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Robotics – Facts and Data

A handbook on robotics technology, the Chinese industry and opportunities in Hungary

EDITED LIANTA EDITION

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Foreword

This handbook brings together Lianta's research on robotics technology, embodied AI, the Chinese robotics industry and application opportunities in Hungary.

It organizes technical, market, company and industry information, while distinguishing documented facts, company disclosures, policy objectives and calculation-based estimates.

The edited Lianta edition follows the topic from robot operation and applications through Chinese manufacturers and supply chains to the Hungarian market, technology transfer and industrial implementation.

Chapters 13, 17, 21, 22 and 23 of the original manuscript are omitted. The remaining chapters and subsections have been renumbered continuously.

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CHAPTER I

Basic concepts, categories and areas of application of robotics



The aim of this chapter is to provide a unified conceptual framework for describing robots. Purpose, body structure, locomotion, and control are presented as separate data fields. The volume assesses the maturity and performance of the application based on measurable evidence. [1][2]

Data cut-off date 15 September 2026. The project's knowledge base source map and background research provide the starting point; the current status of ISO, IFR and manufacturer primary sources was subject to separate verification. [1][5][8][12]

Chapter structure

	Subchapter
1.1	The concept and purpose of the robot
1.2	Physical design and movement style
1.3	Control method
1.4	Application tasks
1.5	Usage environments
1.6	Technological maturity and performance

Structural source: Robotics – sub-chapter resource map, September 10–11, 2026. [1]

1.1. The concept and purpose of the robot

A robot is a programmed, actuated mechanism that performs movement, manipulation or positioning with some degree of autonomy. The conceptual basis is provided by the robotics vocabulary of ISO 8373:2021; the public definitions of the IFR are aligned with this. The third edition of ISO 8373:2021 was published in November 2021 and remains the published standard as of 15 September 2026. A fourth edition is under development as ISO/DIS 8373. [5][8][9]

"Robot" is therefore a generic term. A specific system must be described in terms of several distinct properties: what it is used for, what its body is like, how it changes position, and what tasks it performs autonomously. This manual uses this four-dimensional description consistently. [1][2]

Main categories by purpose

Category	Classification criteria	Typical example
Industrial robot	Automatically controlled, reprogrammable, multi-purpose manipulator with at least three programmable axes; for industrial automation environments.	Welding, painting, machine service, palletizing, assembly.
Service robot – personal use	It performs a useful task for an individual or household.	Robot vacuum cleaner, private garden robot lawnmower, some home companion robots.
Service robot – professional use	It performs a useful task in a professional, business or institutional environment.	Hotel delivery robot, commercial cleaning robot, warehouse mobile robot, patrol robot.
Medical robot	A robot used as a medical electrical device or system.	Robotic surgery system, some rehabilitation robotic systems.

Source: IFR summaries of the ISO 8373:2021 conceptual system and the project's targeted conceptual research. [2][6][7][8]

Category boundaries are part of every measurement

Statistical, technical and product law categories serve different purposes. ISO 8373:2021 treats medical robots separately. The IFR service robot statistics also link medical robots to the service robot market in some analyses. For market data, the product range covered and the definition of the source should therefore be recorded together with the number. [2][7][8]

Editing rule The manual uses a market or unit figure only in conjunction with the source's own category boundary. The figures for personal service robot, professional service robot, and medical robot are presented as separate measurement universes. [1][2]

Industrial robot and collaborative application

An industrial robot can be a fixed or mobile platform-attached system. The term "collaborative" refers to the shared workspace of a human and a robot, and the application designed for it. Safety is determined by the overall application design, task, speed, force, workpiece, tool, and risk assessment. [6][19]

Four independent axes of description

Aspect	Question	Examples
Destination	What is it used for?	industrial; personal service; professional service; medical
Body structure	What is its structure and working system?	robotic arm; carrier platform; mobile manipulator; humanoid; quadruped
Change of location	How does it move in the environment?	mounted; wheeled; tracked; bipedal or quadrupedal; flying; aquatic
Control	Which tasks does it perform independently and when does a human intervene?	programmed execution; teleoperation; supervised autonomy; autonomous operation within a task

Source: conceptual supplement of the project and the approved sub-chapter source map. [1][2]

A hotel food delivery robot, for example, is a professional service robot with a tray body, wheels, and typically performs the assigned delivery task with autonomous navigation. The fleet may also have human supervision and remote assistance. A humanoid body shape can also be used for multiple purposes. [2][3]

1.2. Physical form and movement

The body shape and movement of a robot are two separate properties. A robot arm can operate on a fixed base, a linear track, or a mobile platform. A mobile robot can carry a simple box, a cleaning unit, one or two arms, or a human-like upper body. The term humanoid describes the body structure; the task must be specified separately. [1][3]

Basic body structures

Structure	Technical characteristic	Strength	Typical task
Stationary robot arm	Articulated kinematic chain; the position of the base is constant.	High repeatability, high speed, easy to protect workspace.	Welding, machine service, palletizing, assembly.
Mobile carrier platform	Wheeled or other mobile base; useful without a separate manipulator.	Material or tool transport, long operating time, simpler mechanics.	AMR, hotel and hospital delivery robot.
Mobile manipulator	Mobile base and at least one robot arm/gripper.	Changing location and moving objects in one system.	Shelf work, machine servicing, picking.
Humanoid	Trunk, limbs, and often hands partially following human proportions; walking on feet is common, but humanoid form and gait are distinct features.	The ability to achieve human-sized tools and workplaces; complex balance and manipulation.	Industrial pilot project, research, reception, variable manipulation task.
Four-legged robot	A mobile platform on four legs, typically with a sensor and payload interface.	Off-roading, stair climbing, stable mobile sensor platform.	Industrial inspection, hazardous areas, mapping.
Hybrid architecture	A combination of two movement principles or body architectures.	Movement and workspace that can be adapted to the task.	Wheel-leg hybrid; humanoid upper body on wheeled base; arm mounted on rails.

Movement and environment

Movement mode	Typical physical condition	Common environment	Consequence
Installed	There is no independent relocation.	Fixed work cell; known geometry.	High accuracy and cycle speed.
Wheeled	Smooth or moderately uneven floor.	Factory, warehouse, hotel, hospital, shopping mall.	Energy efficient; long operating time; may be restricted by stairs and large thresholds.
Tracked	Uneven, loose or more difficult ground.	Outdoor, industrial/hazardous environment.	Great traction; turning and pavement protection are important indoors.
Walking on two legs	Space, stairs, and level differences designed for people.	Humanoid platforms.	High mechanical and control complexity; balance and fall control are key issues.
Walking on four legs	Stairs, rougher terrain, industrial route.	Inspection, mapping, sensor carrying.	Off-road and stability; manipulation may require a separate module.
Air/water	3D space or water environment.	Drones, ROV/AUV systems.	Separate energy, communication and control conditions.

Humanoid ≠ application area The humanoid body form is a technological architecture. The same body form can work in a factory, warehouse, hotel, shop or research laboratory. For economic and safety evaluation, the specific task and environment must always be specified. [1][3]

The advantage of a specialized form in a structured task

The experience of the Chinese service robot market in 2026 shows that in narrowly defined, well-structured workflows, the purpose-specific form can be scaled quickly. In the case of hotel delivery, a wheeled robot must reliably navigate, call an elevator, handle a handover point, and return. A general humanoid may require object recognition, grasping, full-body movement, human interaction, and error recovery in addition to navigation. [3]

1.3. Method of control

Robot control ranges from direct human control to autonomous execution within a task. A single robot can operate in multiple modes: autonomously following a normal path, requesting remote assistance in the event of an exception, and directly controlled during servicing. Autonomy must therefore be described for the specific task and the type of human intervention. [1][2][3]

Common control modes

Mode	What's happening?	Human role	Example
Pre-programmed operation	The robot performs the operation in a known sequence, based on known parameters.	Start, stop, recipe/program selection, troubleshooting.	Repetitive cycle of an industrial robot cell.

Mode	What's happening?	Human role	Example
Direct remote control / teleoperation	The human gives movement or task commands in real time.	Continuous operator control.	Hazardous environment exploration; robot training data collection.
Supervised autonomy	The robot performs normal tasks independently, and in case of exceptions, it asks for help or a human decides.	One person can supervise multiple robots; remote intervention.	A delivery robot requests remote assistance when encountering an unknown obstacle.
Autonomous execution within a task	The goal is given; the robot itself performs the situation estimation, planning and execution within the allowed operating range.	Monitoring, emergency shutdown, exception handling, maintenance.	AMR route planning; autonomous cleaning; some manipulation subtasks.

The manual describes the operation; it is not a universal, numbered scale of autonomy levels. [1][2][3]

The same task in three control modes

Task	Control	Human role	Measurement consequence
Hospital drug delivery	Teleoperated	The operator guides the robot throughout.	High operator time; simpler autonomous software; network connection is critical.
Hospital drug delivery	Programmed route + monitoring	The robot follows a fixed path; a human handles deviations.	Limited flexibility; easily measurable exception rate.
Hospital drug delivery	Supervised autonomous	The robot chooses its own route and avoids obstacles; it requests remote assistance if it gets stuck.	The main indicator is the frequency of intervention and successful, safe delivery.
Hospital drug delivery	Higher task autonomy	The system manages the entire workflow, from task assignment, route and elevator use to safe handover.	Integration, authorization management, fault tolerance and auditability are part of the performance.

Human supervision is a measurable attribute

The resource requirements of supervision directly determine the operating value. The economics of two seemingly similar robot fleets are different if one requires a remote operator for every two robots and the other requires one for every twenty or fifty robots. For humanoid tasks, a useful metric is the ratio of autonomous productive robot hours to human support hours. [3]

It is worth logging remote assistance events by type: path blockage, elevator or door failure, grip failure, network failure, battery or docking problem, software error, security event. This way, the development of autonomy can be measured on a specific error population. [3][4]

1.4. Application tasks

The business value of a robot comes from the useful work it successfully performs. The application should therefore be broken down into task, input, output, human connection, and measurable performance. The same robot can have multiple applications; different tasks require different KPIs. [1][3]

Task	Input	Robot output	Main operational KPI	Human connection
Manufacturing and assembly	Component, workpiece, assembly instructions, machine condition.	Gripping, inserting, screwing, machine servicing, inspection.	Task success; cycle time; scrap; position/force error; intervention; availability.	Material preparation, quality control, exception management, maintenance.
Transportation and material handling	Task title, item, source and destination, route/authorization.	Delivery or handover of goods or equipment.	Task/hour; delivery time; route success; elevator/door success; intervention; uptime.	Loading/unloading or integrated transfer; exception handling.
Cleaning	Area, cleaning recipe, contamination, water/chemicals, prohibited zones.	Surface cleaning and documented coverage.	m ² /hour; coverage; re-cleaning; water/chemical; docking success; operator/robot.	Equipment charging, maintenance, handling difficult spots and obstacles.
Customer reception	Visitor, question, destination, language, authorization.	Information, directions, queue or entry support.	Interactions; successful response/directions; wait time; human handover; service outcome.	Handling complex issues, sensitive decisions, and complaints.
Care and assistance	User status, request, object, environmental sensing.	Assistive task, rehabilitation, mobility or object handling support.	Successful assistance; caregiver minute; safety incident; intervention; comfort.	Supervision, decision-making, physical and clinical responsibility.
Inspection and patrolling	Route, sensor data, alert rule, reference state.	Image/thermal/acoustic data, anomaly detection, map.	Coverage; alert accuracy; omission; intervention; terrain/weather availability.	Alarm evaluation, intervention, maintenance.

KPI structure: based on the Chinese service robot market background research, sub-chapter source map and validation research. [1][3][4]

Manufacturing and assembly

The robot must recognize an object or pick it up from an identified position, move it and place it down, insert it or process it in a controlled manner. In a structured cell, the environment is known, and the workpieces and fixtures can be standardized. A mobile or humanoid solution comes to the fore when the task involves multiple workstations, changing positions or the use of tools tailored to the human. [3]

Relevant performance data include cycle time, success rate, position and orientation error, grip slippage, peak force, object damage, intervention frequency, and availability per shift. In the case of a humanoid, this is also accompanied by falls/near misses and whole-body stability. [4]

Transportation and material handling

One of the most clearly measurable tasks in mobile robotics. The robot picks up or takes an object, follows a route, handles authorization, uses an elevator or door if necessary, and then delivers. The performance of the process is measured by the number of successful tasks, average and p95 delivery times, elevator and door interaction success, intervention rate, and fleet availability. [3]

Cleaning

A professional cleaning robot maps an area, plans a route, avoids obstacles, operates a cleaning module and docks. The natural unit of the task is the area to be cleaned and the desired cleaning result. m²/hour is only one indicator; coverage, re-cleaning, water and chemical consumption, docking success and the number of robots supervised by the operator together provide an operational picture. [3]

Customer reception, care and inspection

In addition to physical movement, speech, display, directions, and connection to information systems become important in the case of a customer reception robot. In care tasks, the unpredictable movement of humans, touch, close-body assistance, and sensitive information create higher safety and operational requirements. In the case of a control robot, sensor coverage, alarm quality, and remote operator escalation are the central indicators. [3][4]

Task first, robot form second When deciding on an application, the workflow, expected outcome, and environment must first be captured. Then, the appropriate body shape, mobility, and autonomy can be selected. The subsequent market chapters of this handbook follow this order. [1]

1.5. Usage environments

The operating environment consists of measurable technical conditions. Clear passage, turning space, thresholds and stairs, slope, floor adhesion, temperature, water and dust exposure, lighting, network coverage, and shared space with people all affect the robot's suitability. [2][4]

Environmental requirements by operating context

Environment	Physical situation	Critical requirements	Common integration
Factory	Dedicated or mixed traffic route; machinery, pallets, cables; industrial communications.	Machine safety; work area boundaries; E-stop; industrial integration; dust/heat/vibration according to the given location.	MES/ERP, machine and cell control, access control, security system.
Warehouse	Long route, intersecting forklift/pedestrian traffic, shelves, loading zones.	Traffic management, congestion, cargo safety, route blocks.	WMS/WES/ERP, gates, elevators, docks.
Hotel	Guest traffic, carpet and hard floors, elevator, door, hallway, room level.	Quiet operation, safe people-avoidance, elevator and door use, aesthetics.	PMS, phone/message, elevator, door, ordering system.
Restaurant	Narrow, crowded hallway, tables/chairs, spilled liquid, rush hour.	Dynamic obstacle avoidance, stable tray transport, cleanability.	POS/KDS, task allocation, staff workflow.
Healthcare	Patient and visitor traffic, elevators, entry, hygiene zones.	Safe handover, infection control, authorization, documented route and events.	HIS/logistics system, elevator, access control, drug or sample management.
Public area	Weather, road surface, curb, slope, pedestrian/bicycle traffic, GNSS/network.	Outdoor protection, braking and detection, remote assistance, legal/operational environment.	Map, fleet center, telecommunications, customer application.
Home	Narrow spaces, carpets, thresholds, furniture, children/animals, changing routines.	Small size, quiet operation, object and person detection, simple user operation.	Home Wi-Fi, app, smart home optional.

Manufacturer-specific environmental data

The values below are product-specific examples. They show the operating limits of different robot categories; they should not be interpreted as a common performance test. [2]

Model	Environment	Reported data	What does it show?	Source type
Roborock Saros 10	Home	Device height 79.8 mm with recessed LDS module; 93.5 mm with raised sensor.	The clearance under furniture depends on the current configuration of the robot.	Manufacturer's product page.
PUDU CC1 Pro	Professional indoor cleaning	Minimum path width 70 cm; obstacle/threshold clearance 20 mm without cleaning, 8 mm during cleaning; IPX4.	Physical restrictions during cleaning may be stricter than during transportation.	Manufacturer's product page.
Husqvarna Automower 430X BLACK	Outdoor lawn	Area capacity 3200 m ² ±20%; maximum slope in working area 50%, at boundary 25%.	There is a different slope limit for the inner working area and near the boundary.	Husqvarna HU product page.
Boston Dynamics Spot	Industrial/outdoor inspection	IP54; operating temperature –20–55 °C; maximum step height 300 mm; maximum speed 1.6 m/s.	Off-road mobility and industrial environmental range on a four-legged platform.	Manufacturer's specification.

Current manufacturer specifications, checked September 15, 2026. [14][15][16][17]

Public space example: Starship and S Group in Finland

According to a December 2025 Starship corporate announcement, the Finnish S Group network reached its one millionth robot delivery in less than three years. The service was connected to more than 170 stores and 79 municipalities, and there were more than 800 Starship robots operating in Finland. According to the announcement, up to 20% of online grocery orders for some stores were delivered by robots. [18]

Finnish operation presents special winter operating problems: snow, slush, cold batteries, reduced traction, snowdrifts, and snow-modified path geometry. Starship describes winter tires and a “snow mode” function; the announcement also mentions the development of battery heating. This case clearly shows that the suitability of the robot must always be assessed in a specific operating environment. [18]

Environmental data sheet: what is worth recording before every pilot project?

Data group	Items to be recorded
Geometry	Door and aisle width; turning point; threshold; stairs; slope; ramp; elevator size.
Surface	Floor type, adhesion, carpet, gap, slipperiness, outdoor covering.
Traffic	Pedestrian, forklift, vehicle or animal traffic; rush hour; intersections.
Environment	Temperature, humidity, dust, water, precipitation, outdoor light, reflection.
Communication	Wi-Fi/4G/5G coverage, roaming, latency, outage zones, local server.
Integration	Elevator, automatic door, access control, PMS/HIS/WMS/MES/ERP, telephone or ordering system.

Data group	Items to be recorded
Human process	Who gives tasks, who fills/cleans, who handles exceptions, who decides in the event of a security incident.
Operation	Charging point, battery replacement, parts, daily inspection, service availability, storage.

1.6. Technological maturity and performance

The evidentiary value of a claim about the performance of a robot is determined by the environment, the number of repetitions, the time span, and the degree of human assistance. A spectacular demonstration, a real-world pilot project, and a permanent operational installation are three distinct levels of evidence. These are marked separately in the manual. [1][3]

Three levels of evidence

Status	Minimum content	What does it prove?	What should be communicated?
Demonstration	Pre-prepared or tightly controlled task; short time; often familiar objects and route.	It shows the existence of the ability.	Number of repetitions, preparation, operator assistance, knowledge of failed attempts.
Pilot project	Real or realistic place of operation; limited scope of duties; days/weeks/months; supervision logged.	It measures site suitability, integration, and defect population.	Task success, cycle time, intervention, uptime, errors, maintenance, environmental conditions.
Normal operation	Repetitive business or institutional process; regular users; maintenance and responsible operator; measurable service outcome.	Evidence of sustained operational and economic viability.	Fleet time, task number, SLA/availability, operational work, bug fixes, TCO, version management.

The three statuses are the level of editorial proof of the manual. They are not ISO maturity classes. [1][3]

2026 application maturity overview

Application	Maturity 2026	Nature of evidence
Warehouse AMR / goods-to-person	Very high	Large fleets, standardized workflow, WMS integration, productivity KPIs.
Indoor transportation	High	Mass deployment in hotels, restaurants and other institutional environments; elevator and fleet integration.
Professional cleaning	Tall, fast growing	Measurable m ² /hour and area coverage; automatic docking; multiple verticals.
Hospital logistics	Medium-high	Material flow, safe transfer and institutional integration can be documented.

Application	Maturity 2026	Nature of evidence
Customer service / retail	Medium	Technically working systems; economic results depend on the use case.
Security patrol	Medium	Sensory patrolling and remote escalation; autonomous physical intervention is rare.
Elderly care robotics	Low-medium	Many pilot projects and targeted assistive products; human interaction and responsibility are a strong constraint.
Humanoid service	Early	Manipulation, data requirements, reliability, and cost per successful task are the main limitations.

Analytical maturity synthesis from the project China Service Robot research; not an official Chinese or ISO classification. [3]

Common KPI dictionary

Indicator	Definition	Measurement note
Task success rate	Successfully completed tasks / all started, assessable tasks.	The condition for success must be set in advance; partial completion is a separate category.
Cycle time	The time elapsed from the start of the task to its accepted completion.	On average, p50/p95 is useful; waiting and human assistance can be marked separately.
Intervention rate	The proportion of tasks or events requiring human assistance.	Remote assist, on-site assistance and safety stop should have separate event codes.
Availability	The proportion of time actually used out of the planned service time.	Maintenance, charging, unexpected failures and disruption of external infrastructures are required.
Uptime	Time spent in operational state according to the chosen measurement definition.	The definition and denominator must be stated; availability and uptime are not always the same.
Operator/robot ratio	Number of robots that can be monitored simultaneously per person.	A key indicator of fleet economics.
Recovery time	The time from an error or hang to the return to a safe, productive state.	Automatic recovery and human recovery can be measured separately.
Energy/task	The energy requirement of an accepted task; for mobility, Wh/km or a normalized indicator can also be used.	Battery condition, load and environment should be recorded.
Accuracy / repeatability	Deviation from the target position or the variance of repetitions of the same target.	The two indicators are separate concepts; measurement uncertainty and a reference instrument are required.
Security incident	Collision, fall, near-miss, dangerous contact, safety envelope violation, E-stop.	Event definition and exposure (hour, km, task) should be interpreted together.

What should always be recorded next to the KPI?

