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Research

APAC Industrials & US Autos: Humanoid Robot (II): Go big and go home

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Executive summary: Humanoid robot – Go big and go home

2024 was a year of rising **use/testing cases** of humanoids in factories and warehouses. We expect **2025/26** to be years of **accelerated production ramp-up**. Looking beyond, we believe humanoids should proliferate from here, driven by AI (humanoid is **AI in physical form**), increasing proven use cases, and maturing supply chain. In the long term, we think humanoid robot should become a big market worth **US$1tn by 2050** as it penetrates households as well as the hospitality and the manufacturing industries globally.

Mass-production plans led by Tesla, Figure and Agility: Humanoid robot OEMs in the US and China have laid out plans for mass production starting from 2025. We note the production plans are **more aggressive by US OEMs**. Elon Musk (**Tesla**) talked about "a few thousands" units in 2025, 50k-100k in 2026 and 500k in 2027. **Figure** is looking to manufacture 100k humanoids over the next four years. **Agility Robotics** has opened a factory in the US with "hundreds" units capacity in the first year and to scale to 10k units. In China, **UBTECH** expects 1-2k orders in 2025 and **Galbot** targets 10k units in five years. **BYD** expects to deploy 20k humanoids in their factories by 2026.

Real-life use cases accelerating since 2024: Real-life use cases of humanoids accelerated since 2024, adopted mainly by **automotive OEMs and suppliers** (BMW, NIO, Mecedes, Magna, Dongfeng Motor, Geely, BYD, Hyundai, Schaeffler), **logistics and warehouse service owners and providers** (Amazon, Ocado, GXO) and **electronics assemblers** (Foxconn). We believe once humanoids improve their capabilities via real-life learning (data collection and training), the return of investment should become more attractive for customers.

Flourishing number of humanoid OEMs with increasing AI-ties: We categorise the key humanoid OEMs into four groups: **1) independent vendors**: some are start-ups and some originated from making robot dogs like Unitree; **2) AI-based vendors** like Figure; **3) auto OEMs** like Tesla and Xiaomi; and **4) research labs** like Boston Dynamics. **NVIDIA** unveiled their humanoid partners at the CES in early January 2025 featuring 17 channel partners for NVIDIA's Cosmos world foundation model platform. By region, while Japan was the first to develop concept humanoids, most humanoid OEMs now concentrate in the US and China, with some from Canada, Germany, Israel, Norway, the UK and Japan.

Upgrading humanoid market forecast – US$75bn by 2035, US$1tn by 2050: We upgrade our numbers and now forecast the humanoid robot market to reach **US$75bn by 2035 and US$1tn by 2050**, on **5mn/70mn units** and pricing of **US$15k**. While humanoids are currently adopted in factories, we believe the largest end-market for humanoids is homes for general purpose. We assume household penetration of humanoids will catch up with that of passenger vehicles by 2050. There is upside potential as Elon Musk estimates 1,000x more uses for humanoids than cars, although the training needed for humanoids are at least 10x vs cars.

Design and supply chain update: The new dexterous hand of Tesla's Optimus Gen3 has replaced worm drives with screws, resulting in 3-4x number of **screws** used per humanoid **from 14 to up to 48** (the full design of Gen3 is not yet released), in our understanding. Supply chain discussions are being actively held and we believe the potential suppliers are mostly in **China**, **Japan** and **Europe** for the hardware components.

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Executive summary: Humanoid robot – Stock picks

APAC Industrials sector:

Humanoid robot has been **an investment theme** among Chinese investors **since mid-2022** and the related names have gone through **multiple rounds** of outperformance based on news flows. We feel investor interest on humanoid recently picked up since late 2024 and remains strong – the interest level in this round **is the strongest and the broadest** we have seen.

Companies in our APAC Industrials coverage play a role in hardware components with a focus on strain wave reducers (谐波减速器), roller screws (滚柱丝杠) and actuator integration (执行器/关节模组). We **prefer suppliers** that **1)** are in talks with **multiple humanoid OEMs**; **2)** have the **best quality** and **competitive** products; **3) supply screws** as we estimate TAM (total addressable market) for screws for humanoids to be **3x** the TAM for reducers by 2035; and 4**)** could deliver **healthy growth of non-humanoid** business in the near term while humanoid is brewing.

