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From Autonomous Cars to Humanoids

Automotive industry embraces Humanoids

The Global Auto sector embraces the Humanoid space globally through the entire value chain ranging from part suppliers, to manufacturing of Humanoids as well as integrating Humanoids in the manufacturing process. In this note, we identify by region within our coverage some of the companies most likely to benefit from the Humanoid megatrend.



From Autonomous Cars to Humanoids. Elon Musk first made this comparison during Tesla's AI Day in August 19, 2021, when he initially unveiled the concept of the Tesla Bot. He explained that a humanoid robot is essentially "like an autonomous car on legs" because both rely on the exact same underlying artificial intelligence platform. He reiterated this analogy frequently, emphasizing that both systems share the same vision-based neural networks, cameras, and Full Self-Driving (FSD) inference chip.

China - Nick Lai: Xpeng is currently the most ambitious player in the humanoid robotics space, with its IRON robot progressing rapidly toward software and hardware integration and aiming for mass production by the end of 2026, targeting over 1,000 units per month. Initial deployments are expected in XPeng stores, with broader commercial deliveries in China and overseas beginning in 2027. XPeng has also recently started to articulate its robot strategy and plans, indicating that more developments are forthcoming. Beyond the OEMs, several Chinese auto component suppliers are highly relevant to the humanoid discussion, as it is likely that 70% or more of humanoid robot components will be sourced from existing automotive supply chains—at least in China—demonstrating the sector's deep integration and readiness to support rapid scaling of humanoid production.

Korea - Sonny Lee: We see actuators—accounting for roughly half of a humanoid's bill of materials—as the most likely near-term supply bottleneck,

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making cost reduction, customization, and standardization urgent priorities. In the early stages of mass production, actuator suppliers hold significant leverage, as robot OEMs will prioritize partners who can deliver high-quality, reliable components at scale and enable rapid design iterations. However, as the market matures and mass production standards are established, OEMs will gain bargaining power by optimizing hardware and software, adding second sources, and standardizing platforms, which could commoditize actuator parts. We note that actuators are key to mass market entry, given their high content per robot and substantial BOM contribution, but supply chains remain constrained as many suppliers are still focused on automotive actuators. We expect the industry to shift from diverse, prototype-era designs to a standardized, QDD-dominant architecture, driving significant cost reductions—illustrated by HMG's (Hyundai Motor Group) humanoid, where actuator costs could fall by about 70% from prototype to early mass production. Over the long term, we view software—such as fleet management and continuous updates—as a higher-margin, more resilient profit pool, with Autoever well positioned to play a meaningful role.

Japan - Akira Kishimoto: Toyota and Honda both have over 20 years of experience in developing humanoid robots. Their advantage of expertise in hardware design and manufacturing enables them to develop robots equipped with more efficient and precise mechanisms. In the past few years, companies' adoption of AI technology has also been accelerating. Toyota has been working with emerging robot makers such as Boston Dynamics to develop motion control algorithms. Moreover, the company also constructed an in-house world-model-wise robot development platform with real world test field "Woven City". Honda has combined its control fidelity leadership with sim-real correlation AI technology, which empowers its multi-finger robot hand to overcome "last millimeter" of real-world dexterity. Japanese automakers used to be conservative about practical deployment of humanoid robots, eyeing the 2030s as the earliest. However, with recent technology breakthroughs, Toyota is expanding pilot trials of both industrial and everyday life applications. We believe the timing of commercialization could be as early as the late 2020s.

India - Amyn Pirani: India's humanoid robotics ecosystem is at a nascent stage, with near-term value creation likely skewed towards component suppliers that can help OEMs drive cost efficiency. Sona Comstar is positioning itself as a key beneficiary by entering the humanoid supply chain by developing motors and actuators and targeting 53-60% of a humanoid robot's BOM. It has partnered with Germany-based NEURA Robotics to industrialize advanced humanoid technologies, and is investing US$6.5mm in robotics components manufacturing. India's ecosystem also includes unlisted players such as Addverb Technologies (backed by Reliance with a ~US$132mm investment for a 54% stake) and General Autonomy (recently raised ~US$3.4mm), both of which are continuing to advance humanoid and quadruped platforms for industrial and general-purpose applications.

USA - Rajat Gupta: TSLA's commitment to a sub-$30K humanoid unit at scale is a pivotal anchor for market expectations, noting that the bill of materials curve should decline exponentially as the industry matures, but early-innings cost data could meaningfully re-anchor market expectations around both the ultimate cost trajectory and the adoption curve it implies. TSLA's edge in humanoid robotics stems from the compounding benefits of vertical integration across hardware, software, and manufacturing, and the structural advantage of being its own captive customer, which eliminates go-to-market friction and external RoI validation, creating a self-reinforcing loop between deployment, data collection, and iteration that accelerates with scale. The shared AI architecture between FSD and Optimus enables dual returns on infrastructure investments, as the same training compute and custom silicon serve both platforms, allowing Tesla to amortize AI capex across vehicles, robots, and energy storage, while competitors must build or procure infrastructure for single use cases. Click here for our recent deep-dive on TSLA, which includes our bottom-up TSLA Humanoid model.

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Europe - Jose M. Asumendi: The European Automotive landscape has a longstanding tradition of automotive suppliers and OEMs which are naturally very interested in participating in the Humanoid end market. The opportunity is not only from the perspective of supplying components or manufacturing Humanoids but also integrating Humanoids in the manufacturing or supply chain to reduce labour cost in high labor cost countries. We would mention the following suppliers: Valeo, Schaeffler, Forvia, SKF, Aumovio, and Bosch with exposure to the humanoid space, whether through manufacturing investments, supplying key components, or early-stage partnerships. This positions them to potentially benefit as the humanoid robotics ecosystem evolves within the automotive sector. On the OEM side, notably Renault, Mercedes-Benz, BMW, Audi, Volvo Cars, and Porsche are actively collaborating with robotics companies including Wandercraft, Apptronik, Hexagon Robotics, Figure AI, Humanoid, Mimic Robotics, and Neura Robotics amongst other companies. These engagements highlight the industry's growing commitment to integrating humanoid and advanced robotics technologies into both production and broader industrial applications.

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The Global Auto Industry Embraces Humanoids

From an automotive perspective, we have outlined in the following section by region how the automotive sector is involved in the Humanoid space as well as highlighting which suppliers or OEMs could represent an opportunity in this space.

Europe: Automotive Industry and Humanoid Value Chain

The European Automotive landscape has a longstanding tradition of automotive suppliers and OEMs which are naturally very interested in participating in the Humanoid end market. The opportunity is not only from the perspective of supplying components or manufacturing Humanoids but also integrating Humanoids in the manufacturing or supply chain to reduce labour cost in high labor cost countries. We see the following suppliers: Valeo, Schaeffler, Forvia, Aumovio, and Bosch with exposure to the humanoid space, whether through manufacturing investments, supplying key components, or early-stage partnerships. This positions them to potentially benefit as the humanoid robotics ecosystem evolves within the automotive sector. On the OEM side, notably Renault, Mercedes-Benz, BMW, Audi, Volvo Cars, and Porsche are actively collaborating with robotics companies including Wandercraft, Apptronik, Hexagon Robotics, Figure AI, Mimic Robotics, and Neura Robotics. These engagements highlight the industry's growing commitment to integrating humanoid and advanced robotics technologies into both production and broader industrial applications.

Wandercraft

Wandercraft, founded in 2012 by engineers determined to offer an alternative to the wheelchair for individuals unable to walk, develops, manufactures, and markets autonomous walking exoskeletons. Based in Paris, the company builds AI-powered, self-balancing exoskeletons that enable hands-free standing and walking for people with mobility impairments, aiming to replace or complement wheelchairs.

Wandercraft's Calvin -40 is a headless, human-scale industrial humanoid robot developed in just 40 days for the Renault Group to handle physically demanding, non-ergonomic factory tasks. It features autonomous navigation, a 40kg payload capacity, and medical-grade, self-balancing technology derived from earlier exoskeletons. The robot uses voice commands, day/night cameras, and LED status indicators for safe human-robot collaboration.

Key products:

- **Atalante X:** FDA-cleared and CE-marked flagship exoskeleton used in 100+ rehabilitation centers across Europe and the USA for gait rehabilitation in patients with stroke, spinal cord injuries (SCI), and other neurological conditions.
- **Personal Exoskeleton (Eve):** In clinical trials; designed for daily, personal use to navigate homes and communities.

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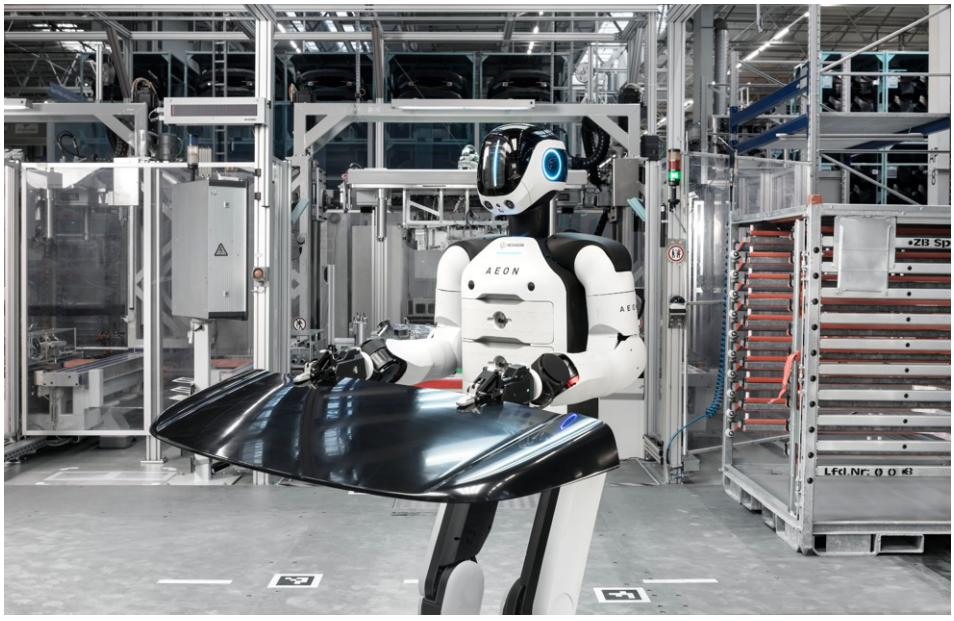
- **Calvin-40:** Humanoid robot launched in 2025 for Renault Group; built for industrial, physically demanding tasks.

Hexagon Robotics

Hexagon Robotics, a specialized division of Hexagon AB, was established in 2025 to develop advanced humanoid robots for industrial applications. The division leverages Hexagon's global expertise in sensors, software, and autonomous solutions to address workforce shortages and enhance productivity in manufacturing environments.

- **Flagship Product:** AEON is a 165 cm tall humanoid robot engineered for industrial settings, capable of performing tasks such as machine tending, material handling, quality inspection, and real-time reality capture for digital twin updates.
- **Innovative Mobility and Functionality:** Unlike traditional humanoid robots focused on walking, AEON utilizes wheels to achieve faster movement (up to 2.4 meters per second) and greater efficiency, enabling it to navigate complex and dynamic factory environments.
- **Operational Features:** AEON is equipped with a battery-swapping mechanism for continuous operation and employs imitation learning, allowing it to acquire new tasks through demonstration by human operators.
- **Strategic Partnerships:** Hexagon Robotics collaborates with leading technology companies, including NVIDIA for simulation and AI (utilizing Omniverse and Isaac platforms) and Microsoft for cloud-based AI and data management via Azure.
- **Leadership and Vision:** The division is led by President Arnaud Robert, who is focused on integrating Hexagon's extensive measurement technology expertise with advanced robotics to deliver practical solutions for industrial automation.

Figure 1: BMW and Hexagon



Source: Company

Neura Robotics

Neura Robotics, founded in 2019 by David Reger and headquartered in Germany, is a rapidly growing developer of cognitive robots designed for safe, direct collaboration with humans in both industrial and domestic settings. The company's mission is to bridge the gap between technology and humanity by creating intelligent, adaptable robots that address labor shortages and enhance productivity. NEURA Robotics distinguishes itself through a one-device approach, offering versatile solutions for a wide range of applications. All core components—including AI, software, and sensors—are developed in-house, ensuring tight integration and high performance.

Key products include **MAiRA**, recognized as the world's first cognitive robot capable of operating safely alongside humans, **MiPA**, an intelligent assistant robot, and **4NE1**, a humanoid robot designed for both industrial and household use. Neura Robotics is expanding its reach through the Neuraverse partner network and strategic collaborations with major industry players such as Kawasaki. The company's growth trajectory is supported by a recent €120 mn Series B funding round, positioning NEURA Robotics as a leader in the next generation of intelligent robotics solutions.

Mimic Robotics

Mimic Robotics, founded in 2024 as a spin-off from ETH Zurich, is a Swiss company specializing in the development of dexterous, human-like robotic hands for automating complex and unstructured tasks in manufacturing and logistics. The company leverages **physical AI** and diffusion-based generative models trained on human motion data to achieve sub-millimeter precision. Mimic Robotics pairs its tendon-driven, five-fingered hands—capable of handling delicate objects or items weighing up to 7 kilograms—with standard industrial robot arms, enabling rapid learning and deployment through imitation learning techniques such as VR or sensor-based demonstrations.

Designed for high-mix, low-volume industrial environments, Mimic Robotics' solutions are ideal for assembly, packaging, and sorting applications. The robots can learn new tasks in less than an hour and are compatible with existing robot arms from leading manufacturers like FANUC and Universal Robots. The company recently secured $16 mn in seed funding led by Elaia and Speedinvest, supporting its transition from research to real-world industrial applications and positioning Mimic Robotics as an emerging player in advanced automation technology.

Humanoid

Humanoid, founded in 2024 and headquartered in London, is a UK-based startup focused on developing advanced humanoid robots for automation in industrial, logistics, and retail environments. The company's flagship product, the HMND 01 Alpha, is a 220 cm tall robot with 29 degrees of freedom, featuring a modular design that allows for both wheeled and bipedal configurations. Capable of speeds of up to 7.2 km/h and handling payloads of up to 15 kilograms, HMND 01 Alpha is targeted for commercial deployment by late 2026. Humanoid's mission is to address labor shortages by automating repetitive and hazardous tasks with intelligent, safe robotic solutions.

The company's technology stack is built around AI-driven, end-to-end reasoning and proprietary simulation-based training, enabling rapid adaptation to complex environments. Humanoid operates under a Robots-as-a-Service (RaaS) business model, providing flexible automation solutions to clients without the need for upfront capital

investment. Notably, the company claims an accelerated development cycle, moving from concept to prototype in just seven months, positioning itself as an agile and innovative player in the emerging humanoid robotics market.

Figure 2: Humanoid & Schaeffler



Source: Schaeffler

OLO Robotics

OLO Robotics is a UK-based robotics software company developing a cloud-native platform that simplifies the development, deployment and management of robotic applications. Rather than manufacturing robots, the company focuses on the software stack, leveraging ROS 2 to enable low-code workflow design, simulation, remote operation and fleet management across multiple robotic platforms. By abstracting the complexity of robotics software, OLO aims to accelerate time-to-market for autonomous mobile robots (AMRs), industrial automation solutions and next-generation AI-powered robotics. As the humanoid robotics ecosystem matures, platforms such as OLO could benefit from increasing demand for interoperable middleware and developer tools, positioning the company as an enabler of software-defined robotics rather than a direct hardware competitor.

Renault with Wandercraft (covered by Jose M Asumendi)

In 2025, Renault Group finalized the acquisition of a minority stake in Wandercraft, a French company renowned for its advanced robotic exoskeletons designed to assist individuals with mobility challenges. Wandercraft is now broadening its expertise to include mobile robots tailored for industrial environments. This investment is complemented by a partnership agreement aimed at jointly developing a new generation of robots leveraging Wandercraft's technology, with initial deployment focused on Renault Group's manufacturing operations.

The collaboration is structured to combine Renault Group's extensive experience in industrial processes with Wandercraft's technological capabilities. The objective is to

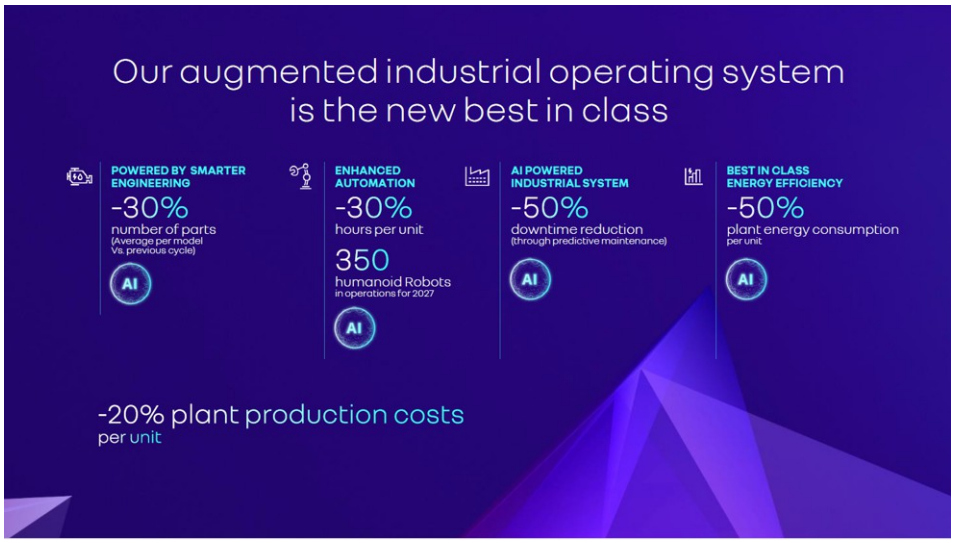
scale up the production of exoskeletons and industrial robots, enhancing operational efficiency and workplace ergonomics within Renault's facilities. Additionally, the partnership is expected to create new commercial opportunities for Wandercraft in the broader robotics sector.

Overall, this move positions Renault Group at the forefront of integrating robotics into automotive manufacturing, supporting both productivity gains and potential expansion into new markets for its partners.

Following are the latest developments for Renault:

- Renault Group has reported plans to deploy 350 humanoid robots, including models such as Calvin, across its production lines over the next 18 months, starting with French plants and extending to highly automated facilities.
- Developed in partnership with Wandercraft, these robots are designed to handle heavy loads and physically demanding tasks, improving ergonomics in areas such as tire handling.
- Management indicated that Renault is one of the first automakers to integrate humanoid robots directly into the production line for complex and varied tasks.
- The company also emphasized that its strategic focus remains on its core automotive business and that it has no interest in developing humanoids for the defense sector.

Figure 3: Renault's Humanoids



Source: Company reports.

Mercedes-Benz with Apptronik (covered by Jose M Asumendi)

In 2024, Apptronik entered into a collaboration agreement with Mercedes-Benz to explore innovative robotics solutions within the automaker's manufacturing operations. As part of this initiative, Mercedes-Benz is incorporating Apptronik's Apollo, a leading commercial humanoid robot, into its production facilities. This move aligns with Mercedes-Benz's commitment to operational excellence and the adoption of advanced technologies to enhance workforce capabilities.

The partnership is focused on piloting Apollo in logistics applications, such as delivering assembly kits to production lines and conducting component inspections. Additional use cases include transporting containers of assembled parts during later stages of manufacturing. Mercedes-Benz has transitioned from initial testing to active pilot programs, investing in Apptronik and deploying robots at its sites in Berlin and Hungary.

This collaboration underscores Mercedes-Benz's strategy to automate logistics and optimize factory operations through robotics, positioning the company as an early adopter of humanoid robots in automotive manufacturing.

Following are the latest developments for Mercedes-Benz:

- **Investment & Funding:** In Feb'26, Mercedes-Benz contributed to a $520 mn investment round for Apptronik, supporting the expansion of Apollo robot production.
- **Active Deployment:** In Mar'26, Apollo robots are now operating regularly at the Digital Factory Campus in Berlin-Marienfelde, marking a shift from pilot projects to ongoing use.
- **Use Case:** The robots are responsible for delivering totes and moving parts to assembly lines, as well as assisting with organizing components. They are designed to work alongside factory staff.
- **Integration:** Apollo robots are being introduced into existing manufacturing sites, allowing Mercedes-Benz to enhance operations without major changes to factory layouts.
- **Strategic Goal:** This initiative is focused on easing labor shortages in physically demanding roles and improving overall production efficiency.