- Robot ID and hardware version; firmware, control software, and AI model version/hash. [4]
- Task definition and success condition; task type, subject, workload and target. [4]
- Environment: track geometry, flooring, lighting, temperature, network, human traffic. [4]

- Battery status, total mass and payload; cold start or thermally stable state. [4]
- Number of repetitions, test days, randomization, and any human intervention. [4]
- Measuring instruments, calibration identifier, time synchronization and, if necessary, measurement uncertainty. [4]

Performance measurement standards – current status

Standard	Object	Status as of 2026.09.15	What does it measure?
ISO 8373:2021	Robotics – dictionary	Published, 3rd edition; November 2021. Next edition is a draft DIS.	Concepts and terminology.
ISO 18646-2:2024	Service robots – navigation	Published; January 2024.	Position, navigation, obstacle detection/avoidance, route deviation, narrow passage, mapping.
ISO 18646-3:2021	Service robots – manipulation	Published; June 2021.	Gripping, sliding, object size/force, door and drawer manipulation.
ISO 18646-5:2026	Service robots – walking on legs	Published; July 2026.	Testing the locomotion performance of walking robots; complete robot test.
ISO 9283:1998	Industrial robots – performance criteria	Published; still a used reference, under review.	Accuracy, repeatability and industrial robot performance characteristics.

Based on primary ISO sources, checked on 15 September 2026. [8][9][10][11][12][13]

Performance and safety The parts of the ISO 18646 series referenced here provide performance test methods. Product safety, machine safety, functional safety and conformity assessment requirements are covered in Chapter IV. [10][11][12]

Humanoid-specific measurement problems

Problem	Measurable content
Falling and getting up on your own	Fall frequency, impact, recovery success, recovery time, injury/fault, E-stop status.
Manipulation while walking	Combined task success of locomotion and manipulation, trajectory deviation, grasp error, cycle time.
Endurance and drifting	Changes in task success, temperature, energy/task, accuracy, and intervention over hours/days.
Energy–motion–heat	Wh/task, Wh/km, runtime, temperature and thermal derating on the same task.
Changing perception	In addition to light, cover, reflection and moving target, there are precision/recall, miss, latency, calibration drift.
Human–robot interaction	Distance, contact, reaction time, handoff, unintended motion and human intervention.
Network loss	Latency, packet loss, complete link loss, safe-state latency, stale command, reconnect.

Problem	Measurable content
Continuously updated AI	Model version/hash, test manifest, data and software version; reproducible comparison.

Based on the gap map of the project's humanoid validation background research. The detailed test protocol belongs to the validation center subsection of Chapter VI. [4]

The operational meaning of “95% autonomy”

The economic impact of autonomy is asymmetric. If the remaining 5% occurs at unpredictable times and requires continuous human availability, the overall labor savings of the robot may be small. In daily operations, therefore, intervention rates, recovery rates, and operator/robot ratios provide more direct information than a general autonomy label. [3]

In humanoid robots, the long tail is particularly important: deforming objects, liquids, clothing, confined spaces, changing human behavior, and unexpected object positions. Training data collection and feedback of teleoperated interventions aim to cover these rarer cases. [3]

Chapter resources

Internal research materials provide the editorial and evidence map for the manual. Primary IFR/ISO sources were used for conceptual and standard statements, and manufacturer sources were used for product specifications. Reference numbers are given in square brackets in the chapter.

- [1] Robotics – facts, figures | Resource map. Project workbook, updated September 11, 2026.
- [2] Robotics – facts, data: Source-based addition of six subchapters. Project research, data closure: September 11, 2026.
- [3] China's Service-Robot Market: From Delivery Machines to Embodied Artificial Intelligence. Project Research, September 9, 2026.
- [4] Humanoid Robot Test Track and Validation Center at Óbuda University. Project Research, September 2026.
- [5] International Federation of Robotics (IFR): Standardisation / robot definitions. Retrieved: 15 September 2026. [Source](#)
- [6] International Federation of Robotics (IFR): Industrial Robots. Retrieved 15 September 2026. [Source](#)
- [7] International Federation of Robotics (IFR): Service Robots. Retrieved: 15 September 2026. [Source](#)
- [8] ISO 8373:2021. Robotics — Vocabulary. 3rd edition, 2021-11. [Source](#)
- [9] ISO/DIS 8373. Robotics — Vocabulary. Draft for next edition; status checked: 15 September 2026. [Source](#)
- [10] ISO 18646-2:2024. Robotics — Performance criteria and related test methods for service robots — Part 2: Navigation. [Source](#)
- [11] ISO 18646-3:2021. Robotics — Performance criteria and related test methods for service robots — Part 3: Manipulation. [Source](#)
- [12] ISO 18646-5:2026. Robotics — Performance criteria and related test methods for service robots — Part 5: Locomotion performance of legged robots. [Source](#)
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- [14] Roborock: Saros 10 – official product page. Retrieved: September 15, 2026. [Source](#)
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- [16] Husqvarna: Automower 430X NERA – official Hungarian product page. Retrieved: September 15, 2026. [Source](#)
- [17] Boston Dynamics: Spot – official product page. Retrieved September 15, 2026. [Source](#)
- [18] Starship Technologies: One million deliveries in Finland / S Group case. Company announcement, December 2025. [Source](#)
- [19] International Federation of Robotics (IFR): Collaborative Robots – How Robots Work alongside Humans. Position paper update, December 4, 2024. [Source](#)

Manuscript Status This Word file is the edited manuscript of Chapter I of the manual. References to subsequent chapters follow the chapter numbering of the approved September 10–11, 2026 structure. [1]

CHAPTER II

How robots work: hardware, software, artificial intelligence and robot data

The operation of the robot is determined by the mechanics, sensing, control and data processing together. The chapter presents the relationship of these system elements, then organizes the data requirements of the fleet consisting of several robots, robot training and operation into a clear structure. Product data refers to the given model, research results to the published experiment. Calculations and editorial schemes are identified by a separate notation.

AI is the standard abbreviation for artificial intelligence. Embodied AI describes an intelligent system that can perceive and act on its environment. In robotics, the focus is on the link between the physical body, sensors, movement and learned behavior.

Data cut-off September 15, 2026. The chapter is based on the project's technical manuscript and background research as of September 11, 2026; key points of rapidly changing ISO, developer, and manufacturer specifications re-checked September 15, 2026.

Chapter structure

	Subchapter
2.1	Mechanical structure, drives, robot arms and grippers
2.2	Sensors, on-board computing and power supply
2.3	Robot control, positioning, navigation and manipulation
2.4	Fleet management and connection to building and enterprise management systems
2.5	Physical AI, robot teaching and simulation
2.6	Robot data collection, processing and quality control
2.7	Software updates, diagnostics and technical reliability

Structural source: the project's sub-chapter source map and the Chapter II technical manuscript dated September 11, 2026.

2.1 Mechanical structure, drives, robot arms and grippers

The mechanical system carries the robot's mass, transmits the power of the drives, and determines the possible movements. The wheel, leg, arm, and gripper perform different tasks. For example, the loading surface of a transport robot carries a load; the robot arm also changes the position and direction of the object it grips. To plan the motion, the software must know the robot's parts, the connection of the joints, and the allowed ranges of motion ([Movelt, n. n. ; Pudu Robotics, n. n.](#)).

Powertrain components

The electric motor produces rotational motion and torque; torque characterizes the rotating effect of the force. The gear ratio of the gear unit modifies the relationship between the speed and the output torque. The bearing guides the motion and absorbs the load. The encoder provides feedback on the position of the shaft; the drive electronics convert the controller command into an electric drive. These elements can be built as separate units or as integrated actuator modules. The actuator is an intervention unit that converts the controller command into physical movement; the integrated design combines several drive elements. The CubeMars AK series includes such robotic actuators ([CubeMars, n. n. ; Harmonic Drive SE, n. n. ; HEIDENHAIN, n. n.](#)).

In the related data sheets, the interface means the connection method for data exchange between the controller and the drive. A degree of freedom is an independent movement option; an active degree of freedom has a controlled drive. In a robot hand, the movements of several joints can be linked, so the number of joints and independently controlled movements may differ ([CubeMars, n. n. ; Inspire Robots, n. n.](#)).

Table 2.1. Documented examples of mechanical and drive systems

System component	Original manufacturer data or design	Technical report
Integrated Actuator – CubeMars AK Series	The engine, transmission and drive form a combined unit.	A module that can be integrated into a robot joint; the control mode and interface must be identified by type.
Gearbox – Harmonic Drive CobaltLine-CP	The product family has a gear ratio range of 50:1–160:1.	The range includes a selection of several sizes and designs.
Position feedback – HEIDENHAIN KCI 120 Dplus	Position measurement on the input and output side of the gear unit.	The position of the motor and the driven joint can be observed separately.
Robot hand - Inspire Robots RH56E2	Five fingers, 6 active degrees of freedom and 12 joints.	The movements of several joints can be mechanically linked; the number of joints and the number of independently controlled movements may vary.

Source: the four rows are based on the documentation of CubeMars, Harmonic Drive, HEIDENHAIN and Inspire Robots respectively. The right column is the editorial technical interpretation ([CubeMars, n. n. ; Harmonic Drive SE, n. n. ; HEIDENHAIN, n. n. ; Inspire Robots, n. n.](#)).

To interpret the torque data, the operating state must also be known. The peak torque allowed for a short time, the torque that can be used continuously and the power available at a given speed are separate data. When comparing integrated actuators, it is therefore necessary to identify the nominal and peak values, the control mode and the design ([CubeMars, n. n.](#)).

The relationship between the arm and the gripper

The arm moves the tool mounted on the end in the workspace. The gripper is connected to the object: it holds, releases, and sometimes arranges it within the grip. The movements of the multi-fingered robotic hand are limited by the hand's own mechanics and control. The range of objects that can be grasped can therefore be described together with the design of the hand, the available grips, and the task (Inspire Robots, n.d.).

The load capacity data sheet requires a separate field for the load carried, the mass moved by the arm, and the load on the gripper. The dead weight of the gripper is also part of the load on the arm. In addition to the load capacity, the reach, the type of gripper, the location of the load, and the movement tested should be included in the manual database. This is an editorial data sheet rule: it makes it possible to compare the kilogram values given for different tasks.

2.2 Sensors, on-board computing and power supply

Sensors measure various details of the environment and the robot's own state. The camera provides an image, depth sensing helps estimate spatial distances, and the joint encoder tracks the position of the mechanics. To link the data, the position, settings, and timestamps of the sensors must also be known (Campos et al., 2021 ; HEIDENHAIN, n. n. ; Orbbec, n. n.).

Table 2.2. Main data groups of robotic sensing

Sensor or data source	What is it describing?	What can it be used for?
Color camera – RGB	Red, Green, Blue: an image of the scene composed of red, green and blue color channels.	Recognition of objects, surfaces, and the visual environment of the task.
Color and depth image – RGB-D	Red, Green, Blue, Depth: depth, or distance information, is associated with the color image.	Estimation of spatial object position, obstacles and grasping environment.
Laser distance sensor – LiDAR	Light Detection and Ranging: distance measurement using emitted and reflected light. The measurements reveal the shape of the environment.	Mapping, location and obstacle detection.
Joint and wheel sensors	Position and movement of the driven axles.	Regulatory feedback and motion estimation.
Inertial Measurement Unit – IMU	Inertial Measurement Unit: a unit that measures acceleration and angular velocity, i.e. the speed of rotation.	Motion and state estimation, also combined with visual perception.
Force, torque and tactile data	Characteristics of physical contact.	Touch and grip control, object movement data collection.

Source: edited data grouping based on Orbbec and HEIDENHAIN product descriptions, referenced location and mapping research, and documented solutions from the AgiBot World robotic data collection project (AgiBot-World-Contributors et al., 2025 ; Campos et al., 2021 ; HEIDENHAIN, n.d.; Macenski & Jambrecic, 2021 ; Orbbec, n.d.).

Sensor and computer as system components

The sensor's integration is determined not only by the measurement, but also by the data connection, power supply and physical connection. The Orbbec Gemini 335Lg stereo depth camera uses images from two viewpoints to estimate the distance. The GMSL2 (Gigabit Multimedia Serial Link 2) high-speed serial data connection transmits the camera data to the computer. This is equipped with a FAKRA connector; the name comes from the German Fachkreis Automobil, i.e. automotive expert circle. From the robot's point of view, the role of the cable is to provide a secure physical connection (Orbbec, n. n. ; Rosenberger, n. n.).

IP65 is the code for the protection of the housing against dust and water ingress. The IP (International Protection) rating of 6 indicates dust-tightness and 5 indicates protection against jets of water under specified test conditions. The Orbbec manufacturer's data sheet also requires the use of cables with a protection rating appropriate to the camera's specified protection rating (International Electrotechnical Commission, 2013 ; Orbbec, n.d.).

To interpret the calculation data sheets, the operation and consumption must be read separately. TFLOPS (Tera Floating Point Operations per Second) indicates trillions of floating-point calculation operations per second; the floating-point representation is also suitable for computer processing of fractional numbers. FP4 (4-bit Floating Point) is a 4-bit version of this, with limited numerical precision. Sparse calculation takes advantage of the omission of operations associated with zero values. The watt, symbol W, is the unit of power: here it shows the electrical power range with which the module operates (NVIDIA, n. n.).

Table 2.3. Checkable characteristics of two onboard components

Component	Reported technical data	Interpretation of the data
Orbbec Gemini 335Lg	Stereo 3D camera; GMSL2/FAKRA connection; IP65.	Connectivity and environmental protection characterize the installation. The positioning accuracy of the robot must be measured separately.
NVIDIA Jetson T5000	Up to 2,070 TFLOPS FP4 with sparse computing; 128 GB memory; 40–130 W power envelope.	Module specification. The FP4 calculation data is tied to the specified accuracy and operating mode; the total robot consumption includes additional units.

Source: Orbbec and NVIDIA. Jetson data is for the T5000 module; NVIDIA specifies a 130 W requirement for peak performance (NVIDIA, n.d. ; Orbbec, n.d.).X

The on-board computer can run image processing, mapping, motion planning and AI models. Fast control loops can also be implemented on a separate controller: the controller repeatedly compares the desired and measured states, then corrects the drive command. When selecting a computer, the model's memory requirements, the sensor data flow, processing latency and heat dissipation are all taken into account. A complete software chain is built between the manufacturer's peak calculation value and the task execution measured on the robot (NVIDIA, n. n. ; ros2_control, n. n.).

Energy supply data

The energy content of the battery can be given in watt-hours (Wh) or kilowatt-hours (kWh), the power input in watts (W). One watt-hour is the energy used in one hour with one watt of power; one kilowatt-hour is one thousand watt-hours. A simple energy estimate of the operating time is the ratio of the usable energy to the average power. The calculation also takes into account the consumption of drives, computer, sensors and auxiliary equipment. The BMS (Battery Management System) is the battery monitoring system: it monitors the operating status and helps manage charging and discharging. The operating data sheet includes the charge level, status, temperature and charging events.

The manufacturer's data sheet for the Pudu BellaBot Pro states an operating time of 11 hours without load. To determine the operating time during a task, the load, the ratio of movement to waiting, the route and the charging order must also be recorded ([Pudu Robotics](#), n. n.). The data repository should handle the manufacturer's operating time and the operating time measured on site in separate fields, indicating the test conditions next to both.

2.3 Robot control, positioning, navigation and manipulation

The operation of the robot is a feedback process. The system senses the state, evaluates information relevant to the task, plans a movement, and then remeasures it during execution. Navigation is the process of guiding the robot to a goal, and manipulation is the process of grasping, moving, and placing objects. Both require a proper description of the robot and its environment ([MoveIt](#), n. n. ; [Open Navigation](#), n. n. b).

ROS 2, the second generation of the Robot Operating System, is a software toolkit for building and interoperability of robot programs. Nav2 supports navigation for mobile robots, and MoveIt supports motion planning for arms and other movable robot parts. ros2_control is used to connect control programs to the robot hardware ([MoveIt](#), n. n. ; [Open Navigation](#), n. n.-b ; [ROS 2](#), n. n. ; [ros2_control](#), n. n.).

Table 2.4. Processing chain from perception to execution

Platoon	Main input	Result produced
Perception	Images, distances, joint and inertial data.	Time-stamped measurements.
Condition assessment	Sensor data, previous state and motion model.	Estimated position, direction, and movement status.
Environment description	Measured geometry, map, detected objects.	A map or scene model that can be used for planning.
Motion planning	Goal, robot model, environment and constraints.	A path or executable movement description.
Regulation and back-measurement	Movement command and current status.	Drive commands, execution status and deviation indication.

Source: the volume's organizational scheme based on the functions described in the documentation for Nav2, MoveIt and ros2_control ([MoveIt](#), n. n. ; [Open Navigation](#), n. n.-b ; [ros2_control](#), n. n.).X

Mapping and positioning

SLAM (Simultaneous Localization and Mapping) means simultaneous localization and mapping. The system estimates its own location and a map of the environment from the measurements of the moving robot. SLAM Toolbox is one of the mapping software that supports this. In addition to the map, it can also store the relationship system of the measurement positions, the so-called pose graph. The points of the graph describe the previous positions and directions of the robot, and its connections describe the measured relationships between them; this supports the later continuation of the mapping ([Macenski & Jambrecic](#), 2021).

AMCL (Adaptive Monte Carlo Localization): uses a probabilistic method to estimate the robot's location on an already available map. It maintains several possible positions and then modifies them based on motion and sensor data. The method calls these possible positions particles. In the Nav2 documentation, the lower default value for the particle number is 500 and the upper default value is 2,000. These are the settings of the algorithm; the localization, or location error, is given by a separate measurement ([Open Navigation](#), n.d.).

ORB-SLAM3 is a research software that maps and estimates position from camera images and, in some modes, inertial measurements. The table contains pre-recorded test data from the EuRoC (European Robotics Challenge) and TUM-VI (Technical University of Munich Visual-Inertial dataset). Researchers use such collections to verify and compare the accuracy of the methods ([Campos et al., 2021](#)).

Table 2.5. Three numerical data and their corresponding conditions

System	Reported value	What does it apply to?
Nav2 AMCL	500 and 2,000 particles.	The default value of the minimum and maximum parameters is in the documentation of the Rolling, i.e. continuously updated development release under review.
ORB-SLAM3	3.6 cm average accuracy on the EuRoC dataset; 9 mm on the TUM-VI room sequences.	The authors' research measurements using a stereo camera and inertial data, in two different test environments.
ros2_control Controller Manager, controller manager	The default refresh rate is 100 hertz (Hz), which is 100 cycles per second.	The parameter of the read-control-write cycle. The nominal cycle time calculated from this is 10 milliseconds (ms), or 10 thousandths of a second.

Source: *Open Navigation; Campos et al.; ros2_control*. 10 ms is an editorial calculation from the conversion of 1/100th of a second ([Campos et al., 2021](#) ; *Open Navigation, n.d.-a* ; *ros2_control, n.d.*).X

In navigation, global planning searches for a path to the destination. Path tracking generates a movement command from the current position. Obstacles and the robot's outline are included in the assessment of walkability; a changed environment may require replanning or stopping ([Open Navigation, n. n. b](#)).

The above values of ORB-SLAM3 are the results of a research procedure on specific datasets. In the test of the installed robot, the path, the assembly and adjustment of the sensors, the lighting, the coverings and the recovery events are also part of the measurement protocol. In addition to the location error, the arrival at the destination, the stops and the necessary human interventions give a picture of the overall operation.

Object recognition, grasping and movement

Manipulation requires a grasp target position and an executable arm movement. MoveIt checks for collisions based on the robot model and the scene, then generates joint motion that conforms to the specified velocity and acceleration constraints. The result is also timed ([MoveIt, n.d.](#)).

Grasp position estimation is a separate research task. GraspNet-1Billion provides data and an evaluation framework for images, object positions, and grasp positions ([Fang et al., 2020](#)). The evaluation of the entire workflow from the creation of the grasp to the placement of the object: it also takes into account holding, moving, releasing, and checking the desired final state.

2.4 Fleet management and connection to building and enterprise management systems

Fleet management manages the tasks, status, and shared resources of multiple robots. This includes task assignment, charging scheduling, route coordination, and exception event reporting. As the robots operate, they also need to exchange data with other systems in the building or company.

IoT (Internet of Things) refers to the networked exchange of data between physical devices. The manufacturer of the KEENON BUTLERBOT W3 documents the use of an elevator with such a connection. In this example, the data exchange enables the robot and the elevator to cooperate ([KEENON Robotics, n.d.](#)).

The description of Hai Robotics' HaiQ software includes integration with WMS (Warehouse Management System) and WES (Warehouse Execution System). WMS helps to record and organize inventory, storage locations, and warehouse operations; WES coordinates the execution of current work (Hai Robotics, n.d.). During installation, the interface of the specific building and business system must be checked.

In manufacturing tasks, the MES (Manufacturing Execution System) is the system that tracks and controls the execution of production. The ERP (Enterprise Resource Planning) enterprise management system connects data from several business areas, such as inventory management, purchasing and production. The API (Application Programming Interface): defines the requests and data that programs can use to access each other's functions. The following editorial schema also records these system connections.

Table 2.6. External connections of the robot fleet

Related system	Request or data transmitted	Feedback needed	Relationship status
Elevator control	Elevator call, level and travel demand.	Elevator availability, appropriate level, door condition.	In the case of W3, the manufacturer documents the IoT elevator usage; the data fields here follow an editorial breakdown.
WMS or WES	Transport or material handling task, goods and location identifier.	Task status, arrival and deviation.	The HaiQ system description documents the integration option.
Hotel management or ordering system	Delivery request, destination and task ID.	Receipt, delivery, failure.	General integration requirement; connection to the given system must be verified separately.
MES and ERP	Reference to a production, inventory, or company task.	The completion event of the robot operation.	Editorial alignment schema; available API and data model depends on installation.
Door, entry and charger	Right of way or charging request.	Access, equipment status and operation closure.	On-site technical requirement, to be checked per device.

