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State of Robotics 2023

The definitive annual report on global robotics — hardware, data collection, AI training methods, and deployment trends across the industry's recalibration year.

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KEY FINDINGS

2023 by the Numbers

$14.2B

Global robotics market in 2023, up 18% year-over-year from $12.1B in 2022.

72% RL

Reinforcement learning remains the dominant training method, used in 72% of commercial robot deployments.

$520/hr

Average data collection cost per hour — expensive, manual, and artisanal. The single biggest bottleneck.

2

Commercial humanoid platforms available — Agility Digit and Boston Dynamics Atlas dev program. An era begins.

3.9M

Industrial robots installed globally (IFR), with China accounting for 68% of new installations.

$4.1B

Global VC investment in robotics, down from the 2021–22 peak as macro headwinds forced capital discipline.

CHAPTER 01

Executive Summary

2023 was the recalibration year. After two years of breakneck investment, ambitious timelines, and a wave of humanoid prototypes that looked more like tech demos than products, the global robotics industry spent 2023 reckoning with the gap between aspiration and deployment. That reckoning was productive. The companies and research groups that emerged from 2023 in a strong position are the ones that focused on the fundamentals: reliable hardware, better training data, and rigorous deployment validation.

The global robotics market reached $14.2 billion in 2023, an 18% increase over 2022. That growth rate, while healthy, represents a deceleration from the 22% pace of 2021–2022 — reflecting tighter capital markets and a correction in the speculative end of the industry. VC investment fell to $4.1 billion, down from a peak of $6.3 billion in 2021. The money that did flow was more disciplined: strategic investors replaced momentum-driven generalists, and the median due diligence period for robotics Series A rounds lengthened from 6 weeks to 11 weeks.

On the hardware side, traditional industrial robots remained the vast majority of the installed base, with 3.9 million units globally (IFR). China solidified its position as the world's largest robot market, accounting for 68% of new installations. The humanoid segment, while capturing headlines, remained pre-commercial: only two platforms — Agility Robotics' Digit and Boston Dynamics' Atlas development program — could credibly be described as available for structured customer engagement.

> **The recalibration thesis:** 2023 was not a step backward for robotics. It was the year the industry stopped confusing prototype demonstrations with deployment readiness. The companies that accepted this recalibration early — and redirected resources toward data infrastructure, operator training, and deployment reliability — will define the next cycle.

On the AI side, reinforcement learning remained the dominant training paradigm, powering 72% of deployed robot systems. Imitation learning was gaining traction at 22%, driven by academic work that demonstrated its potential for manipulation tasks. The hybrid category (6%) remained small but represented a growing recognition that no single method would solve all deployment scenarios. The most significant AI event of 2023 happened in October, when Google DeepMind published RT-2 — the first large-scale demonstration that a vision-language model could directly output robot actions. It was a research result, not a product, but it signaled a paradigm shift that would reshape the industry over the following two years.

Data collection remained the industry's most persistent bottleneck. At an average cost of $520 per hour for high-quality teleoperation demonstrations, building the datasets required for training was prohibitively expensive for all but the best-funded organizations. No standardized data format had yet achieved broad adoption. Most teams collected data in proprietary schemas, making cross-

organizational sharing impractical. This would begin to change in 2024 with the emergence of RLDS and LeRobot formats, but in 2023, the data problem was largely unsolved.

CHAPTER 02

The Hardware Landscape

The robotics hardware market in 2023 was a story of two speeds. The traditional industrial segment — six-axis arms, SCARA robots, and cartesian systems manufactured by Fanuc, ABB, KUKA, and Yaskawa — continued to grow steadily, driven by automotive and electronics manufacturing demand. Meanwhile, a new generation of lower-cost, research-oriented hardware was beginning to emerge from Chinese OEMs, though it had not yet achieved the scale or ecosystem depth that would characterize 2024 and beyond.

Traditional Industrial Dominance

The International Federation of Robotics reported 3.9 million industrial robots installed globally by end of 2023, a new record. Annual shipments reached approximately 553,000 units, with 73% destined for three verticals: automotive, electronics, and metal/machinery manufacturing. The average selling price for a mid-range industrial arm held steady at $28,000–$45,000, reflecting the maturity and competitive discipline of this market segment.

China was the gravitational center. With 68% of global installations by country, China's dominance was not merely proportional — it was structural. Chinese manufacturers (including domestic brands like SIASUN, Estun, and Inovance) gained market share from Japanese and European incumbents, particularly in the sub-$20,000 segment. Government subsidies under the "Made in China 2025" initiative continued to accelerate adoption in small and medium enterprises.