Apptronik

Apptronik CEO Jeff Cardenas presented an overview of the firm's strategy and partnership with Mercedes Benz as well as key strengths of the firm that should enable the firm to provide automation solutions for Mercedes Benz across different applications. It is important to note that the implementation of Humanoids does not need to be in the form of two legged versions; it can also adopt different forms including wheels or Humanoid arms, across a range across different applications including box handling, cast parts handling, body shop part loading, bin picking amongst other actions. Mercedes Benz sees the implementation of Humanoids on the assembly line becoming a reality by 2030 -2035. By then, Humanoid Dexterity and Humanoid development should have considerably evolved. Jeff Cardenas, the CEO of Apptronik, also mentioned several end markets that could become meaningful going forward, defined as a) Back of the house: manufacturing and logistics; b) Front of the house: healthcare, retail and shops; and c) Home applications: applications in the home and home care, this latter could represent the largest opportunity for the firm. Having said this, Apptronik reiterated the concept of safety when implementing Humanoids in the manufacturing environment as well as the business model of offering a robotic solution for the industrial environment correctly adapted to the level of dexterity and mobility required for the task.

Apptronik Solutions Overview

- **Goods-to-Person Automation:** Apollo enables flexible automation by picking

products from storage and transporting them to shipping. This increases throughput, reduces manual material handling, and improves consistency in fulfillment operations. By automating repetitive transport tasks, human workers can be reallocated to higher-value activities, and operations can scale more easily during peak demand periods.

- **Person-to-Goods Picking:** Apollo automates repetitive picking tasks by navigating aisles, identifying items, picking goods, and placing them into totes. Its humanoid form factor allows it to operate in spaces designed for people, using existing shelving and carts. This reduces walking time, improves picking consistency, and supports higher order throughput. Automation helps fulfillment operations remain resilient during labor shortages or seasonal peaks, while reducing the physical strain on workers.
- **Packout Automation:** Apollo supports packout by placing picked items into boxes and positioning packages onto conveyors for shipping. It works within human-designed workstations, helping maintain steady package flow from packout to outbound shipping. Automation improves packing consistency, reduces manual handling, and minimizes bottlenecks, resulting in faster order fulfillment and improved customer satisfaction.
- **Kitting:** Apollo assembles part kits by retrieving items from bins and placing them into divided containers. Its design allows interaction with standard manufacturing bins and workstations. Automation improves kitting accuracy, reduces manual tasks, and supports consistent production flow. This minimizes the risk of missing components and allows skilled workers to focus on more complex activities.
- **Inspection & Sorting:** Apollo automates end-of-line inspection and sorting by examining parts for defects and placing them into appropriate bins. Its perception, mobility, and manipulation capabilities enable consistent quality control in production environments. Automation reduces manual inspection burden, improves classification reliability, and helps maintain production flow, reducing errors from fatigue.
- **Machine & Tool Tending:** Apollo tends machines by loading/unloading materials, monitoring equipment, and keeping assets supplied. Its form factor allows operation within existing plant layouts, interacting with tools and workstations without specialized automation. Automation reduces equipment downtime, improves production continuity, and frees skilled workers for higher-value tasks, supporting a more resilient production environment.

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Figure 4: Mercedes-Benz is testing the use of Apollo, a humanoid robot from Apptronik, in production.



Source: Mercedes Benz

BMW with Hexagon Robotics and Figure AI (covered by Jose M Asumendi)

BMW Group has launched a pilot program in partnership with Hexagon Robotics to introduce the AEON humanoid robot at its Leipzig facility in Germany. The initiative is designed to enhance production efficiency by automating physically demanding and repetitive tasks, such as high-voltage battery assembly. The pilot began in late 2025, with further testing planned and full-scale integration expected by summer 2026.

Following are the latest developments for BMW:

- **Pilot Launch:** AEON, developed by Hexagon Robotics (Zurich), began initial operations at BMW's Leipzig plant in December 2025. Broader testing is planned and full integration is expected by summer 2026.
- **Design & Capabilities:** The robot features a humanoid torso and a wheeled base, allowing it to navigate factory floors efficiently and perform complex, ergonomic tasks.
- **Operational Focus:** AEON is being deployed to automate the handling, scanning, and inspection of automotive parts—such as car doors—addressing repetitive and physically demanding roles.
- **Expansion Objective:** The pilot aims to increase automation and production flexibility in battery and component manufacturing, with the Leipzig program positioned as a template for wider adoption across BMW's global facilities.
- **Technical Partnerships:** The project draws on Hexagon Robotics' sensor technology expertise, with DH-Robotics providing advanced robotic hands to enhance dexterity and task execution.

Prior to the introduction of AEON at the Leipzig plant, BMW Group conducted a ten-month pilot program at its Spartanburg facility in South Carolina, deploying

the Figure 02 humanoid robot developed by Figure AI. Throughout the pilot, Figure 02 operated on a demanding schedule—working 10-hour shifts, five days per week—where it was tasked with retrieving and positioning sheet-metal parts for welding on the BMW X3 production line. Over the course of the program, the robot handled more than 90,000 components and contributed to the assembly of over 30,000 BMW X3 vehicles. In total, Figure 02 logged approximately 1,250 operating hours and took about 1.2 mn steps, consistently demonstrating reliable performance and millimeter-level placement accuracy. The pilot also provided BMW with valuable operational insights, including enhancements to production safety protocols—such as the implementation of barriers and partitions—and improvements in 5G network coverage within the plant. These learnings are now informing BMW's evaluation of next-generation robotic solutions, including the potential deployment of Figure 03.

BMW Group intensifies the use of digitalization and the use of artificial intelligence in production. With so-called physical AI, which connects digital AI with real machines and robots, intelligent systems such as humanoid robots can be integrated into real production processes. Following a successful deployment with the humanoid robot Figure 02, the further-developed successor, Figure 03, will now start at Spartanburg, working on complex sequencing applications in logistics.

Our take is that BMW management sees the Spartanburg plant as a pioneer in integrating humanoid robotics into everyday manufacturing operations. They view the successful pilot with Figure 02 as proof that these robots can add real value beyond just experimental use. Management is now moving forward with deploying Figure 03 for logistics, showing their confidence in robotics to help build a more flexible and reliable workforce. Overall, BMW sees these advancements as a way to tackle more complex tasks and strengthen their manufacturing capabilities.

Next step with the next-generation Figure 03 robot

BMW management sees the results from the Figure 02 project as the foundation for moving forward with the next model, Figure 03. They believe the Figure 03 brings important upgrades, such as safer soft components, wireless charging for better uptime, audio features for speech communication, and improved hands with tactile sensors and palm cameras to boost precision and dexterity. This shows BMW's focus on expanding the practical uses of robotics in their manufacturing operations.

In the new sequencing use case application, the delivered components initially arrive in larger containers, unsorted. Figure 03 will pick them up and sort them into a sequencing trolley. The trolley will then be taken to a defined collection point for onward transport. An automated tugger train or a Smart Transport Robot will then transport the parts to the installation location, where they will be provided to assembly employees "just in sequence". This use case occurs frequently in automotive production logistics and offers potential for further development and scalability.

The use of humanoid robots is part of the BMW Group's broader strategy to expand its automation portfolio with Physical AI. Humanoid robotics is a value-adding complement to existing automation. Its potential lies particularly in monotonous, ergonomically demanding, or safety-critical activities. The goal is to protect and most effectively utilize employees while further improving workplaces.

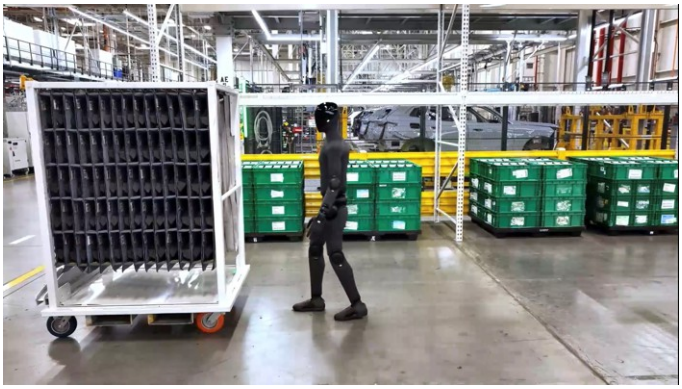
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Figure 5: Figure AI x BMW at Spartanburg Plant



Source: Company data.

Figure 6: Figure AI x BMW at Spartanburg Plant



Source: Company data.

Figure 7: Figure AI x BMW at Spartanburg Plant



Source: Company data.

VW - FAW with UBTech Robotics (covered by Jose M Asumendi)

In 2025, FAW-Volkswagen's Qingdao branch entered into a strategic partnership with UBTECH Robotics to integrate humanoid robots into automotive manufacturing and develop highly intelligent, flexible production lines for next-generation facilities. At the Qingdao plant, which produces the all-new Bora and Audi A3 at a rate of over 1,400 vehicles per day, equating to a car rolling off the line every 54 seconds, UBTECH's industrial humanoid robot, Walker S Lite, is currently undergoing trials for vehicle quality inspection. The robot is fully integrated with the plant's automation control system, enhancing the precision and efficiency of complex tasks. Walker S Lite leverages advanced sensor technology and dynamic operational optimization to ensure high-performance and safe operation in demanding automotive environments.

Recent developments include a) active testing of the Walker S robot at the Qingdao factory, with a focus on quality inspection and assembly tasks for both Volkswagen and Audi models. The partnership's overarching goal is to establish a highly flexible, intelligent, and largely automated production line. b) The Walker S robot, along with its successor Walker S2, is engineered for tasks such as bolt tightening and component handling, featuring more than 40 DoF and autonomous battery-swapping capabilities. c) UBTECH is currently delivering hundreds of Walker S2 robots to industrial partners, including FAW-Volkswagen, and has announced plans to scale production to 10,000 units annually by 2027.

Volvo Cars with Neura Robotics (covered by Jose M Asumendi)

Volvo Cars has entered into a strategic partnership with NEURA Robotics, a recognized leader in cognitive and humanoid robotics, through an investment by the Volvo Cars Tech Fund, its corporate venture capital arm established in 2018. In January 2025, Volvo Cars Tech Fund participated in NEURA Robotics' €120 mn Series B funding round, marking a significant step in Volvo's ongoing efforts to enhance manufacturing operations. The collaboration is focused on utilizing NEURA Robotics' advanced humanoid technology to drive improvements in production efficiency, workplace safety, and sustainability across Volvo's manufacturing facilities.

The investment aligns with Volvo Cars' broader strategy to integrate cutting-edge robotics into its operations, building on its established use of industrial robots from FANUC and collaborative robots designed to work alongside human operators in production environments.

Audi with Mimic Robotics

Audi has entered into a partnership with Swiss-based Mimic Robotics to introduce advanced humanoid-style robotic hands on its vehicle assembly lines. Announced in early 2026, this collaboration is designed to automate intricate and delicate assembly tasks that are beyond the capabilities of conventional industrial robots, such as installing flexible sealing strips and trim components. The initiative reflects Audi's commitment to leveraging next-generation robotics to enhance production efficiency and maintain high quality standards.

Key Features of the Mimic Robotics Partnership

- **Innovative Technology:** The robotic system utilizes a **pixel-to-action** model, processing real-time visual data from cameras to enable the robots to learn directly from human workers.
- **Human-Like Dexterity:** Each robotic hand offers approximately 21 DoF, closely replicating human motion. This allows for submillimeter precision and the flexibility needed to handle soft or variable materials.
- **Deployment and Integration:** The dual-arm robotic platforms are being tested and deployed in actual production environments, working collaboratively with human employees to improve efficiency in specialized assembly steps.
- **Strategic Focus:** Audi's approach centers on deploying robotic hands for fine-motor tasks, rather than replacing workers with full-body humanoid robots.

Other Robotic Initiatives at Audi

- **UBTECH Collaboration:** In 2025, Audi FAW began piloting UBTECH's Walker S series humanoid robots at its China plant, focusing on quality inspection and logistics.
- **Factory360 Strategy:** Audi's 360 factory strategy incorporates advanced robotics and automation to increase production flexibility and accelerate the assembly of new electric vehicle models.

Porsche with Neura Robotics (covered by Jose M Asumendi)

Porsche is actively incorporating humanoid robots into its automotive production processes to address workforce shortages and enhance operational efficiency. The company's approach is anchored in partnerships with NEURA Robotics and ongoing consulting projects aimed at advancing robotics adoption across its manufacturing ecosystem.

Major Partnerships and Projects

- **Next-Generation Robot Design:** At CES 2026, Studio F.A. Porsche collaborated with NEURA Robotics to unveil the 4NE1 humanoid robot. The model is engineered to combine physical agility with intelligent, human-like interaction, supporting tasks such as assembly and logistics.
- **Consulting Initiatives:** Porsche Consulting is driving the adoption of cognitive humanoid robots in industrial environments, outlining a phased approach to implementation.
- **Operational Focus:** The primary application for these robots is to support human workers by automating repetitive or physically demanding tasks, including kit picking in supermarket zones on factory floors.

Bosch

Bosch is deeply involved in humanoid robotics, focussing on manufacturing, component supply, and physical AI training. Bosch will be manufacturing Humanoids for robotic start ups and will also provide some components for the Humanoid related to the movement and integration of the brain in the Humanoid.

Bosch is the manufacturing partner for Humanoid (UK based). Bosch will mass-produce Humanoid's HMND 01 robots for the European market, handling hardware design, supply chain optimization, and production. Bosch has been testing the Humanoids in a logistics plant where Humanoid's bipedal and wheeled robots autonomously moved boxes of various sizes and weights.

Bosch has partnered with Neura Robotics (Germany based). Bosch participated in Neura's fundraising round of $1.4bn amongst other partners such as Amazon and Nvidia. Bosch is using data from hundreds of its own global factories to train the **physical AI** models for these robots in order to optimize the workflow. Workers at Bosch facilities wear sensor-equipped suits to record real-world movement and workflow data, which helps improve the robots' cognitive abilities.

Humanoid components. Bosch is using its strong expertise in microelectromechanical systems (MEMS) and sensors to give humanoid robots the fine touch and spatial awareness needed for delicate tasks. Bosch plays a pivotal role as a supplier in the humanoid robotics ecosystem, providing advanced MEMS sensor technology that underpins intelligent movement and interaction across a variety of robotic applications. Their sensors are integral to the performance, reliability, and adaptability of modern robots, addressing the unique requirements of each category. Following are the use-cases of Bosch's MEMS across robotic applications:

- **In the realm of mobile robots,** which include logistics, delivery, and household vacuum robots, Bosch's sensors ensure accurate positioning, real-time motion tracking, and reliable operation even on uneven terrain. Their accelerometers, gyroscopes, and magnetometers are engineered for exceptional sensitivity and low-noise performance, enabling these robots to navigate complex and dynamic environments with confidence.
- **For humanoid and social robots,** which require human-like interaction and precise perception of both their environment and their own movements, Bosch's MEMS sensors allow for the detection of fine movements, maintenance of stability during complex tasks, and seamless adaptation to surroundings. This technology enables humanoid robots to move naturally and interact effectively with humans, redefining the possibilities of human-robot interaction.
- **In static robots,** such as industrial robotic arms used for repetitive and precise operations, Bosch's sensors deliver high precision, long-term stability, and noise immunity. These features support dynamic motion control, self-monitoring, and predictive maintenance, ensuring consistent performance and reducing wear over time.

Aumovio (covered by Jose M Asumendi)

Aumovio, the technology spinoff from Continental, has partnered with Mentee Robotics to manufacture physical AI humanoid robots. Under the deal, Aumovio will handle large-scale manufacturing with robot production starting in 2027. Aumovio provides high-performance sensors (radar, camera, and lidar systems), software, and AI integration for robots, alongside trial operations of embodied AI on factory assembly lines. Aumovio will supply advanced radar, camera, and lidar systems applied to humanoids. The firm has currently deployed AI robots in trials at Aumovio's Chinese factories to test automated assembly line tasks.

Initial industrial rollouts are targeted for 2028, followed by in-home applications in 2030. The push to mass-produce these humanoids follows Mobileye's acquisition of Mentee Robotics. Leveraging Aumovio's automotive-grade manufacturing and supply chain expertise, this collaboration aims to address the rapidly growing demand for physical AI. Mentee Robotics is an Israeli AI-driven humanoid robotics startup founded in 2022 by Amnon Shashua (founder of Mobileye), Lior Wolf, and Shai Shalev-Shwartz. They are the developers behind the MenteeBot, a humanoid designed for household and industrial applications that learns tasks through human imitation and simulation.

SKF (covered by Chitrita C Sinha)

SKF and precision robotic component maker Leaderdrive formed a joint venture in China to develop and supply high-precision transmission components for humanoid robot joints. SKF will hold a majority 60% stake in the venture, targeting the growing industrial humanoid robotics market.

Stabilus (covered by Jose M Asumendi)

The Stabilus Group provides critical motion control and industrial automation solutions for robotics. In 2024, Stabilus acquired Destaco, an industrial automation company specializing in robotic end effectors and grippers, to significantly expand its automation capabilities.

- **Destaco End-of-Arm Tooling (EOAT)**: Destaco provides grippers, vacuum tools, and robotic tool changers that help humanoids and industrial arms securely grip and handle payloads across various industries.
- **Stabilus4Automation:** This concept bundles the technologies of Stabilus, Destaco, ACE, and Hahn Gasfedern to provide comprehensive speed control, damping, and motion solutions to system integrators.
- **Cobot and Small Payload Tooling:** Destaco manufactures off-the-shelf tooling kits designed specifically to improve the dexterity and efficiency of collaborative robots (cobots).

Schaeffler AG (covered by Jose M Asumendi)

Schaeffler has been a four-division pure-play player (Figure 8), consistently ranking among the top three players in each segment. The company is now working on a 5th division focused on humanoid technology, marking a move into new business areas. The new division builds on Schaeffler’s strengths in its existing industrial and automotive businesses, aiming to tap into fresh growth opportunities with both current and new customers. By applying its expertise from other divisions, Schaeffler is positioning itself to become a leader in the emerging humanoid sector, with a clear focus on innovation and expanding its market reach.

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Figure 8: Schaeffler's 4 Pure Play Divisions plus the "5th Division"



Source: Company data.

Schaeffler's strategy is to leverage its broad portfolio of motion-related products to address the technical and commercial requirements of humanoid robots, ensuring they deliver human-like performance, are cost-effective, and can be produced at scale.

Schaeffler's core strengths in the humanoid market lie with its integrated linear and rotary actuators, which account for approx. 50% of the bill of material costs for humanoids. Schaeffler leverages its broad portfolio, which includes repair and monitoring services, battery and hydrogen solutions, E-motors and E-drives, power electronic units, actuators, electric control units and sensors, transmission and engine components, and bearings and linear guides, to address key motion requirements in humanoid robots. The company's holistic system understanding enables it to establish a strong market position, with deep expertise in both rotary actuator integration (about 25% of material costs) and linear actuator integration (about 30%). These components, along with specialized parts for dexterous hands and vision systems, are critical to the performance and efficiency of humanoid robots. Schaeffler's focus on actuator technology and system integration positions it as a major contributor to the development and manufacturing of advanced humanoid solutions.