Source: Editorial integration schema. The original source of the two named product relationships is KEENON and Hai Robotics; the other lines describe a general requirement (Hai Robotics, n.d. ; KEENON Robotics, n.d.).X

Two typical workflows

The editorial process model for a hotel delivery starts with the receipt of the order. The fleet manager selects an available robot, the robot arrives at the elevator, moves between floors, and then delivers it to the destination. The closing is accompanied by a delivery feedback. The product example for elevator use is W3; the connection of the ordering system and the delivery feedback is the task of the given installation (KEENON Robotics, n.d.).

In a warehouse environment, a WMS or WES can assign a task to a robotic system. Fleet management organizes the movement, the workstation reports receipt or processing, and the enterprise system updates the task status. HaiQ describes this as route optimization and inventory information (Hai Robotics, n.d.). The fulfillment unit – such as a case, item, or order – requires uniform identification in the related systems.

Linking events

To ensure traceability of operations, it is advisable to manage the robot, task and location identifiers together. In the data repository, a task should at least contain the creation, acceptance, start and end times; in case of failure, an error code and human intervention should be associated with it. This is an editorial event schema.

The operation after the connection is broken must also be recorded: whether the task is still there, whether a completion feedback has been received, and on what basis the process is restarted. The software update record can be linked to the same robot identifier. This way, the task result can be examined together with the actually running software.

2.5 Physical AI, robot learning and simulation

Physical AI refers to a system's ability to perceive, interpret and act in the physical environment. In robotics, robot learning connects observations with actions. A learned control model selects a movement or action from the available information. A demonstration is the recorded execution of a task used as a training example. Reward-guided learning and language-conditioned control represent different learning approaches (Black et al., 2024; Isaac Lab Project Developers, n.d.-a, n.d.-c).

Table 2.7. Main approaches to robot training

Approach	What are you learning from?	Characteristic role	What should be checked specifically?
Learning by imitation	Demonstrated observation–action pairs.	A movement or task taught by human demonstration.	The quality of the demonstration and the situations not seen in teaching.
Reinforcement learning	From the consequences of actions and the reward signal.	Practicing movement, balance, and other control tasks.	The relationship between reward and actual task, the limits of behavior.
VLA model - Vision-Language-Action	From robotic data combined with visual and linguistic information.	The name connects vision, language, and action: the model chooses a robot action based on the situation it sees and the instruction.	Performance related to the robot and task used.
Retraining, fine-tuning	From additional, targeted data collected for an existing model.	Application to a new task, object, or environment.	Improvement and retention of previous skills.

Source: edited comparison based on Isaac Lab teaching documentation and $\pi 0$ research paper. The right column contains editorial evaluation criteria (Black et al., 2024 ; Isaac Lab Project Developers, n.d.a , n.d.c).X

Demonstration and teleoperation

During teleoperation, a human remotely gives movement commands to the robot. The recorded data is composed of inputs, issued commands, robot state, and task results. Teleoperation can therefore also be used to generate demonstration data. DROID (Distributed Robot Interaction Dataset) is a robot interaction dataset collected at multiple locations. Its common data collection equipment includes a robotic arm, external and wrist-mounted cameras, and teleoperation using a VR (Virtual Reality) device. In the example, the controller used for virtual reality transmits the human's movement commands to the robot (DROID Dataset Team, n.d.).

The correspondence between the control device and the robot movement must be recorded alongside the data. This includes the meaning of the command, the coordinate system, i.e. the reference system used to specify the position, as well as the unit of measurement and timing. A delayed or incorrectly assigned command can create a false connection between the seen position and the desired action during training. Therefore, testing the demonstration system is part of data quality control.

The $\pi 0$ example

Introduced in 2024, $\pi 0$, pronounced pi zero, combines visual, linguistic, and robot state data to produce continuous actions. Continuous actions here refer to numerical commands that control the robot's movements. The reported research involved pretraining on over 10,000 hours of robot data, followed by task-specific posttraining. Pretraining builds the model's initial capabilities on a larger dataset; posttraining adapts them to the selected task. The tasks tested included folding clothes, arranging tables, and assembling boxes ([Black et al., 2024](#)).

The amount of data from the pre-training shows the scale of the model development. The results reported for each task include the robot used, the objects, the environment, and the evaluation procedure. A research demonstration can be used to determine the capability tested in a given application.

The role of simulation

Isaac Lab is a robotics framework based on physical and sensor simulation. Its calculations are accelerated by a GPU (Graphics Processing Unit): a processor capable of performing many similar calculations in parallel. The simulation models the operation of the robot and its environment on a computer, so that multiple experimental environments can be run simultaneously. Isaac Lab supports reinforcement and imitation learning, as well as motion planning workflows ([Isaac Lab Project Developers, n.d.](#)).

In the simulated environment, the parameters of the robot and the task can be changed, that is, the set of settings that determine the operation. Random changes to environmental or physical properties are called domain randomization: the goal is to make the learned behavior work under a variety of conditions ([Isaac Lab Project Developers, n.d.](#)). Sim-to-real (simulation to reality) is the transfer of the operation learned in the simulation to the real robot; this includes a separate verification phase. Based on the task success, physical contact, stopping and human intervention measured on the real robot, it can be decided whether the learned behavior can be used in the given environment.

2.6 Robot data collection, processing and quality control

Robot data consists of temporally linked measurements, states, actions, and results. An episode is a data unit of a related task experiment. A trajectory describes the temporal course of a movement or sequence of actions; its exact content depends on the definition of the dataset. The frame number, trajectory number, and robot hour are separate metrics ([DROID Dataset Team, n.d.](#) ; [Hugging Face, n.d.](#) ; [Open X-Embodiment Collaboration, n.d.](#)).

Table 2.8. Robotics datasets and reported units of measurement

Dataset	Reported quantity	Nature and interpretation of data
Open X-Embodiment	Over 1 million real robot trajectories; 22 robot designs.	A collection that combines data from multiple robot platforms. The quantity refers to motion sequences.
DROID	76,000 demonstration trajectories; approximately 350 hours; 564 scenes.	Manipulation in real environments. Duration and number of demonstrations are different characteristics of the same collection.
AgiBot World	More than 1 million trajectories.	Manipulation data created with a unified collection process and human verification.
GraspNet-1Billion	190 scenes; 88 objects; 97,280 RGB-D images; over 1.1 billion grip positions.	Dense grasping marks attached to images and objects. The number of positions represents the amount of annotation, i.e. the amount of marking assigned to the data.

Source: the four lines are based on original submissions by Open X-Embodiment, DROID, AgiBot World and GraspNet, respectively. The GraspNet numbers describe the dataset published on the project website ([AgiBot-World-Contributors et al., 2025](#) ; [DROID Dataset Team, n.d.](#) ; [Fang et al., 2020](#) ; [Open X-Embodiment Collaboration, n.d.](#)).X

From raw recording to training data

The rosbag2 tool in ROS 2 can be used to record and replay robotic message streams. A message stream is a time-series of measurements, status signals, or commands transmitted between the software elements of a robot. rosbag2 supports multiple storage formats; a file format called MCAP, which stores time-stamped messages, is available with a separate storage module. The recording settings determine which data streams are saved to the files and in what format ([ROS 2, n. n.](#)).

For training, data must be organized into episodes, time windows, and a uniform field structure. LeRobotDataset v3.0 is a data format for organizing robot training data. It handles numerical states, actions, and timestamps in Parquet tables, image data in video files, and descriptive data in JSON and Parquet structures. Parquet is a tabular file format organized by columns. A file can contain multiple episodes; the boundaries are identified by metadata, i.e. additional information describing the content and structure of the data ([Hugging Face, n.d.](#)).

The manual processing scheme is as follows: recording, acceptance control, time alignment, episode formation, marking, quality control and versioned release. The original recording, the processing version and the released training data are linked by a separate identifier. This allows for the correction of an incorrect marking or the subsequent re-production of the training data.

The data sheet firmware refers to the hardware-related operating software of the device. Calibration is the assignment of the measuring system to known reference values; the associated parameters help in the correct interpretation of the measurements. In a robot, such data is the relative position of the cameras or the zero point of the joints. Sampling is the recording of successive measurements; its frequency determines how often new data is generated.

Table 2.9. Suggested data sheet for a robotics episode

Field group	Data to be recorded	What is it for?
Identification and task	Episode ID, location, task description, starting state.	For experiment retrieval and comparison.
Robot and execution	Robot type, unique identifier, arm or hand, form of command data.	To determine on which device and with which movement command the data was generated.
Software and calibration	Firmware, controller and model version; calibration of cameras and joints.	To reconstruct the recording state.
Timing	Start and end, common time base, sampling, frame drops.	To link observations and actions.
Result and quality	Success or failure, subtask, intervention, stop, control status.	For selection for teaching and assessment purposes.
Origin and use	Raw file identifiers, processing and marking version, license, access.	To record origin and permitted use.

Source: Editorial datasheet schema. The technical background for episode, state, action, and metadata management is provided by the original documentation of DROID, LeRobot, and rosbag2; the table field division is an editorial suggestion (DROID Dataset Team, n.d.; Hugging Face, n.d.; ROS 2, n.d.).X

Timing and quality

The maximum sensor sampling rate, the actual data collection frequency, and the frequency used for teaching are separate settings. Even with a common time base, latency and data loss must be checked. A local buffer, i.e. temporary data storage, on the robot or collection station can help preserve data in the event of a network outage; acceptance testing should then detect any gaps.

Table 2.10. Editorial schema for data quality control

Investigation	Phenomenon to be checked	Result to be recorded
Fulness	Missing camera, status, or command data.	Affected data stream and time period.
Temporal coherence	Clock lag, lag, dropped frames.	Measured deviation and applied correction.
Calibration	Incorrect camera alignment, joint zero point, or force measurement baseline.	Calibration ID and validity.
Notation	Incorrect assignment limit, success rate, or error category.	Improved markup, verification, and versioning.
Diversity	Excessively repetitive subject, scene, or opening situation.	Distribution of tasks and environments.
Separation of teaching and assessment	Identical or closely related shots in both subsets.	The division rule and the episodes involved.

Source: Editorial review scheme; the importance of completeness, calibration, annotations, and scene diversity is also illustrated in the data collection description of DROID and AgiBot World (AgiBot-World-Contributors et al., 2025 ; DROID Dataset Team, ed.).X

Task failure and data error are separate categories. A well-recorded failed grip can be used for error analysis and later correction. Quality control therefore treats the technical usability of the recording and the robot task result in separate fields.

Storage requirement planning model

The following table uses three assumed data profiles: 30, 120, and 500 GB/robot hour, which is the number of gigabytes of data generated by a robot during one hour of recording. These are design values. The annual volume is calculated with 1,500 recorded hours per robot; the relationship is: number of robots × annual robot hours × hourly data volume. The annual results are in petabytes (PB), which is one million gigabytes in the decimal calculation used here.

Table 2.11. Annual robot data volume for three design data profiles

Data profile	GB/robot hour	10 robots, PB/year	50 robots, PB/year	100 robots, PB/year
Image data, status and action	30	0.45	2.25	4.5
Data combining multiple sensors	120	1.8	5	12
Detailed raw research footage	500	7.5	37.5	75

Source: Editor's calculation based on the stated design assumptions, with 1,500 hours of data collection per robot per year. Decimal units: 1 PB = 1,000,000 GB. Numbers indicate the logical volume of a data copy; copies and processing require additional storage.

The 120 GB/robot hour profile corresponds to a net data flow of approximately 0.267 gigabits per second (Gbit/s) for a robot recording continuously. This unit is the amount of data transmitted per second, in billions of bits. For fifty robots recording simultaneously, this is approximately 13.3 Gbit/s. The calculation follows from the byte-to-bit conversion, i.e. 1 byte = 8 bits, and the 3,600-second clock. Additional network traffic, readback, and copy traffic are added to this.

The size of the data asset is described by the number of bytes stored, the number of accepted episodes, task types, environments, and usable sensing channels. The design table serves as a capacity sizing; the value of the training data is shown by the quality and the verified performance of the models.

2.7 Software update, diagnostics and technical reliability

The software state of a robot consists of several related elements: boot system, firmware, controller, application, AI model, configuration, i.e. operating settings, and calibration. An update may change one or more of these. To record the operation, both the actual installed state and the result of the change must be preserved.

Verified update and recovery

NIST (National Institute of Standards and Technology) is the United States' national standards and measurement institute. Its professional publication series is designated SP (Special Publication). Publication 800-193 of the series describes three basic functions for firmware resilience: tamper prevention, deviation detection, and secure recovery. In robotics applications, these principles are also the basis for boot and update controllability (Regenscheid, 2018).

Uptane 2.1.0 is a framework originally developed for automotive electronics updates. It manages update authenticity and attribution with digitally signed metadata, software images, and a registry of target devices. The digital signature serves to verify origin and integrity; the software image is a software file compiled for deployment. Robotics is an engineering application of the principles; meeting Uptane requirements requires separate testing (Uptane, n.d.).

The file fingerprint in the update list is a checksum calculated from the file contents: it helps detect changes to the content. A dependency indicates which additional components a software element requires to function. Keeping track of these makes it possible to track exactly what assembly is installed on the robot.

Table 2.12. Traceable process of software update

Step	Technical task	Evidence to be preserved
Compilation of an edition	Identify components, dependencies, and compatible hardware.	Release notes, versions, and file impressions.
Authenticity check	Verification of signature and authorized release.	The result of the check and the key ID used.
Limited launch	Test environment, then update selected robot group.	Test result and list of updated robots.
Installation and functional test	Checking the installed status and basic functions.	Starting and final version, time, result and error code.
Recovery	Create an approved working state after a failed update.	Recovery event and the active software state.

Source: Editorial operation scheme based on NIST firmware recovery principles and Uptane update framework. Robotic assembly of steps editorial model (Regenscheid, 2018 ; Uptane, ed.).X

Reverting to the previous software should only be used if compatibility and security conditions are taken into account. The recovery should also remain consistent with the handling of known vulnerabilities (Uptane, n.d.). After replacing the AI model, the result of the physical task should also be re-verified: successful installation confirms the transfer of the software, and a separate test evaluates the robot's behavior.

Robot technical data sheet

The software bill of materials (SBOM) supports the identification of installed components. The software bill of materials (BOM) shows which components and versions are included in the release. SPDX (System Package Data Exchange) is a standard description framework for exchanging data about system components; in this application, it supports the registration of software packages (SPDX, n. n.-a , n. n.-b). The technical registration of the entire robot can also contain hardware, calibration and service data.

Table 2.13. Technical record linked to robot identifier

Registration unit	Main content	What is your answer?
Hardware status	Serial numbers, built-in modules, replacements.	What physical setup works?
Software status	Firmware, application, AI model, file fingerprint and SBOM.	Exactly which components are running?
Setup and calibration	Configuration, sensor alignment, joint and force measurement basic data.	What parameters does the robot work with?
Changelog	Installation, update, configuration change, recovery.	When and how did the situation change?
Service and inspection	Fault, diagnosis, repair, part replacement and verification test.	What happened after the failure?

Source: Editorial technical record schema. For the SBOM function, SPDX is used as a technical example, and for the backup and diagnostic functions, ABB's original documentation serves as a technical example (ABB, n. n. ; SPDX, n. n. b).X

ABB Connected Services includes condition monitoring and diagnostics, backup management, remote access, fleet assessment and asset optimization. Condition monitoring can also track trends in mechanical units and control measurements; backup management helps restore robot programs (ABB, n.d.).

Failure data and metrics

The basis of reliability records is a consistently defined event. Hardware failure, software failure, task failure, operator stoppage, and planned maintenance may require separate categories. Time data should be handled in the same consistent manner: active operating hours, availability time, and calendar time are different denominators.

MTBF (Mean Time Between Failures) is the average operating time between failures: it expresses how much operating time is available for a considered failure. MTTR (Mean Time to Restore) in this chapter is the average recovery time, i.e. the average time required to restore functionality. The indicators can only be interpreted by accurately defining the monitored failures and time limits.

Table 2.14. Reliability and recovery metrics

Indicator	Calculation used in this chapter	Condition to be recorded
MTBF – Mean Time Between Failures	Total operating hours tested / number of relevant failures.	The monitored system, the definition of the error and the method of counting operating hours.
MTTR – Mean Time to Recovery	Total recovery time / number of recoveries.	The starting and ending events; for example, from error detection to the completion of a functional test.
Technical availability	In an approximate model, $MTBF / (MTBF + MTTR)$.	Same system boundary and time interpretation; separate handling of planned outages.
Remote solution rate	Number of remotely closed faults / faults investigated.	Acceptance criteria for closure and affected error categories.
Rate of defects resolved on first repair	Cases restored with one intervention / repair cases.	The repeated error monitoring time window.
Successful update rate	Verified successful installations/attempted installations.	The result of the technical installation and the subsequent operational test.

Source: Editorial measurement definitions and calculation scheme. The table does not provide a manufacturer target or industry average. The use of the term MTTR may vary by source; the chapter refers to the duration of the entire recovery process.

The metrics should be grouped by robot type, hardware and software version, task, and environment. The log, repair, and verification test linked to the ticket provide the basis for feedback. This allows you to examine how a component replacement, controller modification, or new model version changed the execution of the same task.

Sources used

References are to the original manufacturer, developer, and research publications. “n.d.” indicates no publication date. The access date for changing product pages and developer documentation is September 11, 2026; version-specific data is listed separately. The editors’ tables and calculations in this chapter are identified by the associated source note.

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ROBOTICS AND EMBODIED ARTIFICIAL INTELLIGENCE

CHAPTER III

The Chinese robotics market and industry

China's robotics industry in 2026 is simultaneously a mass market for industrial automation, a rapidly expanding professional service robot market, and a rapidly industrializing humanoid and embodied AI sector.

The chapter separately treats production volume, installation, company shipment, market revenue, public list price and policy target. The service robot market figures are included in two separate data sets: the broad manufacturing category of China's NBS and the market databases tracking professional commercial robots. For humanoids, the production milestone, shipment, customer site usage and nominal production capacity are separate indicators.

Data cut-off: September 15, 2026. Product prices are listed by date and sales channel. Manufacturer volume data, policy targets, and analyst cost models are marked separately.

Structure of Chapter III

Part	Topic	Main question
3.	China's robot economy, industrial policy and market size	What is the size of the manufacturing and user base, and what government tools are accelerating the robotics industry?
4.	Chinese service robot manufacturers, models, prices and deployments	Which segments have reached serial commercial use, and what public price levels are visible?
5.	Chinese humanoid robot manufacturers, models, prices and deployments	Which OEMs are scaling, what platforms do they offer, and what evidence is there of production or deployment?
6.	Chinese component manufacturers, supply chains and cost structure	Which components account for the majority of the robot's cost and technology dependency?
7.	Robotics ecosystem of Shanghai, Beijing, Shenzhen and Zhejiang–Hangzhou	How are manufacturing, AI, data, testing, and the component industry divided between the four main regions?

3. China's robot economy, industrial policy and market size

Production volume, installations and exports

The production data of the National Bureau of Statistics of China, NBS, refers to industrial enterprises with an annual main business revenue of at least 20 million yuan. Production shows how many robots were produced in the country in a given period. IFR installation data counts industrial robots put into use, and inventory data counts equipment in operation. The three indicators describe different economic events. [F1]

Table 3.1. Production and installation data of the Chinese robotics industry

Indicator	Period	Value	Annual change or share
Production of industrial robots	2025	773,074 pcs	+28.0%
Production of service robots, broad NBS category	2025	18,581,081 pcs	+16.1%
Production of industrial robots	2026. First semester	537,689 pcs	+28.0%
Production of service robots, broad NBS category	2026. First semester	10,319,211 pcs	+11.9%
Revenue of major robotics companies	January–May 2026	>90 billion CNY	+26.9%
New industrial robot installations in China	2024	295,000 pcs	54% of world installations
Share of Chinese manufacturers in Chinese installations	2024	57%	Domestic installation share
Operational industrial robot fleet in China	End of 2024	>2 million pcs	43.5% of the world's stock

Source: NBS, IFR World Robotics 2025 and industry revenue release; processed source: [F1], pp. 5 and 18.

Annual growth is calculated on a comparable basis from the releases. No full-year estimate was made from the interim data.X

The 54% global share of Chinese installations in 2024 shows the size of the end-user market. The 57% share reported in the same year by Chinese manufacturers in this domestic market is the same. The Chinese production figure is a geographical indicator and therefore does not in itself indicate the global market share of Chinese-owned manufacturers. The 18.58 million service robot production includes products for household and personal use; the professional commercial segment is significantly smaller. [F1 ; F2]

Industrial robot export

In the time series between 2021 and 2025, the value of Chinese industrial robot exports increased more than fourfold, and the number of industrial robots produced approximately doubled. In addition to the quantity sold, the increase in export value may also reflect changes in product mix and prices; therefore, the value index and the number index are separate indicators. [F1]

Table 3.2. Reported indicators of China's industrial robot exports

Period	Number of pieces in the design	Annual change
January–May 2026	86,597 pcs	+39.5%

Period	Number of pieces in the design	Annual change
May 2026	20,090 pcs	+51.2%

Source: Chinese Ministry of Commerce; [F1], p. 6. May data is part of the January–May total.X

China became a net exporter of industrial robots in terms of units for the first time in 2025: exports exceeded imports. Manufacturers organize local integration and service for overseas sales. The analysis of the Ministry of Commerce cited in [F1] highlights long-term reliability, total cost of ownership and local service as operating conditions for exports.