Collaborative Robots (Cobots)

The collaborative robot segment grew 19% in 2023, outpacing the broader industrial market. Universal Robots maintained its market leadership, but Chinese cobot manufacturers — particularly JAKA, Dobot, and Elite Robots — captured significant share in Asia-Pacific markets. Cobots remained a niche within the broader industrial category (approximately 8% of total shipments), but their growth trajectory signaled a market that was diversifying beyond the traditional cage-and-fence paradigm.

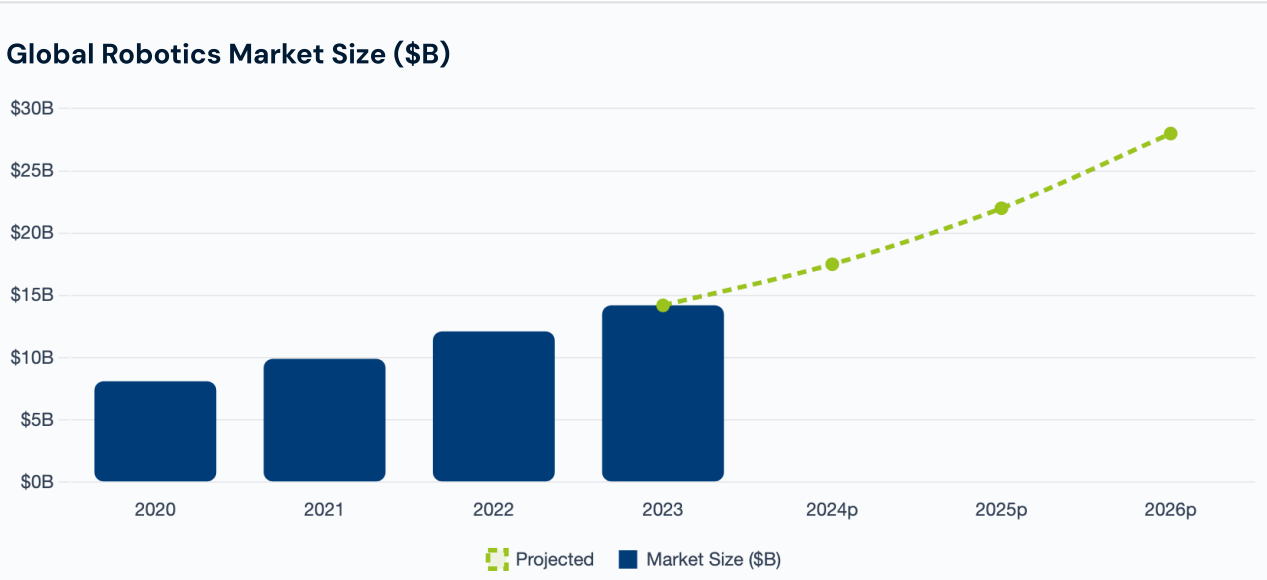
The Dawn of Commercial Humanoids

Humanoid robotics in 2023 was a sector of intense activity and limited commercial output. Agility Robotics' Digit became the first humanoid robot to be deployed in a structured commercial pilot, with Amazon announcing a testing program at its fulfillment centers in October. Boston Dynamics continued its Atlas development program, transitioning from the hydraulic Atlas platform toward an electric redesign that would be unveiled in 2024. Beyond these two, the humanoid landscape consisted primarily of well-funded startups in various stages of prototype development: Figure AI (founded in 2023), Apptronik, 1X Technologies, and several Chinese entrants including Unitree (which would later pivot from quadrupeds to humanoids).

Hardware reality check: Despite the headlines, fewer than 50 humanoid robots were deployed in any form of real-world testing in 2023. The gap between demonstration video and deployment reality remained vast. The companies that acknowledged this gap publicly — rather than over-promising on timelines — earned credibility that would prove valuable in subsequent fundraising rounds.