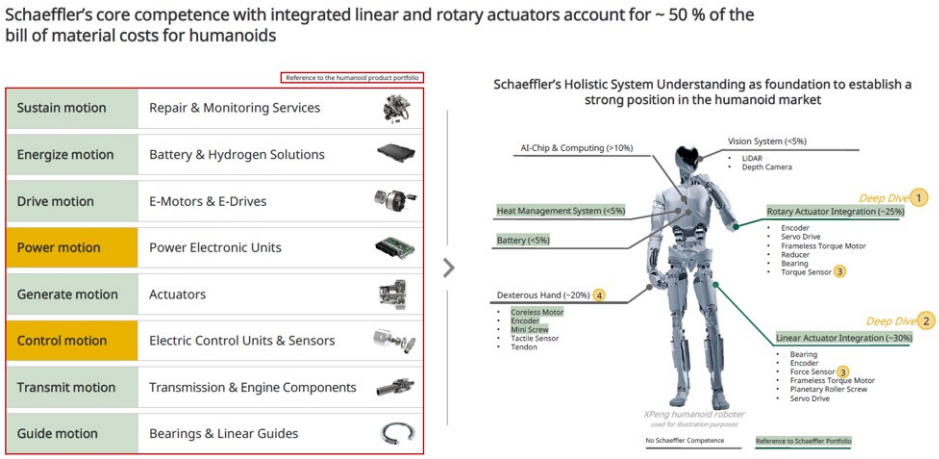
Strengths of Schaeffler in Humanoid Development

- **Vertical Integration:** Schaeffler's ability to design specifications in-house and leverage manufacturing capabilities gives it strong control over quality and cost, supporting efficient and scalable production.
- **Adaptability:** The company's expertise in developing parts that serve both humanoid and automotive applications allows for flexible, adaptive solutions, enhancing operational efficiency and product versatility.
- **Customer Engagement:** Schaeffler stands out for its proactive engagement with high-profile robotics businesses, surpassing competitors in building strong industry relationships and collaborative opportunities.
- **Order Sources:** Schaeffler expects its order backlog in the humanoid sector to reach hundreds of millions of euros by 2030, targeting roughly 10% of the addressable market for humanoid materials and components. Schaeffler has secured five customer contracts and over 30 sample orders in the humanoid market, highlighted by a major multi-year deployment and supply agreement with British robotics firm

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Humanoid to integrate up to 2,000 robots across Schaeffler's global factories by 2032.

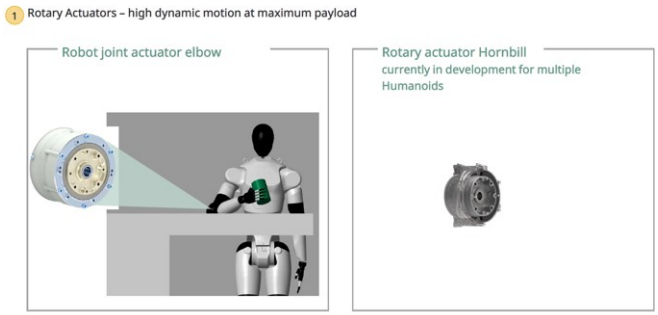
Figure 9: Schaeffler's Contribution to BOM



Source: Company data.

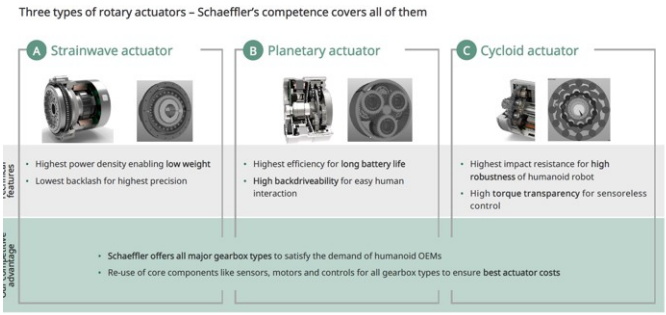
As shown below, Schaeffler is involved in the supply and development of different actuators to meet customer demands as well as components in hand development which is considered as one of key components to develop a highly functional humanoid.

Figure 10: Rotary Actuators



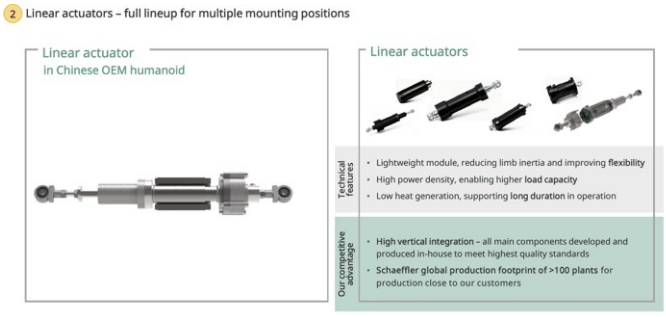
Source: Company data.

Figure 11: Types of Rotary Actuators



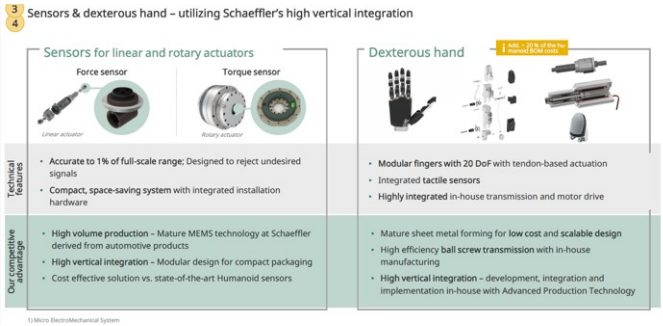
Source: Company data.

Figure 12: Linear Actuators



Source: Company data.

Figure 13: Sensors and Dexterous Hands



Source: Company data.

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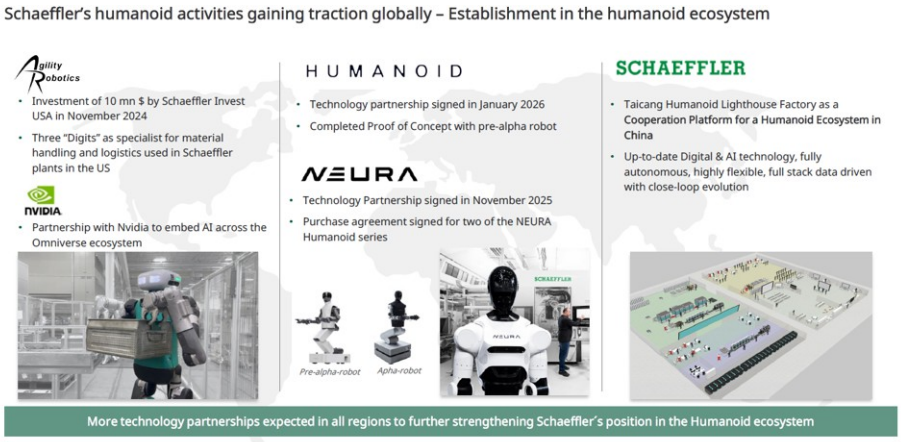
Schaeffler's Partnerships in the Humanoid Ecosystem

Schaeffler's growing global presence in the humanoid ecosystem is increasing through strategic investments and partnerships. The company invested $10 mn in Agility Robotics in the US and uses Digits robots for logistics in its US plants. Schaeffler has also partnered with Nvidia to integrate AI across the Omniverse ecosystem. Schaeffler has signed technology partnerships with HUMANOID and NEURA, including proof-of-concept projects and purchase agreements for NEURA humanoid robots. More technology partnerships are expected, further strengthening Schaeffler's position in the global humanoid ecosystem.

Schaeffler's Robogym facility at the Taicang Humanoids Lighthouse provides a dedicated space for training robots and allows OEMs to develop and build actuators all in one location.

The company has set an ambitious production goal of reaching 1m humanoid robots by 2030. With this scale, Schaeffler is targeting a 10–12% market share and expects to contribute up to 50% of the bill of materials for humanoids, underscoring its significant role in the industry's supply chain and technology development.

Figure 14: Schaeffler's Partnerships in the Humanoid Ecosystem



Source: Company data.

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Figure 15: EU Humanoid selected names

Country	Region	Company	Product
Europe	UK	Engineered Arts	Humanoid Robot
Europe	Spain	PAL Robotics	Humanoid Robot
Europe	UK	Shadow Robot Company	Humanoid Hand
Europe	Spain	Macco Robotics	Humanoid Robot
Europe	UK	Humanoid	Humanoid Robot
Europe	Italy	Oversonic Robotics	Humanoid Robot
Europe	Luxembourg	LuxAI	Humanoid Robot
Europe	Germany	Neura Robotics	Humanoid Robot
Europe	Germany	Devanthro	Humanoid Robot
Europe	Germany	robominds	Humanoid Robot
Europe	France	Wandercraft	Humanoid Robot
Europe	France	Pollen Robotics	Humanoid Platfom
Europe	France	Enchanted Tools	Humanoid Robot
Europe	France	Capgemini (in collaboration with Orano)	Humanoid Robot
Europe	France	Valeo	Supplier
Europe	France	Forvia	Supplier
Europe	Germany	Aumovio	Humanoid Robot/Supplier
Europe	Germany	Schaeffler	Supplier
Europe	Germany	Bosch	Humanoid Robot/Supplier
Europe	Germany	Stabilus	Suppliers
Europe	Germany	Volkswagen	Humanoid Integration
Europe	Germany	Porsche	Humanoid Integration
Europe	Germany	BMW	Humanoid Integration
Europe	Germany	Mercedes Benz	Humanoid Integration
Europe	France	Renault	Humanoid Integration
Europe	Germany	Volvo car	Humanoid Integration

Source: J.P. Morgan.

Mapping out a sample of OEMs with Humanoid related companies

Figure 16: OEMs & Humanoids Basket

European OEMs	Humanoid Companies
Renault	Wandercraft
Mercedes-Benz	Apptronik
BMW	Hexagon Robotics & Figure AI
FAW-Volkswagen	UBTech Robotics
Volvo Cars	Neura Robotics
Audi	Mimic Robotics
Porsche	Neura Robotics

Japanese OEMs	Humanoid Companies
Toyota	Agility Robotics, Bpston Dynamics
Honda	In-House
Nissan	In House- Iruyo Furry Robots

US OEMs	Humanoid Companies/Product
Ford	Humanoid, Agility Robotics
Tesla	In House- Optimus
General Motors	Kepler Humanoid Robots, NVIDIA
Rivian	Mind Robotics (Spin-Off)

Korean OEMs	Humanoid Companies
Hyundai/Kia	Boston Dynamics

Chinese OEMs	Humanoid Companies/Product
Xpeng	In House- Iron Robot
BYD	UBTech Robotics
Li Auto	In House- Nexus
FAW	UBTech Robotics
SAIC	Kepler Humanoid Robots, Neura Roboitcs

Source: J.P. Morgan.

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USA : Automotive Industry and Humanoid Value Chain

Apptronik

Apptronik has established itself as a leader in the development of next-generation general-purpose robots aimed at transforming both industrial and everyday environments. Founded in 2016 out of the Human-Centered Robotics Lab at the University of Texas at Austin, the company's mission centers on leveraging advanced robotics to address major societal challenges and enhance the way people live and work. Apptronik's flagship product, Apollo, is a humanoid robot specifically designed to operate safely and efficiently alongside human workers in spaces built for people. Apollo's development draws on the company's experience with more than ten prior general-purpose robots, including significant contributions to NASA's Valkyrie project.

Standing 5 feet 8 inches tall, weighing 160 pounds, and capable of lifting up to 55 pounds, Apollo represents a significant advancement in robotics integration for industrial applications. The company's recent partnership with Mercedes-Benz signals a major step forward for the automotive sector as it begins to incorporate human-shaped robots into assembly operations, supporting greater flexibility and productivity on the factory floor.

Figure AI

Figure AI, founded in 2022 by Brett Adcock and based in Sunnyvale, California, is at the forefront of developing autonomous, general-purpose humanoid robots aimed at addressing labor shortages and automating physically demanding or hazardous tasks in sectors such as manufacturing, logistics, and warehousing. The company's flagship robots—Figure 01, 02, and 03—are engineered to replicate human movement and dexterity. Figure 01 focuses on basic labor, while Figure 02, unveiled in late 2024, introduces enhanced hardware, improved battery life, and advanced onboard intelligence for commercial applications. Figure 03, launched in October 2025, is tailored for domestic environments, featuring a redesigned form factor with softer materials, improved safety, and a sophisticated sensory suite.

A key differentiator for Figure AI is its proprietary Helix neural network, a Vision-Language-Action (VLA) model that enables real-time perception and manipulation without the need for extensive pre-programming. Initially developed in partnership with OpenAI, Helix is now built entirely in-house. The company has attracted significant investment from leading technology firms and investors, including Nvidia, Microsoft, the OpenAI Startup Fund, Intel Capital, and Jeff Bezos, with a Series C round in September 2025 valuing Figure AI at over $39 billion. Commercially, Figure AI has partnered with BMW Manufacturing to deploy its robots on assembly lines in South Carolina. To support its ambitious growth targets, Production is centered at the dedicated BotQ factory, which operates at a capacity of ~12K units per year. Monthly deliveries have doubled for three consecutive months through April, with production tracking at ~150 units/month in April. Commercial traction is evident, with BMW expanding its pilot from Spartanburg, South Carolina, where Figure robots loaded ~90K parts in ~1,250 robot hours across more than 30K X3 vehicles, into additional European facilities.

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Tesla Optimus (covered by Rajat Gupta)

Optimus is TSLA's general-purpose bipedal humanoid robot, engineered to perform physical tasks across industrial, commercial, and consumer settings. The humanoid form factor is designed to allow robots to operate seamlessly in environments built around human dimensions, eliminating the need for facility redesigns or specialized tooling. TSLA's Gen 2 humanoid stands ~5'8" tall and weighs ~125 lbs. The concept was first introduced at AI Day in August 2021, where TSLA presented the vision, rather than physical hardware, that its FSD neural network expertise, manufacturing scale, and vertical integration would enable it to deliver a commercially viable humanoid more rapidly than traditional robotics players. Since then, the program has advanced through several prototype generations, with Gen 3, the first version engineered for mass production, expected to be unveiled closer to the start of production, currently targeted for July/August.

TSLA has not formally committed to a specific revenue model for Optimus, leaving open whether the company will pursue outright unit sales (commentary suggests that this is management's preferred route) or a Robot-as-a-Service (RaaS) subscription model. Broadly, the commercialization strategy is expected to unfold in two phases, with the initial phase centered on internal deployment within TSLA's own factories, where robots will take on repetitive, ergonomically challenging, or mildly hazardous tasks, serving both as a labor cost offset and as a live data-collection environment to advance AI training. The subsequent phase will focus on external sales to industrial, commercial, and consumer customers, with public availability targeted for the end of 2027. On pricing, management has cited a target production cost below $20K per unit (not inflation-adjusted) at volumes above 1 mn units/year, with an anticipated sale price in the ~$20-30K range. *Please reach out to our TSLA analyst team for a bottom-up TSLA Humanoid model.*

Latest Key Developments

TSLA's Optimus program has progressed through multiple hardware generations since its initial unveiling, with the cadence of iterations accelerating materially over the past couple of years. The timeline below captures the company's key milestones in this segment.

- **August 2021: Concept unveiled at AI Day.** No physical hardware was shown. TSLA articulated the rationale for applying its FSD neural network architecture to humanoid robotics and highlighted its intent to leverage manufacturing scale for unit economics advantages.
- **September 2022: First physical prototype at AI Day 2022.** The Gen 1 unit walked untethered onstage and performed basic wave gestures. A more refined Gen 1 chassis was also displayed but was not independently mobile.
- **December 2023: Gen 2 prototype publicly demonstrated via video.** The demo showcased significant improvements in walking speed (~30% improvement), squatting, object sorting, and delicate object handling (e.g., eggs, small items) relative to the prior generation. Gen 2 featured redesigned actuators, a streamlined body, 11 DoF in each hand (vs. basic grippers for Gen 1), and eliminated visible external wiring. Walking speed and balance represented a step-function improvement over the September 2022 prototype.
- **Mid-2024: First factory deployment.** Optimus units began operating within TSLA

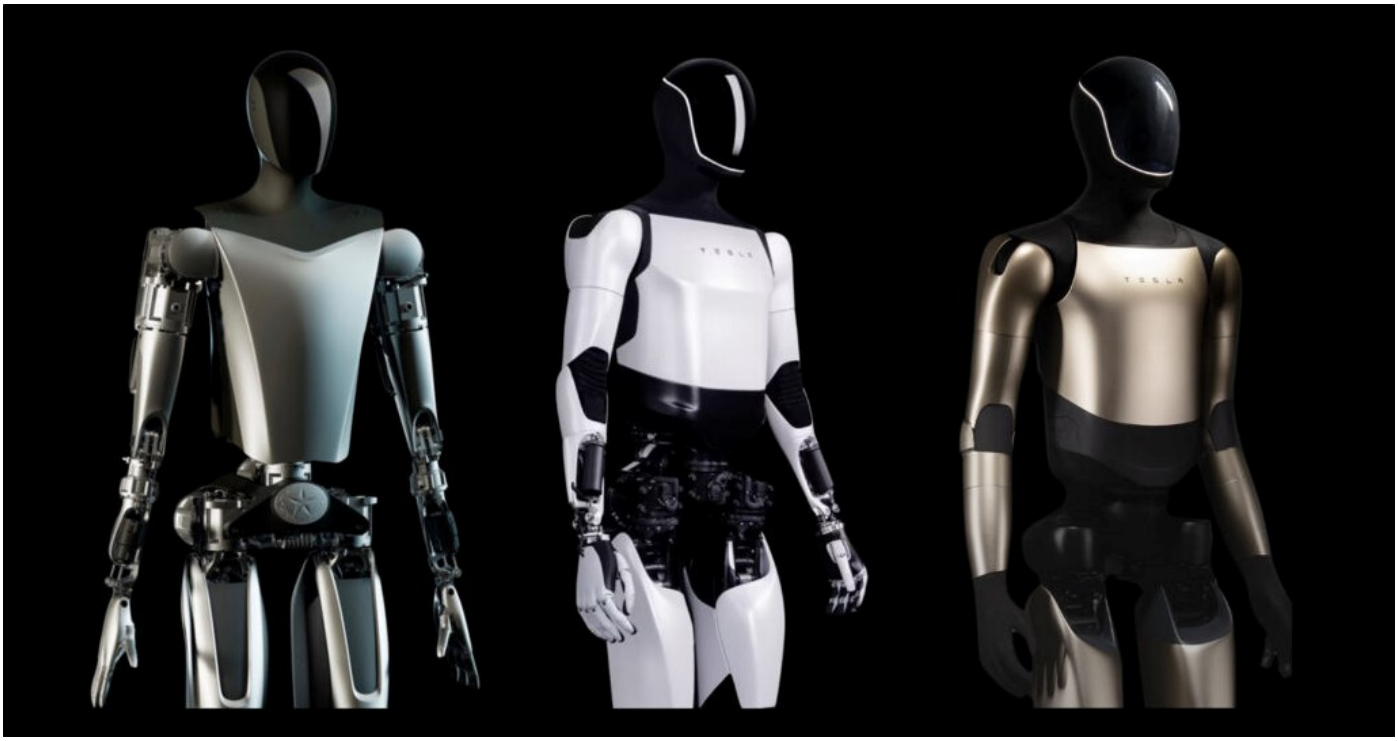
factories, performing basic repetitive tasks such as battery cell sorting. These deployments functioned primarily as live data-collection exercises.

- **October 2024: We, Robot event.** TSLA showcased Optimus units serving drinks and interacting with attendees.
- **Late 2024.** Optimus units demonstrated walking autonomously around TSLA's Palo Alto headquarters and performing tasks including sorting factory components. These were informal demonstrations shared via social media and press visits.
- **June 2025: Leadership transition.** AI director Ashok Elluswamy takes over following the resignation of Optimus program director Milan Kovac.
- **January 2026: Model S/X discontinuation announced.** TSLA confirmed it would cease production of Model S and Model X (final units rolled off the Fremont line in early May 2026), converting that factory floor to Optimus production capacity, with an anticipated unprecedented factory conversion timeline of ~4 months.
- **March/April 2026: Gen 3 was previewed at the 2026 Appliance & Electronics World Expo in Shanghai.** Management noted that Gen 3 was in the final stages of completion but opted to delay the formal public unveiling until closer to the production timeline (~July/August 2026), citing competitive considerations.
- **April 2026: AI5 chip tape-out completed.** The custom silicon that will power both FSD and Optimus inference has reached its design finalization milestone.
- **July-August 2026 (expected): Optimus Gen 3 formal public unveiling and production commencement.** The first version is engineered for mass production, with SoP anticipated in July/August. The production ramp is expected to be gradual, reflecting the complexity of the new supply chain and underlying technology.
- **2027 (targeted): Volume production ramp.** Public sale targeted for end of 2027. Optimus production line at the Gigafactory Texas is likely to start production in summer 2027, with a long-term production target of ~10 mn units/year.

