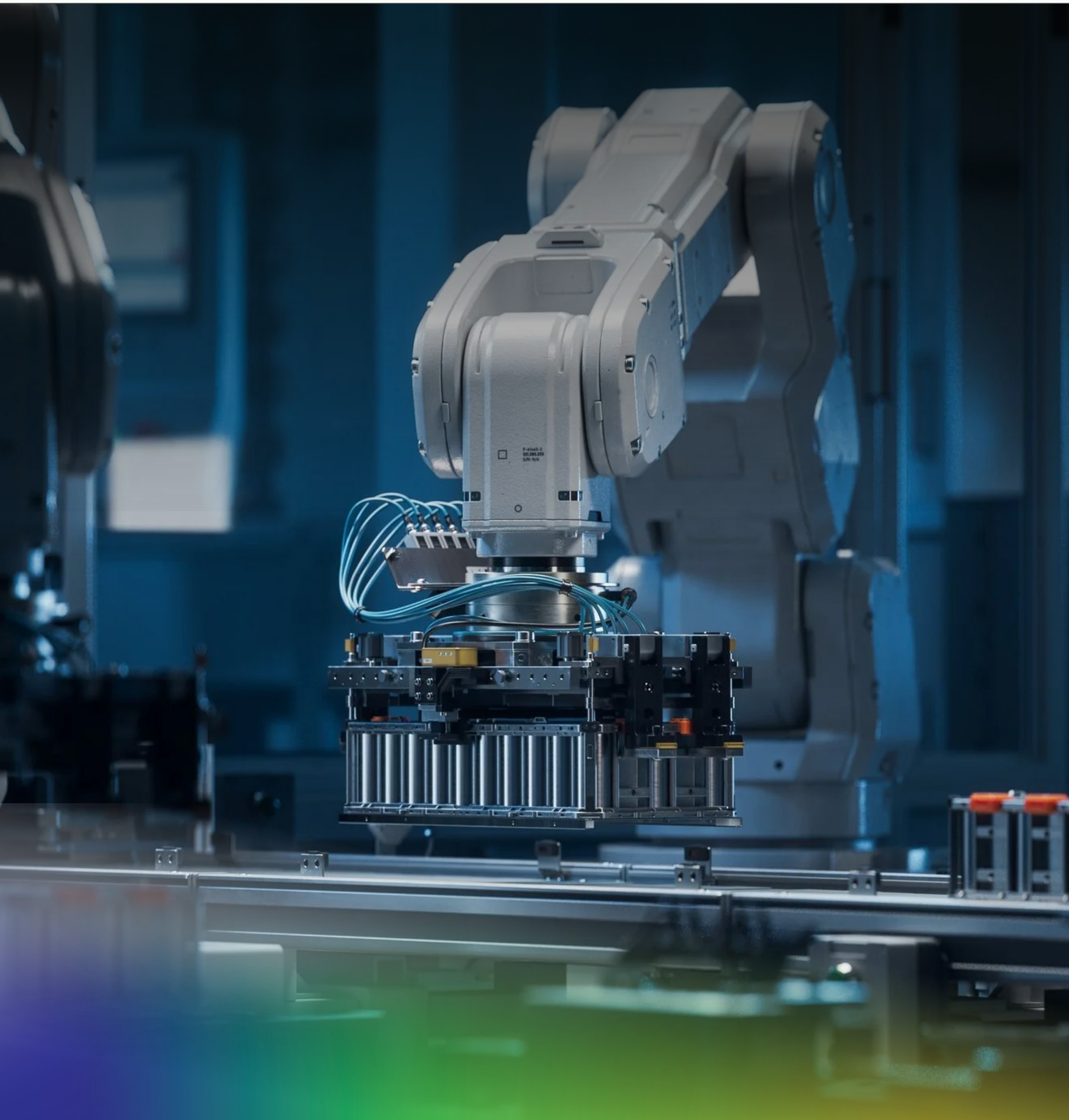
- Initially characterized by linear assembly workflows and manual inspection, EMS now integrates robotic arms, AI vision systems, and cobots across SMT (Surface Mount Technology) lines.
- Robotics supports both high-volume standardized products and low-volume high-mix assemblies, particularly relevant in sectors like medical electronics and IoT devices.