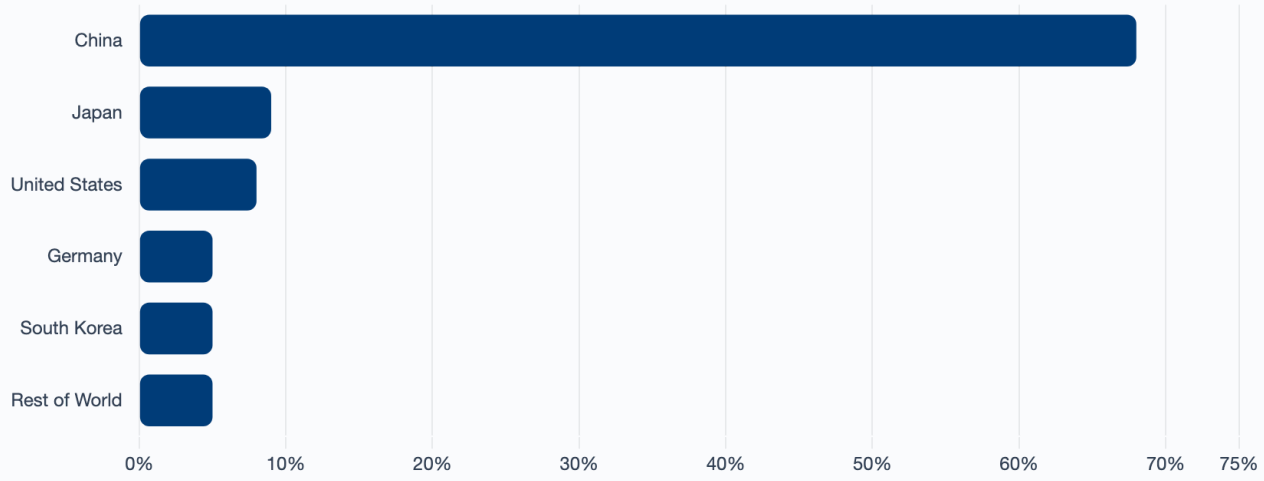
China's Rising Hardware Ecosystem

While Chinese OEMs had long dominated the low-cost industrial segment, 2023 marked the beginning of their push into the research and AI-ready hardware category. Companies like Unitree (with its B1 and B2 quadrupeds), AgileX (mobile bases), and Elephant Robotics (desktop arms) began shipping platforms that, while not yet matching the precision of Western research hardware, offered dramatically better price-to-capability ratios. A research-grade arm that cost $15,000 from a US or European manufacturer could be approximated for $4,000–$7,000 from a Chinese supplier. This price compression would accelerate dramatically in 2024.



Source: RCSV Research, IFR, PitchBook

Robot Installations by Country 2023 (%)



Source: RCSV Research, IFR

COUNTRY	SHARE OF INSTALLATIONS	KEY DRIVER
China	68%	Government subsidies, EV/electronics manufacturing
Japan	9%	Automotive, aging workforce
United States	8%	Logistics, reshoring initiatives
Germany	5%	Automotive OEMs, Industrie 4.0
South Korea	5%	Electronics, shipbuilding
Rest of World	5%	Mixed

CHAPTER 03

The Data Problem

If there was a single sentence that captured the state of robot learning in 2023, it was this: everyone knew data was the bottleneck, and almost nobody had a scalable plan to fix it. The cost, complexity, and fragmentation of robot training data collection remained the industry's most binding constraint — more so than compute, more so than algorithms, and more so than hardware.

The $520/Hour Reality

The average fully loaded cost of one hour of high-quality teleoperation data in 2023 was approximately $520. This figure includes operator labor, hardware depreciation, environment setup, data cleaning, and format conversion. For a standard pick-and-place task requiring 200–500 demonstrations to train a reliable policy, the data budget alone ranged from $50,000 to $130,000 — before a single training run was attempted. For more complex manipulation tasks requiring 1,000+ demonstrations, budgets could exceed $250,000.

The cost curve was declining — from $820/hour in 2020 to $520 in 2023 — but the pace of decline was insufficient to unlock broad adoption. The primary cost drivers were operator expertise (trained teleoperation operators were scarce and commanded premium rates), hardware setup time (each data collection session required significant calibration), and the absence of standardized quality scoring (teams spent substantial effort on manual quality review of collected episodes).

> **The artisanal data problem:** In 2023, robot data collection resembled craft manufacturing more than industrial production. Each team built its own collection setup, trained its own operators, defined its own quality standards, and stored data in its own format. This artisanal approach produced high-quality individual datasets but made aggregation, sharing, and benchmarking extraordinarily difficult.

No Standard Formats

The absence of a widely adopted robot demonstration data format was perhaps the most damaging structural problem in 2023. Research groups stored episodes in custom HDF5 schemas, proprietary binary formats, or loosely structured file directories. Google's RLDS (Reinforcement Learning Datasets) format existed but had not achieved critical mass outside of Google-affiliated projects. The LeRobot project at Hugging Face was in early development. The practical consequence: a dataset collected at one lab could not be directly used at another without significant engineering effort, even when both labs used similar hardware.