Technology and Software Behind Optimus

Tesla's Optimus robot features a vertically integrated hardware stack, including custom-designed actuators, sensors, compute chips, and battery packs, optimized for humanoid form and performance. The software leverages Tesla's E2E neural network architecture, similar to FSD, with training sourced from teleoperation, simulation, and vision-only models. AI training for Optimus is significantly more compute-intensive than for vehicles, with inference powered by the advanced AI5 chip fabricated at Samsung and TSMC facilities. Tesla's Cortex clusters and upcoming Dojo 3 supercomputer provide the necessary training infrastructure, supporting rapid task acquisition and manipulation in complex environments. (Link to the note).

Figure 17: TSLA Optimus Gen 1, Gen 2, and Gen 2.5 (in order from left to right)



Source: Company reports.

Ford to Partner with Humanoid (covered by Rajat Gupta)

Ford Motor Company's involvement with humanoid robots has primarily centered on proof-of-concept trials and exploratory projects, rather than large-scale production partnerships or direct investments in humanoid technology developers.

Recent Proof-of-Concept Trials

- **Cologne Innovation Center Pilot:** Ford recently completed a six-week proof-of-concept trial at its Innovation Center in Cologne, Germany, collaborating with Humanoid, a UK-based robotics startup. The trial featured the Alpha HMND 01 robot, which was deployed in automotive workflows for tote handling and dual-arm manipulation of large metal car body parts.
- **Performance Outcomes:** The robot exceeded productivity targets, demonstrating notable speed, precision, and safety in real industrial tasks. The trial underscored the readiness of humanoid robots for practical deployment in manufacturing environments.
- **Next Steps:** Following the successful pilot, Ford and Humanoid are considering further demonstrations and evaluating potential integration of humanoid robots into actual production operations.

Historical Robotics Initiatives

Agility Robotics Collaboration: In 2019, Ford partnered with Agility Robotics to explore last-mile delivery solutions using the Digit humanoid robot in conjunction with autonomous vehicles. Ford acquired two Digit units in 2020 for testing purposes, but

there have been no significant recent developments or expansion of humanoid robotics within Ford's factory operations.

General Motors (covered by Rajat Gupta)

General Motors is actively integrating humanoid robots and advanced robotic technologies into its manufacturing operations to enhance safety, efficiency, and quality control. The company's approach spans early collaborations with NASA and extends to current real-world testing and digital innovation in production environments.

Key Partnerships and Projects

- **Kepler Humanoid Robots (SAIC-GM):** As of April 2025, GM is piloting Kepler humanoid robots at the SAIC-GM plant in Shanghai, a joint venture with SAIC Motor. These robots are being tested for their ability to support material handling and precision tasks on the factory floor.
- **NVIDIA Collaboration:** GM is working with NVIDIA to develop self-driving vehicles and to leverage NVIDIA's platforms for factory planning and robotics. The partnership includes the use of NVIDIA's Omniverse platform to create digital twins of manufacturing facilities, enabling virtual training and testing of robots for tasks such as material handling and welding.
- **NASA and Robonaut 2 (R2):** GM's collaboration with NASA led to the development of Robonaut 2, a dexterous humanoid robot designed to operate alongside humans both in space and in automotive manufacturing plants. The project focused on creating robots capable of performing complex tasks safely, improving workplace safety and productivity.
- **RoboGlove Development:** Building on the Robonaut partnership, GM and NASA developed RoboGlove, a wearable device equipped with sensors and actuators to enhance grip strength and reduce worker fatigue. The technology, later refined by Bioservo, is now used to prevent injuries during repetitive manufacturing tasks.

Rivian (covered by Rajat Gupta)

Rivian is expanding its presence in the robotics sector, primarily through the launch of a dedicated spinoff and a strategic partnership with Amazon. The company's approach emphasizes practical factory automation and innovative last-mile delivery solutions, rather than direct development of humanoid robots for manufacturing.

Mind Robotics Spinoff (2026)

- **Formation and Leadership:** In March 2026, Rivian announced the creation of Mind Robotics, an industrial robotics company founded by Rivian CEO RJ Scaringe. Rivian remains a major shareholder and strategic partner.
- **Operational Focus:** Mind Robotics is developing advanced robots tailored for factory environments, prioritizing dexterity and adaptability to complex tasks. The company's strategy centers on traditional, functional robot designs rather than humanoid forms.
- **Data and Collaboration:** Rivian provides manufacturing data from its electric vehicle plants to support the development and training of Mind Robotics' systems.
- **Funding and Valuation:** Mind Robotics secured $500 mn in Series A funding, resulting in a $2 billion valuation.

Amazon Partnership (2025)

- **Last-Mile Delivery Innovation:** Rivian is working with Amazon to integrate humanoid robots with its electric delivery vans for last-mile logistics.
- **Testing and Application:** Amazon is piloting humanoid robots—including models from Unitree—alongside Rivian's e-vans. The robots are designed to autonomously exit the vehicle and deliver packages directly to customers' doors.

Figure 18: USA Humanoid selected names

Country	Company	Product
USA	Agility Robotics	Humanoid Robot
USA	Apptronik	Humanoid Robot
USA	Boston Dynamics	Humanoid Robot
USA	Figure AI	Humanoid Robot
USA	1X Technologies	Humanoid Robot
USA	Tesla Inc	Optimus
USA	Magna International Inc	Humanoid Integration/Investments
USA	Lear Corp	Supplier
USA	Aptiv PLC	Supplier and Investments

Source: J.P. Morgan.

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China : Automotive Industry and Humanoid Value Chain

Xpeng (covered by Nick Lai)

Xpeng has transitioned from its roots as an electric vehicle manufacturer to position itself as an **embodied intelligence** company, with a strong focus on humanoid robotics. The company is preparing to launch mass production of its second-generation humanoid robot, Iron, in 2026. Iron represents Xpeng's eighth generation of robotics projects and is designed with advanced features including a bionic spine, biomimetic muscles, flexible skin, and highly dexterous hands with 22 DoF—comparable to leading industry models. Iron is powered by three in-house Turing AI SoCs, giving it industry-leading edge compute and intelligence capabilities. The company is leveraging its full-stack, in-house developed technology system—including SoC, foundational models, data, EE architecture, and AI infrastructure—to drive both vehicle and robot development, with a focus on commercial, industrial, and household application scenarios. Initial deployments will support reception, guidance, and retail assistance across XPeng stores and campuses in China and overseas.

The initial deployment strategy targets commercial service roles such as receptionists, sales assistants, and tour guides within Xpeng's own showrooms and offices. Hundreds of earlier robot units are already being tested on Xpeng's automotive production lines for sorting and logistics tasks, generating valuable data to refine the technology. Xpeng's development philosophy emphasizes full-stack integration, with hardware and software designed in tandem to support scalable production. The company has also established a strategic partnership with Baoshan Iron & Steel (Baosteel) to pilot its humanoid robots in industrial settings, including inspection and logistics. To support its mass production ambitions, Xpeng is building a comprehensive manufacturing base in Guangzhou, with construction of a 1.18-mn-square-foot factory slated to begin in the first quarter of 2026. The initiative is further bolstered by a strategic cooperation agreement with the Tianhe District government, underscoring local support for Xpeng's robotics expansion.

BYD (covered by Nick Lai)

BYD is actively integrating humanoid robots into its electric vehicle manufacturing operations, with a notable partnership involving UBTECH's Walker S1 robots for logistics, sorting, and assembly tasks. The robots are deployed in BYD's Changsha factories, working alongside autonomous vehicles to enhance smart manufacturing efficiency. In addition to external collaborations, BYD is recruiting talent to advance its own humanoid robotics and related technologies, signaling a commitment to in-house development. The company is also a significant investor in Agabot (Shiuan Robotics), which is mass-producing humanoid robots, and is engaged in discussions with PaXini to explore industrial synergy, particularly in tactile sensing for advanced assembly applications. The strategic goal of these initiatives is to leverage advanced robotics to boost productivity and streamline factory operations. Looking ahead, BYD is reportedly considering the production of low-cost humanoid robots, positioning itself to capitalize on broader industry trends as the Chinese EV sector increasingly adopts robotics for assembly and other manufacturing processes.

Li Auto (covered by Nick Lai)

Li Auto is aggressively expanding into AI and humanoid robotics, aiming to integrate embodied intelligence with its automotive expertise. The company has established dedicated robotics teams—reportedly codenamed Nexus and specializing in spatial/ wearable tech—and plans to develop its own humanoid robots.

FAW and UBTECH

FAW Group is strengthening its manufacturing operations through a strategic partnership with UBTECH, focusing on the deployment of industrial humanoid robots from the Walker S series. At FAW-Volkswagen's Qingdao branch, these robots are being integrated to automate tasks such as component assembly, bolt tightening, and handling automotive parts. In parallel, the Audi FAW New Energy Vehicle (NEV) factory in Changchun is utilizing Walker S1 robots for real-time quality inspections, including air conditioning leak checks, with millimeter-level precision. The robots are designed to operate alongside human workers, targeting roles that are repetitive, hazardous, or require high consistency.

The collaboration leverages advanced technologies including 3D object localization, semantic navigation, and deep learning-based quality inspection to improve efficiency and safety in automotive manufacturing. Looking forward, FAW and UBTECH plan to establish a joint laboratory dedicated to AI and humanoid robotics applications, aiming to revolutionize traditional manufacturing processes and accelerate the shift toward highly automated, "unmanned" car factories.

SAIC (covered by Nick Lai)

SAIC Motor is actively integrating humanoid robots into its automotive manufacturing operations, with a notable deployment of Kepler Robotics' Bumblebee K2 robots at the SAIC-GM plant in Shanghai. The robots are being tested for a range of tasks, including quality inspections, heavy parts lifting, and vehicle assembly. The K2 robot, developed by Shanghai-based Kepler Robotics, features 52 degrees of freedom, allowing for precise movement and the ability to manage demanding tasks such as handling large automotive components and working full 8-hour shifts. This initiative underscores SAIC's commitment to advancing intelligent, automated production lines.

In addition to the Kepler partnership, SAIC Volkswagen is collaborating with Neura Robotics to integrate advanced robotics and leverage the "Neuraverse" platform for smart manufacturing. SAIC has also invested in LimX Dynamics, a Chinese company specializing in modular robot bodies and intelligent systems, participating in a $200 mn Series B funding round to accelerate industrial robot adoption. Beyond physical humanoids, SAIC-GM has implemented the "RoboTest" autonomous testing system for vehicle durability, which enhances testing precision compared to traditional human-driven methods. These combined efforts reflect SAIC's strategic push toward intelligent automation and next-generation manufacturing capabilities.

Xiaomi (Covered by Gokul Hariharan)

Xiaomi has unveiled a significant upgrade to its CyberOne humanoid platform, with the latest development centered on robotic manipulation rather than locomotion. The company has introduced a full-palm tactile sensing system that extends sensing capability beyond the fingertips to the finger pads and entire palm, providing

approximately 8,200 mm² of tactile coverage, comparable to a human hand. This enables the robot to detect distributed contact forces, adjust grip in real time, identify object slippage, and manipulate delicate objects with greater precision. Xiaomi has also leveraged haptic data collected from human operators wearing sensor-equipped gloves to train the robot on more natural grasping strategies, improving dexterity across a wider range of manipulation tasks.

Alongside the sensing improvements, Xiaomi has redesigned the hand to closely match human dimensions, reducing its size by around 60% to achieve a 1:1 scale relative to a 1.73-metre adult. The company has also incorporated an artificial sweating thermal management system to dissipate heat generated by onboard electronics during prolonged operation, addressing one of the key challenges for continuous industrial deployment. These hardware enhancements are aimed at improving reliability and enabling sustained operation in factory environments where robots are required to perform repetitive tasks over extended periods.

Early industrial validation suggests tangible progress. Xiaomi reported that the upgraded CyberOne initially achieved a 90.2% success rate during continuous self-tapping nut loading tests over a three-hour production run, while subsequent iterations have improved this to 98%, narrowing the gap with human operators to approximately one percentage point. The company has also expanded the robot's application to the center console side panel sorting and parts-bin folding and recycling, with both tasks reportedly achieving around 90% success rates. Xiaomi's progress reinforces the industry's increasing focus on robotic end-effectors, where improvements in tactile sensing, dexterity and durability are becoming key differentiators for expanding humanoid deployment beyond simple material handling into more complex manufacturing workflows.

UBTech Robotics (covered by Karen Li)

UBTECH Robotics, founded in 2012 and headquartered in Shenzhen, is a global leader in intelligent robotics, specializing in humanoid and service robots for industrial, commercial, educational, and home applications. Listed on the HKSE, UBTECH is recognized for its robust portfolio, including the Walker series of humanoids, Alpha educational robots, and Cruzr service robots. The company's core strength lies in its full-stack technology capabilities, spanning proprietary servo actuators, advanced motion control, and integrated AI algorithms. UBTECH operates manufacturing hubs in Shenzhen and Liuzhou, maintaining a strong focus on in-house R&D and AI integration. The company has established itself as a pioneer in the commercialization of humanoid robots, with significant deployments across the electric vehicle and electronics sectors.

Key Highlights:

- **Humanoid & Service Robots:** UBTECH's Walker S2 is designed for industrial tasks, featuring autonomous battery swapping and a 15kg payload. The company also offers Walker C and logistics robots (Chitu L4, F3000, T8000) for factory automation.
- **Commercial & Home Products:** The Cruzr S2 service robot, smart home devices, and cleaning robots expand UBTECH's reach into consumer and business environments.
- **Education Solutions:** The Alpha series and uKit platforms support AI learning and robotics education.

- **Core Technology:** UBTECH develops proprietary, high-performance servo actuators, advanced motion planning, AI algorithms, and the ROSA 2.0 operating system.
- **Some developments (2025-2026):**

    1. Initiated the world's first mass delivery of humanoid robots (Walker S2).
    2. Secured over 800 mn yuan in orders from major manufacturing partners.
    3. Developed the first industrial agent (Co-Agent) for humanoid robots.
    4. Achieved 24/7 operational capabilities with autonomous battery swapping technology.

Unitree Robotics

Unitree Robotics is a Chinese robotics company specializing in high-performance quadruped robot dogs and affordable bipedal humanoids. Founded in Hangzhou in 2016 by Wang Xingxing, it is a leading Chinese original equipment manufacturer (OEM) in the humanoid and quadruped robotics sector, recognized for its rapid transition from research and pilot projects to real-world deployment and mass production. Unitree targets approximately 20,000 units in 2026—nearly four times its 2025 production of over 5,500 units.

Unitree is collaborating with NVIDIA, integrating its H2 Plus humanoid chassis with NVIDIA's Isaac platform and advanced onboard compute. The partnership aims to accelerate the development of autonomous, general-purpose robots and expand the total addressable market for physical AI. The Unitree H2 Plus, built on NVIDIA's Isaac platform, is expected to be available in late 2026 and will be used by leading research institutions to advance humanoid robotics research.

Key Humanoid Models:

- **Unitree G1:** Compact humanoid standing 4 feet 2 inches tall (~1320 mm) and weighing around 75–80 lbs. Features 23 degrees of freedom, 3D LiDAR, and depth cameras.
- **Unitree R1:** Lightweight, highly budget-friendly base entry model standing at ~1210 mm tall and weighing ~25 kg.
- **Unite H1: A full-sized**, high-performance general-purpose humanoid standing at roughly 1.8 meters tall (~5.9 ft) with extreme torque and running capabilities.
- **Unitree H2 Plus:** Advanced research platform integrated with NVIDIA's Jetson Thor hardware and Isaac GR00T AI framework for complex embodied AI testing.

AgiBot

AgiBot is a Shanghai-based company specializing in general-purpose embodied AI and humanoid robotics. Founded in February 2023 by former Huawei engineers Deng Taihua and Peng Zhihui, the firm develops full-stack robotic hardware and software platforms designed for industrial, commercial, and research applications. In 2025, Agibot shipped over 5,000 units, and in 2026, it has already shipped 5,000 units in the first few months, tracking toward an annualized output of approximately 20,000 units—about four times its 2025 base.

Agibot's production ramp is notable, with over 10,000 units produced year-to-date in 2026—more than double last year's output. The Walker S model has over 13,000 units in preorders against a targeted 10,000-unit capacity by year-end, demonstrating strong demand and rapid scaling.

Key Humanoid Models

- **Agibot A3 Ultra:** A 1.74-meter-tall, 60 kg full-size humanoid with 51 active degrees of freedom (DoF), 5 kg per-arm payload capacity, and up to 8 hours of operating time powered by NVIDIA Thor.
- **Agibot X2 EDU:** A modular, 1.3meter-tall research and education platform featuring 29 DoF and open hardware/control interfaces for secondary development.
- **Agibot G2 Max:** The **Agibot G2 Max** is an industrial-grade wheeled heavy-payload robot featuring force-controlled arms, omnidirectional mobility, and an adjustable working height.
- **OmniHand 3 Ultra-M:** A direct-drive dexterous robotic hand with 20 active DoF, vision-based tactile fingertip sensors, and a whole-hand gripping load capacity of up to 5 kg.
- **Agibot C5:** An autonomous commercial floor-cleaning and facility maintenance robot designed for corporate and public spaces.