Market size and category boundaries

Different estimates of the service robot market cover different product ranges. In IDC's database tracking commercial service robots, delivery and cleaning robots account for the majority of shipments. The Chinese NBS manufacturing category is much broader than this. Market revenue and the theoretically available market, TAM, should also be read separately. [F2]

Table 3.3. Service Robot Market Size in 2025

Area and indicator	Value	Data type and coverage
Global Commercial Service Robot Shipment, IDC	155,000 units; +44.1%	Professional commercial category; mainly transportation and cleaning
Sales revenue of the same global market category	Approximately 1.37 billion USD	Market revenue estimate
Delivery robots in the global market IDC category	84,000 units; >\$380 million	Annual growth in units +30.2%
Cleaning robots in the global market IDC category	58,000 units; >760 million USD	Annual growth in units +83.8%; revenue +48.5%
China Commercial Service Robot Products and Solutions	2.2 billion CNY	Frost & Sullivan estimate in UDI's stock market filings; narrow commercial category
Theoretically available market for the same Chinese commercial category	CNY 78.91 billion	TAM estimate; potential market, unrealized revenue
The value of China's vast service robot market	Approximately 85 billion CNY	SCIO's 2025 forecast; wider product range

Source: IDC, SCIO, UDI/Frost & Sullivan; [F2], pp. 1, 4-5. Global USD data and China CNY data differ in geographic and product coverage. Forecast and TAM are not expressed as actual annual revenue.X

China received approximately 38% of IDC's global commercial shipments in 2025. Keenon, Pudu, and Gausium together accounted for 53.2% of the global market in the same database. The first ratio shows the sales target market, the second the combined share of the three manufacturers. For cleaning robots, unit sales grew faster than revenue; market revenue per unit shipped thus decreased. This is an indicator that also includes changes in product and channel mix. [F2]

Industrial robot and cobot manufacturing background

For industrial robot arms, the scope of application is determined by load capacity, repeatability, motion control, force regulation and system integration. The Chinese company offering includes collaborative arms, traditional industrial robots, adaptive manipulators and lightweight development platforms. The following company list organizes the product ranges listed in the sources; the order is not a market ranking. [F4]

Table 3.4. Companies offering industrial robotic arms and manipulation platforms

Company	Center	Product or technology scope
JAKA Robotics	Shanghai	Pro and other collaborative robot families
Elite Robots	Shanghai	CS and EC collaborative robot arms, related automation tools
DRUM	Shenzhen	Collaborative, desktop and educational robots; industrial automation
ROKAE	Beijing	Industrial robots, collaborative arms, force-controlled automation
Flexible	Shanghai	Adaptive, force-controlled manipulators; AICO embodied AI platform
FAIRINO	Suzhou	Collaborative robots and open automation platform
RealMan Robotics	Beijing	Lightweight robotic arms, integrated joints, mobile manipulation, remote control and data acquisition
UFACTORY	Shenzhen	xArm and Lite series collaborative and development arms

Source: [F4], “Corporate profile and first European entry evidence”, company data sheets 1–7 and 12. The centres and product areas follow the company data survey closed on 11 August 2026.X

JAKA reported over 10,000 collaborative robots in operation and over 300 automation partnerships in 2022. It announced approximately \$150 million in Series D funding during the same period. A later company statement from Elite Robots, as recorded in the source, mentions over 20,000 robots deployed and over 50 countries. Cumulative company data from different dates, therefore does not provide a direct sales ranking. [F4]

Central industrial policy and financial instruments

Robotics developments are supported by central R&D programs, local grants, government-run investment funds, tax incentives and customer-side financing. The support can be for research, component development, manufacturing capacity, data collection or the first application of a new robot. The nominal size of a fund is the capital that can be invested over several years; a grant ceiling is the upper limit of the support that can be given to a beneficiary or project. [F3]

Table 3.5. National robotics and related programs

Program	Announced date or horizon	Subject and financial nature
Robotics Industry 14th Five-Year Development Plan	Release: December 28, 2021; target horizon: 2025	Technology, components, products, applications and clusters; target of more than 20% average annual industry revenue growth and 3–5 clusters of international significance
Robot+ Application Action Plan	January 2023; target horizon: 2025	Manufacturing, agriculture, energy, healthcare and logistics applications; >100 innovative technologies or solutions and >200 typical application targets
Humanoid Robot Innovation Guidelines	November 2023; milestones: 2025 and 2027	Basic models, control, actuators, sensors and complete robots; targets for mass production by 2025, mature industry collaboration by 2027
National R&D Plan, Intelligent Robots Priority Program	2025 Round Guide: December 22, 2025; Submission: January 4–February 5, 2026.	Central project funding for research institutes, universities and companies; the processed communication does not provide the full robotics budget
AI+manufacturing measure	January 2026	Connecting AI agents, industrial robots and intelligent manufacturing systems; strategic and implementation direction

Program	Announced date or horizon	Subject and financial nature
Extra tax base deduction for R&D costs	The rule described in the study will be effective from January 1, 2023.	100% extra tax base deduction for eligible, non-capitalized R&D expenditure; tax incentive, not direct financial support

Source: [F3], “Central Government Programs and Mechanisms”, and the “Program / Instrument” table. Target horizons do not in themselves prove the achievement of the objectives. The tax incentive is subject to the eligibility and settlement conditions described in the source.X

The timing of the national Intelligent Robots Program shows the difference between the year of the call and the year of project implementation. The 2025 round was open for applications in early 2026. One of Shanghai’s specific R&D calls in 2025 set a typical project period between December 1, 2025 and November 30, 2027. The application label therefore cannot be considered as the year of full grant disbursement. [F3]

Investment funds and broader frameworks

Table 3.6. Funds and national frameworks related to robotics

Fund or program	Nominal amount announced	Content and time frame
Beijing Robotics Industry Development Investment Fund	10 billion CNY	Multi-year investment capacity for robotics
Shenzhen AI and Robotics Industrial Base	10 billion CNY	Fund announced in 2025; division between AI and robotics not fixed in announcement
Beijing’s broader government investment system	100 billion CNY	Multiple future industries, 15-year time horizon; possible overlap with separately published robotics foundation
National large equipment modernization program	200 billion CNY	2026 multi-sectoral framework from long-term special government bond resources

Source: [F3], “Executive Summary”, “Aggregate Funding Picture” and the central program table. These are separate financial categories; the amounts do not constitute an aggregated national robotics funding framework.X

The Beijing 10 billion robotics fund and Shenzhen 10 billion mixed fund together represent a nominal investment capacity of 20 billion CNY. The proportion of the total amount allocated to robotics and its annual allocation require separate data. The addition of Beijing’s 100 billion system may cause double counting, and the 200 billion national framework supports many equipment categories in the economy. [F3]

Local grants, data and computing incentives

City and provincial programs often specify specific subsidy rates and ceilings. The beneficiary usually has to prove local operation, proper legal and financial status, eligible investment or completed sales. The maximum amount specified in the program is not automatically due. [F3]

Table 3.7. Direct development and investment subsidies

Area and device	Support rate and maximum	The time period recorded in the source
Shanghai, a large-scale embodied AI R&D project	Up to 30% of the approved investment; 50 million CNY/project	July 28, 2025–July 27, 2028
Shanghai, joint innovation service platform	Up to 50%; 20 million CNY/project	The same program for 2025-2028

Area and device	Support rate and maximum	The time period recorded in the source
Shanghai, application demonstration	Up to 20%; 10 million CNY/project	The same program for 2025-2028
Shanghai Minhang District, R&D of core components	Up to 30%; 30 million CNY/project	March 3, 2026–March 2, 2029
Shanghai Minhang District, Pilot Production Platform	Up to 30%; 10 million CNY/project	The same program for 2026-2029
Shenzhen, robot or component factory and capacity expansion	Up to 20%; 10 million CNY/project; minimum investment of 10 million CNY	The measure issued on February 27, 2026
Shenzhen, robotics data collection plant	Up to 20%; 10 million CNY/project; minimum investment of 10 million CNY	The same measure in 2026
Guangdong, manufacturing innovation center	Up to 50 million CNY for national-level centers and 10 million CNY for provincial-level centers	Implementing rule: 1 September 2025 - 31 December 2027.
Guangdong, AI industrial demonstration and open source development	Demonstration 3-8 million CNY; open source community up to 8 million CNY	Same framework 2025-2027; conditions depending on category
Jiangsu, manufacturing innovation and key technology	Innovation center up to 30 million, collaborative key technology project 6 million CNY	The source's project financing framework for 2024–2026
Jiangsu, data collection or teaching center	10% of eligible equipment and software costs; up to CNY 4 million	Separate 2025 round; non-automatically renewable annual budget

Source: [F3], Detailed table of “Provincial and City Programs”. The possibility of stacking subsidies for the same investment depends on the program. For the Guangdong robotics enterprise category, the implementation rule requires at least 50% of the previous year’s revenue to be related to robotic products and services.X

Table 3.8. Data, computing and application incentives

Area and device	Reported amount or rate	Unit of account and limit
Shanghai, data and corpus service voucher	Up to 5 million CNY	Per company per year; in the 2025–2028 program
Shanghai, computing capacity voucher	Up to 40 million CNY	Corporate annual cap; subject to program terms
Shanghai, sales and leasing incentives	Up to 5% of the contract value; maximum CNY 5 million	Separate application tool; not the same as R&D support
Beijing Economic and Technological Development Zone, data voucher	Annual program budget of CNY 100 million; maximum CNY 1 million per company	The total amount of the program and the ceiling per beneficiary are separate values
Ibid., Robotics Secondary Development Community	Up to 30 million CNY per year	Community development infrastructure
Ibid., humanoid robot sales	Up to 10 million CNY per year	Corporate Sales Support Cap
Ibid., robot leasing and insurance	Lease up to 3 million; insurance up to 1 million CNY per year	Separate tools to finance usage
Shenzhen, embodiedrobot product sales support	5% of annual sales; up to 3 million CNY	Corporate ceiling, according to annual announcement

Source: [F3], Detailed program data of the development zones of Shanghai, Shenzhen and Beijing. The reported time frame of Beijing's zone measures is August 12, 2025 - August 31, 2028.X

Data and computing vouchers support the use of services required for robot development. Sales, leasing and insurance instruments act on the use side. Thus, research, production and demand subsidies are also linked to the same industry in the source. Their financial impact may appear at different times and for different beneficiaries. [F3]

Export financing

Table 3.9. Financial and institutional instruments for foreign robot sales

Institution or device	Funded or supported activity	Financial nature
China Exim Bank, export buyer credit	Procurement of mechanical, electromechanical or high-tech equipment by a foreign buyer	Transaction-linked loan; robotics project may be eligible based on product scope
China Exim Bank, export seller credit	Equipment or system delivery by a Chinese exporter	Export financing with individual credit terms
SINOSURE and export credit insurance programs	Risk related to foreign buyer, country or payment	Insurance; insured turnover is not a subsidy payment
Ministry of Commerce and local foreign market programs	Trade fairs, sales channels, overseas warehouses	Program-related trade development
China Council for the Development of International Trade	Partner search, exhibitions and legal services	Institutional market entry support

Source: [F3], “Export support and foreign market financing”; [F1], p. 7. The sources do not record a general amount of support for all exported robots. The terms and conditions for loans and insurance are transaction-specific.X

In the case of a robotic production line, an export buyer's credit can help finance the foreign investor. The manufacturer's R&D support and the buyer's investment credit thus affect two separate financing sides of the same product. Export credit insurance can be linked to bank financing by managing payment and certain political risks. [F3]

4. Chinese service robot manufacturers, models, prices and deployments

Manufacturers and product ranges

Chinese service robot manufacturers operate with a variety of business models. Keenon and Pudu offer products for multiple application areas. Gausium specializes in cleaning, while Yunji specializes in connecting hotel robotics and hotel IT systems. Geek+ and HAI Robotics supply warehouse material handling systems. [F2]

Table 3.10. Chinese service robot and warehouse robot manufacturers

Company and headquarters	Main product range	Quantitative corporate disclosure and period
Keenon Robotics; Shanghai	Restaurant and hotel delivery, cleaning, reception, humanoid service	Cumulative sales of >100,000 service robots by May 2025
Pudu Robotics; Shenzhen	Transportation, cleaning, industrial mobile robots, mobile manipulation	>120,000 cumulative shipments by early 2026; >80 countries and regions

Company and headquarters	Main product range	Quantitative corporate disclosure and period
Gaussium; Shanghai	Indoor and outdoor professional cleaning	According to a company statement cited in the September 2026 study, there are >5,000 operating robots in Japan
Yunji Technology; Beijing	Hotel robots and operating software, hospital and intra-building transportation	2025 revenue 301.2 million CNY; of which hotel business 243.9 million CNY, 81%
UDI Robotics; Jiangsu Province	Indoor and outdoor transportation, cleaning, mobile sales	According to the announcement on the stock exchange materials, >600 Chinese cities and >10,000 trading locations
Geek+; Beijing	Autonomous mobile warehouse robots, delivery of goods to people, sorting	>72,000 robots installed, >800 corporate customers, >40 countries; 2025 revenue >438 million USD
HAI Robotics; Shenzhen	Box and storage unit handling warehouse robots, automatic storage and retrieval	During the 2021 European organization building >1000 employees, >600 patents, >30 countries
TMiRob; Shanghai	Hospital material transport and healthcare service robots	The source provides an application description; no comparable total installed count

Source: [F2], pp. 8–11; for HAI 2021 data [F4], “Executive summary” and “Corporate profile and first European entry evidence”. The numerical company data are from own reports. The undated cumulative numbers indicate the status recorded in the cited study, not sales in 2025.X

Pudu's later data in the market research closed on August 23 is already more than 130,000 deliveries and more than 85 countries and regions. The two figures belong to separate publications; the earlier value of over 120,000 relates to the situation at the beginning of 2026. In the absence of an exact turning point, period sales cannot be calculated from the difference. [F1 , p. 9; F2 , p. 2 and 8]

Models and public price benchmarks

The price of service robots depends heavily on the equipment, software license, charging and docking system, on-site integration, warranty and service package. The following data are public channel and reseller price anchors; a separate manufacturer or distributor offer is required for a purchase contract.

Table 3.11. Publicly observable price and product data for service robots

Model	Task	Documented technical/business data	Public price indication
Pudu BellaBot Pro	Restaurant and hotel delivery	40 kg total load; up to 4 trays; approx. 11 hours manufacturer's operating time without load; visual, marker and laser SLAM	approx. 73,999 CNY, public channel price in September 2026 research
Pudu CC1	Commercial floor cleaning	Professional, multi-functional cleaning platform; also available in European distribution channels	EUR 16,310–19,000 net, two German reseller offers, 12/09/2026.
Keenon W3	Hotel delivery	Elevator and building IoT integration documented	There is no uniform public OEM list price in project resources
Gaussium Scrubber 75	Large area professional cleaning	Commercial cleaning robot; system sold through partner and integrator channels	There is no uniform public OEM list price in project resources

Source: [F2] for BellaBot Pro product and channel price data; [F9] for Pudu CC1 German net reseller price observation as of September 12, 2026. Keenon W3 functional example [F2]. Prices include tax, shipping, on-site integration, and optional services in a non-uniform manner.

Deployment examples and operating scale

The hotel delivery robot receives the shipment in the lobby or service area, uses the elevator, goes to the guest room, notifies the guest, and then returns. The task requires autonomous transportation and building IT connectivity. In Yunji systems, the robot is part of the software that connects orders, the elevator, room communication, and task assignment. [F2]

Table 3.12. Chinese examples documented in service environments

Location or service provider	Period and scale	Tasks and nature of communication
Traders Hotel Shanghai Hongqiao; Keenon	8 robots, 6 models from autumn 2025	Reception, room service, cleaning, restaurant service and baggage handling; an on-site application example
Yunji's hotel clientele	>40,000 hotels by the end of 2025	Locations reached with robotic solutions; the number does not represent the same number of active robots
Yunji's online robot stock	In 2025, an average of about 32,000 simultaneously online robots per day	Operational activity indicator; not annual shipments and not cumulative robot hours
Yunji Hospital Clientele	By the end of 2025, approximately 200 hospitals	Hospital solutions deployment scope; company report
Saiter hospital systems	Hundreds of hospitals; >100 robots or smart devices in some large installations	Transport of medicines, samples, sterile materials, food, textiles and waste; many large installations involve a mixed range of equipment

Source: [F2], pp. 2, 5 and 10. Saiter's statement does not have a uniform annual cut-off date in the study. The number of hotels, the number of online robots and the mixed asset portfolio are separate indicators.X

Warehouse robotics is now an industrial-scale systems business. Geek+ reported over 72,000 installed robots, over 800 enterprise customers, and over 40 countries; Hai Robotics specializes in box and storage unit handling automation. The product value in these systems is the combination of the robot, fleet management, WMS/WES integration, and on-site process. [F2]

Commercial maturity per application

Table 3.13. Maturity picture of Chinese service robot applications in 2026

Application	Maturity based on resources	Typical characters	Main operating standard
Warehouse AMR / goods-to-person	Very high	Geek+, Hai Robotics	throughput, reliability, WMS integration
Indoor delivery	High	Keenon, Pudu, Yunji, UDI	navigation, elevator integration, task/day, intervention rate
Commercial cleaning	Tall, fast growing	Gaussium, Pudu, Keenon	m ² /hour, autonomy, maintenance, labor replacement value
Hospital logistics	Medium high	TMiRob, Yunji, Saiter	safe material flow, integration, availability
Retail / Reception	Medium	Keenon, Pudu, UBTECH	interaction quality, conversion, operational economics

Application	Maturity based on resources	Typical characters	Main operating standard
Security patrol	Medium	specialist UGVs and quadruped robots	coverage, detection, robustness, operator escalation
Elderly care	Low-medium	multi-manufacturer pilot projects	safety, human-robot interaction, financing model

Source: [F2]. The maturity rating is an analyst's summary of documented installations and application programs, not an official Chinese rating system.

5. Chinese humanoid robot manufacturers, models, prices and deployments

Manufacturer field and platform trends

The humanoid offering also includes platforms for industrial material handling, research, education, and service tasks. In addition to the many driven joints and hand mechanics, the product includes motion control, task planning, a development environment, and a data acquisition system. The maturity of an application is described by the successful, repeatable execution of the task; the delivery of the robot alone does not measure this. [F2 ; F4]

Table 3.14. Humanoid and Embodied Artificial Intelligence Companies in Sources

Company and headquarters	Platform or main profile	Documented development direction
AGIBOT; Shanghai	Humanoids, mobile manipulation, robot data platform	Series production, AGIBOT World data and development environment, X1 open production documentation
Unitree Robotics; Hangzhou	Humanoids and quadrupedal robots; examples R1, G1, H2	Research and development use, multiple sizes of robot platforms
UBTECH; Shenzhen	Humanoid, educational and interactive service robots	Expanding industrial humanoid applications
Leju Robotics; Shenzhen	KUAVO and Roban humanoid platforms	Pilot production, design validation and larger series assembly
Fourier Intelligence; Shanghai	Rehabilitation robotics and humanoids	Healthcare technology background, humanoid research and application platforms
Booster Robotics; Beijing	Compact humanoids	Research and education applications, operating system and development tools
LimX Dynamics; Shenzhen	Full-size humanoids, TRON multi-motion robots	Manipulation algorithms and embodied agent system
Galbot; Beijing	General purpose mobile and humanoid systems	Embodied intelligence, research and industry partnerships

Source: [F2], pp. 8–10; [F4], company data sheets 13–18 and 39; [F6], pp. 1–3. The table reports product and development directions, not uniformly validated autonomy capabilities.X

The Chinese humanoid field includes full-scale industrial platforms, research robots, compact educational machines, and mobile manipulation systems. The public product price only reflects the entry-level hardware; the hands, compute, developer licenses, integration, spare parts, and local support required for the customer task are additional costs.

Public price anchors: Unitree

Table 3.15. Official webshop prices of Unitree humanoid robots, September 15, 2026.

Model	Official webshop price	Comment
R1-D	From 4,290 USD	entry-level humanoid version
R1	From 4,900 USD	entry-level humanoid platform
G1	\$13,500	basic webshop price; developer and optional configurations may vary
H2	\$29,900	full-size platform for public webshop
H1	Price displayed: \$90,000	the webshop also requests contact for the actual price
H2 Plus	\$100,000	higher-equipped full-size version

Source: [W1] Unitree official webshop, Humanoid Robot collection, checked: September 15, 2026. Webshop prices are not the same as the total project cost of the industrial installation.