We identify six companies in our coverage that are the most relevant to the humanoid robot theme. Our **order of preference** is: Hengli Hydraulic (Buy, TP Rmb81.7) > Shuanghuan Driveline (Buy, TP Rmb43.6) > Hiwin (Buy, TP NT$416) > Leaderdrive (Hold, TP Rmb172) > Harmonic Drive (Hold, TP ¥4,835) > Sanhua (Hold, TP Rmb36). Of these, Hengli Hydraulic and Shuanghuan Driveline are on our top list for the sector:

- **Hengli Hydraulic** (601100.SS, Buy, TP Rmb81.7): We see large upside from humanoid given the exponential increase in screws used per humanoid (from 14 to up to 48) and higher ASP opportunity for Hengli to supply the whole actuators. The bottomed excavator sales in China are also helpful;
- **Shuanghuan Driveline** (002472.SZ, Buy, TP Rmb43.6): Shuanghuan is co-developing a next-negation reducers for humanoids so has the potential. Its main business automotive gears should benefit from higher ASP opportunity from co-axle gearboxes and smart actuators.

US Autos & Mobility sector:

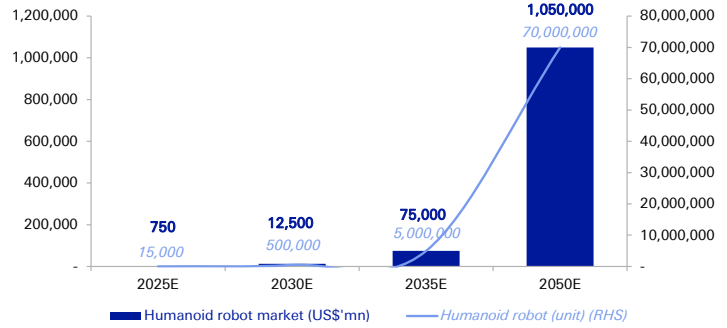
Interest in humanoid robots has continued to grow over the past few quarters from US investors primarily due to Tesla's progress with Optimus. Moreover, such efforts are being underpinned by the belief that advancements in **end-to-end real-world AI** can eventually lead to creation of **generalized humanoids** that can perform a wide variety of tasks. Nearer-term, we think the goal will be to reduce costs by replacing expensive human manual labor in factories which in turn can enable greater onshoring of manufacturing back to the US.

In our coverage, **Tesla** (TSLA, Buy, TP $420) provides the clearest exposure to the investment theme and we expect a few thousand robots to be deployed this year. While the 50k/500k production targets in 2026-27 seem aggressive to us, we view these as directionally achievable given its deep manufacturing/supply chain experience (e.g., Model Y production increased 15x in 3 years) . On the software, similar to robotaxi, Optimus will be trained by large amounts of vision data to essentially learn by watching, suggesting progress will likely not be linear.

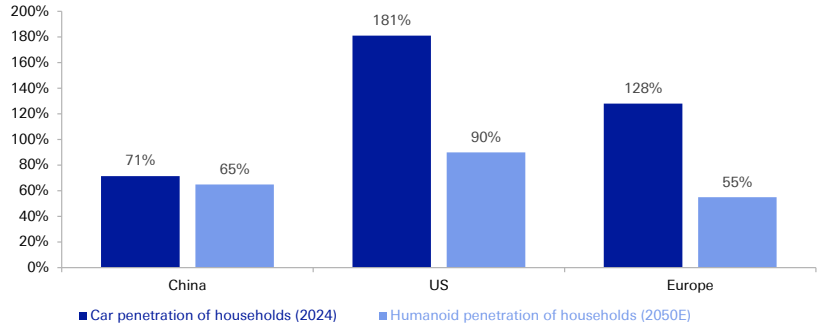
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Key charts

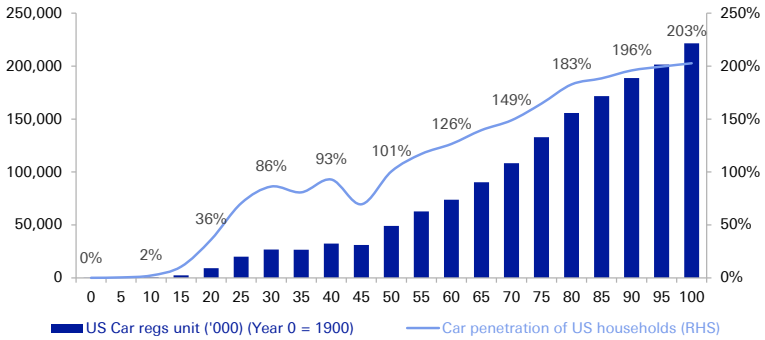
Humanoid robot market to reach US$75bn by 2035 and US$1tn by 2050