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J.P.Morgan

Figure 19: Humanoid Robot Comp Table

Company Name	Stock Code	JPM Rating	Share price (LC)	JPM PT (LC)	Upside / downside (%)	Mkt Cap (US$MM)	P/E (x) (FY26E)	P/E (x) (FY27E)	Humanoid business type	Region
Leader Drive	688017 CH	OW	295	481	63%	7,991	277	185	reducer	China
Sanhua-A	002050 CH	OW	35	60	71%	20,825	32	27	actuator	China
Sanhua-tH	2050 HK	OW	25	42	68%	20,825	NM	NM	actuator	China
Ningbo Tuopu	601689 CH	UW	46	48	5%	11,702	24	20	actuator	China
Minth	425 HK	OW	27	57	108%	4,087	9	7	mechanical parts	China
Zhongda Leader	002896 CH	NC	59	NC	NA	1,723	NM	NM	reducer	China
Shuanhuan	002472 CH	NC	35	NC	NA	4,436	21	18	reducer	China
Ningbo Joyson	600699 CH	N	19	20	4%	4,201	17	14	hands, sensor,etc	China
Hengli Hydrulic	601100 CH	OW	107	121	13%	21,135	41	34	ball screw	China
Robosense	2498 HK	OW	22	45	104%	1,328	135	27	Lidar	China
Johnson Electric	179 HK	N	17	21	22%	2,056	8	8	motor	China
Wolong Electric	600580 CH	N	28	37	30%	6,562	36	30	motor	China
Orbbee	688322 CH	NC	88	NC	NA	5,336	113	59	vision	China
Horizon Robotics	9660 HK	OW	4	11	140%	8,213	NM	NM	AI chips	China
UBTech robotics	9880 HK	OW	79	161	105%	5,103	NM	278	robot OEM	China
Shenzhen Dobot	688322 CH	NC	88	NC	NA	5,336	113	59	robot OEM	China
OneRotics	6600 HK	NC	56	NC	NA	1,613	3,234	243	robot OEM	China
Geekplus	2590 HK	NC	9	NC	NA	1,559	71	24	robot OEM	China
Xpeng	9868 HK	OW	49	108	118%	12,089	NM	43	robot OEM	China
Xpeng	XPEV US	OW	13	27	112%	12,225	NM	44	robot OEM	China
Hiwin	2049 TT	UW	313	160	-49%	3,420	37	29	ball screw	Taiwan
Bizlink	3665 TT	OW	2,205	3,100	41%	13,286	33	19	cable	Taiwan
Sinbon	3023 TT	N	285	235	-18%	2,113	19	16	cable	Taiwan
TM Robot	4585 TT	NC	300	NC	NA	969	NM	NM	robot OEM	Taiwan
HDS	6324 JP	NC	6,560	NC	NA	3,858	385	116	reducer	Japan
Nidec	6594 JP	UW	2,549	1,800	-29%	18,564	23	16	reducer	Japan
Minebea Mitsumi	6479 JP	OW	3,879	5,500	42%	10,117	22	18	force sensor	Japan
NVIDIA	NVDA US	OW	209	280	34%	5,051,992	45	23	AI chips	US
Tesla	TSLA US	N	320	445	39%	1,262,631	178	135	robot OEM	US
Siemens	SIE GR	OW	271	345	27%	241,451	25	21	application	Europe
Schaeffler	SHAQ GR	N	8	10	24%	8,681	38	14	ball screw	Europe
Hyundai Motor	005380 KS	OW	400,000	640,000	60%	55,999	9	8	robot OEM	Korea
Average							**198**	**55**		

Source: Bloomberg Finance L.P., J.P. Morgan estimates for covered names

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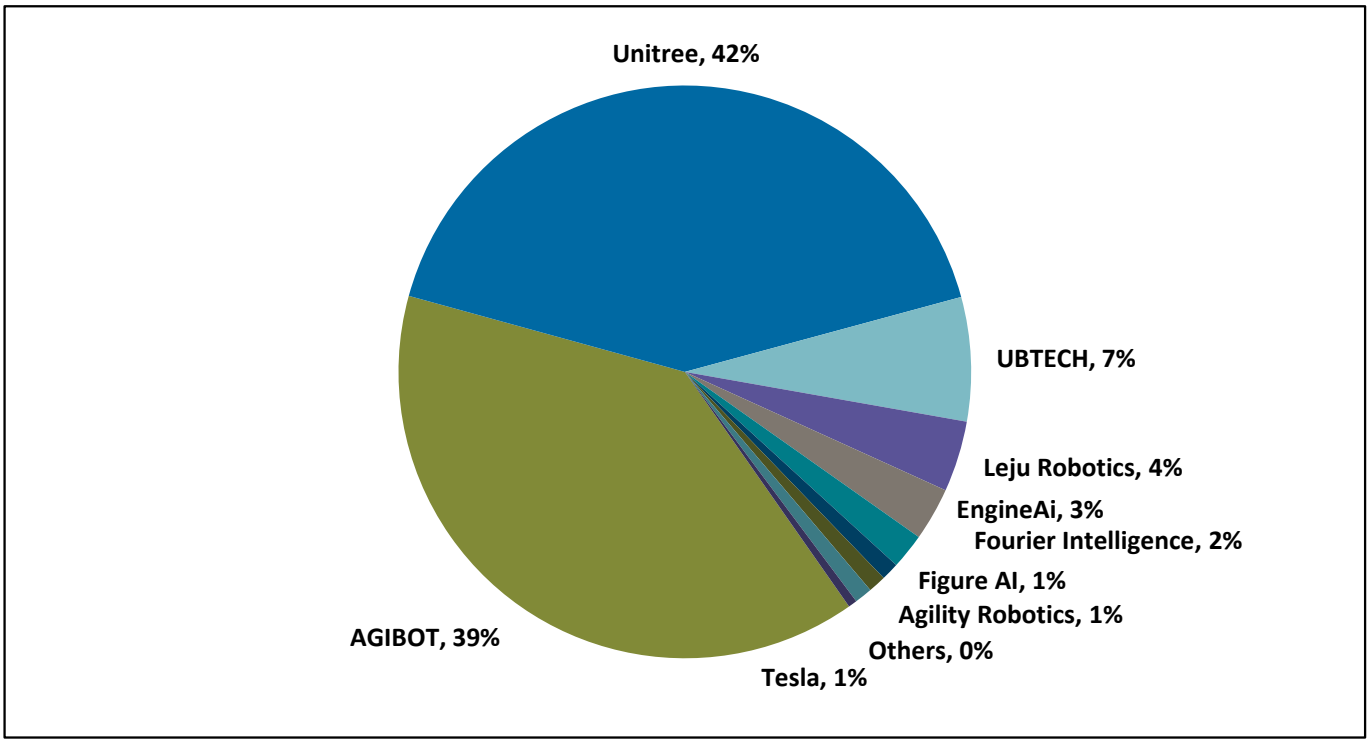
Figure 20: China Humanoid selected names

Country	Region	Company	Product
China	Shenzhen	UBTECH Robotics	Humanoid Robot
China	Hangzhou	Unitree Robotics	Humanoid Robot
China	Shanghai	Fourier Intelligence	Humanoid Robot
China	Guangzhou	XPeng	Humanoid Robot
China	Beijing	AgiBot (Agibot Robotics)	Humanoid Robot
China	Beijing	Kepler Robotics	Humanoid Robot
China	Beijing	RobotEra	Humanoid Robot
China	Shenzhen	EngineAI	Humanoid Robot
China	Hangzhou	DEEP Robotics	Humanoid Robot
China	Shanghai	LimX Dynamics	Humanoid Robot
China	Beijing	Xiaomi	Humanoid Robot
China	Suzhou	Leader Harmonious Drive	Actuators
China	Shenzhen	Orbbec	3D Vision System
China	Shenzhen	Zhaowei Machinery & Electronics	Robot Hand
China	Shenzhen	Fortior Technology	Supplier
China	Guangzhou	Haozhi Industrial	Supplier
China	Changzhou	Hengli Hydraulic	Electric Actuators
China	Hangzhou	Shuanghuan Driveline	Supplier
China	Shaoxing	Sanhua Intelligent Controls	Actuators

Source: J.P. Morgan.

Figure 21: 2025 Humanoid Market Share Split

% of overall production volumes



Source: Omdia Research, Company reports and J.P. Morgan estimates.

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Japan : Automotive Industry and Humanoid Value Chain

Toyota (covered by Akira Kishimoto)

Toyota has been investing in the development of humanoid robots since 2000, with the first prototype demonstrated in 2005. In past years, Toyota has been focusing on the advance of robot's 1) physical agility, 2) functional dexterity and 3) social intelligence. In particular on physical agility, Toyota has developed a unique set of joints and power delivery structure, which enables more efficient output of motors. Also, with the original shock absorption/ kinematic energy recovery mechanism, the robot is able to balance the body on its own with less energy consumption. The outcome of the development is a basketball robot named "CUE", which holds 2 Guinness World Record titles.

Beyond the company's strengths in mechanical design and manufacturing, Toyota has been accelerating AI integration. Similar to other automakers, Toyota has deployed humanoid robots in its plants. With over 70 production sites across the world, Toyota has the greatest amount of data and usecases to be utilized. Toyota's strategy, grounded in the principles of the Toyota Production System, emphasizes the use of robots to improve worker ergonomics and manage physically demanding jobs, positioning the company at the forefront of industrial robotics innovation. Human support robot "ELEY" announced in December 2025 features 2 human-like arms and can skillfully assemble objects.

Figure 22: Toyota: Basketball Robot "CUE"



Source: Company data

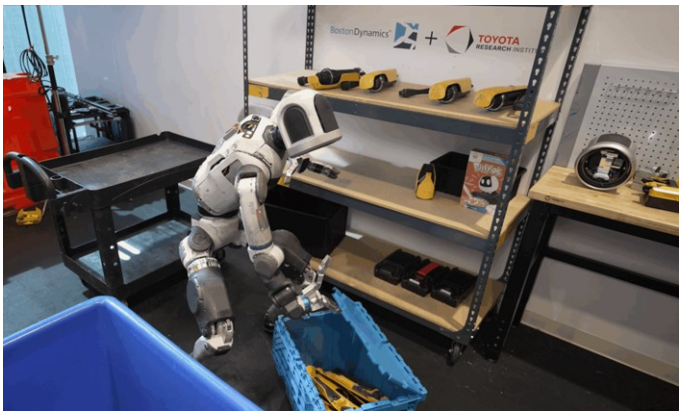
Figure 23: Toyota: Human Support Robot "ELEY"



Source: Company data

In addition to industrial usage, a subsidiary of Toyota has constructed a world-model-wise system "Woven City Robot Platform" and a test field "Woven City" with residents living in it. This pilot program was created with real world application creation in mind, and it has been able to streamline and accelerate the process of data capturing, training, verifying with simulation and real world deployment.

Figure 24: Toyota: Demonstration of Large Behavior Model (LBM) Co-Developed with Boston Dynamics



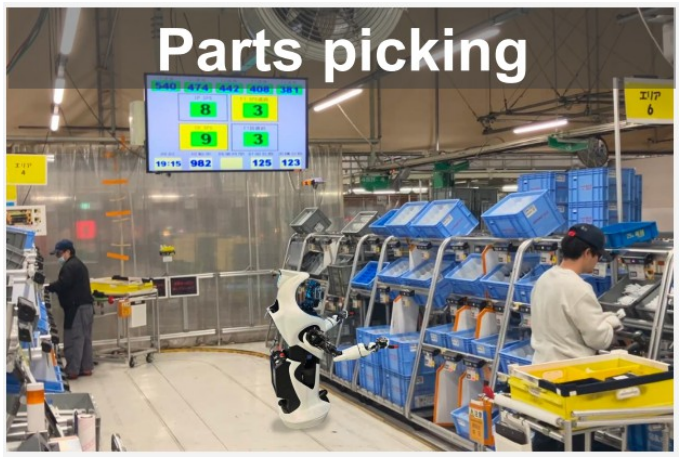
Source: Company data.

Figure 25: Toyota: Showcase of Robot Deployment in Plants (Component Pickup)



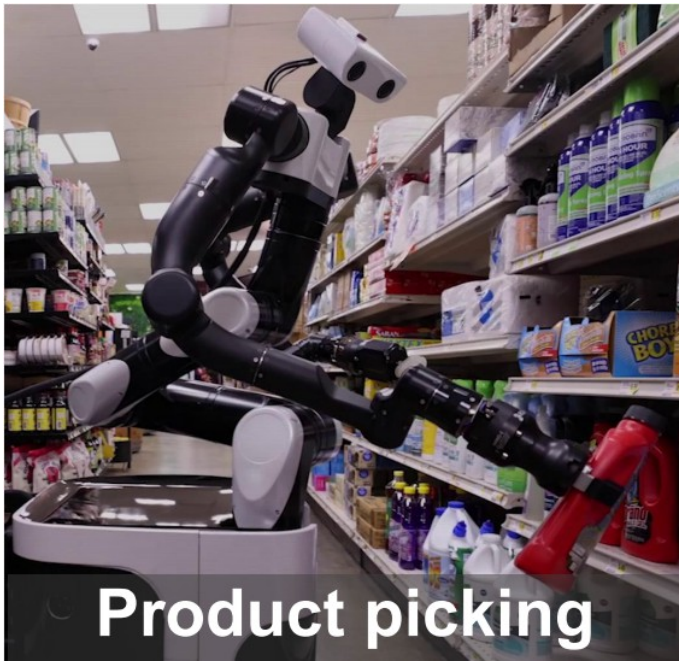
Source: Company data.

Figure 26: Toyota: Utilizing Robots at Plants



Source: Company data

Figure 27: Toyota: Utilizing Robots in City



Source: Company data

Toyota is open to collaboration with other robot makers. The Toyota Research Institute has been collaborating with Boston Dynamics to advance robotics capabilities since 2024. Announced in August 2025, the two have developed a Large Behavior Model to enablethe Atlas robot for continuous sequence of complex tasks that require combining object manipulation with locomotion.

Another notable showcase was the introduction of Agility Robotics' Digit robots at Toyota Motor Manufacturing Canada. As of February 2026, Digit robots have been deployed in Woodstock, Ontario, for logistics and repetitive tasks, following a successful pilot program. The move reflects Toyota's commitment to leveraging

robotics for operational improvements and addressing labor-intensive roles within its production lines.

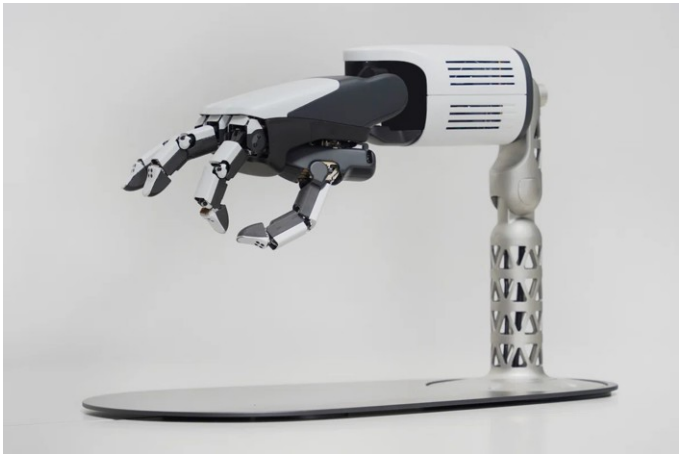
Beyond the intracompany collaboartion, Toyota is an active contributor to the "Human Support Robot" community. Teleoperation system for HSR developed by Toyota has been adopted as a fundamental model that is open to service and assistive robot developers.

Honda (covered by Akira Kishimoto)

Honda has been a pioneer in humanoid robotics since 1986, and it was Honda that first investigated the principles of bipedal walking. The famous humanoid robot, ASIMO, was introduced in 2000 to assist people and navigate human environments. Although the project was retired in 2018, Honda continues to develop next-generation avatar robots with a focus on robot hands. The 4th generation robot hand developed by Honda is a multi-finger hand with human-scale size while achieving strength, high responsiveness, and precision. With the development of control algorithms, it could perform tasks like screw driving and connector insertion.

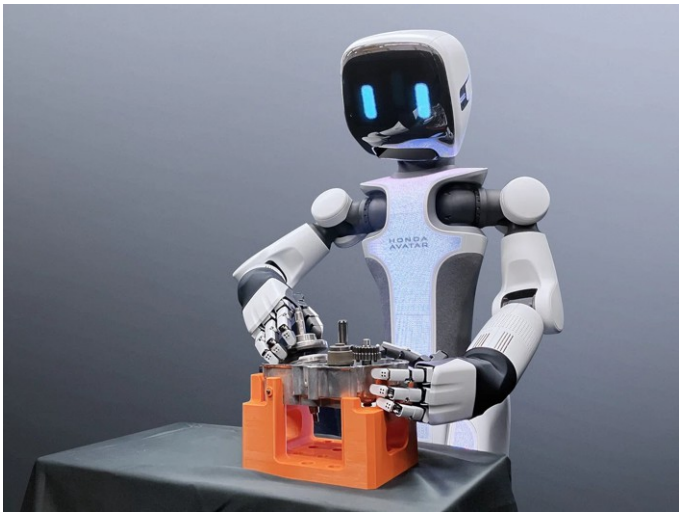
Moreover, to overcome the "last millimeter" of real-world dexterity (e.g., handling cloth or wet/slippery objects), Honda has developed a set of Embodied AI and crossponding transimission mechanisim. Honda's Embodied AI takes sensorimotor experience as input (forces, contact, motion), and it distinguishes itself by high sim-to-real correlation. Honda has created a new approach to millimeter-level positioning and sub-Newton force control with hardware and control fidelity innovation.

Figure 28: Honda: Latest Multi-finger Hand



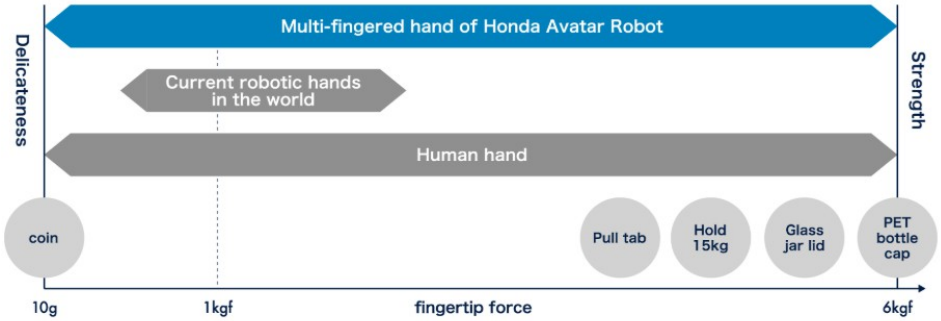
Source: Company data

Figure 29: Honda: Latest Avatar Robot



Source: Company data

Figure 30: Honda: Capability of Honda Avatar Robot Hand



Source: Company data

The development of avartar robots aligns with Honda's idea of "Transcend" and the concept of "four-dimensional mobility" (overcoming distance and time-to-travel via robots). Company aims to have robots in practical everyday use by the 2030s, and a core application will be remote control. Honda's approach is to keep the human in charge of situation understanding and decision-making, while AI infers the operator's intent and corrects the hand's motion and forces to make grasping smoother and feel more natural. Beyond basic grasping, Honda is training the robot in delicate skills like grasping a tool, sliding it within the hand, then re-grasping it in a new configuration (e.g., changing the screwdriver angle).

Nissan (covered by Akira Kishimoto)

Nissan is not actively developing humanoid robots, but the company is integrating advanced robotics and automation technologies across its manufacturing sites. At its Tochigi plant, Nissan has deployed specialized robotic arms to handle high-precision tasks such as painting, welding, and assembly, effectively reducing manual workload and improving operational efficiency.

Mitsubishi Motors (covered by Akira Kishimoto)

Mitsubishi Motors announced on July 9 that it will start mass production of humanoid robots at its Kyoto plant in a collaboration with University of Tokyo startup Highlanders. Mitsubishi Motors, which has invested in Highlanders, will start production of humanoid robots in 2027, using idle facilities at its Kyoto plant, with target production capacity of 1,000 units/month. According to the company, it will first confirm the effectiveness of humanoid robots at its own plants and then consider external sales in the future. Assuming annual production of 12,000 units (based on 1,000 units/month) and a unit price of ¥10 million, we estimate potential sales at around ¥120 billion. However, we need to keep in mind that, ultimately, Mitsubishi Motors will be in the position of a contract manufacturer and value-added could be biased toward Highlanders.

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Figure 31: Japan Humanoid selected names

Country	Listed	Company	Product
Japan	Y	Toyota Motor	Humanoid Robot
Japan	Y	Honda Motor	Humanoid Robot
Japan	Y	Hitachi	Humanoid Robot
Japan	Y	Kawasaki Heavy Industries	Humanoid Robot
Japan	Y	SoftBank Group	Humanoid Robot
Japan	Y	THK	Humanoid Robot
Japan	N	donut robotics	Humanoid Robot
Japan	N	GMO AIR	Humanoid Robot
Japan	N	Highlanders	Humanoid Robot
Japan	N	Kawada Robotics	Humanoid Robot
Japan	N	Telexistence	Humanoid Robot
Japan	N	Tmsuk	Humanoid Robot
Japan	Y	Fanuc	Supplier
Japan	Y	Hephaist	Supplier
Japan	Y	Japan Aviation Electronics Industr	Supplier
Japan	Y	KYB	Supplier
Japan	Y	Mabuchi Motor	Supplier
Japan	Y	Murata Manufacturing	Supplier
Japan	Y	Nabtesco	Supplier
Japan	Y	NOK	Supplier
Japan	Y	NSK	Supplier
Japan	Y	Renesas Electronics	Supplier
Japan	Y	Sony Group	Supplier
Japan	Y	Sumitomo Electric	Supplier
Japan	Y	Sumitomo Heavy Industries	Supplier
Japan	Y	Yasukawa Electric	Supplier
Japan	N	Mujin	Supplier

Source: J.P. Morgan.

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Korea : Automotive Industry and Humanoid Value Chain

Hyundai Motor Group (covered by Sonny Lee)

Hyundai Motor Group's (HMG) robotics strategy is closely tied to Boston Dynamics (BD), in which it holds a controlling stake. Starting in 2028, Hyundai Motor/Kia will be responsible for mass-producing Boston Dynamics' humanoid robots. These robots are expected to be deployed first in HMG's factories, with their use cases gradually expanding over time. BD's strategic partnerships with NVIDIA and Google DeepMind enable scalable AI training and enhanced reasoning, while BD's integration within HMG strengthens its manufacturing, deployment, and data-collection advantages.