AGIBOT: production and delivery milestones

AGIBOT was founded in 2023 and, according to its own company history, started its factory in Shanghai in January 2024. The reported milestones show rapid production expansion, but the cumulative number of robots produced and the machines delivered during the period form a different data set. [F6 ; F7]

Table 3.16. AGIBOT production and delivery milestones

Date or period	Reported value or event	Indicator
2023	Company formation	Organizational milestone
January 2024	The factory in Shanghai is launched.	Production milestone
January 2025	Completion of the 1000th robot	Cumulative production milestone
2025	5168 robots	Annual delivery
March 30, 2026	The 10,000th robot is completed	Cumulative production milestone
2026. First semester	Approximately 8,400 robots	Semi-annual delivery
June 2026	Completion of the 15,000th robot	Cumulative production milestone

Source: AGIBOT company history and company announcements, and company data taken over by the Serbian Development Agency; [F6], p. 3; [F7], p. 1. Production milestones are not added to the shipment data.X

The AGIBOT X1 documentation lists 29 actuators and two grippers, and includes a bill of materials, CAD files, and manufacturing work instructions. Actuator identification, firmware verification, communication addressing, and table motion testing are performed before the entire machine is powered up. A separate step on the complete robot is to check the power rails for short circuits, zero point alignment, software installation, and inertial measurement unit communication. This is a documented manufacturing order for a specific platform. [F6 , pp. 2–3]

Leju: from pilot project to series production

Leju's pilot plant in Shenzhen was launched in April 2026. Production is divided into four main blocks: component assembly, complete machine assembly, power-up and parameterization, and functional testing. The manual, flexible assembly is supported by a manufacturing execution system, MES. The plant in Foshan, established with Dongfang Precision, operates with higher-volume material supply and production-line-connected testing. [F6]

Table 3.17. Two Chinese production levels of Leju

Characteristic	Pilot plant in Shenzhen	Leju–Dongfang Precision Plant in Foshan
Reported annual capacity	500–1000 robots	>10,000 robots
Reported time data	Up to 120 minutes pilot cycle	A robot that is completed approximately every 30 minutes
Process structure	4 main technological blocks	24 assembly operations
Assembly and material supply	Flexible manual assembly, modular process	Automated warehouse and AGV service ensuring materials arrive on time
Testing	>30 tests; 30-minute standing walk test demonstrated	77 checkpoints and 41 automated tests
Digital systems	MES-based production data collection	Connecting ERP corporate management, WMS warehouse management and MES
Reported development experience	>170 manufacturing technology modifications in two design iterations of Roban 2; KUAVO 5 pilot validation 4–5 months	Material management, scheduling, quality alerting and bottleneck monitoring

Source: [F6], pp. 1–3; related summary [F7], p. 3. Annual data are reported capacities. The 120-minute cycle and 30-minute release rate do not represent the total working time per robot. The 77 inspection points and 41 automatic tests are separately reported numbers; their overlap is not resolved and therefore cannot be summed up into 118 individual tests.X

The pilot plant production data also serves to improve the design. The more than 170 modifications of Roban 2 show that manufacturability was part of the design iteration. In the Foshan example, standardized assembly operations are combined with warehouse and material supply automation. Actual annual production, shift schedules, or utilization cannot be determined from the reported schedule data alone. [F6]

UBTECH: industrial application evidence

The project's humanoid robot dossier treats 1,079 humanoid robot sales linked to UBTECH's 2025 annual report as audited corporate data. In a separate communication, the company revealed the presence of hundreds of Walker S-series robots in production environments at BYD, Geely, FAW-Volkswagen, Dongfeng Liuzhou and Foxconn, among others. This is a fleet-scale manufacturer statement. A 2026 Airbus deal has named 100 Walker S2 units for early concept testing. [F10]

The handbook addresses four types of evidence in the humanoid market: completed robots, robots shipped or sold, customer site deployments, and nominal production capacity. The four data may belong to the same company, yet describe different levels of industrial maturity.

6. Chinese component manufacturers, supply chains and cost structure

Motion systems and manipulation

In the robot's motion system, the motor, the gear, the position sensor, the bearings and the control electronics together form the joint. The complete actuator organizes several of these elements into a single module. The supplier's offer can therefore include a motor, a precision gear or a complete joint unit as a separate product. When aggregating parts and costs, the content of the integrated module must also be taken into account. [F5]

Table 3.18. Chinese suppliers in the movement system

Component	Chinese company examples	Role and documented product data
Integrated actuator	CubeMars	Motor, gearbox and drive in one unit; product examples AK80-9 and AK10-9
Precision wave drive	Leaderdrive, Laifual	Low backlash robotic transmission; Leaderdrive reports >1800 global customers
Frameless and brushless motor	CubeMars, MOONS'	Joint drive motors; the motor and the complete actuator are separate product levels
Force and torque sensor	Sunrise Instruments, Kunwei	Measuring forces and torques acting on the robot; the table shows a range of six-axis sensors
Multi-fingered robotic hand	Inspire Robots	10,000 hands delivered in 2025 according to company statement; a product example with 6 active degrees of freedom and 12 joints
Robotic hand and gripper	DH Robotics	DH-5-6 hand; manufacturer specification gives more than one million gripping cycles
Tactile sensing	PaXini	Multidimensional tactile sensing, multi-fingered hand and humanoid developments

Source: [F5], pp. 4–6; PaXini: [F4], company data sheet 20. Customer number and delivery are company information. Cycle life is a manufacturer specification; it does not replace the lifetime of the assembled robot or the specific application.X

CubeMars' direct selling price for the AK80-9 was approximately \$480-580 and for the AK10-9 was approximately \$699-799 in the September 2026 study. One U.S. reseller price for the Inspire RH56E2 robotic hand is \$8,900. These are prices for named products and channels; they do not describe volume discounts, custom configurations, shipping, or system integration. [F5 , pp. 4-6]

Precision drive, sensing and joint control are built on top of each other. The accuracy of the component, assembly and calibration together determine the behavior of the finished joint. The Chinese supplier map therefore shows manufacturing connections: components with the same function cannot be considered automatically interchangeable. [F5]

Sensing, electronics and energy

Mobile robots use cameras, distance sensors, inertial measurement units, on-board computers and communication devices. A significant part of the components for wheeled service robots are also available from Chinese electronics, electric vehicle and automation suppliers. In humanoids, this is associated with more joint sensors, more complex motion control and manual manipulation. [F2]

Table 3.19. Examples of Chinese sensor and electronics suppliers

Area	Company	Product or role in source
3D camera	Orbbec	Gemini 335Lg stereo 3D camera; GMSL2/FAKRA interface, IP65 design
Robotic LiDAR	Hesai	JT128; 128 channels, 265g weight in product description
Robotic LiDAR	RoboSense	Airy; official online price of \$999 at the time of study data collection
Spatial sensing of mobile robots	Livox	Mapping, localization and obstacle detection; Communication with Gaussium robots
Industrial 3D machine vision and robot AI	Mech-Mind	Spatial vision, robot programming and learning systems; reported >27,000 installed units include cameras and AI units
Battery cell	CATL, Sunwoda, EVE	Cell industry supplier background; the appropriate cell format and load profile for the humanoid must be determined separately

Source: [F5], pp. 5–7; Livox: [F2], p. 12; Mech-Mind: [F4], company data sheet 8. Product data refers to the named variants. The listing of battery manufacturers does not constitute a confirmed supply contract with any listed humanoid manufacturer.X

Onboard AI computing is also linked to an international supply chain. The localization study uses NVIDIA Jetson Orin and Thor-class compute units as technical references. The Chinese mechanical and electronic manufacturing background does not imply that all critical semiconductors or software components are of Chinese origin. [F5]

Humanoid BOM and cost structure

The hardware cost of a humanoid is dominated by the motion system. Bank of America Global Research estimated a Chinese-built humanoid BOM of around \$35,000 by 2025, and expected it to be below \$17,000 by 2030. Morgan Stanley's 2025 analysis showed a BOM range of \$10,000–300,000 depending on the design, and estimated the Optimus Gen2 hardware at \$50,000–60,000 without software. [F5]

Table 3.20. Humanoid hardware cost: external benchmark and project target cost

Data type	Volume / time	Reported or modeled value	Interpretation
Bank of America benchmark	China, 2025	approx. 35,000 USD BOM	external analyst estimate for a Chinese-built humanoid
Bank of America forecast	2030	<\$17,000 BOM	forecast, not today's purchase price
Project target cost	50–200 robots/year	55–85 thousand USD / robot	small series; higher NRE and test costs
Project target cost	1,000+ robots/year	32–50 thousand USD/robot	volume pricing and partial localization assumption
Project target cost	3,000–5,000+ robots/year	24–38 thousand USD / robot	assuming mature construction and greater vertical integration

Source: [F5]. Project target cost lines are design models, not manufacturer quotes. External BOM estimates may be prepared for different robot architectures.

In the Bank of America 2030 cost model, linear actuators were given a share of 27%, rotary actuators 24%, and hands 19%. Together, these three motion and manipulation component groups account for 70% of the modeled BOM. The key to cost reduction is therefore the industrialization of the actuator module, precision drive, motor, encoder, and hand, as well as increasing production volume. [F5]

International technological dependencies

China's robotics supply chain is deep in motors, drives, batteries, sensors, electronics, castings, and plastic parts. Some of the onboard high-performance AI computing is connected to an international ecosystem; project sources use NVIDIA Jetson Orin or Thor-class compute as a reference or product configuration for several robots. Therefore, the origin and security of supply analysis of the entire robot also includes critical chips, firmware, SDKs, and cloud services. [F5]

7. Shanghai, Beijing, Shenzhen and Zhejiang–Hangzhou robotics ecosystem

China's robotics industry is geographically specialized. Shanghai is strong in service robots, humanoid platforms, and heterogeneous robot data infrastructure. Beijing connects AI, standards, healthcare, and application testbeds. Shenzhen provides the deepest manufacturing and commercial ecosystem. Zhejiang–Hangzhou connects cost-oriented robot platforms, component industry, and real-simulated teaching infrastructure.

Table 3.21. The four main Chinese robotics ecosystems

Area	Corporate examples	Main profile
Shanghai	Keenon, Gausium, AGIBOT, Fourier, Kepler, Leaderdrive, Kinco	service robots, humanoids, components, heterogeneous robot data and training infrastructure
Beijing	Yunji, Geek+, ROKAE, RealMan, Booster, Galbot	robotics AI and software, logistics, healthcare, humanoid innovation and application centers
Shenzhen / Guangdong	Pudu, UBTECH, Leju, HAI Robotics, DOBOT; Foshan: Dongfang Precision	robot and electronics production, export, pilot plants, series production, 6S commercial and service model
Zhejiang / Hangzhou	Unitree and regional motor, gear, encoder and sensor manufacturers	humanoid and quadruped platforms, component manufacturing, simulation, field and application tests

Source: [F2], [F3], [F4], [F6]. The company examples do not represent a complete company register.

Shanghai: platform, data and multi-vendor ecosystem

Shanghai's 2025 embodied-intelligence program manages computing capacity, teaching sites, pilot production, investment and leasing infrastructure under a single industrial development framework. In the Zhangjiang region, the government-backed announcement identified more than 70 embodied-intelligence companies, including complete robot platforms and component manufacturers. The city has targeted embodied AI output of over CNY 50 billion, at least 100 leading companies, 100 applications and 100 competitive products by 2027. [F2; F3]

Beijing: AI, standards and application scenarios

Beijing's robotics plan is based on humanoids, medical and healthcare robots, collaborative systems, special robots and logistics. The 2025 target was more than 30 billion CNY core robotics industry sales, 100 high-tech robotics products and 100 nationally replicable application scenarios. In the Yizhuang area, more than 300 robotics and intelligent manufacturing enterprises and an industry size of over 10 billion CNY were announced by 2025. [F2]

Shenzhen: manufacturing and trade engine

Robot trade and service in Shenzhen

In Shenzhen, a 6S robot store, bringing together more than 60 robotics companies, opened in July 2025. The six services are sales, parts supply, service, feedback collection, rental and customization. The local report in July 2026 reported a turnover of more than 20 million CNY and approximately 300,000 visitors. [F2 , p. 17]

The store organizes the robot presentation and the services required for its use in the same commercial system. For a later AI 6S platform, more than 350 partners and 600 products were already included in the announcement. This is a broader range of AI products; the numbers cannot therefore be considered the unchanged company and product portfolio of the original robot store. [F2]

Shenzhen produced 7,966,500 units of the broad service robot category of Chinese statistics in 2025, accounting for 42.9% of China's total production. The city's robotics industry reported an output value of approximately CNY 242.6 billion, with a designated robotics cluster revenue of CNY 37.903 billion. The 2025-2027 embodied robot action plan targeted more than 1,200 related companies. [F2]

Zhejiang–Hangzhou: cost engineering, components and real-world testing

Within Zhejiang province, there is a division of labor: Hangzhou and Ningbo are in control and new sensors, Wenzhou and Shaoxing in humanoid-specific motors, and Taizhou and Quzhou in precision gears, servo systems, and encoders. Hangzhou's Unitree-centric robotics ecosystem connects AI and digital infrastructure to this. [F2]

A district in Hangzhou has launched a virtual robotics teaching initiative based on the digitization of real-world urban locations in 2025. A public status image of the Hangzhou Bay Embodied Intelligence Innovation Center in the Shaoxing area showed 50 humanoids and operator demonstration tasks, including folding clothes, sorting documents, and screwing. [F2; F8]

Robot data and teaching infrastructure

Embodied AI development requires data describing both the perception and the action of the robot. Images and depth data can be linked to robot state, joint motion, force data, task description, and result. A human operator demonstrates a task remotely, the system records the execution, and the verified data is then used to train the model. The trained behavior is tested again on a physical robot. [F2 , pp. 12–13; F8 , pp. 3–7]

Chinese centers can accommodate robots from multiple manufacturers and multiple task environments. The shared infrastructure organizes data verification, storage, model training, and feedback in addition to collection. A “trajectory” refers to a fixed execution path or sequence. The term “data sample” in public communications is broader and may vary by source, so the two numbers cannot be added together as a single data volume. [F2 ; F8]

Table 3.22. Robotic data collection and application centers

Center and location	Reported scale	Tasks and status
National and Local Humanoid Robot Innovation Center, Shanghai	>100 robots simultaneously; >500 trajectories/robot/day	Joint training of robots from multiple manufacturers; target of 10 million high-quality physical data records by 2025
Humanoid robot data center, Beijing Shijingshan District	108 robots as reported in the source	Home care, retail, automotive assembly, electronics manufacturing, bathroom cleaning, towel folding and catering
Hangzhou Bay Embodied Intelligence Innovation Center, Shaoxing area	50 humanoids at the time of the referenced report	Operator demonstration, folding clothes, sorting documents and screwing; in Zhejiang Province, outside Hangzhou City

Center and location	Reported scale	Tasks and status
Intelligent elderly care robot station in Beijing	Approx. 1100 m ² ; 24 companies, >40 robotics products	Walking assistance, rehabilitation, food preparation and serving, social interaction; application and feedback environment

Source: for the first two rows [F2], pp. 2 and 13; for the Shaoxing data [F8], pp. 3–4; for the elderly care center [F2], pp. 6 and 16. The scale data also indicate central capacity, actual number of robots, and product range; these are separate indicators. The daily rate of teaching does not prove annual utilization.X

One study reports an area of over 5,000 m² for the center in Shanghai, while the other reports an area of 4,600 m². The delimitation of the two data is not agreed upon, so the area is not included as a standardized comparative indicator. Both descriptions mention a capacity of over a hundred robots. [F2 , p. 13; F8 , p. 3]

A district in Hangzhou has launched a virtual robotics teaching initiative in 2025. The plan would create a simulation environment by digitizing real-world urban locations, including a pedestrian street, a historic building complex, and a train station. The virtual location allows for practice of the task, but the actual physical operation will require separate on-site feedback. [F2 , pp. 17–18]

Datasets and enterprise platforms

Table 3.23. Reported indicators of Chinese robotics data platforms

Platform	Reported data	What does the indicator calculate?
RoboMIND and open components of the Tiangong platform, humanoid robot innovation center in Beijing	>30,000 downloads by August 2025	Reported download count of open data and development resources; not trajectory count
AGIBOT World	>1 million trajectories, approx. 100 real robots, >100 scenarios	Real robot data collection according to company and related research specifications

Source: RoboMIND: [F2], p. 13; AGIBOT World: [F8], pp. 1 and 3–4. AGIBOT data represents the scale of the dataset described in the study, not a single year of verified data sales.X

In heterogeneous data collection, robots work with different body structures and sensors. The common task record therefore needs to include the type of robot, the temporal association of sensing and movement, the result of execution, and human intervention. The description of the center in Shanghai highlights the organization of data from different robot manufacturers into a common system. [F2 ; F8]

Yunji’s average of around 32,000 robots online at the same time each day could be a large source of operational data. However, the online stock only shows the potential for data collection: the company’s reported data does not imply that every operational log of every robot is used for AI training. The quantity and quality of data used for training are the subject of separate measurements. [F2 , p. 13]

Sources used

[F1] Lianta. Entry of Chinese robotics companies into the European market. Market research: market size, entry paths, entry barriers, competition. Data cut-off: August 23, 2026. Parts used: Chinese production, export and policy background data.

[F2] China’s Service-Robot Market: From Delivery Machines to Embodied Artificial Intelligence. Research date: September 9, 2026. 27 pages. Sections used: market size, service robot manufacturers, applications, supply chain, robot data and regional ecosystems.

[F3] Chinese government funding for robotics R&D, development and exports: outlook 2026–2028. Parts used: central and local programs, investment funds, export financing and incentives.

[F4] Chinese Robotics Companies Entering Europe, and Their Presence in Hungary and CEE, 2020–2026. Data cut-off: August 11, 2026. Parts used: industrial robot and humanoid company data sheets.

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<https://shop.unitree.com/collections/humanoid-robot>

CHAPTER IV

Hungarian market and business opportunities

Hungary is a limited robotics market in itself, but its industrial structure, university and test environment, existing robotics sales channels and Central and Eastern European connectivity make it suitable for supporting pilot projects, integration, service, market entry and later regional industrialization. The chapter organizes documented Hungarian applications, bottom-up demand estimation, the economics of the robotics business and the business framework of Sino-Hungarian cooperation.

Data cut-off: September 15, 2026. Most Hungarian and CEE market research is as of September 12, 2026. Company pipeline, demand volume, willingness to pay, ROI, and financing scenarios are different types of evidence; estimates and editorial models are marked separately.

Table 4.1. Structure of Chapter IV

Part	Topic	Main question
8.	The Hungarian robotics ecosystem and partner network	What research, integration, sales, testing, and end-user capabilities are already in place?
9.	Sales models, total life cycle cost and return on investment	What is the real customer cost of the robot, and what business model can it be repaid in?
10.	The suitability of Chinese robot manufacturers as partners in Hungary	Which OEM types are suitable for the Hungarian market and what evidence should be requested before partnership?
11.	Chinese-Hungarian corporate, contractual and intellectual property models	Distribution, license, contract manufacturing, JV or hybrid model – when is which one justified?
12.	Partnerships, exhibitions and market building	How does a relationship become a paid pilot project and then a repeatable regional business?

8. The Hungarian robotics ecosystem and partner network

The Hungarian robotics market consists of several different players. Research institutes and universities provide technology and measurement competence; integrators build industrial systems; distributors sell robots, components and first-level support; end users bring a specific workflow and willingness to pay. The European introduction of a new Chinese robot platform is viable if at least the buyer, the integration, the service and the compliance responsibility can be identified. [F2; F3]

Table 4.2. Hungarian robotics ecosystem – roles and documented examples

Layer	Examples in project resources	Market function
Research and robotics R&D	HUN-REN SZTAKI; Óbuda University; BME; Széchenyi István University; ELTE related HRI/ethological competencies	algorithm, robotics, AI, HRI, development, training
Test and autonomous systems	ZalaZONE; university lab and test environment capacities	validation, controlled test environment, measurement infrastructure
Industrial integration	Robot-X; Elvotec; Advanced Robotics; E4Solution	robot cell, industrial automation, on-site integration, support
Robotic distribution and local channel	JAKA-Elvotec; Pudu-Advanced Robotics; Keenon-ASBIS / domestic sales channel; Unitree-Infuze; Gausium domestic sales and service channel	sales, demo, parts, warranty, front-line service
Industrial end users	Mercedes-Benz, Audi, BMW, Bosch, Schaeffler, CATL, logistics and energy players	specific task, pilot project, multi-shift operating data, purchasing decision
Service end users	banks, private healthcare, cultural institutions, hotels	reception, information, internal logistics, cleaning, visitor services

Source: [F2] and [F3]. The list is a targeted market research sample, not a complete list of Hungarian companies or institutions. The status of partnerships is date-dependent; the book records the public status as of August–September 2026.

Existing Chinese robotics channels in Hungary

Several Chinese robotics product categories have already entered the Hungarian market through distribution or integrator channels. Project sources identify JAKA industrial robots, Pudu and Keenon service robots, Unitree quadruped and humanoid platforms, and Gausium cleaning robots as Hungarian channels. This reduces the risk of first-time product import, but territorial rights, OEM support, repair authorization, and spare parts supply must be clarified separately for each brand. [F3; F6]

Table 4.3. Four levels to check for a local channel

Level	What needs to be proven?	Why is it important?
Commercial law	which countries, customer groups and products are eligible	avoids parallel channel and customer conflict
Integration law	API/SDK, elevator/door/WMS/PMS interface, configuration access	the robot itself is often not a complete workflow
Service law	diagnostics, repair, spare parts, warranty settlement, firmware recovery	local SLA and uptime depend on this

Level	What needs to be proven?	Why is it important?
Compliance documentation	DoC, technical dossier access, version and serial number management	Distribution and operational responsibility can only be handled with documentation

Source: [F6], [F7], [F9]. Detailed legal and compliance requirements are included in the regulatory and industrial implementation sections later in this manual.

Data limit of the Hungarian market

The institutional research of September 12, 2026 did not find a unified Hungarian database that would provide annual purchase volume, willingness to pay and conversion from pilot project to commercial launch by robot category. The Hungarian market should therefore be structured based on specific locations, tasks, available decision-makers, public installations and price quotes. [F1]

Market evidence: contact, interest, offer, accepted pilot plan, signed contract, paid invoice and operational performance are separate levels of evidence. A contact or demonstration in itself is not demand.