We believe households to be the biggest market for humanoids; We use car penetration to derive our assumptions for humanoids for 2050



Car penetration among US households rose quickly to 100% in 50 years, suggesting fast adoption of humanoids is possible



Market size of key hardware components by 2035

Time	Country	Customer	Robot	Robot OEM
Late 2025	US / South Korea	Hyundai	Atlas	**Boston Dynamics**
Jan 2025	China	Foxconn (Hon Hai Precision) (Apple iPhone assembler)	Walker S1	**UBTECH**
Nov 2024	Germany	Schaeffler	Digit	**Agility Robotics**
Oct 2024	China	BYD	Walker S1	**UBTECH**
Aug 2024	Germany / US	BMW	Figure 02	**Figure**
Jul 2024	China	Zeekr / Geely	Walker S Lite	**UBTECH**
Jun 2024	US	GXO	Digit	**Agility Robotics**
Jun 2024	US	Tesla	Optimus	**Tesla**

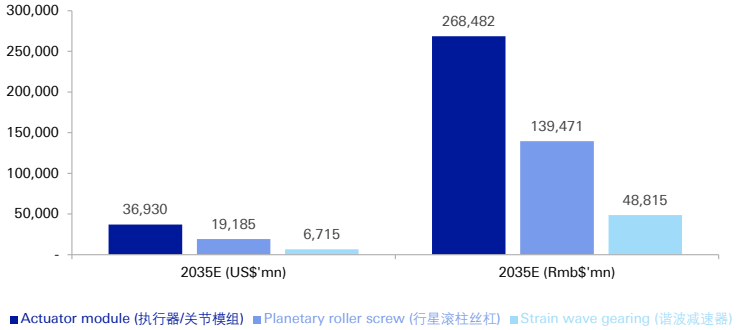
Time	Country	Customer	Robot	Robot OEM
Jun 2024	China	Dongfeng Motor	Walker S	**UBTECH**
Apr 2024	China	NIO	n/a	**Unitree**
Apr 2024	Canada	Magna	Phoenix	**Sanctuary AI**
Mar 2024	Germany	Mercedes	Apollo	**Apptronik**
Feb 2024	China	NIO	Walker S	**UBTECH**
Jan 2024	US	BMW	Figure 01	**Figure**
Oct 2023	US	Amazon	Digit	**Agility Robotics**
May 2020	UK	Ocado	ARMAR-6	**Karlsruhe Institute of Technology (KIT)**

Source: Deutsche Bank estimates, company data, Deutsche Bank estimates, National Bureau of Statistics, Eurostat, US Federal Highway Administration (FHWA)

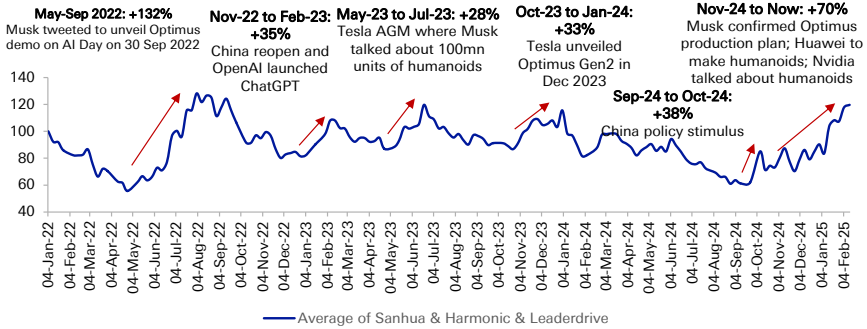
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Key charts

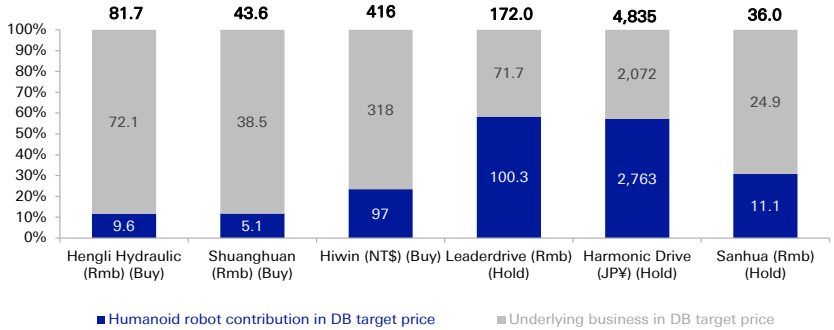
APAC Industrials: Market size of key hardware components by 2035