- Atlas (humanoid): An enterprise-grade, electric humanoid robot designed for flexible, autonomous industrial material handling with high strength, robust perception, and workflow integrations.
- Spot (non-humanoid): A quadrupedal mobile robot that automates inspections and site sensing with 360-degree perception.
- Stretch (non-humanoid): A mobile warehouse robot with an arm that automates case handling and unloading within existing infrastructure, working continuously to move hundreds of boxes per hour with minimal operator intervention.

Korean actuator suppliers

Key actuator suppliers in Korea

We highlight below Korean actuator suppliers who come from different industry roots. We group them into three categories: 1) traditional auto parts suppliers (e.g., Mobis, Mando), leveraging technology that overlaps with components such as electric power steering and transmission gears; 2) appliance motor/reducer suppliers (e.g., SPG), with adjacent capabilities relevant to robot actuator applications; and 3) pure-play actuator makers (e.g., Robotis), which have been in the robotics industry for a considerable period before the addressable market took off with the humanoid theme.

- **Mobis (Overweight)** is leveraging its electrified auto parts capabilities (MDPS: motor driven power steering, also known as EPS: electric power steering) to expand into actuators. The company has been designated as the sole supplier of QDD actuators in the early mass production phase of HMG's humanoids. Mobis delivers detailed guidance on supplying ~30 actuators per HMG's humanoids, implying annual production would reach 900k units/year once the Group's humanoid production reaches 30k units/year.
- **Mando (Neutral)** is also applying its electrified auto parts know-how (e.g., EPS) to enter the actuator space. Its actuator business has gained initial references through HMG's quadrupedal robots, and the company expects to secure actuator orders from an existing auto customer that is also developing humanoids.
- **SPG (058610 KS, Not Covered)** generates the bulk of its revenue from AC fan motors (for home appliances) and reducers, producing all three reducer types (planetary, cycloidal, harmonic). The company plans to move downstream into QDD actuators to capture rising humanoid demand.
- **Robotis (108490 KS, Not Covered)** is a pure-play robotics actuator supplier, producing both QDD and cycloidal-based actuators. The company provides a full

humanoid actuator lineup (including robot hands) and plans to in-house motors next year; 2026 production guidance is ~600k units.

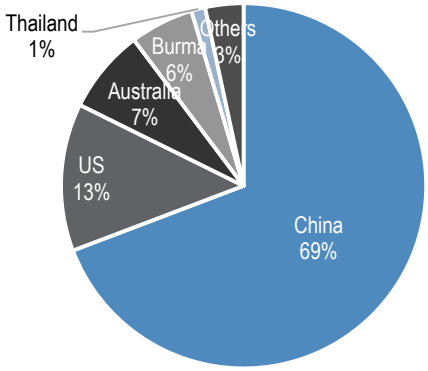
Risks to Mobis and Mando (covered by Sonny Lee)

- **Robot makers aim to commoditize actuators.** Early movers in robot mass production are already setting actuator standards and, in some cases, producing actuators in-house. This strengthens robot makers' bargaining power vs. suppliers. As robot makers retain proprietary software and AI data that enable robust motion across diverse environments, actuator suppliers risk being relegated to "hardware-only" providers. Moreover, QDD actuators with planetary reducers are among the simplest actuator form factors, with fewer manufacturing hurdles than harmonic-based actuators. We see a parallel to autos: just as OEMs are capturing more value by owning software and system integration, robot makers are likely to leverage their integrator role and software moat to gradually compress margins for actuator hardware suppliers.
- **Robot actuators depend more on motor specifications, and are structurally more exposed to rare earth elements (REEs).** QDD actuator performance is increasingly motor-driven: torque density, peak power, thermal limits, and efficiency are determined less by the reducer and more by the motor's design (magnet grade, cooling approach, etc.) and the current/inverter controls. Our concern is that high-performance motors typically rely on NdPr magnets (often with Dy/Tb for heat resistance), making actuator BOMs structurally exposed to rare earth pricing and export/supply disruptions, with supply chains heavily concentrated in China. As humanoid volumes scale, this rare earth linkage could create margin volatility for actuator suppliers unless they secure long-term sourcing, cost pass-through contracts, or redesign toward reduced REE content.
- **Competitive risks from the Chinese.** Chinese companies benefit from scale, capital, and track record in manufacturing actuators and key upstream components. We also see them potentially having better access to REEs as a structural advantage, supporting both price competitiveness and supply stability. If robot makers successfully commoditize actuators, Chinese suppliers could further gain share by quickly adapting to OEM-driven specifications. **We also point out that the Chinese suppliers' ambitions are not limited to non-US regions.** Minth announced in February 2026 that it is establishing a JV with Leader Harmonic Drive to design, manufacture, and commercialize humanoid robot actuators for the North American market. The partnership combines Minth's customer reach and established US manufacturing footprint with Leaderdrive's expertise in high-precision actuator components. The JV's vertical integration across harmonic reducers, roller screws, motors, and bearings could position it to capture an outsized share as adoption accelerates (link). **The American Security Robotics Act, introduced in April 2026, seeks to prohibit government agencies from procuring or operating certain unmanned ground vehicle systems. However, we expect the bill to have limited impact on Chinese firms given**: 1) the bill's scope is confined only to public entities; 2) there are no conclusive comments on specific components or subsystems subject to restriction; and 3) the bill has not yet been signed into law.

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Figure 32: Rare earth production by country

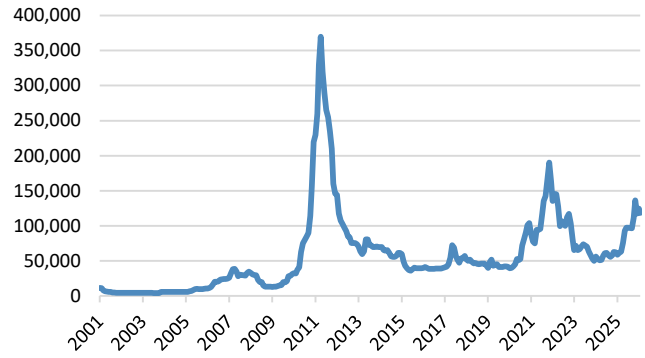
% ton



Source: United States Geological Survey

Figure 33: REEs have shown extremely volatile price trends

Neodymium oxide, $/ton



Source: Bloomberg Finance L.P.

Winning formula for Mobis and Mando

In the humanoid era, we believe component suppliers' sustainable business models will hinge on: 1) large-scale order visibility; 2) diversification; and 3) rare earth elements sourcing capability.

- **Large-scale order visibility.** Humanoid ramps are likely to be lumpy, driven by development milestones, safety validation, and customer adoption. For suppliers, the risk is either building capacity too early and carrying underutilized assets, or scaling too late and losing design wins. In this context, "order visibility" needs to translate into clear, contractual commitments, such as long-term supply agreements, rolling forecasts with firm order windows, and take-or-pay capacity reservations.
- **Diversification.** Over-reliance on a single humanoid OEM exposes suppliers to risks such as platform cancelations, redesigns, and procurement renegotiations as OEMs' bargaining power increases. Diversification should be pursued across: 1) multiple humanoid OEMs; 2) adjacent robot categories (industrial arms, collaborative robots, mobile manipulators, etc.); and 3) non-robotics markets that use similar electromechanical modules. The goal is to protect utilization and pricing discipline even if one program slips.
- **Rare earth elements sourcing capability.** As QDD actuator performance becomes more motor-driven, actuator suppliers are increasingly exposed to rare earth magnet availability and pricing, with supply chains heavily concentrated in China. Disruptions can quickly drive BOM inflation and margin volatility, particularly as OEMs push for cost cuts. Mitigation strategies include: 1) long-term sourcing/offtake and diversification; 2) cost pass-through/indexed contracts; 3) REE-reducing design optimizations; and 4) disciplined inventory control.

We are positive on Mobis on their large-scale order visibility; need to see more development on Mando

- We are constructive on Mobis' actuator positioning, given it has already been designated as the sole actuator supplier for HMG's humanoid in the early stage. We expect its track record in adjacent auto parts to transfer relatively smoothly to robot actuators. In addition, HMG's plan to standardize actuator form factors should help Mobis transition facilities into mass production more seamlessly. Over the longer term, however, we see diversification as a key challenge: Mobis may remain heavily

reliant on intra-Group demand, with margins gradually pressured as the robot OEM customer's bargaining power increases.

- For Mando, we would like to see clearer progress on actuator order wins. While the company has references from supplying actuators for quadrupedal robots, its track record in electrified auto parts does not necessarily translate into meaningful actuator awards from humanoid OEMs, in our view

Figure 34: Korea Robotics Supply Chain

Company	Ticker	Description	Mkt cap ($mn)	P/E (2026E)	P/E (2027E)	Foreign ownership (%)
Rainbow Robotics	277810 KS	Collaborative robots for industrial use, ultra-precision mounts for space observation, and walking robot platforms for navigation.	5,669	NM	NM	7.7
Doosan Robotics	454910 KS	Develops and manufactures industrial robots, linear actuation devices, automated production equipment, and other products.	2,867	NM	NM	3.3
Robotis Co Ltd	108490 KS	Manufactures and distributes educational robots, smart actuators, and other related products.	1,938	390	126	7.6
HL Mando Co Ltd	204320 KS	Manufactures and distributes automotive parts, hydrogen fuel cell converters, radar, cameras, lidars, and other related products.	1,432	11	9	1.1
SPG Co Ltd	058610 KS	Produces a wide range of industrial motors, including reversible, electromagnetic, shaded pole, and condenser motors, and is expanding into robotics and semiconductor equipment.	1,102	119	100	6.1
Higen Rnm Co Ltd	160190 KS	Manufactures a variety of motors, including general-purpose motors for power transmission, servo motors for control, actuators for robotics, and motors for electric vehicles.	334	NM	NM	0.7
Clobot Co Ltd	466100 KS	Business structure consists of robot solutions, robot services, and related product supply for service delivery.	426	NM	NM	1.4
Yuil Robotics Co Ltd	388720 KS	Produces collaborative robots, articulated robots, orthogonal robots and related products.	485	NM	NM	14.1
Robostar Co Ltd	090360 KS	The company's line of business includes the manufacturing of general industrial machinery.	409	NM	NM	3.3
Yujin Robot Co	056080 KS	The company's products include cleaning robots, network home robots, instructional robots, field robots and industrial robots to improve the lives of human beings by providing convenience and safety.	306	NM	NM	3.3
Curexo	060280 KS	Engaged in medical robotics, implant, and trading businesses, offering orthopedic surgical robots, rehabilitation robots, and other medical devices.	228	NM	NM	2.3
Angel Robotics Co	455900 KS	Provides services for rehabilitation, healthcare, defense, industrial, and other industries.	176	NM	NM	2.3
T-Robotics Co	117730 KS	Develops autonomous logistics robots and the development and manufacturing of vacuum robots and vacuum transfer modules for the semiconductor and display industries.	189	NM	NM	1.6
Neuromeka Co Ltd	348340 KS	Produces co-industrial robots, mobile robots, delta robots, and other industrial robots.	231	NM	NM	1.8
Intops Co Ltd	049070 KS	Produces plastic injection and mold, and computer peripherals.	214	NM	NM	1.2
SBB Tech Co Ltd	389500 KS	Manufactures and distributes precision and special equipment driving devices.	142	NM	NM	3.3
PHA Co Ltd	043370 KS	Produces and markets auto latching systems, auto door systems, power window systems, hinges, and modules.	154	NM	NM	2.7
RS Automation Co	140670 KS	The robot motion control division develops, manufactures, and sells controllers, sensors, and related products used in advanced manufacturing industries.	78	NM	NM	2.4
Zenix Robotics Co	381620 KS	Develops automated material handling systems.	51	NM	NM	2.8
V One Tech	251630 KS	Develops and manufactures LCD/LED inspection equipment for domestic and international display clients, and autonomous mobile robots for smart factories and logistics warehouses.	38	NM	NM	0.9

Source: Bloomberg Finance L.P

Figure 35: Korea Humanoid selected names

Country	Company	Product
Korea	Hyundai Autoever Corp	Software-Defined Factory (SDF) Integration:
Korea	Samsung SDI Co Ltd	Supplier
Korea	Kia Corp	Humanoids Integration/ Parent Co Exposure
Korea	Hyundai Motor Co	Humanoids Integration/ Investments
Korea	Rainbow Robotics	Humanoid Robot
Korea	HD Hyundai Robotics	Robot
Korea	AeiROBOT	Humanoid Robot
Korea	WIRobotics	Humanoid Robot
Korea	ROBROS	Humanoid Robot
Korea	Holiday Robotics	Humanoid Robot
Korea	Doosan Robotics	Robot
Korea	Hanwha Robotics	Robot

Source: J.P. Morgan.

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India - Automotive Industry and Humanoid Value Chain (covered by Amyn Pirani)

India's humanoid industry includes a handful of unlisted companies developing humanoid and quadruped robots; however, much of the near-term momentum is likely to come from parts suppliers that can help manufacturers drive cost efficiencies across the supply chain. Sona Comstar, a technology-focused auto component supplier, plans to enter the humanoid supply chain by developing humanoid motors and robot actuators. It has entered into a strategic partnership with Germany-based NEURA Robotics to jointly develop and industrialize advanced robotics and humanoid technologies. The partnership should leverage Sona's precision engineering and manufacturing capabilities alongside NEURA's expertise in cognitive robotics. Sona is also investing US$6.5mm in a robotics components manufacturing facility to produce components and systems for advanced robotics applications. Building on its driveline and motor capabilities, Sona is targeting 53-60% of the total BOM cost of a humanoid robot by supplying components such as frameless torque & coreless motors, planetary roller screws, and reducers & gears. India also has a few unlisted companies, such as General Autonomy and Addverb Technologies, developing humanoid and quadruped robots for general-purpose and industrial uses. Addverb Technologies is backed by Reliance Industries with a ~US $132mm investment for a 54% stake, while General Autonomy has recently raised ~US $3.4mm to develop multi-tasking robots, with the broader goal of making robotics more affordable and scalable.

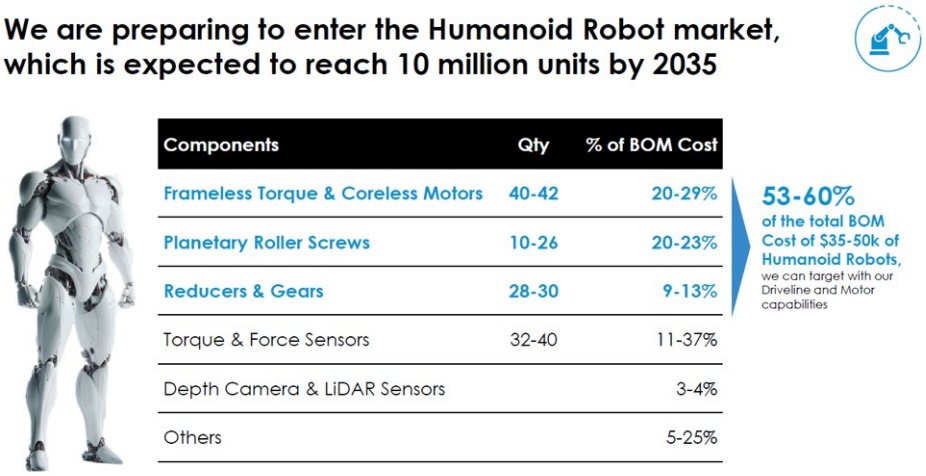
Figure 36: India Humanoid selected names

Company	Country	Listed	Product	Description
Sona Comstar	India	Yes	Potential supplier	Sona is a technology-focused auto component supplier that operates in the segments of differential gears, starter motors and EV motors/control units. Company is planning to enter Humanoids supply chain by developing Humanoid Motors and Robot Actuators.
General Autonomy	India	No	Humanoid and quadruped robots	The startup is working on developing multi-tasking robots capable of navigation, manipulation, and cleaning and handling tools, with the broader goal of making robotics more affordable and scalable. In May 2026, it raised ~US$3.4mm at ~US$29.4mm valuation.
Addverb Technologies	India	No	Humanoid and quadruped robots	Addverb is a robotics company, offering innovative warehouse automation solutions with intelligent robots. In Jan 2022, Reliance acquired 54% Stake In Addverb Technologies For US$132mm valuing the company at US$270mm then.

Source: J.P. Morgan.

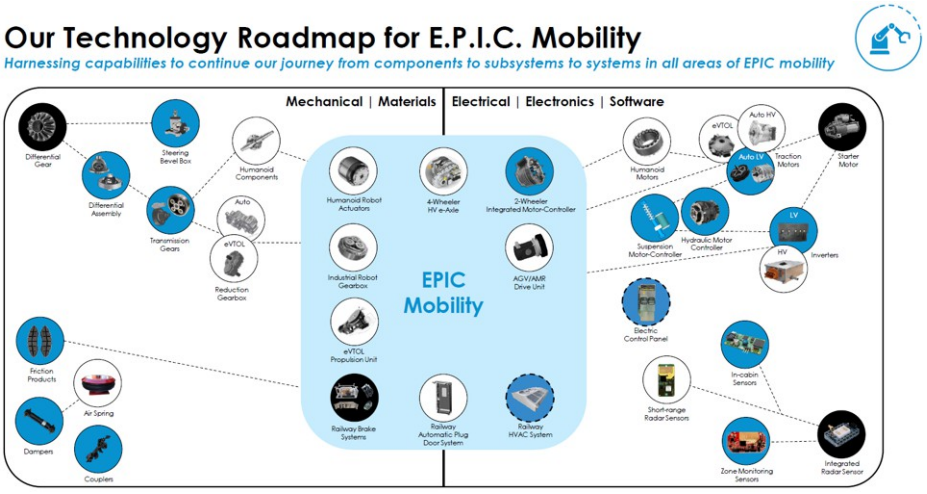
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Figure 37: Sona Comstar: To target 53-60% of total BOM cost of Humanoid Robots



Source: Company data; 4QFY25 Earnings presentation

Figure 38: Sona Comstar: Future products include Humanoid Motors and Robot Actuators



Source: Company data; 4QFY26 Earnings presentation

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Is the EV/Autonomy Cars Playbook common for Humanoids?

Elon Musk first made this comparison during Tesla's AI Day on August 19, 2021, when he initially unveiled the concept of the Tesla Bot. He explained that a humanoid robot is essentially "like an autonomous car"on legs because both rely on the exact same underlying artificial intelligence platform.

We think there is high commonality between humanoid robots and electric/autonomous vehicles. The main technology parts like power, sensors, computing, and control can be used in both robots and vehicles, which helps lower costs and speeds up development. Car makers with EV and AV experience can reuse batteries, cameras, chips, and software for humanoid robots. This gives them a big advantage, making it easier and faster to build safe and capable robots.

1. **Batteries and Power Systems:** Both use lithium-ion battery packs for energy storage and runtime as it reduces R&D costs, EV-scale production lowers prices for humanoid batteries.
2. **Computing Power Chips (AI Processors and Controllers):** High-performance SoCs/GPUs for AI inference, like NVIDIA Jetson or Tesla’s FSD chips, handle real-time processing in both applications.
3. **Cameras and Vision Systems:** RGB-D depth cameras provide 3D mapping and object recognition. As proven in harsh conditions for cars, they enhance humanoid reliability indoors and outdoors.
4. **Sensors (IMUs, Force/Torque, Ultrasonic):** Inertial Measurement Units (IMUs) track motion and orientation in both applications. Force and torque sensors monitor interactions (e.g., grasping in humanoids, suspension in EVs). Ultrasonic and proximity sensors aid collision avoidance. Humanoids add tactile fingertip arrays, but the core multisensory tech (e.g., radar for some models) overlaps with EV safety systems. We also think that sensor fusion algorithms from EVs can improve humanoid stability and interaction.
5. **LiDAR (Light Detection and Ranging):** Used for precise 3D mapping in some humanoids. EV advancements in weather-resistant LiDAR boost humanoid performance in dynamic environments.