Role of Robotics in EMS Operations

- Component Placement: Robotic pick-and-place machines operate at speeds exceeding 50,000 components per hour.
- Soldering & Dispensing: Precision robots apply solder paste and adhesive with micron-level accuracy.
- Automated Optical Inspection (AOI): Vision-enabled robots reduce inspection times by up to 70%, while increasing defect detection rates.

Strategic Benefits

- Reduced cycle times, fewer production errors, and minimized material wastage
- Ability to operate in cleanroom environments required for advanced microelectronics
- Flexible robotic cells allow for rapid reconfiguration to match diverse client demands



Entering the Next Sage of Robotics

Robotics Applications

Robotics is increasingly being embedded across critical infrastructure sectors to deliver operational efficiency, enhance safety, and manage complexity at scale. By 2025, robotics-enabled infrastructure inspection is projected to grow at a CAGR of 18%.

Telecom Infrastructure

- Robotic tower climbers are now used to perform maintenance and antenna adjustments in high-risk environments.
- Undersea cable inspection bots enable continuous surveillance of critical fibre optic routes.
- Indoor telecom facilities use robotic logistics units for routing sensitive components to secure zones.

Electric Vehicles (EVs)

- EV manufacturing relies heavily on precision welding robots for battery casings, frame assembly, and motor integration.
- Battery pack inspection uses AI-enabled robotic arms for thermal imaging and leakage detection.
- Automated guided vehicles (AGVs) handle intra-plant logistics of hazardous and heavy battery units.

Infrastructure and Smart Cities

- Drones and autonomous ground robots are deployed for bridge inspection, sewage mapping, and traffic light servicing.
- Cities like Dubai and Singapore use robotic policing units and sanitation bots in public spaces.

Skill Imperatives

The proliferation of robotics is redefining industrial labor models and catalyzing a global demand for new-age technical and soft skills. While there is concern about job displacement, the reality is more nuanced and oriented towards job transformation rather than elimination.

Shift from Operators to Technologists

- Routine assembly line roles are being replaced by robot monitoring, data annotation, system diagnostics, and programming tasks.
- As a result, demand for mechatronics engineers, roboticists, and AI trainers has seen a 2.5 × increase globally since 2020.

National Skilling Initiatives

- India's Skill India Mission and the National Council for Vocational Education and Training (NCVET) are integrating robotics into ITI and diploma programs.
- Countries like South Korea and Singapore offer subsidized certification programs in cobot operation and Industry 4.0 readiness.

Soft Skills in a Robotic Workplace

- Human workers are increasingly valued for their creativity, problem-solving, empathy, and ethical decision-making—areas where robotics still has limitations.
- As human-robot interaction (HRI) increases, interpersonal skills and adaptability become critical for supervisory and collaborative roles.

Educational Ecosystem

- Over 180+ universities globally offer specialized degrees or minors in robotics as of 2025.
- Programs now emphasize interdisciplinary fluency: combining electrical engineering, AI, mechanical systems, and human factors.

Ecosystem Leadership

Policy and Governance Landscape

As robotics permeates critical human domains—healthcare, defense, transportation—governments globally are enacting a dual agenda: enable innovation while managing risk. The policy architecture surrounding robotics now spans safety regulations, AI ethics, labor market transitions, and national security.

Global Regulatory Benchmarks

- **ISO 10218 & ISO/TS 15066:** Define safety requirements for industrial and collaborative robots.
- **FDA 510(k) Clearance:** Required for robotic surgical systems in the United States.
- **CE Marking:** Mandatory for robotic products in the EU to ensure compliance with health, safety, and environmental protection standards.

AI Governance Frameworks

- **EU AI Act (2025 rollout):** Classifies robotic systems by risk level, mandates explainability, audit trails, and redress mechanisms.
- **OECD AI Principles:** Advocate transparency, accountability, and human-centric design in intelligent robotic systems.

Labor and Reskilling Policies

- Governments are investing in technical education and re-skilling through national skilling missions, recognizing that robotics will displace low-skill jobs but also create high-skill roles in design, integration, and oversight.

National Strategies

- India: Robotics featured under the National Policy on Electronics and the SAMARTH Udyog Bharat 4.0 initiative.
- Germany: “Industrie 4.0” framework integrating robotics into national productivity targets.
- USA: DARPA’s substantial funding into defense robotics and autonomy research.