9. Sales models, life cycle cost and return on investment

The commercial offering is more than the robot hardware

The value purchased by the customer is the working workflow. The hardware is accompanied by site survey, delivery, commissioning, mapping, interfaces, software licensing, training, service, spare parts and often human supervision. Especially for service and humanoid robots, it is misleading to calculate a direct return on the list price. [F5; F9]

Table 4.9. Robotic sales models

Model	Who pays?	Revenue logic	Main risk
Direct robot sales	end user	one-time hardware price + optional service	low recurring revenue; warranty and inventory can remain in the local channel
Distribution	end user	spread between purchase and sale price	price competition, territorial rights, OEM direct sales
Integration project	end user or OEM	engineering and site project fee	scope creep, interface dependency, handover criterion
RaaS / leasing	end user monthly fee	usage fee, often with service and software	financing and residual value risk at the service provider
Managed service	end user pays for results	e.g. cleaned m ² , logistics task, operating hours	robot performance and SLA risk at the service provider
OEM-paid market building	manufacturer	project or monthly fee for local market entry work	public partner program does not prove paid consulting engagement
Commissioned mediation	OEM/seller in case of success	contractual success fee	definition of client assignment, commission base and cash receipt

Source: [F8]. The models describe market roles; specific fees and margins are contractual.

Layers of TCO

Table 4.10. Total life cycle cost – minimum cost list

Cost group	Examples	Management in the business case
Acquisition	robot, gripper/hand, charger, accessory, customs, shipping	one-time investment or financed asset
Introduction	on-site survey, mapping, elevator/door/WMS/PMS interface, configuration	one-time project cost
Software and data	cloud, license, fleet management, data connection, remote support	annual/monthly recurring cost
Service	preventive maintenance, on-site work, diagnostics, SLA	annual fee + event cost
Parts and wear	battery, wheel, motor/actuator, sensor, hand/gripper	lifetime reserve
Human effort	monitoring, remote operator, training, fault reset	to be deducted from robot-induced working hours
Downtime and replacement	downtime, replacement machine, express parts, production loss	risk cost or SLA requirement

Source: [F5], [F9].

European price anchor: Pudu CC1

The German price survey on September 12, 2026 showed a net machine price of EUR 16,310 and EUR 19,000 for the Pudu CC1 professional cleaning robot at two retailers. This is a useful hardware price anchor, but the on-site survey, installation, service, financing and the specific accessory package are not uniform. [F6]

Humanoid ROI: a viable price must be calculated from the workflow

The task-level ROI model calculates the annual labor hours realized based on the planned operating hours, availability, robot-to-human productivity, and the proportion of work that can actually be monetized. Human supervision, service, and energy are deducted from the annual net savings. The total investment includes the robot, integration, and handover. [F5]

Formula: Realized annual working hours = planned working hours × availability × relative productivity × monetization rate. Simple return = total investment / annual net savings.

Table 4.11. Humanoid Industrial ROI – Three Editorial Model Scenarios

Assumption	Careful industrial	Basic industrial	Strong, to be validated
Total investment	120,000 EUR	90,000 EUR	90,000 EUR
Scheduled hours/year	4,000	4,000	6,000
Availability	75%	85%	95%
Relative productivity	50%	70%	90%
Monetization rate	60%	80%	90%
Total hourly cost	15.60 EUR	15.60 EUR	20.20 EUR
Supervision	800 hours/year	400 hours/year	300 hours/year
Annual net savings	–11,940 EUR	12,962 EUR	76,703 EUR

Assumption	Careful industrial	Basic industrial	Strong, to be validated
Simple return on investment	no positive savings	6.9 years	1.2 years

Source: [F5]. All operating ratios are editorial model assumptions. The 15.60 and 20.20 EUR/hour are Hungarian and Czech industrial labor cost proxies for 2025; the robot investment value is not an OEM offer.

The base case net savings of EUR 12,962 per year would give a total investment ceiling of approximately EUR 38,887 for a three-year payback target. This shows why the target price should be determined backwards, from the work performed: a cheap robot can be a bad investment with low availability, while a more expensive system can pay for itself on multi-shift, high-value tasks. [F5]

Extended implementation from a pilot project: the necessary measurement gates

Table 4.12. Minimum to measure for commercial decision

Gauge	What needs to be recorded?	Why is it crucial?
Task success	successful cycle / total cycles attempted	measures repeatable productive work instead of demo
Cycle time	mean, p95, expectation	comparable to human or alternative automation
Intervention	intervention/task and operator minutes/hour	shows the hidden human cost
Availability	time actually ready for work from planned time	directly affects the realized working hours
Quality	scrap, drop, rework, damage	you can write back productivity gains
Service	failure, MTTR, parts and field work	TCO and SLA basis
Security	stop, fall, collision, near miss	go/no-go condition; not just a financial KPI

Source: [F5] and the performance measurement terminology set in Chapter II of the manual.

10. The suitability of Chinese robot manufacturers as partners in Hungary

Partner suitability is not a brand ranking. The same manufacturer can be a strong research platform and a weak end-user system, or vice versa. When selecting a Hungarian partner, the specific task, documented commissioning, EU-compatible product version, developer access, service and the OEM's contractual willingness all count. [F7]

Table 4.13. OEM Partner Eligibility Filter

Dimension	Minimum question	Strong evidence
Task matching	Is there a paying customer problem that this robot can solve better?	operational reference for the same or very similar workflow
Product maturity	demo, pilot project or series product?	installed fleet, operating hours, customer references, error management data
Price and TCO	What is the total EU procurement and support cost?	written, configuration-based offer and service list
Development access	API/SDK/offline mode/diagnostics available?	contractual developer rights, versioned documentation

Dimension	Minimum question	Strong evidence
Service	Who repairs it, with what parts, with what SLA?	trained local technician, kit, diagnostic right, OEM escalation
Compliance documentation	Which EU product law documentation is available?	configuration-related DoC, technical dossier and change management
Data and cloud	Where does telemetry run and who has access to it?	Data architecture, logging and administration that can be planned in the EU
Business relationship	What does OEM undertake for its Hungarian partner?	area, customer protection, margin/fee, support and joint pilot project in writing
Industrialization	Can configuration, assembly or testing be localized?	BOM, manufacturing documentation, technology transfer rights, supplier access

Source: [F7], [F8], [F9].

Manufacturer groups from the perspective of the Hungarian market

Table 4.14. Chinese OEMs – documented strength and open question

OEM/Group	Documented strength	Hungarian/CEE connection	Open question
Pudu	mature delivery and cleaning robot portfolio; public EU partner examples and prices	Hungarian and European channels; CC1 price benchmark	purchase discount, service right, vertical exclusivity
Keenon	Cumulative service robot scale of 100,000; hotel/restaurant/cleaning	Hungarian sales channel and European product launch	local integration and guarantee authorization limit
Gaussium	professional cleaning, large international installed base	Hungarian sales/service presence and European partner program	new vertical, regional project or joint service capacity
Unitree	low public humanoid entry price, open research ecosystem	domestic distributor presence	standard vs EDU rights, local service, full EUR TCO
AGIBOT	rapid production ramp-up, robot data platform, European Minth partnership	Industrial partner and assembly project in Serbia	CEE territorial law, industrial task performance, EU support model
Coming down	KUAVO platforms and documented pilot project→series production process	More of a development/partner candidate in CEE	configuration, price, documentation, development and production rights
UBTECH	industrial Walker S installations and audited company data	European industrial tests/partnerships are developing	specific Hungarian use case, price, service and EU configuration
Fourier	rehabilitation robotics background + humanoid development	relevant for research and healthcare cooperation	separation of medical and non-medical purposes, commercial commissioning

Source: [F6], [F7], Chinese OEM database in Chapter III. The table is not a summary ranking; relevance varies by use case.

Minimum document package for partner decision

Before a pilot launch, at least the exact article number and firmware, prices of the robot and optional modules, EU documentation, developer access, warranty, diagnostic and repair rights, parts list, cloud and data architecture, and customer and territory rights must be recorded in writing. “Open SDK” does not automatically mean the right to modify the safety control, private label distribution or full offline operation. [F7]

11. Chinese-Hungarian corporate, contractual and intellectual property models

The commercial exploitation of Chinese robot technology in Hungary can be deepened in several stages: distribution, system integration, manufacturing license, contract manufacturing, joint venture and hybrid EU-principal model. The appropriate form depends on who bears the product, market, investment and IP risk. Technology transfer research provides a general industrial framework; for a specific robot platform, a separate Hungarian, EU and Chinese legal investigation is required. [F10]

Table 4.15. Comparison of four industrialization contract models

Aspect	Manufacturing license	Joint venture	Contract manufacturing	Hybrid: EU principal + license + CM/JV
Background IP	owned by Chinese licensor; Hungarian party has right of use	preferably stays with parents, gets JV license	owned by principal/licensor	separate from the operational manufacturer
Departure speed	fast/medium	slower	fastest	fast/medium
CapEx	local licensee	common	CM and/or principal	can be divided into phases
Manufacturer change	moderately difficult	difficult	relatively easy	light by design
Regulatory control	available from local licensee	Can be concentrated in JV	To be held by EU principal	Can be easily centralized at EU principal
Governance	low	very high	low	medium
Typical target	local manufacturer authorization	long-term strategic joint investment	fast, tool-efficient production	scalable EU industrialization, uncertain initial volume

Source: [F10]. Edited comparative extract.

IP: background and foreground should be handled separately

The research generally considers the transfer of core background IP to a JV to be avoided. The existing Chinese technology can remain with the original owner and the local company or EU principal will receive a license. It is not appropriate to treat the jointly created new result with a single “all in common” clause: separate categories are product platform development, Hungarian manufacturing process, tooling, EU regulatory adaptation, firmware and independent new invention. [F10]

Table 4.16. Foreground IP – recommended categories

New result	Typical ownership logic	Other party's right
Core product/platform improvement	original platform IP owner	production/use license-back
Hungarian manufacturing process development	HU manufacturer/JV or principal by contract	license back as needed
Tool/jig/fixture design	tool owner or EU principal	production usage right
EU regulatory adaptation	EU principal/JV	access to other markets if necessary
New firmware/platform feature	platform IP owner	territory/field use license
Independent, separable invention	inventor/legal successor	pre-regulated license/option

Source: [F10].

The subject of the license should be specific.

The “right to manufacture” alone is not enough. The right to manufacture and market should separately name the rights to make, have made, assemble, test, repair, refurbish, import, export, sell and service; the product family, field of use, production site, approved subcontractor, firmware and source code access, technical documentation, trademark use and spare parts rights. Manufacturing exclusivity, sales exclusivity and sublicensing are three separate rights. [F10]

The Technology Transfer Block Exemption Regulation 2026/877/EU applies from 1 May 2026. The Regulation uses a safe-harbour threshold of 20% for competitors and 30% for non-competitors; certain hardcore restrictions, grant-back and non-challenge clauses must be examined separately within this. [W2]

Chinese technology exports, FDI and origins

Before the actual handover of the technical documentation, the Chinese technology export classification must also be completed. The Chinese system distinguishes between prohibited, restricted and freely exportable technology; due to the catalogue amended in 2025, it is not advisable to automatically rely on previous classification. In the case of Chinese ownership entry or JV, it is worth checking the applicability of Hungarian FDI screening already at the term sheet phase. [F10]

Assembly in Hungary does not automatically mean Hungarian or EU origin. EU customs law applies the logic of the last significant, economically justified processing in the case of production involving several countries. The license fee may also affect the customs value in certain cases, therefore the license agreement, the component procurement and the customs value cannot be treated independently. [F10]

Proposed contract architecture for deeper collaboration

Table 4.17. Contract package

Document	Main subject
Master cooperation / technology transfer agreement	project, milestones, conditions, governance, compliance
IP License Agreement	background IP, territory, field, exclusivity, sublicense, royalty, improvements
Technology Transfer Schedule	BOM, drawings, software, training, commissioning, acceptance
Manufacturing Agreement	price, forecast, capacity, order, stock, tooling, warranty
Quality Agreement	QMS, inspection, CAPA, traceability, ECN, supplier change, audit
Regulatory Responsibility Matrix	manufacturer/importer/distributor roles, technical file, market surveillance
Shareholders' Agreement - if there is a JV	equity, board, reserved matters, financing, deadlock, exit
Transition / Exit Schedule	open orders, WIP, parts, tooling, temporary license, customer continuity

Source: [F10]. The list is a decision-preparation framework, not a ready-made contract template.

12. Partnerships, exhibitions and market building

The market building funnel

In robotics market building, a relationship is not a business outcome in itself. The challenge is to link each relationship to a specific product, task, decision maker, budget, and follow-up evidence. The same discipline is required on the manufacturer and customer sides: written scope, responsibility, and payment make an OEM partnership and customer pilot a business. [F8]

Table 4.20. Market-building evidence chain

Staircase	Evidence	Next gate
1. Contact	name, company, role, contact information	real interest and relevant use case
2. Discovery	task, current process, problem, decision maker	on-site/technical data request
3. Technical pre-screening	robot-fit, environment, interface, security and data condition	written pilot project scope and measurement plan
4. Commercial offer	price, cost, responsible, timing, acceptance	signed pilot project / PO / advance payment
5. Paid pilot project	robot on site, logged KPIs	accepted performance and ROI
6. Extended introduction	additional robots / sites / service contract	repeatable sales and service model
3. Regional scaling	same task at another CEE location	local channel, service and country-specific compliance

Source: [F8], [F13] edited business development logic.

Exhibition and professional delegation as a sales channel

The exhibition, conference and Chinese business delegation are three separate products. At an exhibition, the goal is robot visibility and lead generation; at a professional conference, access to decision-makers and knowledge; at a delegation, pre-arranged manufacturer or partner negotiations. The number of visitors to the event is not in itself a demand for robots. [F12]

Table 4.21. Public event and delegation price benchmarks

Program	Public award	What does it contain / how can it be interpreted?
European Robotics Forum 2026	EUR 667–920	historical three-day professional admission, non-member, early/onsite; net, 25% local VAT at source
automatic 2027	279–359 EUR/m ² + 1,230 EUR communication fee	exhibitor area; stand construction, insurance, robot service and travel separately
Humanoid Robots Summit	1,499–1,799 EUR	professional ticket; virtual ticket separate product
Business Saxony China Robotics	650 EUR + VAT	professional delegation fee; travel/accommodation separately
CREATORS China	3,900 EUR	public delegation package; flight and hotel included according to the source
Future Robotics Tour China	4,900 EUR + VAT	robotics business trip; max. 15 people; itemized content to be confirmed
China Reisen AI travel	7,524 EUR	premium package, with flight; not a robotics award benchmark in itself

Source: [F12], research cut-off date September 12, 2026. The contents of the packages differ, therefore the prices are not directly comparable unit prices.

Manufacturer market development: who pays and why?

Table 4.22. Four payment models between Chinese OEM and local partner

Partner role	Payer	What are you buying?	Contractual key point
OEM-paid market building	Chinese manufacturer	local research, partner and client work, pilot project preparation	work package, result, monthly fee/project fee, payment schedule
Distributor	final	robot + local sales and warranty service	purchase price, margin, area, stock, warranty
Integrator / test partner	OEM or aftermarket	local technical development, interface, validation	acceptance test, IP, liability, cost
Commissioned broker	OEM/seller in case of success	business development leading to a deal	lead ownership, commission fund, money received, settlement

Source: [F8]. The public call for partners proves the existence of the partner role, but does not prove a fixed monthly market building fee.

The operating minimum for regional market building

In the first regional robotics project, it is not practical to fully support too many platforms at once. Each new OEM requires separate training, parts, diagnostic access, firmware and version management, warranty process and customer communication. The initial portfolio can be managed with one or two actively supported platforms per task, and other manufacturers can be kept on a comparative shortlist. [F7]

The ultimate measure of market building is paid, measurable customer work. Exhibitions, delegations, OEM meetings and pilot projects only build value if the next step has an owner, deadline, document, cost and decision gate. Regional service and integration knowledge can later provide greater strategic value than the robot's reseller margin alone.

Sources used

[F1] 01_Institutional_demand.docx. Hungarian institutional robotics needs assessment; research deadline: September 12, 2026. Parts used: 24 target institutions, Hungarian pilot project and application cases, KSH museum data, levels of evidence.

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[F3] EAG_robotic_market_research_investment_project_2026_prepared.docx. Parts used: Hungarian and CEE channels of Chinese robotics companies, JAKA, Pudu, Keenon and other partner examples.

[F4] Bottom-up humanoid robot demand in Hungary and Central and Eastern Europe, 2027–2030. Data cut-off: September 4, 2026. Parts used: 40 accounts, CEE demand scenarios, Hungarian accounts and WTP bands. Volumes are modeled estimates.

[F5] 05_Humanoid_use_case_ROI.docx. Research package, September 12, 2026. Parts used: task-level ROI formula, three return on investment scenarios, pilot measurement gates.

[F6] 03_CEE_competitors_channel.docx. Research package, September 12, 2026. Parts used: Hungarian and CEE sales/service channels, Pudu CC1 European price benchmark.

[F7] 04_Chinese_OEM_market_entry.docx. Research package, September 12, 2026. Parts used: OEM shortlist, partner document requirements, platform selection and contract gates.

[F8] 04_Gyartoi_piacepites.docx. Desktop research, September 12, 2026. Parts used: manufacturer market building, distributor, integrator and commission business models.

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[F10] Importing Chinese technology or product into Hungarian/EU manufacturing: legal and business structure analysis. Legal status: September 5, 2026. Parts used: license, JV, contract manufacturing, hybrid model, IP, technology export, FDI, customs and contract architecture.

[F11] Financing plan for the production and assembly of humanoid robots in Hungary. 2026. Parts used: EKD, R&D, GINOP, MFB, EIC, Horizon, training and funding stratification.

[F12] 07_Events_and_Delegations.docx. Desktop research, September 12, 2026. Parts used: robotic event and delegation fee benchmarks, paying target groups and business development logic.

[F13] 09_Lianta_integralt_uzleti_terv.docx. Working version, September 12, 2026. Part used: evidence levels and market building process logic; Lianta-specific financial forecasts were not included in the chapter as market facts.

[W1] HIPA. Significant changes to the grant system. April 22, 2025; and EKD changes of October 2025. Official HIPA sources, checked: September 15, 2026.

[W2] Commission Regulation (EU) 2026/877 of 16 April 2026 on technology transfer agreements. EUR-Lex, in force. Checked: 15 September 2026.

CHAPTER V

Technological and industrial implementation in Hungary

The industrial logic of the Hungarian humanoid robot program does not start with the construction of a single factory. The working sequence is testing and OEM benchmarking, technology and supplier localization, Physical AI data and validation capabilities, regional service, and then volume-adjusted assembly and manufacturing. The chapter organizes the Serbian, Hungarian, and Chinese manufacturing, compliance, cybersecurity, service, and economic research completed in the project into a unified industrial model.

Data cut-off: September 15, 2026. The main research in the chapter records the status as of September 4–5, 2026. The operating foreign reference, the existing Hungarian capability, the proposed implementation model and the editorial ROM and target cost estimate are listed as separate categories everywhere. The application dates of the Machinery Regulation and the Cyber Resilience Regulation were also checked on September 15, 2026 based on EUR-Lex.

Table 5.1. Structure of Chapter V

Part	Topic	Main question
13.	European manufacturing and testing environment: Šabac and ZalaZONE	What working European models can we start from, and what do they actually prove?
14.	Localization, technology transfer and Hungarian supplier value chain	Which production layers can be brought to Hungary quickly, and which only with higher volumes?

13. European manufacturing and testing environment: the Minth–AGIBOT plant in Šabac and ZalaZONE

Šabac: the closest European reference for humanoid industrialization

The Minth–AGIBOT project in Šabac, which opened on August 29, 2026, is important for the Hungarian program because it is not a laboratory robot demonstration, but a European robot assembly project installed on an existing industrial production platform. The Serbian official communication describes it as a “mass production base”, while the government statement names the assembly of more than 5,000 robots per year in the first phase. The project research therefore interprets the first phase more precisely as a localized final assembly, calibration and testing plant, from which deeper production may develop later. [F1]

Table 5.2. Šabac and the planned Serbian robotics expansion – documented claims

Element	Documented data	Interpretation
Departure from Šabac	August 29, 2026	a working European industrial reference, not just a declared plan
First phase investment	approx. EUR 20 million	magnitude reported by the Serbian Development Agency
Target capacity of the first stage	Assembling >5,000 robots per year	assembly purpose; the depth of local added value is not disclosed
Location	existing Minth industrial base in Šabac	you didn't have to build a complete robotics industrial ecosystem from scratch to enter
Indija plan	approx. EUR 200 M Robotics Industrial Park	separate, later/planned expansion direction; not identical to the first phase in Šabac

Source: [F1]. Capacity and investment are corporate/government disclosures; full localization depth and product mix are not public.

Minth and AGIBOT: what can be publicly verified?

The public Minth–AGIBOT materials show the cooperation to be deeper than distribution: joint assembly, flexible manufacturing, local production, European sales and life cycle support appear. However, full technology transfer is not proven. Royalty, source-code rights, firmware signing, BOM-disclosure, territorial scope of the manufacturing license and sharing of IP ownership are not public. [F1]

Table 5.3. The most likely public division of labor

Actor	Publicly demonstrable major role	Unproven public law
AGIBOT	product IP, robot architecture, AI/control software layer, core engineering development	transfer of source code and signing rights; full BOM and IP transfer
Mint	European industrialization, assembly/manufacturing, distribution, life cycle support	independent platform IP or OEM-independent firmware control
Common space	manufacturing adaptation, robotic components, commissioning and data collection collaboration	Detailed allocation of foreground IP and data rights

Source: [F1]. The table is a role model derived from public evidence, not a description of the parties' confidential contract.

The question “Can it be made in Europe?” covers six separate rights

Table 5.4. Technology transfer rights that must be separately contracted

Law	What does it enable?	If missing
SKD/CKD assembly right	European series assembly	no local production rights
Production documentation right	Use of SOP, WI, PFMEA, body and process documentation	black box assembly and OEM dependency
Diagnostic / service right	local troubleshooting, repair, RMA	all serious defects are returned to the OEM
Firmware / signing rights	approved software installation and release management	the factory does not control the manufactured configuration
Supplier localization right	Chinese component can be replaced with EU/HU alternative	supplier localization is limited
Data / model right	using robot data, fine-tuned model, and training output	the value of physical AI can be transferred to an external party

Source: [F1]. The first right alone provides assembly; the first five together provide meaningful production localization; the sixth determines the owner of data/model value creation.