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Table 1: Areas of Overlap: Humanoids vs. EVs/Autonomous Vehicles

Subsystem	Representative EV Components	Representative Humanoid Components
Batteries and Power Systems	400–800V packs; module/pack BMS; liquid cooling plates; HV contactors; DC-DC converters	48–52V packs; compact BMS; heat spreaders; quick swap/back mounted packs
Computing Power Chips	AV/ADAS compute (SoCs/GPUs), safety MCUs, domain controllers, vehicle Ethernet	Head/torso AI module, gait controller, arm/hand controllers, joint MCUs, safety supervisor
Cameras and Vision Systems	Front/rear/side cameras; surround view; HDR sensors; heated housings	Head-mounted stereo; chest RGBD; wrist cameras for grasping; protective domes
Sensors	6-axis IMUs; short range ultrasonics; 77/79 GHz radar; load cells	High-grade torso IMU; foot force/torque; fingertip tactiles; proximity sensors on limbs
LiDAR	Roof/fender solid state LiDAR; long range units	Head or shoulder mounted solid-state LiDAR; short to mid range 360° mapping
Motors, Actuators, and Power Electronics	Traction motors; e axle inverters; EPS/ steer actuators; DC-link caps; gate drivers	Joint BLDCs with harmonic drives; shoulder/hip torque dense actuators; miniature inverters; brake/ clutch modules
Materials, Structures, and Manufacturing	Gigacastings, extruded crash beams, sealed enclosures, automotive connectors	Torso/limb frames, swappable panels, sealed joint housings, quick-service connectors
Software, AI, and Tooling	AV simulators, OTA, safety monitors, telematics, data labeling tools	Robot simulators (locomotion/manipulation), OTA for control stacks, telemetry dashboards, safety supervisors

Source: JPM

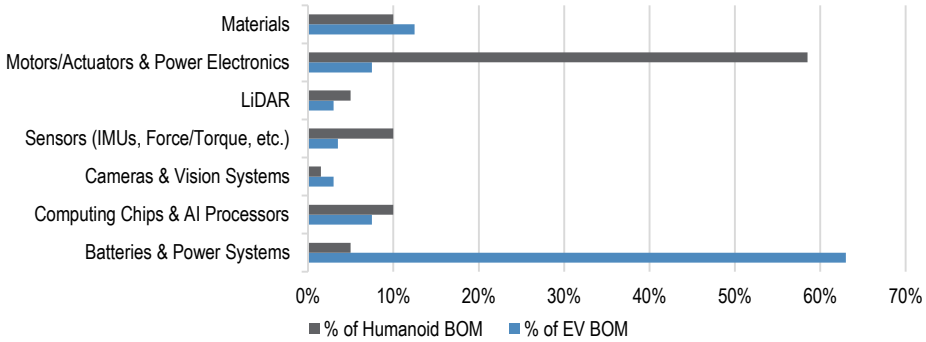
Estimated BOM Overlap and Cost Implications

We see an overlap between humanoid BOM value which can be attributed to EV/ autonomy-shared components today, with higher potential for vertically integrated players reusing batteries, compute, cameras, and inverters. Some notable examples:

- **Battery/Power:** Low single-digit share of humanoid BOM cost but with high reuse of EV tech and strong economies of scale.
- **Compute/Sensors/Vision:** Mid-teens share is plausible where automotive-grade ADAS compute and camera suites are repurposed, given silicon and optics intensity.
- **Actuation/Power Electronics**: Partial overlap given precision requirements; however, inverter/control electronics and motor IP are significantly reusable.

As EV components commoditize and humanoid volumes rise, we could see higher commonality, especially under common suppliers and harmonized standards.

Figure 39: Shared BOM Cars vs. Humanoids



Source: JPM

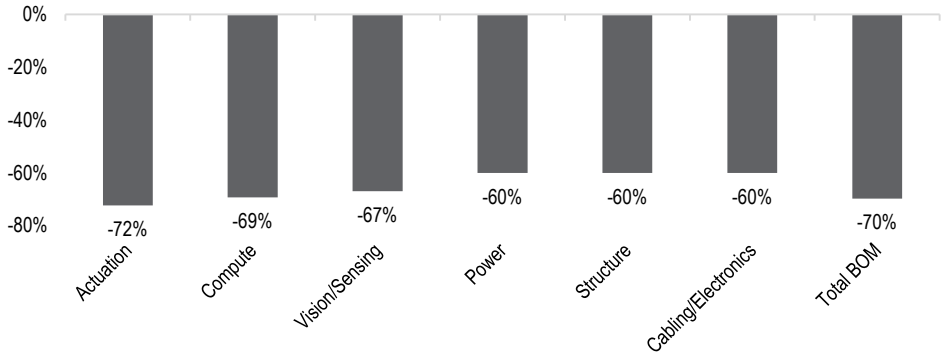
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Path to Affordability

In our view, moving to mass production does three big things at once: 1) costs fall as teams climb the learning curve, especially for actuators; 2) fewer, larger suppliers and long-term contracts push down prices for chips and sensors; 3) standardized designs make wiring, mechanics, and software easier to build and test. As these benefits add up, we expect the cost mix to shift away from expensive actuators toward more affordable compute and sensors, even while total costs keep dropping, meaning the product becomes more about software and less about bespoke hardware. For investors, the signals to watch are: how much actuator manufacturing is brought in-house, how suppliers are split between Asia and the rest of the world, and whether companies are sticking with stable, standardized modules that can deliver high yields without compromising safety or performance.

We believe that at mass production, the total BOM could decline by ~ 70%. The largest step-downs are in actuation (−72%), compute (−69%), and vision/sensing (−67%), with additional reductions across power (−60%), structure (−60%), and cabling/electronics (−60%). The net effect is a shift from prototype pricing to volume pricing, with actuators no longer the dominant cost driver.

Figure 40: Reduction of BOM by Category Once Mass-Production Kicks Off



Source: J.P. Morgan estimates.

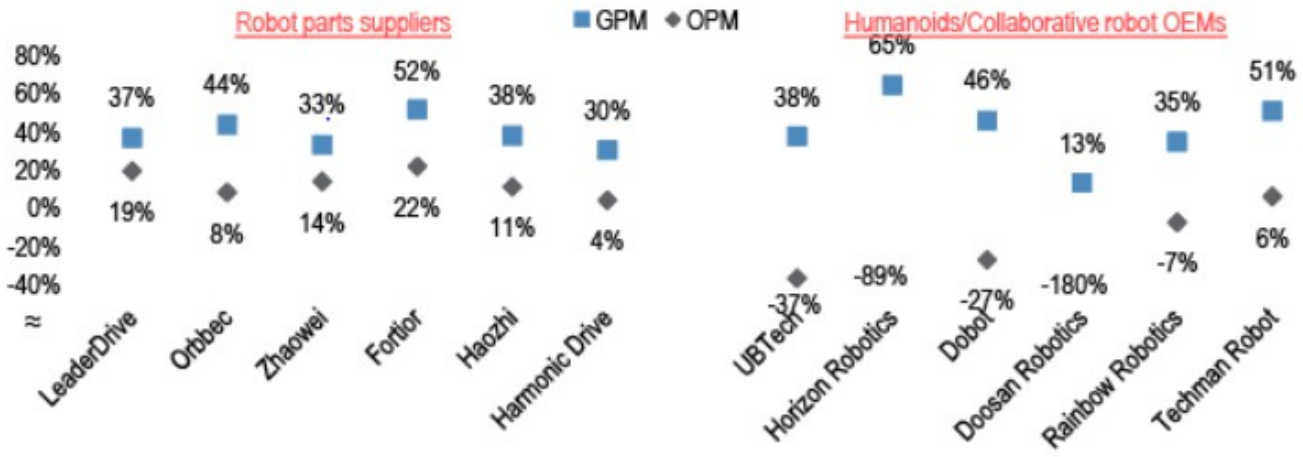
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Current robotics supply chain structure: humanoid will reshape the supply chain landscape (Sonny Lee, Korea Autos analyst)

Today's robotics supply chain shows an interesting dispersion in margin profiles

Traditional industrial robot OEMs sustain decent OP margins (9-21%) on scale and relatively contained R&D/marketing expenses, since it is a largely mature market and there is little need for further step-change advancements in their products. In contrast, collaborative robot players (many of which are expanding toward humanoids) are usually bearing outsized R&D burdens (invested for application engineering, safety validation, integration tooling) without sufficient scale, resulting in weaker profitability (-180-6% OPM). Robot component suppliers are currently in a favorable position, generating a 4-22% OPM. This is led by: 1) competition remaining relatively benign; 2) customer pools are broader across different types of robot OEMs; 3) longer product lifecycles once qualified; and 4) limited incremental engineering and R&D costs per customer.

Figure 41: Robotics supply chain companies GPM/OPM status (2025)



Source: Bloomberg Finance L.P.

We expect two-phase margin dynamics between the OEMs and component suppliers

- **Why Actuators Can Hold Early-Cycle Leverage.** In the early stages of mass production, higher quality components are essential for robot performance, before software and AI mature enough to compensate for more standardized and simplified hardware. At this stage, the binding constraint is not unit cost but whether suppliers can deliver parts at scale, with consistent quality and on schedule. Therefore, Humanoid OEMs will prioritize component partners that can: 1) meet stringent reliability requirements in real-world operating conditions; 2) su in high-volume manufacturing; and 3) enable rapid design iterat environment, actuator suppliers can build leverage by defining r electrical interface standards and calibration procedures.
- **Why robot OEMs' power will likely increase over time.** As th mass production standards are established, the robot OEM beco owner, controlling end-to-end performance by optimizing hardw



and software updates. On a larger scale, OEMs can increase their bargaining power by: 1) adding second sources; 2) tightening control over specifications; 3) "de-speccing" components where software can compensate; and 4) standardizing platforms in ways that commoditize parts without clear differentiation.

Humanoid component suppliers are in a delicate position

To ride the rapidly expanding addressable market that humanoids could create, component suppliers are being asked to actively support standardization and cost-reduction efforts, even though those initiatives seem like they threaten suppliers' bargaining power. However, in reality, this is not necessarily a contradiction. We use actuators as an example, which are the main focus of our following discussion: today, actuator manufacturing is often organized around high-mix, low-volume production, which is inherently inefficient. The actuator market is highly fragmented, with players adopting designs they each deem "optimal," and standardization remains limited even within a single robot, meaning a single humanoid often incorporates several different types of actuators. If suppliers can shift toward low-mix, high-volume production while improving automation and throughput, they can capture strong top-line growth while still protecting profitability through scale and manufacturing efficiency.

Robotis (108490 KS, NC), a pure-play Korean robot actuator supplier, illustrates the current inefficiencies of early-stage manufacturing. The company produces a wide range of actuators tailored to different robot joints, which still requires significant manual labor in assembly. While reducer gear machining is largely automated via CNC milling machine, sub-component alignment and final assembly remain predominantly manual. As a result, Robotis' labor costs have remained elevated at ~35% of operating costs over the last five years (2021-25). We believe this high labor cost structure is currently typical across actuator manufacturers, reflecting the high-mix, low-volume nature of the business. Across the industry as a whole, labour costs should decline over time as designs become more standardized and assembly processes become more automated.

Humanoid actuators entering mass production: how to deliver cost cuts while protecting margins

Actuators are likely a near-term bottleneck and the key to mass market humanoids

Among robot components, we see actuators as: 1) the most likely near-term supply bottleneck; and 2) a key to mass market entry of humanoids, considering: 1) high content per humanoid (30-60 units per robot) and 2) significant BOM contribution (>50% at the prototype stage). 3) Supply chains are likely to face limited capacity flexibility, as many suppliers are still geared toward automotive actuators and have yet to retool meaningfully for robotics-specific actuators. In contrast, many other components can be sourced more readily from the broader electronics supply chain (controllers, cameras, sensors, batteries, etc).

From diverse, prototype-era designs, to a QDD-dominant, standardized architecture

We believe that today's humanoid prototypes often use a mix of actuator types. At a high level, designs split between linear vs. rotary actuators; within rotary, common options include QDD (quasi-direct drive) with planetary reducers, as well as harmonic/cycloidal drive actuators. Robot OEMs typically mix-and-match the use of different joints to maximize performance. However, as the industry moves from engineering prototypes to mass production, we expect: 1) a larger share of the market to shift toward simpler QDD

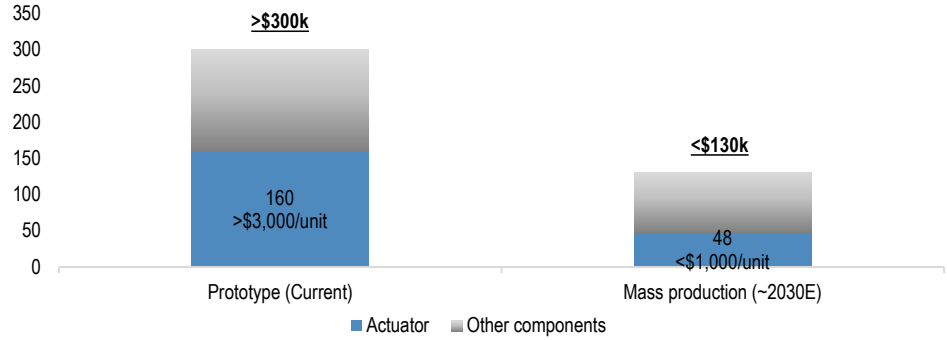
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designs; and 2) fewer actuator variants per humanoid model as standardization increases.

This matters because we see actuators as the largest driver of humanoid cost-down. Using HMG's humanoid as an illustrative case, we estimate a >$300k/unit prototype BOM could decline to <$130k/unit at an early mass production stage: actuator cost alone could fall from $160k (>$3,000 per actuator) at the prototype stage to $48k (< $1,000 per actuator), implying ~70% cost-down. Key drivers include:

- **Shift toward low-cost, scalable actuator architectures.** Humanoid developers are increasingly moving away from expensive linear actuators and high-ratio harmonic/ cycloidal drive systems towards low-ratio QDD systems. While sacrificing some mechanical precision, these designs are significantly cheaper, easier to manufacture at scale, and better suited for mass-market humanoid deployment.
- **Drive economies of scale through actuator standardization.** Scaling humanoid production will require convergence toward a small number of standardized actuator sizes and designs across multiple joints. For example, HMG indicated plans to utilize only two actuator types across ~30 joints (excluding hands), demonstrating how platform standardization can reduce complexity, shorten development cycles, simplify manufacturing ramp up, and lower unit costs.
- **Use software to compensate for mechanical limitations.** Humanoid actuator design is evolving from a hardware-centric approach focused on "mechanical perfection" toward a software-centric control philosophy. Rather than relying on ultra-precise, near-zero-backlash reducers, developers increasingly leverage high-speed sensing, torque feedback, high-resolution encoders, embedded compute, and AI-driven control algorithms to compensate for mechanical non-idealities. This enables acceptable precision and stability using simpler, lower-cost hardware while improving manufacturability and scalability.

Figure 42: HMG humanoid BOM cost breakdown: actuator cost-down is the key lever for overall cost reduction



Source: Company data, J.P. Morgan estimates

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Humanoid addressable market: a rapidly changing industry

When estimating the total addressable market for the Humanoid we have considered different scenarios which include end markets across industries, agriculture, services and household amongst other activities. We foresee that non-household applications will most likely develop earlier before the more complex requirements of the household are met. We forecast the Humanoid market will reach several mn units globally by 2030, and depending on the cost degressions, hand dexterity development and applications across end markets, we could see the market rise rapidly towards >40mn units by 2035 and >70mn units by 2040. Xpeng's Chairman and CEO, Mr.He Xiaopeng, guided for an optimistic outlook for the humanoid robotic industry during a media interview on Nov 5. He projects the market could reach US$20 trillion in the next 10-20 years, with the number of humanoid robots potentially exceeding 200mn, surpassing the scale of the US$10 trillion global automotive market with 90mn cars produced annually. We will follow closely the technology developments in the industry to further refine the estimate. Downside risks to the forecast could be related to the maintenance costs required for a Humanoid in Household applications, later technological in development of the Humanoid or also industrial applications such as robots on wheels with very limited hand dexterity which would lower the cost but would not fall under the strict category of Humanoid as such. We believe that despite the difficulties when looking to address the TAM 10 years out, we are very encouraged by the rapid pace of change in the industry. In particular, the evolution of the hand dexterity over the past quarter at Tesla is a clear example of the rapid pace of change in the industry.

Quantitative guidance from humanoid leaders

- **Tesla** plans to enter formal production of Optimus V3 in 3Q26, with a mid-term target of **1mn units/year by 2030**. The CEO Elon Musk will receive a >$1tn compensation package if he hits a list of ambitious targets over the next decade, including the sale of a mn artificial intelligence robots.
- **Hyundai Motor Group** aims to begin mass production of humanoids with **a 30k units/year production capacity in 2028.**
- **Figure AI** is targeting production of **100k units over the next four years (~2029).**
- **Unitree** targets ~20k units for 2026, nearly 4x its 5.5k+ units produced in 2025, with **5-year humanoid capacity target of 75k units/year.**
- **UBTECH** (covered by Karen Li) raised its **Walker 2026 shipment target** from 2-3k to **5k units** with **capacity** scaling towards **10k**, alongside a broadening product roadmap that includes **retail and household robots** set to launch in 2Q26, targeting another **10k capacity / 5k delivery** scenario.
- **Xpeng's** Iron is set to enter mass production by end-2026 with a **monthly target of 1k+ units,** expanding to **over 10k units/year** capacity by end-2027.
- **Agibot** saw over 5k unit shipments in 2025, with a ~4x increase so far in 2026, shipping 5k units in just the first few months of the year (~20k annualized).

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Regulations in the Humanoid Robot Industry

Regulations vary by region, focusing on safety, ethics, and national security. Humanoids often fall under broader AI/robotics frameworks, with emerging specific standards.

United States: Oversight emphasizes national security and safety. The Humanoid Robot Act of 2025 prohibits federal agencies from procuring humanoids from adversarial nations like China, Russia, Iran, or North Korea, to protect data and economic strength. OSHA standards, including ANSI/RIA R15.06 for industrial robots, require risk assessments and safety protocols; collaborative robots follow TR 606. IEEE is pushing for humanoid-specific standards addressing stability and privacy. Privacy frameworks for embodied AI draw from state/federal laws, recommending cybersecurity best practices. A proposed National Commission on Robotics aims to boost competitiveness via policy recommendations.

Europe: A risk-based approach prevails under the AI Act, classifying humanoids as high-risk if used in healthcare or employment, requiring transparency and human oversight. The Machinery Regulation (EU 2023/1230), effective 2027, mandates safety for autonomous machines like collaborative robots (cobots), including cybersecurity and ethical design. ISO standards (e.g., 10218) address human-robot interactions, emphasizing no exceptions for industrial use. Roboethics policies promote complementing humans, not counterfeiting them, with bans on unacceptable risks like social scoring. Parliamentary resolutions stress forward-looking rules for health, safety, and dignity.

China: Governance prioritizes ethics and state control. Shanghai's 2024 Guidelines for Humanoid Robot Governance require safeguarding dignity, risk warnings, and legal compliance, akin to updated "Laws of Robotics" with 24 rules prohibiting harmful content. National standards for technical requirements (e.g., perception, control) were approved in 2025, led by MIIT's standardization committee to enhance competitiveness and ethics. Goals include global leadership by 2025, with vague targets for mass production, emphasizing safety baselines without stifling innovation.

South Korea: Regulations to integrate robots into society safely. The Intelligent Robots Act and Road Traffic Act (amended 2025) grant certified humanoids (under 500 kg, max 15 km/h) pedestrian status on sidewalks, requiring insurance and operator accountability for violations. The AI Act (effective 2026) mandates human oversight in high-impact sectors like healthcare, labeling for generative AI, and safety assessments via an AI Safety Institute. The law balances innovation with safeguards, though startups note that vague language may burden compliance.

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Latest transactions announced in the space

Agility Robotics' Public Offering (June 2026): Agility announced a $2.5 billion SPAC merger with Churchill Capital Corp XI. The transaction, which is expected to provide $620 million in gross proceeds, positions Agility as one of the first publicly listed pure-play humanoid companies.

Hyundai Motor Group acquired SoftBank's remaining 9.65% stake in Boston Dynamics for $325 million. This buyout makes Boston Dynamics a 100% wholly-owned subsidiary of Hyundai, allowing the automaker to fully integrate the robotics firm into its core electric vehicle (EV) manufacturing and logistics arms without minority shareholder friction.