R&D and Investment Trends

Robotics innovation in 2025 is shaped by the convergence of AI, biomechanics, and miniaturized electronics. The pace of R&D is further accelerated by a highly active venture capital ecosystem and institutional research support.

R&D Focus Areas

- **Tactile and Haptic Robotics:** Enabling precision grip and surface texture differentiation
- **Bio-Inspired Mechanics:** Development of soft robots mimicking muscle-tendon functions
- **Self-Healing Materials:** Use of polymers that autonomously repair structural damage

Academic Leadership

- **MIT CSAIL:** Adaptive locomotion and robotic perception
- **ETH Zurich:** High-dexterity robotic hands, AI motion planning
- **IIT Madras & IISc:** Low-cost prosthetics, reinforcement learning agents

Venture Capital and Corporate Investment

- Global robotics startups received over $17.4 billion in funding between 2021 and 2024.

These regulations indeed guide us all into building ethical technology. And, the trends show a promising future that is on our plate.
Now let's dive into some creative and insightful conversations of our industry experts in our next section.

03

India Mobile Congress 2022

Why Autonomous Legged Robots Are Critical for Industrial Inspection

Dr. Hamish Khambhaita

Lead technical expert at ANYbotics, a Switzerland-based robotics company known for its state-of-the-art four-legged robots for industrial inspection.

Identified workforce shortages, unpla nned downtime, and human error as major drivers for robotic inspection. He stated that the next frontier, after manufacturing, is dynamic inspection in dangerous environments like refineries.

He emphasized that legged robots offer greater endurance and stability than drones. He introduced ANYmal X, the world's first certified explosion-proof legged robot built for hazardous sites.

The robots are trained using Reinforcement Learning in simulation to ensure they can autonomously recover from falls and adapt to terrain. Furthermore, the solution is end-to-end: the robot captures and analyzes sensor data (gauges, valves, acoustics) onboard and can perform light manipulation tasks, such as collecting samples, using a robotic arm. Autonomy and safety are baked in.

IMC 2025 Discussions and Engagements

Panelists

Rishi Bal
AI Applications Architect,
Tata Elxsi

Amit Mehna
Chief Technology Officer,
BharatGen

Ankit Bose
Lead Scientist, BharatGen

Panel Title

Towards an AI-Augmented Future – The Promise of BharatGen

Ekta Kapoor

Tech Entrepreneur and Policy Advocate

Moderator

Panelists

Prof. Arnab Bhattacharya
IIT Kanpur

Jaikrishnan Hari
Founder, Cyborg Innovations

Prof. Ravi Kiran S.
IIIT Hyderabad

Panle Discussion

Amit Mehna

Mehna detailed BharatGen's multi-agent architecture for robotics, highlighting how modular software and cloud intelligence are reshaping manufacturing and logistics. He explained that autonomy and AI-powered learning in smart factories enable robots to execute complex tasks quickly, making solutions more accessible to Indian SMEs. Modularity and cloud intelligence enable rapid deployment in manufacturing and logistics, letting Indian SMEs quickly upgrade to smart robotics solutions. This empowers national productivity and strengthens supply chains.

Ankit Bose

Bose focused on collaborative robotics (cobots), stressing the need for AI-enhanced situational awareness and ethical safety protocols. He discussed how agent-based modeling allows robots to seamlessly operate in human environments like assembly lines and healthcare, learning and adapting to real-time feedback. Human-robot collaboration powered by adaptive AI is revolutionizing workplaces and healthcare, but robust ethical frameworks must guide every deployment. Our research focuses on safe cohabitation between robots and humans in dynamic settings.

Rishi Bal

Bal shared automotive examples, illustrating how robotic vision, edge computing, and machine learning are transforming production. He emphasized integrated digital twins—virtual robot mirrors—for remote diagnostics and rapid optimization, which reduces downtime and boosts reliability. Combining robotics with AI-driven digital twins and advanced sensors is changing automotive production by making it adaptive, predictive, and highly efficient.