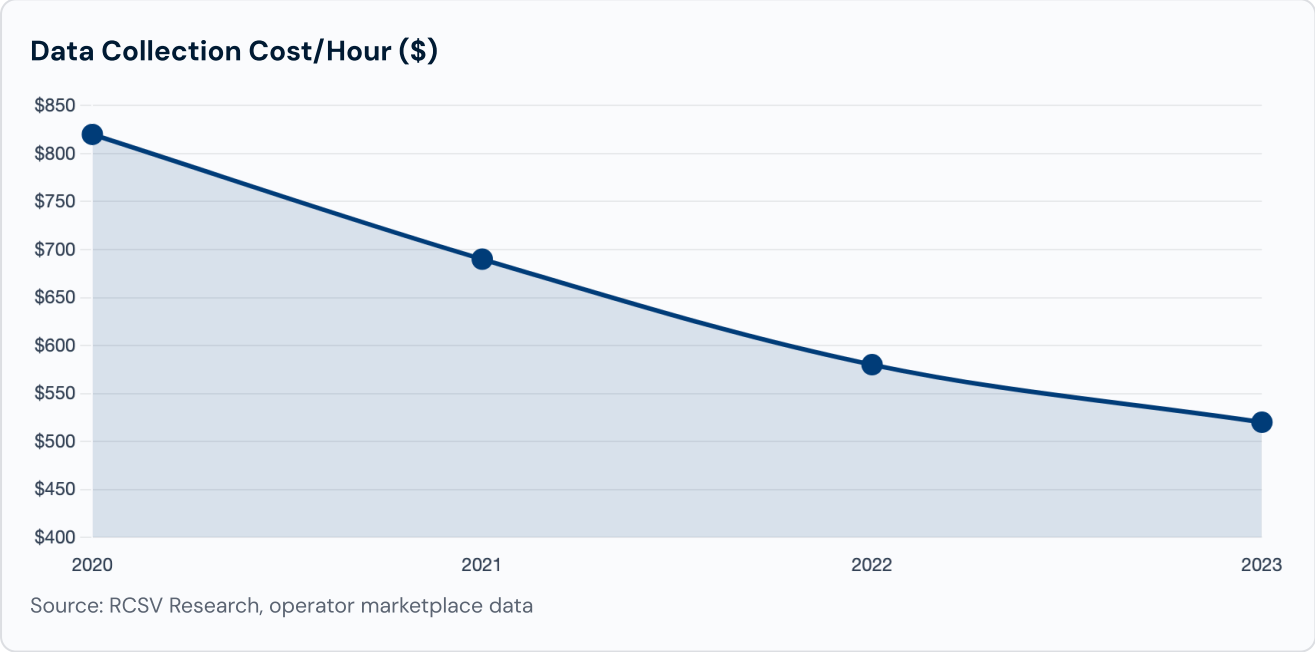
Teleoperation Hardware Limitations

The teleoperation systems available in 2023 were functional but expensive and ergonomically challenging. Leader-follower arm systems from Gello and similar projects cost $5,000–$15,000 and

required significant expertise to operate. VR-based teleoperation (using Meta Quest or similar headsets) offered a lower entry point but introduced latency and mapping challenges that degraded data quality for fine manipulation tasks. Haptic feedback, which improves operator performance and data quality, was available only in research systems costing $50,000 or more.

The Scale Imperative

Despite these constraints, 2023 saw the first attempts at organizing data collection at meaningful scale. Google's RT-X collaboration, involving 21 research institutions, assembled what was at the time the largest multi-embodiment robot dataset: approximately 130,000 episodes across 22 robot types. The project demonstrated both the potential of cross-embodiment data sharing and the enormous coordination overhead required to achieve it. The dataset's existence proved the concept; its construction costs proved that a fundamentally different collection infrastructure was needed.



Source: RCSV Research, operator marketplace data

CHAPTER 04

AI & Learning Methods

The AI landscape for robotics in 2023 was dominated by reinforcement learning but haunted by a question: what comes next? The answer arrived in October with Google DeepMind's RT-2 paper, which demonstrated that large vision-language models could be adapted to output robot actions directly. But the journey from that research result to commercial impact would take another 18 months. In 2023, the tools that actually deployed were older, more proven, and less glamorous.

Reinforcement Learning: Still King

Reinforcement learning accounted for 72% of deployed robot learning systems in 2023. The dominance was concentrated in two domains: locomotion (where RL had proven itself unambiguously superior for legged robots) and structured manipulation (where task rewards could be defined crisply). Companies like Agility Robotics, Boston Dynamics, and Unitree used RL-trained policies as the foundation of their locomotion controllers. In manipulation, RL worked best for tasks with clear success criteria — bin picking, palletizing, and assembly insertion — where reward shaping was tractable.