APAC Industrials: Timeline of humanoid impact on share price; We feel investor interest level in this round is the strongest and the broadest



APAC Industrials: Humanoid contribution in our target price



US Autos: Our SOTP valuation of Tesla

	Sales (bn)	EBITDA	Multiple (x)	Enterprise value	Present value	Per share	Assumptions
Auto (2030E)	$147		8.0	1,184	742	$214	+4m unit sales
Energy (2030E)	$42	$13	20.0	250	157	$45	170 GWh storage deployed
Humanoid robot (2035E)	$20		20.0	400	157	$45	500,000 robots @ $40k per unit
Robotaxi (2035E)	$50		20.0	1,004	394	$114	FSD + robotaxi + licensing stream
Services/other (2030E)	$19		0.5	9	6	$2	accessories, F&I, used car sales
Total					**1,456**	**$420**	

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Source: Deutsche Bank estimates, company data, Bloomberg Finance LP

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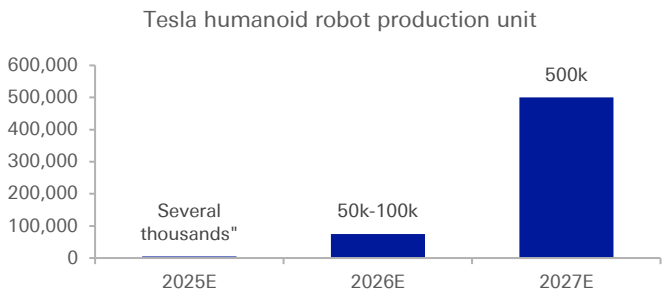
Humanoid robot market update

Production ramp-up accelerating in 2025/26 (1): Led by US OEMs (Tesla, Figure and Agility)

A few humanoid robot OEMs in the US and China have laid out plans for mass production starting from 2025. We note the production plans are **more aggressive by US OEMs** (led by Tesla, Figure and Agility):

- **Tesla:** has the most ambitious and aims for "**several thousands**" to be tested at Tesla's factories in **2025**, and then to increase by 10x and produce **50k-100k** units in **2026,** and then to scale 10x again to **500k** in **2027**.
- **Figure:** recently announced plan to manufacture **100k** humanoids over the **next four years**, implying 25k units per year on average, but likely on an accelerated curve, in our view. Figure has two major customers, one of which is BMW, and the other is referred to as "one of the biggest US companies".
- **Agility Robotics:** has opened a robot factory in the US with capacity of **hundreds of humanoids in the first year**, and will scale up to more than **10k** units;
- **Chinese OEMs:** we note production plans of Chinese OEMs appear less aggressive. **UBTECH** expects 1-2k orders in 2025. **Galbot** targets 10k units in five years. Chinese auto OEMs **BYD**, however, is ambitious and expects **20,000 units** of humanoids to work in their factories **by 2026**.

Tesla has the most ambitious production plan for humanoids



Production plan of major humanoid robot OEMs

Date	Company	Country	Targets
Feb 2025	**Figure**	US	Plan to manufacture **100,000** humanoid robots over the **next four years**. Have two major customers - one is BMW, and the other one is undisclosed but is "one of the biggest US companies".
Aug 2024	**UBTECH (优必选)**	China	UBTECH expects **1,000-2,000** units of humanoid robot orders in **2025** and to deliver **500-1,000 units** of its Walker S series humanoid robot in **2025.**
Jan 2025	**Leju Robotics (乐聚机器人)**	China	Delivered the 100th humanoid robot to Beijing Automotive Group in January 2025.
Jan 2025	**Tesla**	US	Elon Musk plans to produce **several thousands** Optimus humanoid robots in **2025** to be tested at Tesla factories. If things go well, Tesla could produce **50k-100k** humanoids in **2026** and scale 10x to **500k** in **2027**.
Jan 2025	**Boston Dynamics / Hyundai**	US/ South Korea	Hyundai plans to commercialize Atlas within the next 3 to 5 years.
Jan 2025	**AgiBot (智元机器人)**	China	Agibot has manufactured **900+ units** of robots (including bipedal and wheel robots) as of end of 2024, of which 200+ units were for internal use and close to 700 units for external customers. Total shipment of 2024 was about 300 units, of which 200 units were bipedal robots and 100 units were wheel robots. AgiBot has built a **factory for mass production** in Shanghai, China.
Sep 2024	**Agility Robotics**	US	Opened **RoboFab™**, a robot manufacturing facility in Salem, Oregon with the capability to produce more than 10,000 robots per year. Agility anticipates **production capacity of hundreds of Digit robots in the first year**, with the capability to scale to more than **10,000** robots per year. Delivery of first Digits in 2024, with **general market availability in 2025**.
Aug 2024	**Galbot (银河通用)**	China	**Mass production in 2026**. Delivery in **small volume in 2024**. **10,000 units in five years** to for unattended monitoring and factories. To entre the domestic market in 10 years. Production to reach ten million level in 15 years.
May 2024	**Unitree Robotics (宇树科技)**	China	Launched G1 humanoid robot at price of Rmb99,000.