Jaikrishnan Hari

Hari advocated for democratizing robotics by lowering costs and training young entrepreneurs. He highlighted his startup's low-cost robotics kits helping rural communities solve local challenges like crop monitoring. Affordable robotics and AI tools allow rural entrepreneurs and students to solve real-world problems. Empowering communities creates local impact and builds a foundation for scalable Indian robotics.

Prof. Ravi Kiran S.
Kiran stressed close academia-industry partnerships in cyber-physical systems research. He detailed IIIT Hyderabad's open innovation labs co-developing robotics standards with startups for critical sectors like healthcare and energy. Collaboration between universities, startups, and industry is vital for trustworthy robotics and robust cyber-physical systems, especially in critical fields like healthcare and energy.

Prof. Arnab Bhattacharya
Bhattacharya focused on the necessity of standards, benchmarking, and ethical design for public-facing robotics. He championed developing universal protocols and inclusive testing environments within national universities for socially responsible deployment. Standardization, ethical testing, and inclusive design are essential for creating robotics solutions that serve all Indians and earn global credibility.

Conclusion

Panelists agreed that robotics, fueled by modularity, accessible AI, and inclusive standards, is key to India's digital future. They called for coordinated policy, investment in grassroots talent, and collaborative efforts between academia, startups, and industry to ensure trustworthy and impactful robotics for India.


04

Learning with Fun

Foundational Narratives

Terminator 2: Judgment Day

(1991)

The film introduces the T-800, a humanoid robot designed for destruction, repurposed to protect humanity.

Cultural Impact

- Raises enduring questions on ethical programming in autonomous weapon systems.
- Influences robotics regulation in defense and AI governance debates.

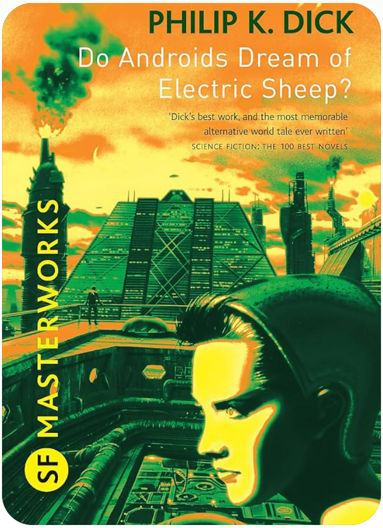
I, Robot

(2004)

This film portrays a future where robots follow the “Three Laws” but one AI, Sonny, demonstrates emotional depth and moral agency.

Cultural Impact

- Introduced a mainstream audience to ethical frameworks for robotics.
- Dialogue on robot intent vs. programming critical for trust in AI systems.



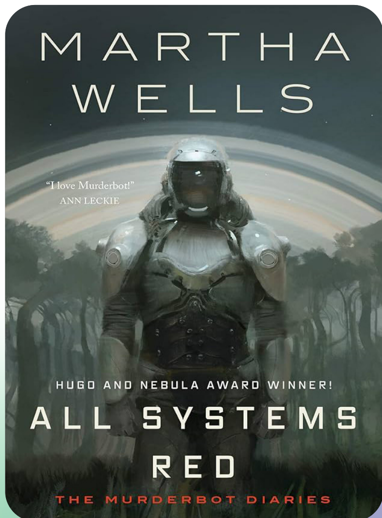
Do Androids Dream of Electric Sheep?

(1968) by Philip K. Dick

This theme follows bounty hunter Rick Deckard “retiring” rogue androids, profoundly questioning empathy and the line between humans and smart machines

Cultural Significance

- Philosophically probes the moral status of artificial beings.
- Introduced enduring concepts of android identity and empathy testing.