The limitation was equally clear: RL struggled with long-horizon, contact-rich manipulation tasks in unstructured environments. Training a policy to fold a towel, prepare a sandwich, or pack a grocery bag via RL alone remained extraordinarily difficult, requiring either massive simulation campaigns or reward engineering so complex that the engineering effort dominated the project timeline.

Imitation Learning: The Rising Contender

Imitation learning (IL) accounted for 22% of deployments in 2023 and was growing rapidly. The catalyst was a series of academic results that demonstrated IL could achieve reliable manipulation performance with surprisingly modest dataset sizes. The ACT (Action Chunking with Transformers) paper from Tony Zhao and colleagues at Stanford, published in 2023, showed that a transformer-based IL policy trained on just 50 demonstrations could perform contact-rich bimanual manipulation tasks — a result that captured the imagination of the applied robotics community because it suggested that the data requirements for useful IL might be lower than previously believed.

The practical appeal of IL was straightforward: instead of engineering a reward function and running billions of simulation episodes, a team could collect a few hundred teleoperation demonstrations and train a policy directly. The tradeoff was generalization — IL policies trained on limited data tended to be brittle outside their training distribution — but for many enterprise use cases with well-defined environments, this limitation was acceptable.

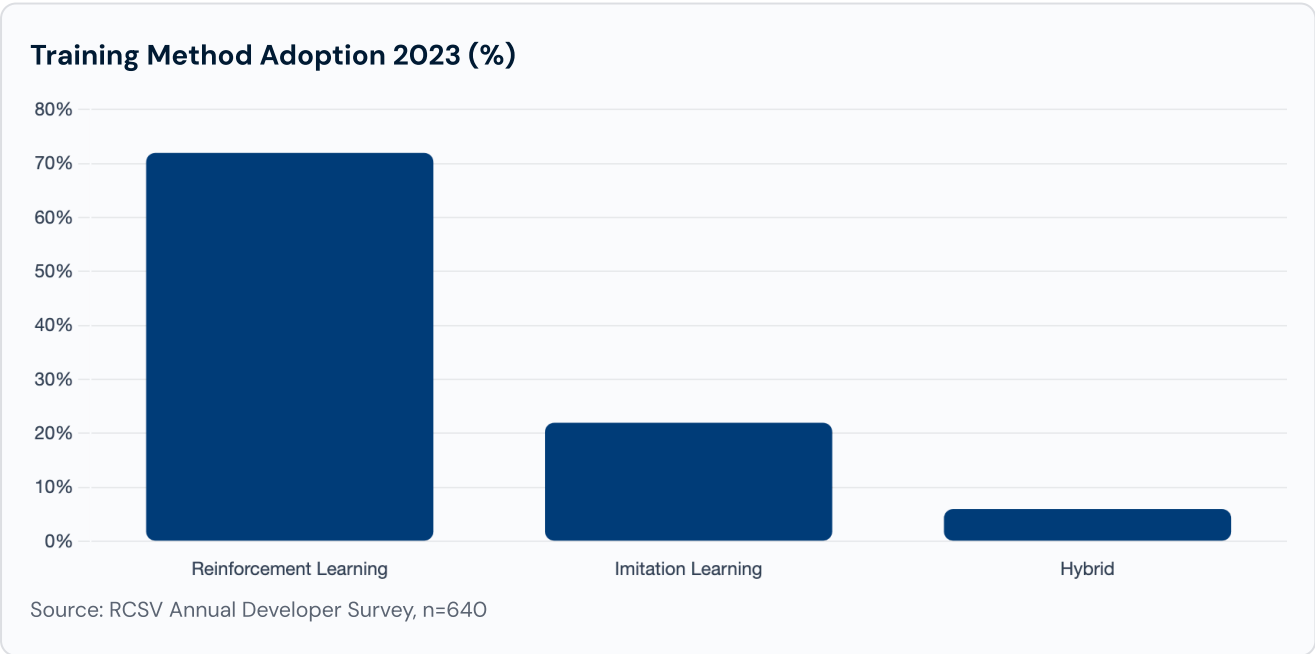
The RT-2 signal: Google DeepMind's RT-2 paper (October 2023) was the single most important research result of the year. By demonstrating that a 55B-parameter vision-language model (PaLM-E) could be fine-tuned to output robot actions from natural language instructions, RT-2 established the Vision-Language-Action (VLA) paradigm that would dominate subsequent years. In 2023, it was a research artifact running on TPU pods. By 2025, its descendants would be running on consumer GPUs.