Chinese benchmark: from pilot project assembly to automated mass production

Table 5.5. Two Chinese production steps to which the Hungarian plant can be measured

Benchmark	Capacity/production image	Important manufacturing date	Hungarian lesson
Shenzhen–Longhua / Down	approx. 500–1,000 robots/year pilot project/industrialization	flexible, partly manual assembly; ≤120 minute full cycle target; >30 tests/finished robot	This is a closer sample to the 100–1,000 Hungarian startups
Foshan high volume line	10,000+ robots/year	24 precise assembly operations, 77 inspection points, 41 automated tests; approx. one robot completed every 30 minutes	It is only worth moving to such automation after a stable design, volume and DFM

Source: [F1], [F9]. Chinese data are from manufacturers/official industry releases; not independently audited factory capacity data.

ZalaZONE: a high-value testing ecosystem, but for a different purpose

ZalaZONE is not a humanoid robot lab, but a 250-hectare automotive test and R&D center. Built for classic vehicle dynamics, electric, ADAS and autonomous vehicle validation; the 4.45 km high-speed oval, smart city environment, 5G/V2X environment, workshops and autonomous mobility programs provide a working model for large-scale, realistic testing. [F2]

Table 5.6. ZalaZONE – existing capabilities relevant to the humanoid program

Ability	Documented status	From a humanoid program perspective
Test area	250-hectare multifunctional automotive proving ground	field test, outdoor mobility and benchmark for complex environment design
High-speed oval	4.45 km; module opened in 2025	a model of high technical and security level infrastructure operation
smart city environment / V2X	urban scenarios, 5G, Wi-Fi/802.11p, C-V2X, RSU and traffic light integration	knowledge applicable to connected autonomous systems, networked and urban robotics scenarios

Ability	Documented status	From a humanoid program perspective
Workshop and measurement	expanded workshop capacity, ADAS and measurement systems	test logistics, asset management, operational benchmark of customer projects
Chinese relations	2025 MOU on Hungarian-Chinese Automotive and Energy Storage Validation Center; CCIC inquiry	institutional Chinese testing and certification cooperation model
Industrial ecosystem	Bosch R&D center and other settlers next to the track	industrial R&D and supplier presence can be organized around test infrastructure

Source: [F2]. The 2025 Hungarian-Chinese center is at the MOU level in the research stage; the investment amount, ownership structure and established JV could not be publicly verified.

ZalaZONE and Óbuda: complementary, not substitutive infrastructure

Table 5.7. Appropriate division of test functions

Test task	ZalaZONE's strength	Strength of the Óbuda Humanoid Center
Outdoor mobility, terrain, large space	strong	additional
Smart-city, networked and autonomous mobility scenario	strong	special indoor/robotics addition
Humanoid walking ground truth, fall/recovery	undocumented humanoid specialty	dedicated mocap + force plate + fall-arrest
Manipulation, payload, two-handed task	not main profile	dedicated F/T and 3D metrology
HRI and contact measurement	not main profile	isolated humanoid HRI lab
Battery/thermal, firmware/model reproducibility	partially available industrial background	robot-specific test and data package
Accreditable humanoid performance testing	there is no such scope publicly available	can be specifically developed in the direction of ISO/IEC 17025

Source: [F2], [F5]. Conclusion: the value of ZalaZONE is the system and field test environment; the value of ÓE is the indoor humanoid metrology and reproducible test protocol.

Conclusion of Part 19: The Hungarian program does not have to copy Šabac or ZalaZONE one-to-one. Šabac shows the industrialization sequence, ZalaZONE the logic of high-value test infrastructure and industrial ecosystem. A humanoid-specific Hungarian chain can be built from the two: test → data → OEM rights → assembly → service → localization → volume.

14. Localization, technology transfer and the Hungarian supplier value chain

The realistic starting point: system integration and gradual localization

According to the localization research, a realistic humanoid industrial capability can be built in Hungary, but not with the assumption that the entire robot BOM must be manufactured locally in the first years. The first value is Hungarian final assembly, EOL, mechanics, cable harness, electronics assembly, compute carrier/thermal, battery pack+BMS, manufacturing IT/MES and service. The precision strain-wave reducer, the high-end encoder, the LiDAR optics, the AI-accelerator and the dexterous hand core technology are later, volume-dependent localization decisions. [F3]

Table 5.8. The reference humanoid – the technical basis of the localization model

Parameter	Modeled reference	Why is it important for localization?
Crowd	approx. 30–35 kg	manageable industrial/test platform; structural and battery requirements
Degree of freedom	28–32 body DoF	24–30 main actuators; high joint piece requirement
Hand	2 medium complexity five-fingered hands	high-cost, license- and reliability-critical module
Perception	RGB/depth + compact 3D LiDAR	calibration and EOL perception test
Energy	approx. 0.8–1.5 kWh	pack/BMS and safety local value creation point
Compute	NVIDIA Orin/Thor-class edge compute	carrier, thermal, provisioning can be localized; chip is not a realistic domestic target

Source: [F3]. This is a design reference robot, not a specific OEM product specification.

Actuators and hands dominate the cost structure. The Bank of America model cited in the research models linear actuators at 27%, rotary actuators at 24%, and hands at 19% of the BOM by 2030. This explains why the joint platform is an economically important area for long-term localization. [F3]

Four industrial phases between 2026–2031

Table 5.9. Hungarian localization schedule

Period	Volume / capacity	Main content coming to Hungary	Targeted HU hardware VA
2026 Q4–2027 H1	10–30 EVT/DVT robots	platform freeze, frame/harness engineering, final assembly, traceability, joint endurance, machinery risk file	Percentage is not the main KPI
2027 H2–2028	50–200 pcs/year	final assembly, EOL, frame, cover, harness, EMS, control PCB, compute thermal, battery pack+BMS, MES	20–30%
2028–2029	300–700 pcs/year	actuator assembly, motor pilot project, F/T calibration, licensed hand assembly	35–45% total; ≥50% in selected actuator family
2029–2031	1,000–3,000+ pcs/year capability	industrialized joint platform, motor deep-localization, selected transmission parts, own F/T and hand subcomponents	55–65% longer term goal

Source: [F3]. Volumes, value-added targets and timing are strategic model values, not a contracted production plan.

Production costs fall with volume and localization

Table 5.10. Modeled direct manufacturing cost per robot

Production level	Estimated direct cost	Main assumption
50–200 pilot projects/year	55–85 thousand USD / 47–73 thousand EUR	COTS/core components, small series, high NRE and test costs
1,000+ pcs/year	32–50 thousand USD / 27.6–43.1 thousand EUR	volume pricing, local mechanics/EMS/harness, standardized joints
3,000–5,000+ pcs/year mature	24–38 thousand USD / 20.7–32.7 thousand EUR	greater vertical integration and purchasing scale

Source: [F3]. Editorial target cost model; not manufacturer's quote or forecast market price.

What can be quickly made a supplier in Hungary?

Table 5.11. Domestic industrial capabilities – potential partners, not agreements

Ability	Example in research	Potential robotics content
EMS / electronics	Flex, Jabil, VIDEOTON, Sanmina, Zollner, Foxconn	control PCB, compute carrier, box-build, NPI, final electronics assembly
Motor / motion control	NCT, Synapticon	servo/frameless motor development, drive electronics, actuator co-development
Precision mechanics	Linamar, Nemak	joint housing, axle, flange, lightweight cast/machined structure
Plastic and casing	Jasz-Plastics	outer shell, electronics housing, injection tooling
Cable and connection	Hungarian automotive harness/connector ecosystem	harness, connectorization, EOL continuity and pull-test
Battery and pack integration	Hungarian battery industry and electronics background	pack+BMS assembly, thermal and pack EOL – after product-specific qualification

Source: [F3], [F4]. The list of companies is a capability-based partner designation; it does not state an existing humanoid robot supplier contract.

Hungarian deficiencies: the robot-specific precision core

According to the research, the biggest domestic gap is not in electronics assembly or final assembly, but in the large-scale robot-specific precision strain-wave reducer, the compact high-end encoder, the six-axis force/torque transducer and the dexterous-hand core. In these, technology transfer, JV or longer co-development may be more important than a simple domestic sourcing tender. [F3]

Table 5.12. Planning investment bands for deeper localization

Component	ROOM CAPEX	Estimated industrialization time	Comment
Frameless engine	EUR 8–15 million	18–30 months	electromagnetic design, winding, thermal and motor-dyno competence
High-end encoder	EUR 15–40 million	36–60 months	sensor physics, ASIC/interface, clean metrology; prefers imports in early stages
6-axis F/T sensor	EUR 5–10 million	18–30 months	flexure CNC, strain gauge, thermal compensation, 6-axis calibration
Dexterous hand – licensed assembly	EUR 3–8 million	12–24 months	lower risk than full own hand-IP
My dexterous-hand IP	EUR 10–30 million+	30–60 months	high R&D and reliability risk
Strain-wave reducer core plant/JV	EUR 25–60 million	30–48 months	only justified with exportable volume
Battery pack+BMS	EUR 3–7 million	9–15 months	faster to localize, but safety/compliance-intensive

Source: [F3]. ROM planning ranges; non-budget figures without supplier offer and site-specific investment plan.

Who could be the “Hungarian Minth”?

The separate partner selection research examined 18 Hungarian manufacturers in terms of contract manufacturing, NPI, electromechanical assembly, quality, traceability, volume ramp-up, repair and life cycle support. The shortlist does not assess robot manufacturing skills, but rather measures which organization can become a humanoid-industrialization partner the fastest. [F4]

Table 5.13. Partner Selection Shortlist – Weighted Research Score

Rank	Company	Score	Strength according to model
1.	Flex Hungary	94.6	complex CM/NPI, electronics, system assembly, life cycle and repair background
2.	Sanmina-SCI Hungary	93.1	high-mix electronics and complex manufacturing services
3.	Jabil Tiszaújváros	93.0	EMS, supply chain, engineering and scaling
4.	Zollner Electronics Hungary	90.6	mechatronics, electronics and contract manufacturing
4.	Foxconn / Cloud Network Technology	90.6	high volume, electronics, global supply chain
6.	VIDEOTON	89.8	regional integrated contract manufacturing and mechanics/electronics

Source: [F4]. Research evaluation board, not tender result. Proposed participants for the first round of negotiations: Flex, Sanmina, Zollner, VIDEOTON, Foxconn; Jabil first reserve/alternative.

Minimum technology transfer package

Table 5.14. Industrialization package to be transferred from OEM to Hungarian manufacturer

Package	Minimum content	Acceptance proof
Product data	frozen BOM, drawing, interface, HW revision	versioned PLM package, change baseline
Production	SOP/WI, PFMEA, control plan, torque specs, fixtures	pilot project build and process capability review
Software	signed edition, flashing process, recovery, calibration package	repeatable, audited EOL build
Quality	incoming/EOL limit, golden unit, failure taxonomy, FRACAS	golden sample + acceptance protocol
Service	diagnostic tool, RMA, service BOM, calibration after repair	L2/L3 repair pilot project
Localization	approved supplier-change/ECN process	first alternative component validation
Data/IP	telemetry, derived dataset and model rights	contractual data rights matrix

Source: [F1], [F3], [F4].

Sources used

[F1] The Šabac humanoid robot factory and the Minth–AGIBOT partnership. In-depth research report, research status: September 4, 2026. Parts used: Šabac/Indija, Minth–AGIBOT division of labor, Chinese manufacturing benchmark and Hungarian replication.

[F2] ZalaZONE: Corporate, Financial, Technical and Geopolitical Due Diligence. In-depth Research Report, September 4, 2026. Sections used: technical testing capabilities, organizational structure, Chinese relations and security/data governance issues.

[F3] Localization strategy for humanoid robot manufacturing in Hungary, 2026–2031. In-depth research report. Parts used: reference robot, BOM, Hungarian industrial capabilities, localization roadmap, component make-or-buy and CAPEX.

[F4] Selection of a Hungarian humanoid robot manufacturing and assembly partner for Óbuda University. In-depth research report. Part used: 18-company evaluation board, shortlist and Hungarian Minth partner profile.

[F5] Humanoid Robot Testbed and Validation Center at Óbuda University. In-depth research report. Parts used: ISO/benchmark, lab zones, measurement backbone, security architecture, ROM CAPEX and personnel.

[F6] physical and embodied AI data processing center for the humanoid robot program of Óbuda University. In-depth research report. Parts used: Chinese benchmarks, data pipeline, 10/50/100 robot sizing, CAPEX/OPEX, headcount plan, stage-gate and data rights.

[F7] European Humanoid Robot Service & Support Hub in Hungary. In-depth research report. Parts used: multi-vendor service architecture, spares, SLA, organization, financial model, break-even and schedule.

[F8] Three-scenario economic and operational model of a humanoid robot assembly and manufacturing plant in Óbuda. In-depth research report. Parts used: A/B/C capacity, FTE, hall, CAPEX, target cost, NRE, working capital and breakeven point.

[F9] Workstation-level technological benchmark for Chinese assembly of humanoid robots and preliminary design of a 500–1,000-unit-per-year pilot plant in Óbuda. Parts used: Shenzhen/Foshan benchmark, workstation, EOL, MES and automation threshold.

[F10] Software-based manufacturing and cybersecurity architecture for humanoid robots for an assembly plant in Óbuda. Components used: RobotID, PKI/HSM, secure boot, provisioning, calibration, Birth Manifest, OTA, SBOM and cyber-cost model.

[F11] EU compliance research for a Hungarian humanoid robot assembly plant. Parts used: legal/standard architecture, DV/type/PVT/EOL test strategy, traceability and external conformity assessment.

[W1] EUR-Lex. Regulation (EU) 2023/1230 on machinery, consolidated version current on 2026-09-15. Article 54: general application from 20 January 2027. <https://eur-lex.europa.eu/eli/reg/2023/1230/en>

[W2] EUR-Lex. Regulation (EU) 2024/2847, Cyber Resilience Act. Article 71: main application from 11 December 2027; Article 14 from 11 September 2026. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32024R2847>

ROBOTICS AND EMBODIED ARTIFICIAL INTELLIGENCE

CHAPTER VI

Reference section

The reference section unifies the economic, industrial, robotics and AI concepts used in the manual, summarizing in one place the most important numerical data, as well as abbreviations, organizations and sources used in the chapters. The definitions record the use of the book; for legal or standard terms, the relevant primary source is the authoritative one.

Data cut-off: September 15, 2026. The numerical data tables carry over the sourced values already used in Chapters I–V. Model values continue to be listed as models, corporate communications as corporate communications, and policy objectives as target values.

Structure of Chapter VI

Part	Content	Use
15.	Economic, business and industrial development glossary	business model, market building, manufacturing and financing terminology
16.	Robotics, AI and technical glossary	hardware, autonomy, data, manufacturing, safety and cyber terminology
17.	Data tables, annexes and indicators	key figures, abbreviations, organization and data table index
18.	References and bibliography	internal research, standards, legislation, technical literature and manufacturer sources

15. Economic, business and industrial development glossary

The glossary captures the meaning used in the manual. The book is particularly strict in separating orders, production, delivery, installed base and capacity, because combining them regularly leads to overestimation in the robotics market.

A–C

Concept	English / abbreviation	Report in the manual
Data closure	data cut-off	The date up to which the facts and market conditions used for the chapter were verified. Not the publication date of the document.
Authorized representative	authorized representative	A designated legal entity in the EU that performs specific manufacturing tasks based on a written mandate; not the same as a distributor.
Background IP	background intellectual property	Pre-existing technology, know-how, software, drawings or patents that the party brings to the joint work.
BOM	bill of materials	The bill of materials and components of the product. In the book, it is a basic unit of hardware cost and localization.
Break-even	breakeven point	The volume or revenue at which the modeled revenue covers the costs considered. The book uses both operating and accounting break-events separately.
CAPEX	capital expenditure	Investment expenditure: building, machinery, measuring system, tooling, IT infrastructure and other durable assets.
CKD	completely knocked down	A form of local assembly from a fully disassembled kit; it does not in itself demonstrate the extent of local value added.
Contract manufacturing	contract manufacturing	Based on the product owner's specifications, an external manufacturer carries out the industrialization or production, with liability and IP limits set out in the contract.
Contribution	contribution coverage	The amount remaining from revenue after deducting modeled variable or direct costs, which contributes to covering fixed costs.
Commissioning	factory installation	Putting a robot into use in a real-world task. It can be a pilot project or a permanent installation; it is not the same as sales or manufacturing.
Distributor	distributor	A partner who buys from the manufacturer and resells to the end market, usually with local sales, warranty and channel responsibilities.
EKD	individual government decision support	Hungarian investment promotion support framework, the intensity and commitments of which depend on the project and location.
EMS	electronics manufacturing services	Electronics contract manufacturing services: NPI, PCBA, box-build, test, supply chain and often full product life cycle support.

D–L

Concept	English / abbreviation	Report in the manual
Foreground IP	IP created in the project	The ownership of any new technology, process, software, drawing, data or know-how resulting from the joint project must be arranged in advance.
FRU	field replaceable unit	Modularly replaceable unit on site or in service. The basis for the service BOM and spare parts strategy.

Concept	English / abbreviation	Report in the manual
Importer of record	official importer	A legal entity that has a customs, documentation and, where applicable, product liability role related to imports.
Installed base	installed stock	The number of supported robots operating in a given market or customer base. For a service business, this can be a more important metric than annual sales.
Integration cost	integration cost	On-site, software and infrastructure costs above the price of the robot: mapping, interface, elevator/door/WMS/PMS, safety and configuration.
Joint venture	JV / joint venture	A business entity jointly owned by two or more parties. It appears in the book as a structure for manufacturing, technology transfer, and market building.
Capacity	production capacity	The theoretical/nominal output capacity of a system or plant over a given period of time. Not the same as actual production or delivery.
Landed cost	total cost of ownership	The sum of shipping, customs, insurance and other arrival costs added to the purchase price.
Lead time	lead time	The time between order and delivery, or demand and availability. For parts, it has a direct impact on inventory and SLA.
License-back	back-licensing	The owner of the newly created IP gives back specific usage rights to the other project party.
Local value added	local added value	Estimated proportion of the value of a product that is locally generated manufacturing, engineering and service content. Model KPI in the book, not customs proof of origin.
Localization	localization	Relocation of manufacturing, supplier, service, software or compliance functions to the target market. Not the same as mere local assembly.
MOQ	minimum order quantity	Minimum order quantity accepted by the supplier; a significant inventory and capital tie-up factor for small-volume robotic projects.

M-R

Concept	English / abbreviation	Report in the manual
NPI	new product introduction	New product industrialization process from prototype to stable, documented, repeatable production.
NRE	non-recurring engineering	One-time engineering and industrialization costs: tooling, test development, fixture, programming, validation and product transfer.
OEM	original equipment manufacturer	In the book, the product owner/manufacturer of the robotic platform. Manufacturing rights, IP, warranty, and firmware control are typically tied to him.
OPEX	operating expenditure	Annual or regular operating costs: staff, lease, energy, cloud, maintenance, licenses and operational services.
Order	order	Contract or commercial order. Not the same as production, delivery, or installation.
Pilot project	trial run	A real-world trial with a limited volume, pre-defined set of tasks and KPIs. In the book, a paid pilot is stronger evidence of demand.
Production	production	The number of units actually produced during a given period. It is not the same as the factory's nominal capacity.
RaaS	robot-as-a-service	Robot as a service: the customer does not necessarily purchase a device, but receives a robot, software, maintenance and support for a periodic fee.

Concept	English / abbreviation	Report in the manual
RMA	return merchandise authorization	A warranty or service return process that records the unit's identification, defect, shipment, and repair status.
ROI	return on investment	Return on investment indicator. For a robot, the net annual economic benefit must be compared to the total implementation and operating costs.
Extended introduction	extension	After a successful pilot project, the solution is standardized for expansion to multiple robots, sites or countries.
Royalty	royalty	A fee paid for the use of licensed technology or IP, which may be fixed, unit-based, or revenue-based.
Service BOM	service parts list	List of parts, modules, part numbers, prices and supply details required for repair and maintenance.

M-R

Concept	English / abbreviation	Report in the manual
Shipping / delivery	delivery / drop-off	The unit actually delivered to the customer or channel. It cannot be added to a production milestone or backlog.
Target cost	model cost	Estimated realistic direct cost based on engineering/procurement. Not a supplier quote and not a market list price.
SKD	semi-knocked down	Local assembly from partially assembled modules. The depth of technology transfer depends on the manufacturing and modification rights obtained.
SLA	service level agreement	Measurable service level: response time, diagnostics, on-site service, repair, parts supply and availability.
System integrator	system integrator	A technical partner that adapts the robot to the customer's process, IT, devices and safety environment.
TCO	total cost of ownership	Total life cycle cost: procurement, integration, software, service, consumables, monitoring, downtime and financing combined.
Technology transfer	technology transfer	Controlled transfer of documentation, manufacturing methods, tooling, software, know-how, training and authorizations to the other party.
Warranty	guarantee	The manufacturer's or seller's agreed-upon repair/replacement terms. The actual service cost also includes reimbursement, parts, freight, and SLA.
Working capital	working capital	Financing requirement tied up in inventory, WIP, accounts receivable and operating cash cycle.
WTP	willingness to pay	Willingness to pay: the price level at which the customer is still willing to accept the value provided by the robot.