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Source: Deutsche Bank, company data, South China Morning Post, Business Korea

Production ramp-up accelerating (2): Comments from Elon Musk on humanoids since 2024



Date	Event	Comments from Elon Musk
29/01/2025	Tesla 4Q24 result	The **training** needs for Optimus humanoid robot are probably at least ultimately **10x** what's needed **for the car**, at least to get to the full range of useful roles. A humanoid robot has probably 1,000x more uses and more complex things than in a car. That doesn't mean the training scales by 1,000 but it's probably 10x. You can do this progressively, so it doesn't mean Tesla is going to spend $500 billion in training compute because we will obviously train Optimus to do enough tasks to match the output of Optimus robots. And obviously, the cost of training is dropping dramatically with time. I think in the long-term Optimus has the potential to be north of **$10 trillion in revenue**. So you can obviously afford a lot of training compute in that situation. In fact, even $500 billion training compute in that situation would be quite a good deal. The normal internal plan calls for roughly **10,000 Optimus robots to be built this year**. Will we succeed in building 10,000 exactly by the end of December this year? Probably not. But will we succeed in making **several thousand**? Yes, I think we will. Will those several thousand Optimus robots be doing useful things by the end of the year? Yes, I'm confident they will do useful things. Those Optimus in use at the Tesla factories for production design one will inform how would we change for production **design two**, which we expect **to launch next year**. Now if we aspire to an order of magnitude ramp per year, perhaps we only end up with a **half order** of magnitude per year. It doesn't take very many years before we're making a 100 million of these things a year. If you go up by, let's say, **a factor by 5x per year**. For this year, Optimus could do dangerous, repetitive tasks that no humans want to do at Tesla, such as loading the hopper and transporting pieces of sheet metal to the robot welding line for the body. It's really with **production version 2**, which I think **launches sometime next year**. I'd like it to be the beginning of next year, but maybe it's more like the middle of next year. And then we have to do it with a production line that is designed for on the order of 10,000 units a month versus 1,000 units a month. The current line that we're designing is for roughly **1,000 units a month** of Optimus robots. **The next line would be for 10,000 units a month, the line after that would be for 100,000 units a month.** I think probably with **version 2,** very rough guess that we start delivering Optimus robots to companies that are outside of Tesla in maybe the **second half of next year**.
09/01/2025	Interview of Elon Musk	We will produce **several thousands** Optimus humanoid robots **in 2025** to be tested at Tesla factories. Assuming things go well, we'll **10x that output next year (2026)**, so we'll aim to do maybe **50,000-100,000** humanoid robots next year, and then **10x** it again the following year (**2027**). It's like **500,000** robots in three years (**2027**).
23/10/2024	Tesla 3Q24 result	With Optimus, we showed a massive improvement in Optimus' **dexterity movement** on October 10 and our next-gen handed form which is **22 degrees of freedom**, which doubles the prior handed form. I feel confident in saying that we have most advanced humanoid robot by longshot. And we're moreover the only company that really has all of the ingredients necessary to scale humanoid robots. Because the things that what other companies are missing is that they're missing the AI brain that they're missing the ability to really scale to very-high volume production.
10/10/2024	Tesla Robotaxi "We, Robot" event	Fundamentally at-scale, you should be able to buy an Optimus robot for **$20,000 to $30,000** long-term. Optimus will basically do anything you want. So it can be a teacher, babysit your kids, it can walk your dog, mow your lawn, get the groceries, just be your friend, serve drinks, whatever you can think of, it will do.