The Hybrid Approach

The remaining 6% of deployments used hybrid methods — typically RL for low-level control (joint torque, balance) combined with IL or classical planning for high-level task sequencing. This architecture was most common in mobile manipulation, where a wheeled or legged base required RL-trained locomotion while the arm performed IL-trained manipulation. The hybrid approach was pragmatic but operationally complex, requiring teams to maintain two separate training pipelines and manage the interface between them.

Simulation: Essential but Insufficient

Physics simulation (primarily via Isaac Gym, MuJoCo, and PyBullet) remained essential for RL training in 2023. Virtually all locomotion policies and many manipulation policies were trained partially or entirely in simulation before being transferred to real hardware. The sim-to-real gap — the performance degradation when a simulated policy encounters real-world physics — remained the central technical challenge. Domain randomization (training across a wide distribution of simulated conditions) was the standard mitigation strategy, but it required significant expertise and compute to implement effectively.



Source: RCSV Annual Developer Survey, n=640

CHAPTER 05

Deployment by Vertical

Robot deployments in 2023 remained heavily concentrated in traditional industrial verticals. Automotive and electronics manufacturing together accounted for 65% of all commercial robot deployments by unit volume. Logistics was the third-largest vertical and the fastest growing, reflecting the ongoing e-commerce boom and persistent warehouse labor shortages. The long tail of verticals — food service, healthcare, agriculture — was beginning to show signs of life, but none had yet crossed the threshold from pilot projects to sustained commercial deployment.

Automotive: The Anchor Vertical

Automotive manufacturing accounted for 38% of global robot deployments in 2023. This is not new — automotive has been the dominant robot vertical since the 1980s — but the composition of automotive robotics was shifting. Traditional welding and painting applications remained the base, but body shop flexibility (rapid retooling for EV platforms), battery pack assembly, and quality inspection were emerging as the fastest-growing sub-segments. Chinese EV manufacturers, particularly BYD and NIO, were among the most aggressive adopters of new robotic systems.

Electronics Manufacturing

Electronics accounted for 27% of deployments, driven by semiconductor fabrication, PCB assembly, and consumer electronics final assembly. The precision requirements of electronics manufacturing continued to push the boundaries of position accuracy and force control. SCARA robots and small six-axis arms dominated this vertical, with average cycle times measured in seconds rather than minutes. The ongoing chip shortage and reshoring investments (CHIPS Act in the US, EU Chips Act) were beginning to drive incremental demand for automation in newly constructed fabs.

Logistics: The Growth Vertical

Logistics and warehousing accounted for 18% of deployments and grew 31% year-over-year — the fastest growth rate of any major vertical. The dominant form factors were autonomous mobile robots (AMRs) for transport and fixed arms for sortation and palletizing. The transition from AMRs to mobile manipulators (bases with arms) was beginning but remained early-stage: fewer than 500 mobile manipulators were deployed in logistics settings globally in 2023. Amazon, Walmart, and several European logistics operators were the primary buyers.

Emerging Verticals

Food service, healthcare, and agriculture each had fewer than 1,000 deployed robot units globally in 2023 but were attracting disproportionate investment interest. Food service automation (automated cooking, dispensing, and serving) was being piloted in QSR chains in Japan, South Korea, and select US markets. Healthcare robotics was largely limited to surgical systems (Intuitive Surgical's da Vinci)

and pharmacy automation, with non-surgical manipulation in early research stages. Agricultural robotics — particularly fruit harvesting and crop monitoring — was constrained by the extreme variability of outdoor environments and the seasonality of deployment opportunities.

Deployment by Industry Vertical 2023

Source: RCSV Research, IFR

VERTICAL	SHARE OF DEPLOYMENTS	YOY GROWTH	LEADING FORM FACTOR
Automotive	38%	+12%	6-Axis Industrial Arm
Electronics	27%	+15%	SCARA / Small 6-Axis
Logistics / Warehousing	18%	+31%	AMR / Fixed Arm
Food / Pharma	8%	+24%	Cobot / SCARA
Other	9%	+18%	Mixed

CHAPTER 06

Investment & Capital

The robotics investment landscape in 2023 was defined by a single word: correction. After two years of historically elevated venture activity — $6.3 billion in 2021 and $5.8 billion in 2022 — global robotics VC investment fell to $4.1 billion. This was not a collapse. It was a return to fundamentals after a period of excess, driven by rising interest rates, tighter LP commitments, and a generalized risk aversion that affected all deep-tech verticals. The robotics-specific dynamic was a growing recognition that deployment timelines had been over-compressed: investors who expected commercial humanoid deployments by 2023 were confronting a reality where even the most advanced programs were 18–24 months from meaningful revenue.