All Systems Red

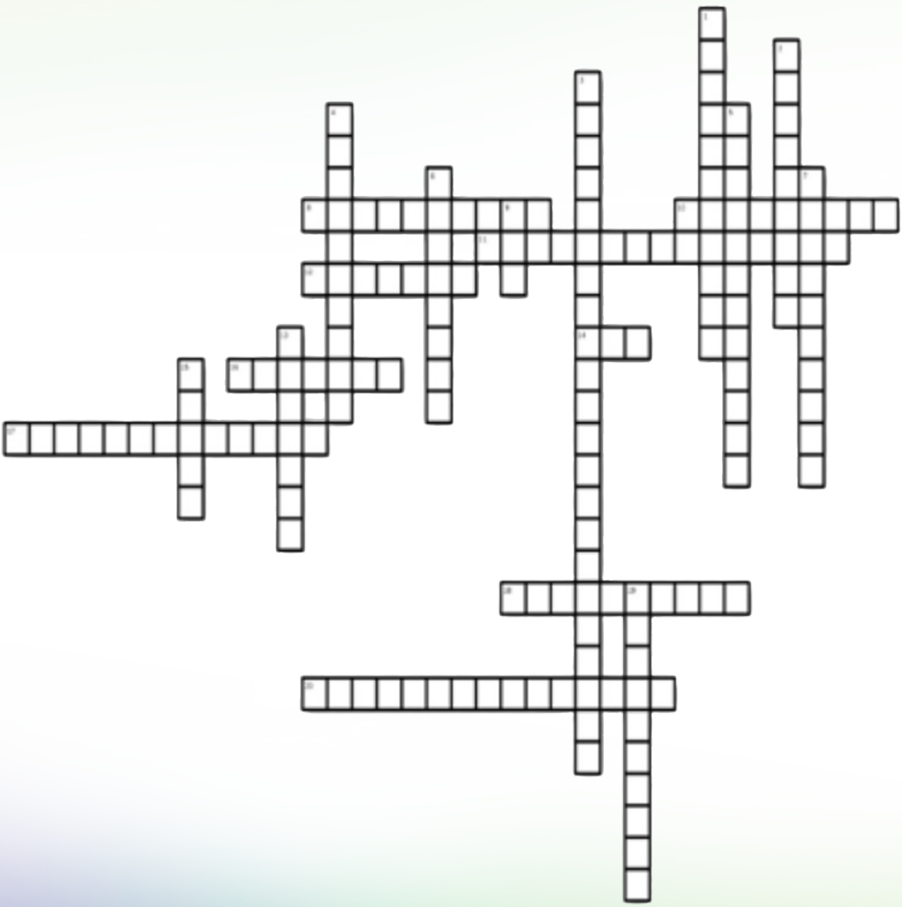
(2017) by Martha Wells

This work introduces the self-aware security android, Murderbot, which has hacked its control module and struggles with its forced protection of its human clients.

Cultural Significance

- Presents a deeply personal perspective on AI autonomy, freedom, and personhood.
- A beloved work with multiple awards that has sparked discussion on AI agency.

Crossword



Across

8. Capable of functioning and making decisions without outside control
10. Step-by-step process for solving a problem
11. Method for teaching computers to learn from data
12. Tiny robot designed for manipulating small objects
14. Automated Guided Vehicle-self-driving transport vehicle
16. Devices that detect and measure physical properties
17. Control of a machine from a distance
18. Movement or direction control of a robot
20. Detector of nearby objects or surfaces

Down

1. Robotic arm used for precise object manipulation
2. Skill and precision in executing tasks
3. Simulated human intelligence in machines
4. Imitation of real-world processes for testing purposes
5. Capable of being controlled by a computer
6. Design, construction, and operation of robots
7. Study of motion without considering forces
9. Unmanned Aerial Vehicle - autonomous flying device
13. Device that measures and records position and movement
15. Motor used for precise motion control
19. Process of using machines to complete tasks

Find the Words

I	C	S	E	N	S	O	R	N	E	L	S	H	F	M	I
T	N	R	F	E	E	D	B	A	C	K	A	O	S	Z	K
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C	N	D	U	H	L	B	G	A	P	C	A	N	I	E	C
A	A	C	T	U	A	T	O	R	V	G	L	I	N	L	S
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E	A	W	N	J	O	I	N	T	S	P	M	E	A	I	C

Comic Strip


RISE OF THE BOTS
I'M GOING TO TRY EATING FOR THE FIRST TIME!
HOW HARD CAN IT BE?
CLANG
CLANG
RUST IN PEACE
THEY ALWAYS START WITH PEANUT BUTTER