23/07/2024	Tesla 2Q24 result	**Optimus** is already performing tasks in our factory, and we expect **to have Optimus production version 1** and **limited production starting early next year**. This will be for Tesla consumption. We expect to **have several thousand Optimus robots produced** and doing useful things **by the end of next year** in the Tesla factories. And **in 2026**, **ramping up production** quite a bit. And at that point, we'll be providing Optimus robots **to outside customers**. That'll be production version 2 of Optimus. Optimus is intended to be a generalized humanoid robot with a lot of intelligence. So it's like saying what kind of accessories would be offered by the human. It's just really intended to be able to be backwards compatible with human tasks. So it would use any accessories that a human would use. I think the **long-term value of Optimus will exceed that of everything else that Tesla combined**. The utility of a humanoid robot that can do pretty much anything you ask of it, I think everyone on earth is going to want one. There's 8 billion people on earth, so it's 8 billion right there. Then you've got all of the industrial uses, which is probably at least as much, if not way more. So I suspect that the long-term demand for general-purpose humanoid robots is in excess of **20 billion units**.
13/06/2024	Tesla AGM	I think the ratio of humanoid robots to humans will probably be at least two to one. One to one, for sure, which means like, somewhere around the order of **10 billion humanoid robots. Maybe 20 billion or 30 billion**. I think the build rate will be probably ultimately like, **a billion a year humanoid robots**. If Tesla just has a **10% share** of that, and there are **100 million Optimus units a year**. For reference, the Auto industry is roughly a 100 million vehicles per year. And I think we could make one for a cost of maybe, at really high scale, of about **$10,000**. It's smaller, it'd be less expensive than a car. If you sell it for $20,000 or something, Tesla would basically make about **$1 trillion of profit** a year from that. So, yes. If the price/earnings multiple is 20x or 25x, that would mean a **$20 trillion market cap** from Optimus alone. And probably $5 trillion to $10 trillion from autonomous vehicles. we have **two Optimus robots** in our **Fremont factory** that are doing basically this task, which is taking cells off the end of the line and placing them in a shipping container. And yes, we actually have quite a few of these cruising around our offices in Palo Alto. I think we've **one major hardware revision**, which should be done **by end of this year or early next**, and then we'll move into a **limited production next year** of Optimus, limited production for use in our factories where we'll test out the product. My prediction is **next year** we'll **have over a thousand**, maybe **a few thousand Optimus robots** working at Tesla. And things are going to scale up very rapidly from there. So, we'll iron out the bugs. **The degree of autonomy will be radically better**. You'll just literally be able to talk to it and say, please do this task, or I'm going to show you something, now do the thing that I'm showing you. I'm confident of the prediction that the **ratio of humanoid robots to humans** will be greater than **one to one**. So, there'll be more than **10 billion** humanoid robots in the world, probably **20 billion** or more. And Tesla is going to be by far the leader in that. I think it's actually very challenging to do Optimus as a robot startup, because what we found to make Optimus work, we've had to design from first principles, from scratch, every part of the robot (motor, gearbox, sensors, power electronics, communication system). We found that there's basically no supply chain. Our next generation has **22 degrees of freedom**. It will be able to play the piano.
23/04/2024	Tesla 1Q24 result	We do think we will have Optimus in **limited production** in the factory doing useful tasks **before the end of this year**. And then I think we may be able to **sell it externally by the end of next year**. These are just guesses.
24/01/2024	Tesla 4Q23 result	AI technologies that we've developed for the car translate quite well to a humanoid robot because the **car is just a robot on four wheels**. Tesla is arguably already the biggest robot maker in the world. It's just a four-wheeled robot. So Optimus is a humanoid robot with arms and legs. I think we've got a good chance of **shipping some number of Optimus units next year**. But like I said, this is a brand new product. There's a lot of uncertainty in your uncharted territory, it's obviously impossible to make a precise prediction. But we will be updating the public with progress on Optimus every few months, and you can see that it's advancing very quickly.