The Shift to Strategic Capital

The most significant change in the 2023 investment landscape was not the quantum of capital but its source. Financial VCs that had driven the 2021–22 peak pulled back sharply. In their place, strategic investors stepped forward. Automotive OEMs (Hyundai, BMW, Mercedes-Benz), logistics operators (Amazon, DHL), and technology companies (NVIDIA, Google, Microsoft) became the dominant capital sources for robotics companies from Series A onward. Strategic investors brought operational expertise, deployment sites, and customer relationships — assets that were more valuable to robotics companies than purely financial backing.

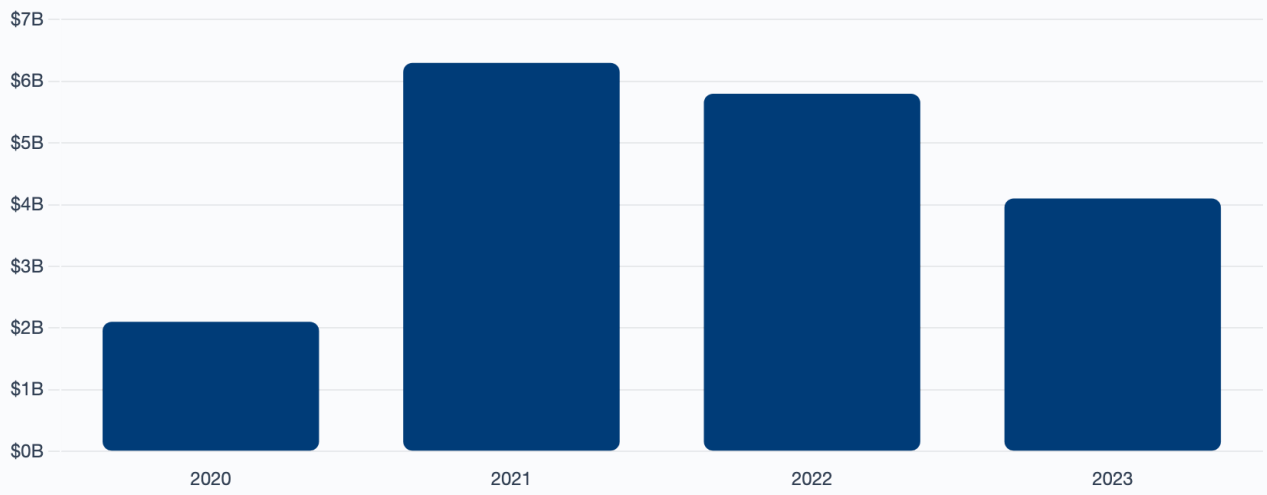
China: Government-Led Investment

China's robotics investment landscape operated on different dynamics. While private VC investment in Chinese robotics companies followed the global correction, government-backed funds and municipal investment programs partially offset the decline. Shenzhen, Shanghai, and Beijing each maintained dedicated robotics investment funds that continued to deploy capital through the correction. The result: Chinese robotics companies raised an estimated $1.2 billion in 2023, a modest decline from $1.5 billion in 2022 but less severe than the correction experienced by US and European companies.

> **The discipline dividend:** The investment correction of 2023 was painful for companies that had raised at inflated valuations in 2021–22 and now faced flat or down rounds. But it was healthy for the industry overall. Companies were forced to demonstrate deployment metrics — units shipped, hours of uptime, tasks completed — rather than relying on narrative and prototype demonstrations. This discipline would prove foundational for the subsequent recovery.

Valuation Compression

Median pre-money valuations for robotics companies at Series A fell from $35M in 2022 to $22M in 2023 — a 37% compression. The correction was most severe for hardware-only companies without a clear software or data differentiation story. Companies that could demonstrate a path to recurring revenue (through data services, software subscriptions, or fleet management) maintained valuations 1.5–2x higher than hardware-only peers at equivalent revenue levels.



Source: RCSV Research, PitchBook, Crunchbase

CHAPTER 07

2023's Breakthrough Moments

Every year produces a handful of events that, in retrospect, prove to be inflection points. 2023 had five that matter most.

1. RT-2: The VLA Paradigm Emerges (Google DeepMind, October 2023)

RT-2 (Robotic Transformer 2) demonstrated that a large vision-language model — specifically, a 55 billion parameter PaLM-E variant — could be fine-tuned to output robot actions directly from visual observations and natural language task descriptions. The model achieved a 3x improvement in generalization over RT-1 on novel objects and could follow instructions it had never been trained on by leveraging the language model's semantic understanding. The result was not yet deployable (inference was too slow for real-time control), but it established the architectural template that would define the next generation of robot learning systems.