16. Robotics, AI and technical glossary

The technical glossary covers everything from robot architecture to robot training to manufacturing, safety, and cybersecurity terminology. Short definitions provide the meaning of the term as used in Chapters I–V.

M–R

Concept	English / abbreviation	Report in the manual
Actuator	actuator	A unit that creates movement. A humanoid joint can also be an integrated unit of a motor, gear/reducer, encoder, drive electronics and mechanics.
AGV	automated guided vehicle	A material handling vehicle that travels on a predefined or infrastructure-bound route. Typically has less autonomous route flexibility than AMR.
AMR	autonomous mobile robot	An autonomous mobile robot that senses its environment and plans routes on the spot.
Autonomy	autonomy	The ability of a robot to perform its task without human intervention. In operational evaluation, it should be interpreted together with the intervention rate and recovery capability.
Availability	availability	The proportion of time in which the robot is operational and available for the intended service.
BMS	battery management system	A system for monitoring the condition, protection, charging and equalization of battery cells.
Bootloader	bootloader	Low-level software that runs when the hardware boots up, checking and starting the next firmware/operating system layer.
Calibration	calibration	Defining and setting the relationship between the measured and reference value of a sensor, actuator or robot; in the book, the result is tied to RobotID.
SHARK	corrective and preventive action	A regulated quality process designed to eliminate the root cause of an error and prevent its recurrence.
Cobot	collaborative robot	A robot or robot application designed to collaborate with humans in a shared workspace. The method and safety requirements of collaboration are task-specific.
Conformity assessment	conformity assessment	Documented proof that the product meets the applicable legal and technical requirements; not a single CE test.
Cycle time	cycle time	The time required to complete a specific process or work cycle. In manufacturing, it is not the same as takt time.
DAQ	data acquisition	Hardware/software system for time-synchronous collection of measurement signals.
Dexterous hand	skillful robot hand	A multi-fingered, multi-degree-of-freedom terminal designed for fine object movement; often with tactile and force sensing.
Digital thread	digital lifecycle chain	A traceable digital data link of the product from BOM and manufacturing through test, firmware, OTA and service.

M–R

Concept	English / abbreviation	Report in the manual
DoF	degree of freedom	Number of independent movement coordinates. Typically approximates the number of joint movements in a humanoid.

Concept	English / abbreviation	Report in the manual
E-stop	emergency stop	Emergency stop function that initiates a quick, defined stop in a dangerous situation. It does not replace the entire safety architecture.
embodied AI	embodied AI	An AI system that interacts with the environment using a physical body, sensors, and actuators and collects data from it.
Encoder	position/angle sensor	A sensor that measures the position, angle, and often velocity of an axis or joint.
EOL	end-of-line test	Release testing performed on each finished unit at the end of production. May include functional, safety, software, and configuration gates.
Episode	robotics episode	A continuous block of data from task start to task end with observations, actions, and results.
ERP	enterprise resource planning	Enterprise resource planning system; top-level management of ordering, purchasing, inventory, finance and production master data.
EVT / DVT / PVT	engineering / design / production validation test	Successive validation gates of product development: verification of engineering operation, design and manufacturing process.
F/T sensor	force/torque sensor	Force and torque sensor; can be used in a humanoid wrist, foot, hand or external test fixture.
Failsafe state	safe error state	A defined state in which, in the event of a failure, the risk is reduced to an acceptable level.
Firmware	embedded software	Software running in the robot's low-level controllers, sensors, and modules that interface directly with the hardware.
FPY	first-pass yield	The proportion of units that passed the first run without repair or retest.
FRACTURED	failure reporting, analysis and corrective action system	A reliability system that manages error reporting, analysis, root cause and corrective action in a closed feedback loop.
Ground truth	referential truth	Reference data that is independent of the robot's own estimation, with higher accuracy, such as mocap, force plate, or calibrated measuring device.
Hash/digest	cryptographic fingerprint	A short identifier calculated from the content of data or software that can be used to check whether the file or configuration has changed.

H-O

Concept	English / abbreviation	Report in the manual
Hazard log	hazard register	A documented list of identified hazards, risks, mitigations, and audit evidence.
HIL	hardware-in-the-loop	A test method that combines a real hardware component with a simulated environment.
HRI	human-robot interaction	Physical, visual, voice-based, or task-level interaction between a human and a robot.
HSM	hardware security module	A hardware security module for the secure creation and use of cryptographic keys.
Humanoid robot	humanoid robot	A robot with a human-like body structure, typically walking on two legs and manipulating with arms. The shape alone does not determine its legal classification.
IMU	inertial measurement unit	An inertial sensor unit that measures acceleration and angular velocity; a basic component of balance, state estimation, and navigation.

Concept	English / abbreviation	Report in the manual
Intended use	intended use	The use, environment and task specified by the manufacturer. It is one of the starting points for the conformity and safety framework.
IP rating	ingress protection	Enclosure protection class against dust and water ingress in the IEC 60529 system.
LiDAR	light detection and ranging	A laser rangefinder and spatial sensor that produces a point cloud or distance profile for navigation and perception.
Manipulation	manipulation	Picking up, moving, placing, assembling or machining an object with a robotic arm/hand.
MES	production execution system	A production execution system that manages operations, traceability, recipe, test, and WIP status at the workstation level.
Mocap	motion capture	External camera or other reference system for high-precision measurement of movement and body position.
MTBF	mean time between failures	Mean time between failures of a repairable system. Public fleet-level data for humanoids is still rare.
Multimodal data	multimodal data	Data that connects multiple sensory channels, such as image, depth, force, position, sound, and language instruction.
SINCE	over-the-air update	Software or firmware update over the network, with a controlled release, rollback, and authorization process.

P–S

Concept	English / abbreviation	Report in the manual
Payload	payload	The mass/load that can be carried or manipulated by the robot under specified conditions.
Perception	perception	Machine interpretation of the environment, objects, people, positions and events from sensor data.
Physical AI	physical AI	In the book, the concept that overlaps with embodied AI is: the unity of AI models, sensors, robot control, and real physical action.
PKI	public key infrastructure	Cryptographic infrastructure for managing certificates, keys, and chain of trust.
PLr	required performance level	The required performance level for the safety function determined from a risk assessment within the logic of ISO 13849.
Policy	robotics policy	A control/learning model that generates robot action from observation. It does not imply corporate policy in this usage.
Pose	position and orientation	The combination of the spatial position and orientation of a body or object.
Provisioning	production setup and identity release	Production allocation of unique keys, certificates, configurations, and licensed software for the robot or module.
Recovery	recovery	The ability of a robot to continue a task without human assistance or with limited support after an error, jam, or fall.
Redundancy	redundancy	Implementing a critical function with multiple, partially independent channels or components to reduce the impact of errors.
Release manifest	release manifest	A machine-verifiable list of firmware, software, model, and configuration versions allowed for RobotID.

Concept	English / abbreviation	Report in the manual
RGB/depth camera	color + depth camera	A sensor system providing simultaneous image and distance information for perception, SLAM, and manipulation.
RobotID	robot lifecycle identifier	An internal global identifier that remains unchanged in the book's manufacturing architecture, with hardware genealogy, software, calibration, testing, and service associated with it.
Trust root	trust root	The lowest, protected hardware or firmware starting point of cryptographic trust, from which secure boot and device identity are built.
Safety PLC	safety PLC	Certified or safety-oriented controller for handling safety inputs, interlocks, E-stop and shutdown functions.

S–W

Concept	English / abbreviation	Report in the manual
SBOM	software bill of materials	A structured list of software components, versions, and dependencies included in the product.
Secure boot	secure boot	A cryptographically verified boot chain that only allows approved firmware and software layers to be booted.
SIL	safety integrity level	Functional safety integrity level in IEC-based frameworks; the required level should be derived from a risk analysis.
Sim2Real	simulation-to-reality	Translating a robot policy/solution taught or tested in simulation to a real robot and real environment.
SLAM	simultaneous localization and mapping	Estimating the robot's own position and simultaneously building a map of the environment.
Takt time	cycle time	The target rate at which the production line must produce finished products, calculated from demand and available production time.
Teleoperation	remote control	Robot operation remotely controlled by a human; can be used for intervention, demonstration data collection, and teaching.
TPM / secure element	trusted platform module / security chip	Hardware cryptographic component for protected storage/operations of device key, attestation and identity.
Traceability	traceability	The ability to retrieve supplier, version, operation, test, configuration and service history at the robot and component level.
Trajectory	trajectory	A sequence of states, observations, and actions ordered in time; in robot training, the basic data unit for executing a task.
Type body	type test	Detailed examination of a product type or representative configuration, which does not need to be repeated on every serial piece.
VLA	vision-language-action model	An AI architecture that combines image observation, language instruction, and robot action in a common model.
WIP	work in progress	Products and components that are under production and not yet finished.
WMS	warehouse management system	Warehouse management system that manages inventory location, picking, movement, and warehouse robot integration.

17. Data tables, annexes and indicators

17.1. Data types: what can and cannot be added?

Indicator	What does it mean?	Typical error
Order	contracted or communicated commercial demand	to take an order for delivery or collection
Production	number of robots completed during the period	add production milestone to annual shipment
Shipping	robot actually delivered to a customer or channel	treat shipment as a working installed base
Installation / commissioning	robot used in real-world situations	Confusing pilot project and permanent expanded implementation
Installed base	operational/supported robot stock	to mix with annual sales
Capacity	plant nominal emission capacity	capacity to be considered as actual production
Market size	sales revenue or volume according to a given definition	adding different product categories and source definitions
Policy objective	planned future target value	to announce as a realized result
Editorial model	estimate calculated from assumptions	to quote as market fact or order book

17.2. China's robotics industry - key figures

Indicator	Period	Value	Status
New industrial robot installations in China	2024	295,000 pcs; 54% of the world	IFR fact data
Share of Chinese manufacturers in Chinese installations	2024	57%	IFR / industry fact sheet
Operating industrial robot fleet	End of 2024	>2 million units; 43.5% of the world	IFR fact data
Production of industrial robots	2025	773,074 pcs; +28.0%	NBS production data
Production of service robots – broad NBS category	2025	18,581,081 pcs; +16.1%	NBS production data; broad category
Production of industrial robots	2026 1st semester	537,689 pcs; +28.0%	NBS production data
Production of service robots – broad NBS category	2026 1st semester	10,319,211 units; +11.9%	NBS production data
Industrial robot export	Jan.–May 2026	86,597 units; +39.5%	reported export indicator
Industrial robot export	May 2026	20,090 units; +51.2%	reported export indicator

Source: Chapter III, Tables 3.1–3.2. The service robot production line is not the same as the IDC professional commercial service robot category.

17.3. Humanoid and service robot industrialization – selected benchmarks

Reference	Reported data	What does it prove?
AGIBOT, 2025	5,168 years of shipping	shipment; not capacity
AGIBOT, 2026 1st semester	approx. 8,400 deliveries	semi-annual shipment

Reference	Reported data	What does it prove?
AGIBOT, March 30, 2026.	10,000th robot completed	cumulative production milestone
Down from Shenzhen to Longhua	Pilot capacity of 500–1,000 robots/year; CT ≤120 minutes; >30 tests/finished robot	pilot project-industrialization level
Leju-Dongfang Precision Foshan	10,000+ robots/year; 24 assembly operations; 77 inspection points; 41 automated tests	high volume production level
Šabac Minh–AGIBOT	first phase: >5,000 robots/year assembly target; approx. 3,000 m ² first phase	European localized assembly reference; target/communicated capacity
Unitree G1	13,500 USD official webshop price, 2026.09.15.	public list price; not OEM volume price
Unitree H2	29,900 USD official webshop price, 2026.09.15.	public list price; configuration dependent

Source: Chapters III and V. Production milestone, shipment, nominal capacity and list price are separate indicators.

17.4. Hungary and CEE – demand model

Indicator	Lower/conservative	Medium/likely	Upper/optimistic
40 nominal CEE account full-commissioning potential	1,013 robots	1,787 robots	2,560 robots
2027 humanoid demand	40	90	180
2028 annual humanoid demand	75	190	400
2029 annual humanoid demand	120	330	700
2030 humanoid demand	170	500	1,050
Cumulative demand 2027–2030	405	1 110	2,330

Source: Chapter IV, Tables 4.6–4.7. Bottom-up model based on 40 named accounts; not order book and not total CEE market size.

17.5. Hungarian industrial implementation – planning ranges

Element	Pilot project / start-up level	Middle level	High volume
Humanoid factory capacity	100–500/year	1,000–5,000/year	10,000+/year
Hall	2,000 m ²	7,000 m ²	20,000 m ²
FTE	48	185	520
Target-state CAPEX	EUR 4 million	EUR 18 million	EUR 60 million
Imported BOM Exposure - Model	~85%	~60%	~30%
Operating break-even	124 robots/year	480 robots/year	1,403 robots/year

Source: Chapter V, Tables 5.31 and 5.34. Editorial operating and financial model; not a site or OEM proposal.

17.6. Hungarian test, data and service infrastructure – planning ranges

System	Reported/modeled starting size	Financial magnitude
Humanoid Test and Validation Center	1,400–1,800 m ² ; core 10–12 FTE, full 16–20 FTE	approx. EUR 2.5–5.5 M for the entire first center; Core Lab EUR 1.5–2.5 M
Physical AI data processing center – seed	700–1,000 m ² ; 10 platforms	2.66 M EUR CAPEX; 1.91 M EUR annual OPEX; 23 FTE
data processing center – 50 robots	50 platforms	10.31 M EUR CAPEX; 6.46 M EUR annual OPEX; 82 FTE
data processing center – 100 robots	100 platforms	18.93 M EUR CAPEX; 11.64 M EUR annual OPEX; 152 FTE
Service Hub – base case	18 FTE; 3 OEMs + 250 active robots	3.393 M EUR launch funding; 1.957 M EUR fixed annual OPEX; approx. 175 robots operating BE with 3 OEMs

Source: Chapter V, Tables 5.17–5.23 and 5.28–5.30. Planning/pre-feasibility models.

17.7. Regulatory and standardization dates

Date / release	Item	Significance in the book
2021	ISO 18646-3:2021	service robot manipulation performance tests
2024	ISO 18646-2:2024	service robot navigation performance tests
2025	ISO 10218-1/-2:2025	updated framework for industrial robot and robot system safety
July 2026	ISO 18646-5:2026	locomotion performance tests of legged robots; incomplete safety standard
September 11, 2026	EU Cyber Resilience Act – Article 14 reporting	application of certain reporting obligations of the CRA
January 20, 2027	Regulation (EU) 2023/1230 on machinery	general application of the Machinery Regulation according to the EUR-Lex status checked in Chapter V
December 11, 2027	Regulation (EU) 2024/2847 – CRA	general application of the main obligations

Source: Chapters I, V; EUR-Lex and ISO sources in Chapter 18.

17.8. Abbreviation index

Abridgment	Unlock
AGV	Automated Guided Vehicle
AMR	Autonomous Mobile Robot
BMS	Battery Management System
BOM	Bill of Materials
SHARK	Corrective and Preventive Action
CAPEX	Capital Expenditure
CKD	Completely Knocked Down
CRA	Cyber Resilience Act

Abridgment	Unlock
DAQ	Data Acquisition
DFM	Design for Manufacturability
DoF	Degrees of Freedom
DVT	Design Validation Test
EBITDA	Earnings Before Interest, Taxes, Depreciation and Amortization
ECN	Engineering Change Notice
ECO	Engineering Change Order
EIC	European Innovation Council
EKD	Individual government-decided support
EMS	Electronics Manufacturing Services
EOL	End of Line
ERP	Enterprise Resource Planning
E-stop	Emergency Stop
EVT	Engineering Validation Test
FPY	First-Pass Yield
FRACTURED	Failure Reporting, Analysis and Corrective Action System
FRU	Field Replaceable Unit
F/T	Force/Torque
HIL	Hardware in the Loop
HIPAA	Hungarian Investment Promotion Agency
HRI	Human–Robot Interaction
HSM	Hardware Security Module
IMU	Inertial Measurement Unit
IP	Intellectual Property / Ingress Protection – depending on context
JV	Joint Venture
KPIs	Key Performance Indicators
LiDAR	Light Detection and Ranging
MES	Production Execution System
MOQ	Minimum Order Quantity
MTBF	Mean Time Between Failures
NPI	New Product Introduction
NRE	Non-Recurring Engineering

Abridgment	Unlock
OEM	Original Equipment Manufacturer
OPEX	Operating Expenditure
SINCE	Over-the-Air Update
PCBA	Printed Circuit Board Assembly
PKI	Public Key Infrastructure
PLC	Programmable Logic Controller
PLr	Required Performance Level
PVT	Production Validation Test
RaaS	Robots as a Service
RMA	Return Merchandise Authorization
ROI	Return on Investment
RUM	Rough Order of Magnitude
SBOM	Software Bill of Materials
SIL	Safety Integrity Level
SKD	Semi-Knocked Down
SLA	Service Level Agreement
SLAM	Simultaneous Localization and Mapping
TCO	Total Cost of Ownership
TPM	Trusted Platform Module
VLA	Vision-Language-Action
WIP	Work in Progress
WMS	Warehouse Management System
WTP	Willingness to Pay

17.9. Organization and company index

Organization / company	Role in the manual	Main chapter(s)
ABB	industrial robotics service benchmark	6, 22
AGIBOT	humanoid OEM, data platform, European localization	9, 11, 15, 19–23
Apptronics	Apollo Hungarian industrial test case	13
Beijing Humanoid Robot Innovation Center	humanoid innovation and open-source/data	7
BME	Hungarian robotics education/research and humanoid platform	12, 20–21
Booster Robotics	Chinese compact humanoid OEM	5

Organization / company	Role in the manual	Main chapter(s)
Boston Dynamics	Spot, environmental, and robot category example	3
CATL	battery cell industrial background	10, 20
CubeMars	actuator and motor supplier	4, 10
Flex Hungary	EMS/contract manufacturing partner candidate	12, 20, 23
Fourier Intelligence	rehabilitation/humanoid OEM	5
Galbot	embodied AI/humanoid OEM	9, 15, 22
Gaussium	commercial cleaning robot OEM	4
Geek+	warehouse robotics	8, 11
Hai Robotics	case handling / warehouse robotics	4, 8
Hesai	robotic LiDAR	6
HIPAA	Hungarian investment promotion	17, 22–23
HUN-REN SZTAKI	robotics and manufacturing research infrastructure	12, 20
IFR	global robotics definitions and market statistics	3, 7, 26
Inspire Robots	dexterous hand supplier	4, 10
Jabil Hungary	EMS/Manufacturing Partner Candidate	12, 20, 23
Keenon Robotics	indoor delivery/service robot OEM	4
TRASH BIN	industrial robotics service benchmark	22
Leaderdrive	precision reducer supplier	6
Leju Robotics	humanoid OEM; Shenzhen/Foshan manufacturing benchmark	9, 19, 23
LimX Dynamics	humanoid and legged robot OEM	5
Livox	LiDAR and mobile robot perception	6
MBH Bank	Hungarian service robot concept	13
Mech-Mind	3D vision and robot AI	6
Mercedes-Benz Hungary	humanoid industrial pilot project reference	13
Minth Group	AGIBOT European Industrialization and Šabac	15, 19, 22
NCT	Hungarian servo/motion-control partner candidate	14
NVIDIA	edge compute and Isaac platform	4–5, 20–21
Óbuda University	Hungarian humanoid test/data/production program	12, 19–23
Orbbec	3D camera supplier	6
PUDU Robotics	delivery and cleaning robot OEM	8, 12–15
RoboSense	robotic LiDAR	6
ROS 2 / Open Navigation	robotics middleware and navigation stack	5

Organization / company	Role in the manual	Main chapter(s)
Sanmina-SCI Hungary	manufacturing partner candidate	20, 23
Shanghai humanoid training center	large-scale robotic data collection	11, 21
Starship Technologies	outdoor delivery robot operation example	3
Synapticon	motion-control and actuator development partner	14
UBTECH	industrial humanoid OEM	9, 15, 22
Unitree Robotics	humanoid/quadruped OEM and public price benchmark	9, 15, 21
Universal Robots	service and education network benchmark	22
VIDEOTON	Hungarian EMS/contract manufacturing partner candidate	20, 23
Yunji	hotel and hospital service robot OEM	8, 11
ZalaZONE	Hungarian test and validation infrastructure benchmark	12, 19, 21
Zollner Electronics Hungary	high-mix mechatronics EMS partner candidate	20, 23

17.10. Featured Data Plates Index

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II	2.2	Main data sets of robotic sensing
II	2.3	Checkable characteristics of two onboard components
II	2.4	The processing chain from perception to execution
II	2.5	Three numerical data and the corresponding condition
II	2.6	External relations of the robot fleet
II	2.7	Main approaches to robot teaching
II	2.8	Robotic datasets and the units of measurement reported
II	2.9	Suggested datasheet for a robotics episode
II	2.10	Data quality control editorial schema
II	2.11	Annual robot data volume with three design data profiles
II	2.12	Traceable process of software update
II	2.13	Technical record linked to the robot identifier
II	2.14	Reliability and recovery metrics
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III	3.2	Reported indicators of China's industrial robot exports
III	3.3	Service Robot Market Size 2025
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III	3.16	AGIBOT production and delivery milestones
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III	3.20	Humanoid hardware cost: external benchmark and project target cost
III	3.21	The four major Chinese robotics ecosystems
III	3.22	Robotic data acquisition and application centers
III	3.23	Reported indicators of Chinese robotics data platforms
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ARC	4.3	Four levels to check for local channel
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ARC	4.7	Modeled annual CEE humanoid demand, 2027–2030
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