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Real-life use cases have been increasing since 2024

Real-life use cases of humanoid robot

Time	Country	Customer	Robot	Robot OEM	Use case
Late 2025	US / South Korea	Hyundai	Atlas	**Boston Dynamics**	Hyundai plans to deploy Atlas in its auto production sites by end of 2025
Jan 2025	China	Foxconn (Hon Hai Precision) (Apple iPhone assembler)	Walker S1	**UBTECH**	Has been trained onsite in Foxconn's Shenzhen factory in China for two months, and is going to be brought into Foxconn's Zhengzhou factory for further training
Nov 2024	Germany	Schaeffler	Digit	**Agility Robotics**	Schaeffler made a minority investment in Agility, and intends to purchase humanoids from Agility for use in its manufacturing and warehouse network. Schaeffler sees the potential to deploy a significant number of humanoids by 2030
Oct 2024	China	BYD	Walker S1	**UBTECH**	Performed handling tasks in coordination with autonomous logistics vehicles
Aug 2024	Germany / US	BMW	Figure 02	**Figure**	Tested for two weeks at BMW's US plant in Spartanburg to insert sheet metal parts into machines
Jul 2024	China	Zeekr / Geely	Walker S Lite	**UBTECH**	Tested for 21 days for material transportation
Jun 2024	US	GXO	Digit	**Agility Robotics**	Signed a multi-year agreement to begin deploying Digit in GXO's logistics operations. To assist with repetitive tasks such as moving totes from cobots and placing them onto conveyors
Jun 2024	US	Tesla	Optimus	**Tesla**	Tesla has deployed two Optimus at its factory
Jun 2024	China	Dongfeng Motor	Walker S	**UBTECH**	For various tasks including inspection, logo sticking and label printing during automotive manufacturing
Apr 2024	China	NIO	n/a	**Unitree**	Tested humanoid robot and robot dog for collaboratively picking up and delivering materials
Apr 2024	Canada	Magna	Phoenix	**Sanctuary AI**	Sanctuary announced a strategic partnership with Magna, and Magna will pilot Sanctuary AI's humanoid for factory use
Mar 2024	Germany	Mercedes	Apollo	**Apptronik**	For logistics (bring parts to the production line for workers to assemble), while simultaneously inspecting the components. Also to be used to deliver the totes of kitted parts
Feb 2024	China	NIO	Walker S	**UBTECH**	Inspection and sticking the car logo at NIO's car factory
Jan 2024	US	BMW	Figure 01	**Figure**	To be integrated into the manufacturing processes including the body ship, sheet metal and warehouse in the next 12-24 months
Oct 2023	US	Amazon	Digit	**Agility Robotics**	Amazon's warehouses for tote recycling
May 2020	UK	Ocado	ARMAR-6	**Karlsruhe Institute of Technology (KIT)**	Help workers with a range of maintenance tasks at Ocado's automated warehouse

The adoption of humanoid robots in real-life has clearly accelerated since 2024 with a surge of number of use cases.

We divide adopters of humanoid robots into three groups:

1) **Automotive OEMs and suppliers** such as BMW, NIO, Mercedes, Magna, Dongfeng Motor, Geely, BYD, Hyundai, and Schaeffler;
2) **Logistics and warehouse** service owners and providers, such as **Amazon**, **Ocado** and **GXO;**
3) Electronics assembler such as **Foxconn** (Hon Hai Precision) which assembles Apple iPhones.

We note that so far, user cases are pilot projects in order to test the performance of humanoid robots in real-life environments. However, **once humanoid robots demonstrate their value for real-life workflows**, we believe take-up could reach **a tipping point** and accelerate exponentially.

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Source: Deutsche Bank, company data

Key humanoid robot OEMs (1) – Flourishing from various backgrounds

We categorise humanoid robot OEMs into four groups: **1) Independent vendors:** most OEMs fall into this category, and some of them are start-ups founded after 2020, and some originated from making robot dogs; **2) AI-backed vendors:** the most famous one is Figure which was backed by funds from NVIDIA and OpenAI (although Figure terminated the Collaboration Agreement with OpenAI in early February 2025); **3) Auto OEMs:** led by Tesla, auto OEMs are leveraging their expertise in autonomous driving and manufacturing for humanoid robot; and **4) Research labs:** in the early days, humanoid robots were developed in research labs.

We note that **NVIDIA** unveiled a **humanoid robot developer program** in July 2024, where 12 developers are listed as the first to join the early-access program. During the CES (consumer electronics show) in January 2025, NVIDIA CEO Jensen Huang showcased a slide where 17 humanoid robot makers are listed as channel partners for the industrial sector of NVIDIA Cosmos world foundation model platform.