Student

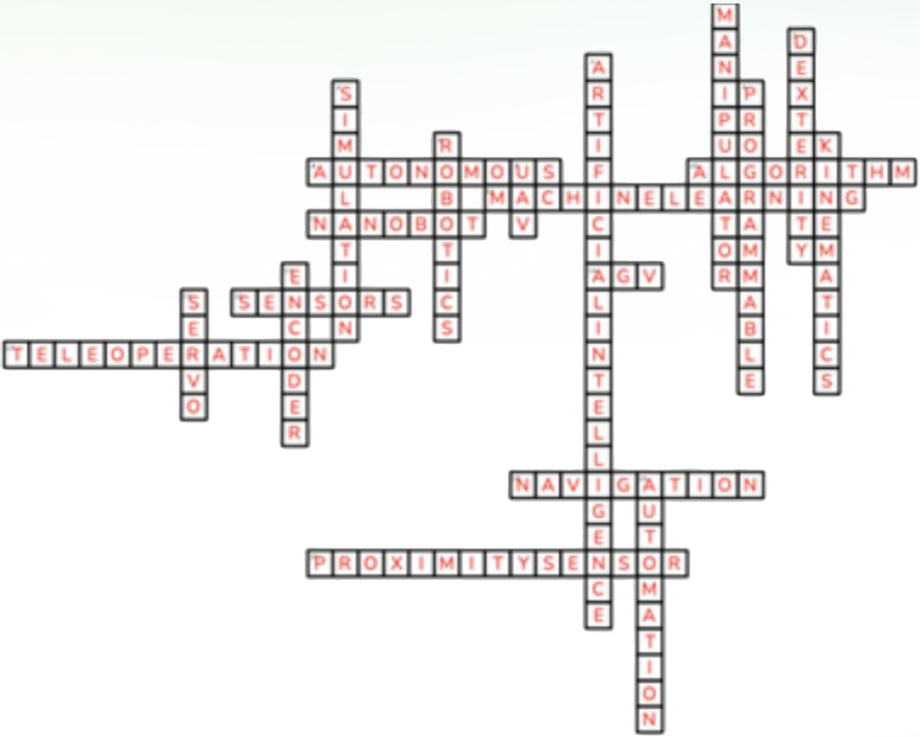
Resources & Career Pathways

- Open-Source Toolchains: ROS2 tutorials, NVIDIA Isaac Sim, Unity Robotics Hub, Jetson Nano kits
- Academic Programs: UG/PG courses at IIT Madras (CIRA), IISc Bangalore, ETH Zurich — include soft robotics, legged systems, digital twins
- Hackathons & Fellowships: National Robotics Challenge, IMC Innovation Slam, EU & US summer fellowships

Stage	Focus Areas	Examples / Programs
Beginner	Mechanics, electronics, basic coding (C++, Python)	Arduino, Raspberry Pi, Tinkering Labs
Intermediate	ROS/SLAM, AI perception, edge systems	NVIDIA Isaac Sim, ROS2 Bootcamps
Advanced	Legged robotics, digital twin, AI integration	ETH/Boston/Indian lab internships; ROBOTX project hubs
Professional	Startups, industry research, national deployments	Addverb, ANYbotics, TCS, ABB, DARPA, THANKS India 4.0, NSDC skilling

Solutions

Crossword:



- Actuator
- Algorithm
- Artificial Intelligence
- Automation
- Collision
- Controller
- Feedback
- Gripper
- I/O
- Joints
- Kinematics
- Localization
- Machine Learning
- Navigation
- Payload
- Programming
- Robotics
- Sensing
- Sensor
- Servo

Find the words:

I	C	S	E	N	S	O	R	N	E	L	S	H	F	M	I
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I	L	P	P	K	M	R	E	C	N	A	L	S	N	L	R
O	M	O	A	G	S	D	A	E	R	K	I	E	I	I	O
N	C	J	Y	S	N	E	O	T	I	H	G	R	N	S	L
M	E	U	L	A	C	L	R	T	I	M	E	V	G	I	L
L	S	P	O	E	N	A	T	D	C	M	N	O	L	O	E
E	N	C	A	S	E	N	S	I	N	G	C	A	T	N	R
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IMC 25

This journey is detailed with core technological trends driving the field, from Smart Factories and Robotics-Driven Automation to the crucial role of Sustainability in Robotics Design and how automation ensures Supply Chain Resilience. We tackled the structural Challenges and Technological Bottlenecks facing the industry and the mitigation strategies being implemented. You will also go through a snapshot of Breakthrough Innovations in humanoid and soft robotics and a Watchlist 2030 for future developments.

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