Unitree Robotics: Unitree filed for a Shanghai STAR Market IPO in March 2026, seeking to raise ~CNY 4.2bn ($608mn) at a targeted valuation of ¥40–50bn (~$5.7–7bn) — roughly 3–4x its June 2025 Series C round of ¥12.7bn led by Alibaba, Tencent and Geely.

Figure AI (Series C): Figure raised $1bn in September 2025 at a $39bn post-money valuation with Intel, NVIDIA, Qualcomm, Salesforce and Brookfield participating, a ~15x step-up that makes it the most richly valued pure-play humanoid company. The follow-on talks are reportedly on for $1.5bn at~$39.5bn, underpinned by commercial traction at BMW (1,250+ runtime hours, 90,000+ parts loaded).

Apptronik (Series A extension): Apptronik closed a $520mn Series A extension in February 2026, taking the round past $935mn and total funding to~$1bn at a ~$5.5bn valuation. Backers now include Google, Mercedes-Benz, AT&T Ventures and John Deere, a strategic investor base that doubles as a deployment pipeline for its Apollo humanoid.

NEURA Robotics (Series C): Germany's NEURA secured a Series C worth up to $1.4bn (milestone-contingent) in June 2026, led by Tether with Qualcomm, Amazon, Nvidia, Bosch, Schaeffler and the EIB, at a valuation of ~$7bn. The round makes it Europe's flagship humanoid bet, reinforced by an AWS partnership and Schaeffler's plan to integrate thousands of NEURA robots by 2035.

UBTech: UBTech trades at a market cap of ~HK$54bn (~$7bn) as the sector's only mature listed pure-play, despite a RMB 790mn loss in 2025 on RMB 2bn revenue. It ranked #1 globally in full-size humanoid shipments and entered the MSCI China Index in November 2025.

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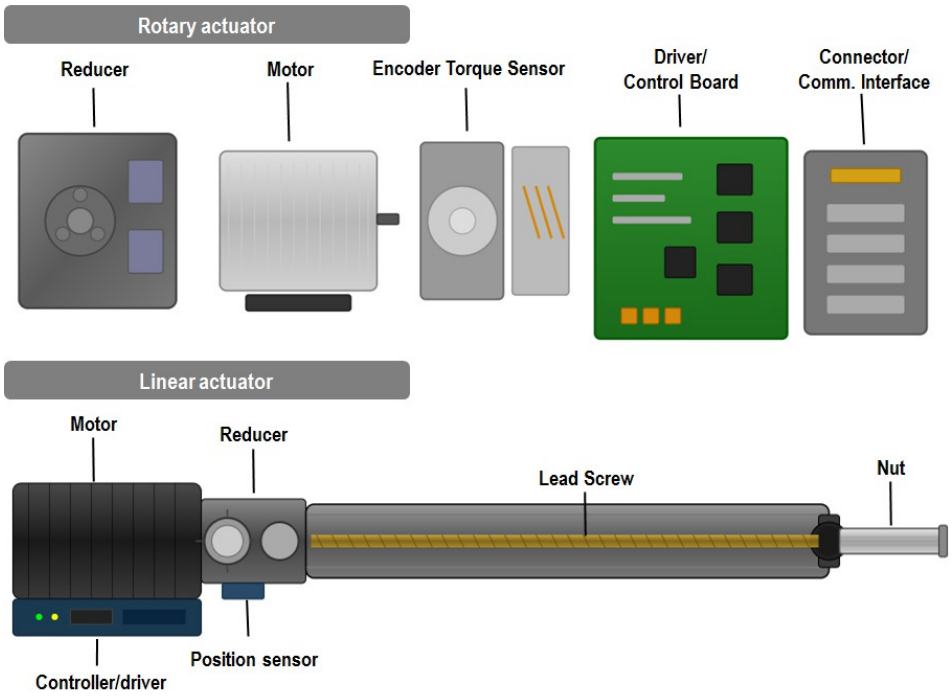
APPENDIX

Actuators: Structure and Key Types (Sonny Lee)

An actuator is an electromechanical system that converts electrical energy into controlled motion and force, enabling a robot joint or mechanism to move. Physically, it consists of a motor, reducer (also called gearbox), sensors/encoders, motor drive electronics, and control software (integrated into a single unit that delivers controlled motion and torque).

Actuators can be broadly categorized into: 1) linear actuators, which generate motion along a straight line, and 2) rotary actuators, which generate rotational motion around a joint axis. Rotary actuators can then be further classified by the type of reducer used to convert motor speed into usable torque. Common architectures include: 1) harmonic drive actuators; 2) cycloidal drive actuators; and 3) QDD actuators, which typically employ low-ratio planetary reducers.

Figure 43: Rotary actuator vs. Linear Actuator: Differences in Process



Source: J.P. Morgan

Table 2: Rotary actuator vs. Linear Actuator: Key Characteristics

	Rotary actuator	Linear actuator
Primary motion	Rotational motion	Linear motion (push/pull)
Typical structure	Motor + Reducer	Motor + Reducer + Ball/Roller screw
Advantages	Fast response, compact structure, easy to control	High thrust, precise positioning, strong stiffness
Negative	High torque requires larger gearbox or more sophisticated reducer (cycloid/harmonic)	Heavier form factor, limited speed
Backlash	Depends on reducer	Very low
Backdrivability	Usually higher	Usually low (especially ball screw)
Efficiency	Generally higher	Affected by screw friction (ball screw is better)
Applications	Shoulder, elbow, wrist, neck, waist	Knees, ankles
Cost	Usually higher due to precision screw manufacturing	Usually lower (especially ones with planetary reducer)

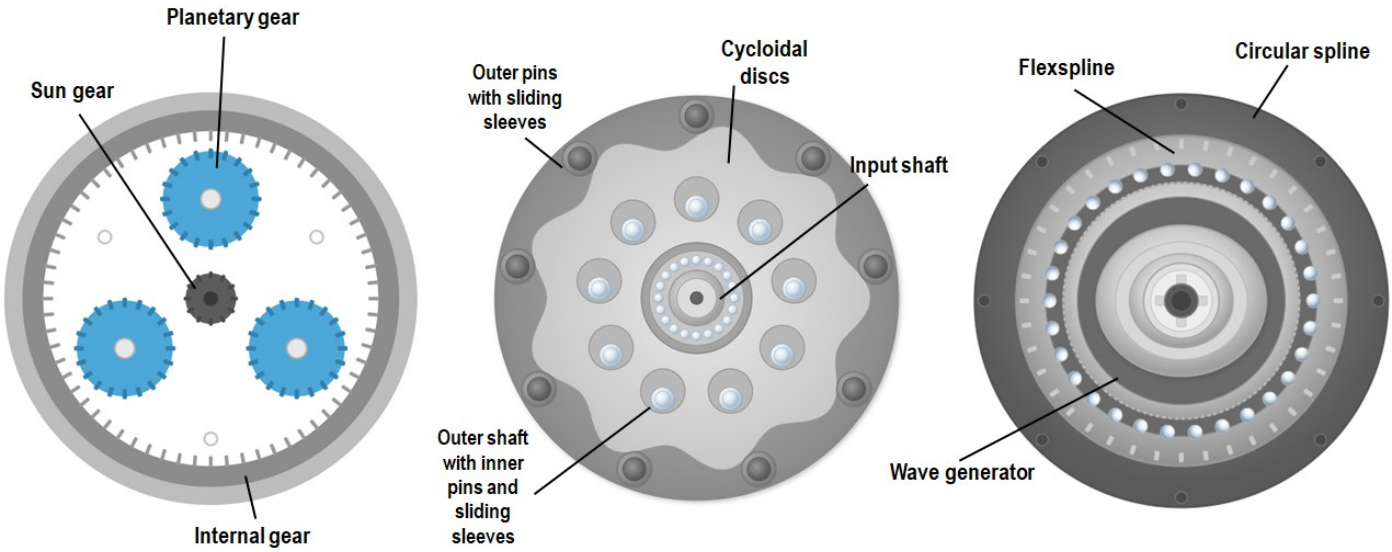
Source: J.P. Morgan

Table 3: QDD actuators* vs. cycloidal-based/ harmonic-based actuators

	QDD with planetary reducer	Cycloidal-based actuator	Harmonic-based actuator
Gear ratio	Low (1:<10)**	High (1:>30)	High (1:>50)
Torque	Relatively low (depends on the motor's torque)	High	High
Backlash	Present (requires sensor compensation for precision)	Low (not as much as harmonic-based actuator)	Very low (enables ultra-precise control)
Backdrivability	Very high (passively absorbs external impacts smoothly)	Low	Very low (highly resistant to backdriving by external forces)
Impact resistance	Sturdy (robust structure ensures high durability against external shock/motion)	Very sturdy (torque and shock loads are distributed across many simultaneous contact points)	Weak (thin flexspline is susceptible to tooth damage from shocks)
Production cost	Relatively low (simple structure)	Medium to high	High (requires high-precision manufacturing)

Note: *QDD actuators typically use planetary reducers, **Gear-ratio can increase with multi-stage reducers
Source: J.P. Morgan

Figure 44: Planetary vs. Cycloidal vs. Harmonic reducer (from left to right): differences in mechanism



Source: J.P. Morgan

Why QDDs (with planetary reducer) are structurally advantageous for humanoids

Traditional industrial robots are designed for highly precise tasks. In applications like CNC (computer numerical control) milling, tolerances can be so tight that even a few micrometers of deviation is unacceptable. However, humanoids intended for human-oriented tasks require different joint characteristics. They need backdrivability (how smoothly an external force can move the output shaft, or how "pushable" the joint feels) and can tolerate some backlash (the free rotational play before the output responds when reversing direction). While high precision is still desirable, ultra-high precision is not essential for many tasks humanoids are likely to perform. Instead, a key requirement is robustness: humanoid joints must withstand shocks and dynamic motion and remain reliable over long operating hours to maximize uptime.

QDD actuators, typically combining a high-torque motor with a low-ratio planetary reducer to achieve near direct-drive behavior, fit humanoid needs well:

- **Human-like motion requirements.** Planetary-based QDD can provide the balance of torque, responsiveness, and "near direct-drive" feel.
- **Cost and manufacturability.** The structure is relatively straightforward, enabling lower-cost production and easier standardization.
- **Backdrivability and robustness over ultra-precision.** Many humanoid tasks can tolerate some backlash, while prioritizing joints that are "pushable," shock-tolerant, and reliable over long duty cycles.

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Companies Discussed in This Report (all prices in this report as of market close on 24 July 2026, unless otherwise indicated)
HL Mando(204320.KS/W44,600/N), Honda Motor (7267)(7267.T/¥1,536/N), Hyundai Mobis(012330.KS/W483,000/OW), Hyundai Motor Company(005380.KS/W397,000/OW), Mitsubishi Motors (7211)(7211.T/¥347/UW), Nissan Motor (7201)(7201.T/¥322/N), Toyota Motor (7203)(7203.T/¥2,897/OW)

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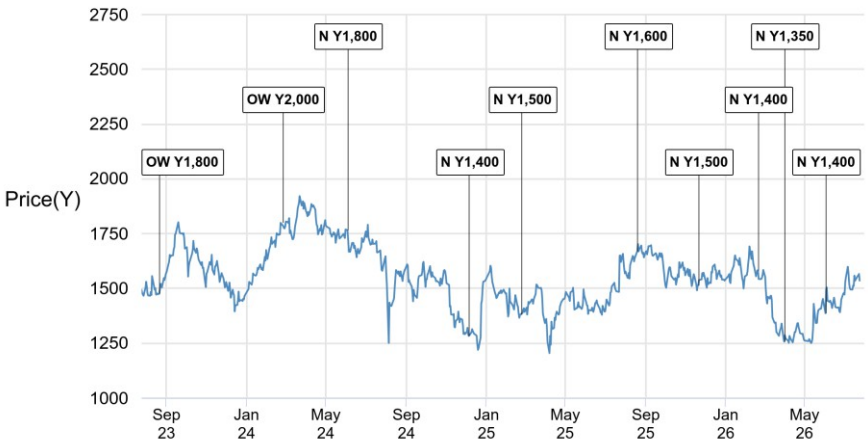
HL Mando (204320.KS, 204320 KS) Price Chart



Source: Bloomberg Finance L.P. and J.P. Morgan; price data adjusted for stock splits and dividends.
Initiated coverage Oct 07, 2014. All share prices are as of market close on the previous business day.
Break in coverage Apr 25, 2025 - Jun 19, 2026.

Date	Rating	Price (W)	Price Target (W)
27-Oct-23	OW	35700	52,000
06-Dec-23	OW	34900	50,000
06-Feb-24	OW	36850	45,000
11-Jun-24	N	46750	50,000
26-Jul-24	OW	39000	50,000
19-Jun-26	UW	69200	50,000
07-Jul-26	N	49700	50,000

Honda Motor (7267) (7267.T, 7267 JP) Price Chart



Source: Bloomberg Finance L.P. and J.P. Morgan; price data adjusted for stock splits and dividends.
Initiated coverage Jul 15, 2002. All share prices are as of market close on the previous business day.

Date	Rating	Price (Y)	Price Target (Y)
22-Aug-23	OW	1476	1,800
26-Feb-24	OW	1800	2,000
04-Jun-24	N	1766	1,800
06-Dec-24	N	1284	1,400
25-Feb-25	N	1380	1,500
20-Aug-25	N	1669	1,600
21-Nov-25	N	1514	1,500
20-Feb-26	N	1582	1,400
01-Apr-26	N	1258	1,350
03-Jun-26	N	1387	1,400

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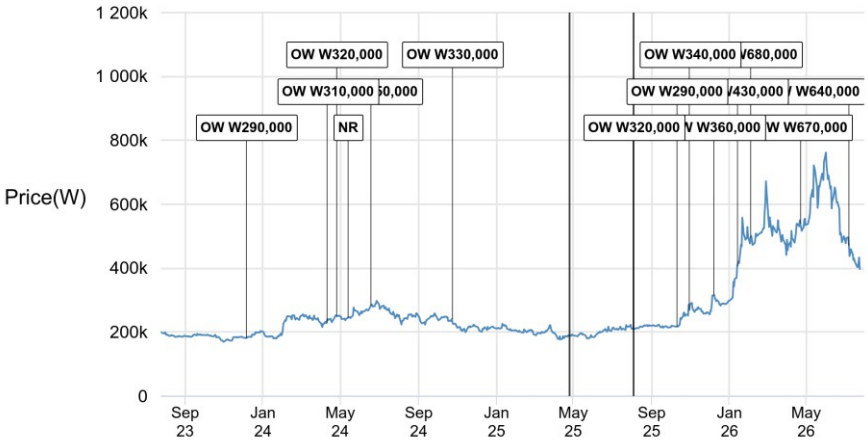
Hyundai Mobis (012330.KS, 012330 KS) Price Chart



Source: Bloomberg Finance L.P. and J.P. Morgan; price data adjusted for stock splits and dividends.
Initiated coverage May 02, 2001. All share prices are as of market close on the previous business day.
Break in coverage Apr 25, 2025 - Jun 19, 2026.

Date	Rating	Price (W)	Price Target (W)
28-Jul-23	OW	234000	290,000
28-Oct-23	OW	220000	300,000
06-Dec-23	OW	225000	310,000
26-Jan-24	OW	209500	280,000
26-Apr-24	OW	244000	300,000
25-Oct-24	OW	250000	330,000
19-Jun-26	N	606000	710,000
07-Jul-26	OW	512000	710,000

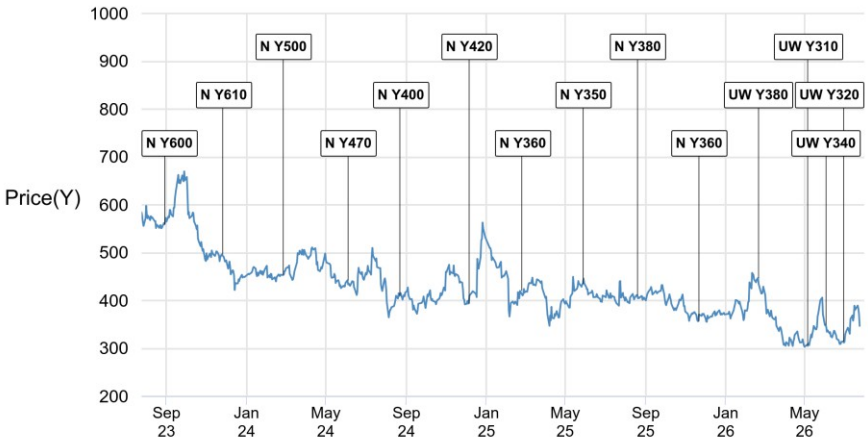
Hyundai Motor Company (005380.KS, 005380 KS) Price Chart



Source: Bloomberg Finance L.P. and J.P. Morgan; price data adjusted for stock splits and dividends.
Initiated coverage Jun 14, 2000. All share prices are as of market close on the previous business day.
Break in coverage Apr 25, 2025 - Aug 04, 2025.

Date	Rating	Price (W)	Price Target (W)
06-Dec-23	OW	181400	290,000
11-Apr-24	OW	228000	310,000
26-Apr-24	OW	250000	320,000
14-May-24	NR	245000	--
19-Jun-24	OW	283000	350,000
24-Oct-24	OW	241000	330,000
04-Aug-25	OW	210000	320,000
11-Oct-25	OW	217000	290,000
31-Oct-25	OW	269000	340,000
08-Dec-25	OW	314500	360,000
14-Jan-26	OW	406500	430,000
04-Feb-26	OW	494500	680,000
23-Apr-26	OW	540000	670,000
08-Jul-26	OW	471000	640,000

Mitsubishi Motors (7211) (7211.T, 7211 JP) Price Chart



Source: Bloomberg Finance L.P. and J.P. Morgan; price data adjusted for stock splits and dividends.
Initiated coverage Dec 17, 2014. All share prices are as of market close on the previous business day.

Date	Rating	Price (Y)	Price Target (Y)
30-Aug-23	N	559	600
27-Nov-23	N	496	610
26-Feb-24	N	454	500
04-Jun-24	N	442	470
23-Aug-24	N	411	400
06-Dec-24	N	394	420
25-Feb-25	N	420	360
29-May-25	N	435	350
20-Aug-25	N	410	380
21-Nov-25	N	357	360
20-Feb-26	UW	447	380
07-May-26	UW	303	310
03-Jun-26	UW	349	340
30-Jun-26	UW	315	320

Nissan Motor (7201) (7201.T, 7201 JP) Price Chart



Date	Rating	Price (Y)	Price Target (Y)
30-Aug-23	N	617	600
27-Nov-23	N	596	650
26-Feb-24	N	570	600
04-Jun-24	N	569	560
23-Aug-24	UW	438	330
07-Oct-24	UW	414	300
25-Feb-25	UW	459	320
29-May-25	UW	359	300
20-Aug-25	N	352	320
21-Nov-25	N	357	360
20-Feb-26	N	450	450
27-Apr-26	N	353	400
30-Jun-26	N	302	350

Source: Bloomberg Finance L.P. and J.P. Morgan; price data adjusted for stock splits and dividends.
Initiated coverage Sep 24, 2002. All share prices are as of market close on the previous business day.

Toyota Motor (7203) (7203.T, 7203 JP) Price Chart



Date	Rating	Price (Y)	Price Target (Y)
30-Aug-23	OW	2432	3,000
27-Nov-23	OW	2803	3,300
26-Feb-24	OW	3521	4,000
23-Aug-24	OW	2665	3,600
07-Oct-24	OW	2615	3,500
06-Dec-24	OW	2632	3,300
25-Feb-25	OW	2706	3,600
29-May-25	OW	2632	3,200
20-Aug-25	OW	2925	3,500
21-Nov-25	OW	3044	3,800
20-Feb-26	OW	3774	4,700
01-Apr-26	OW	3162	4,500
18-May-26	OW	3085	4,100

Source: Bloomberg Finance L.P. and J.P. Morgan; price data adjusted for stock splits and dividends.
Initiated coverage Sep 24, 2000. All share prices are as of market close on the previous business day.

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