2. ACT: Efficient Imitation Learning (Stanford, 2023)

The Action Chunking with Transformers paper from Tony Zhao and colleagues demonstrated that a relatively simple transformer architecture, trained on as few as 50 teleoperation demonstrations, could perform contact-rich bimanual manipulation — inserting a battery, slotting a connector, zipping a bag. The key insight was "action chunking": predicting sequences of actions rather than single timesteps, which improved temporal consistency and reduced compounding errors. ACT became the most replicated result in applied robot learning for the next 12 months.

3. Agility Digit Enters Amazon (October 2023)

Agility Robotics announced that its Digit humanoid robot was being tested at Amazon fulfillment centers for tote-moving tasks. While the deployment was a structured pilot (not a commercial sale), it represented the first time a humanoid robot had been placed in a real commercial logistics environment by a Fortune 500 company. The signal was clear: the largest companies in the world were evaluating humanoid form factors for real work, not just for demonstrations.

4. Boston Dynamics Atlas: The Electric Transition

Boston Dynamics spent much of 2023 transitioning its Atlas platform from hydraulic to fully electric actuation. While the new electric Atlas would not be publicly revealed until April 2024, the engineering work done in 2023 — developing high-torque electric actuators, redesigning the platform for manufacturing scalability, and building a software stack oriented toward commercial applications rather than research — represented a fundamental strategic shift for the company from research showcase to commercial product.

5. Figure AI Founded (2023)

Figure AI was founded in 2023 with the explicit goal of building a general-purpose humanoid robot for commercial deployment. The company raised a $70 million Series A, attracting investors with a team drawn from Boston Dynamics, Tesla, Google DeepMind, and Apple's Special Projects Group. Figure's founding was significant not for its initial product (which was in early development) but for what it signaled about the capital market's belief in humanoid robotics: even during the broader correction, the best teams could raise substantial capital for humanoid programs.

> **The pattern:** Each of these breakthrough moments shares a common thread — the convergence of large-model AI and physical robotics. RT-2 proved the concept. ACT made it practical for small teams. Digit and Atlas showed that hardware was ready for real environments. Figure's founding showed that capital was ready to bet on the convergence. In 2023, these were separate threads. By 2025, they would be a single fabric.

CHAPTER 08

Outlook for 2024

Predicting robotics is humbling work. The 2022 edition of this report overestimated the pace of humanoid commercialization and underestimated the impact of foundation model research on applied robot learning. With that caveat offered honestly, here are the themes the RCSV research team believes will define 2024.

1. Data Infrastructure Will Emerge as a Distinct Category

The $520/hour data collection cost will begin to fall in 2024, driven by cheaper teleoperation hardware (leader-follower systems under $3,000), standardized data formats (RLDS and LeRobot gaining adoption), and the first commercial data collection services. We expect the cost to reach $350–$400/hour by Q4 2024 for standard manipulation tasks. Companies that build data collection infrastructure will attract significant VC interest.

2. VLA Models Will Move from Research to Dev-Preview

Following RT-2, we expect at least two open-source VLA model releases in 2024 that run at interactive speeds on commercially available GPUs. These will not be production-ready, but they will be sufficient for research teams and well-funded startups to begin building VLA-based deployment pipelines. The gap between research and product will begin to close.

3. Humanoid Deployments Will Remain Pre-Commercial

Despite aggressive public timelines from several humanoid companies, we do not expect meaningful commercial humanoid deployments in 2024. Structured pilots will expand — we project 3–5 commercial humanoid platforms will be available for pilot programs by end of 2024 — but revenue-generating, self-sustaining humanoid operations are a 2025–2026 event at earliest.

4. VC Investment Will Stabilize

We expect global robotics VC investment to stabilize in the $4.5–5.5 billion range in 2024, with the mix continuing to shift toward strategic investors. The humanoid segment will attract a disproportionate share of capital (we estimate 30–40% of total robotics VC), driven by a small number of very large rounds from companies like Figure AI, 1X Technologies, and Apptronik.

5. China Will Accelerate

China's robotics ambitions will intensify in 2024, with formal government humanoid programs, continued hardware cost compression, and the emergence of Chinese VLA research that competes with Western frontier labs. The hardware cost advantage of Chinese manufacturers will become a structural force in global robotics economics.

> **Our overarching view for 2024:** 2024 will be the year the robotics industry transitions from "can we build it?" to "can we deploy it reliably?" The companies that will look back at 2024 as a good year are the ones that invested in data collection infrastructure, deployment reliability, and customer success engineering — not the ones that published the most impressive demo videos.

Read the 2024 Report →

Cite This Report

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