Types of humanoid robot OEMs

Independent vendors	AI-backed vendors	Auto OEMs	Research labs
Agility Robotics; Unitree Robotics; UBTECH; IntBot; Sanctuary AI; Argon Mechatronics; Fourier Intelligence; LimX Dynamics; RobotEra; AgiBot; DEEP Robotics; NEURA Robotics; Galbot; Mentee Robotics; Leju Robotics; EngineAI Robotics; Apptronik; Engineered Arts; Macco Robotics; Softbank	Figure (backed by NVIDIA, OpenAI; terminated collaboration agreement with OpenAI in Feb 2025); 1X Technologies (backed by OpenAI); Huawei	Tesla; Xpeng; Xiaomi; Honda; BYD; Chery	Boston Dynamics; UCLA; Toyota Research Institute (TRI); Karlsruhe Institute of Technology (KIT); Waseda University

Humanoid robot partners of NVIDIA

Date	Event	Participants	Details
Jan 2025	CES (consumer electronics show)	1X, Agility, Apptronik, Boston Dynamics, BYD, Figure, Fourier, Galbot, Hexagon, IntBot, LimX Dynamics, Mentee Robotics, NEURA Robotics, RobotEra, Sanctuary, Unitree, XPENG	NVIDIA CEO Jensen Huang introduced the **NVIDIA Cosmos world foundation model platform** (like large language models) for robotics and industrial AI. He shared a slide showcasing its **channel partners** in the industrial sector, including **humanoid robot** makers.
Jul 2024	NVIDIA Humanoid Robot Developer Program	1x, Boston Dynamics, ByteDance Research, Field AI, Figure, Fourier, Galbot, LimX Dynamics, Mentee, Neura Robotics, RobotEra, Skild AI	NVIDIA offers 1) **NVIDIA NIM™ microservices** and frameworks: for robot simulation and learning for generative physical AI in NVIDIA Isaac Sim™, a reference application for robotics simulation built on the NVIDIA Omniverse™ platform; 2) **NVIDIA OSMO orchestration service**: for running multi-stage robotics workloads across distributed computing resources; 3) an AI- and simulation-enabled **teleoperation workflow**: allows developers to train robots using small amounts of human demonstration data

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Key humanoid robot OEMs (2) – Started in Japan but now dominated by the US and China

We note that **Japan** was the first to develop humanoid robots as a concept in the early days. **US companies**, led by Boston Dynamics and Agility, launched their first humanoid model in 2016/17. 2022 saw the emergence of **Chinese OEMs.** The introduction of Optimus Gen 1 by **Tesla** in September 2022 captured the attention of the capital market. As of now, most humanoid OEMs are from the US and China. Among the 35 humanoid OEMs we track, 16 are from China, and 9 are from the US, with some from Canada, Germany, Israel, Norway and Japan.

Thanks to the rapid development of AI, we notice the **launch of new humanoid robot model** has become **more frequent** at about one new model per year, and interval could be as short as seven months.

Timeline of humanoid robot model launch by key OEMs (1)

Time	HQ	Company	Robot	Details and tasks
Jan 2025	US	IntBot	Nylo	Nylo leverages NVIDIA's Cosmos platform for synthetic motion generation and advanced AI training.
Dec 2024	China	BYD	n/a	BYD published recruitment information for embodied AI research covering humanoid and bipedal robot research
Dec 2024	Canada	Sanctuary AI	Phoenix Gen8	It has a wheeled base, which is a design decision informed by Sanctuary customer feedback that bi-pedal legs are too frail to support a strong torso that is needed to carry out useful work precisely and safely.
Dec 2024	China	EngineAI Robotics (众擎机器人)	PM01	EngineAI launched first humanoid model SA01 in July 2024, followed by the scond model SE01 in Oct 2024, and the third model PM01 in Jan 2025
Nov 2024	China	Huawei	n/a	Huawei Embodied Centre signed MoU with 16 companies.
Nov 2024	China	XPeng (小鹏)	Iron	Developed over five years, Iron has 62 degrees of freedom in total, and 15 DoF per hand.
Oct 2024	US	Argon Mechatronics	Argon One	An engineering-oriented humanoid, equipped with multi-tool capabilities like laser, milling, engraving, and 3D printing.
Sep 2024	China	Fourier Intelligence (傅利叶智能)	GR-2	Standing at 175 cm and weighing 63 kg, GR2 offers 53 degrees of freedom (12-DoF dexterous hands) and a single-arm load capacity of 3 kg, enabling it to tackle more complex tasks.
Aug 2024	China	LimX Dynamics (逐际动力)	CL-2	With increased degrees of freedom in the waist, arms, and legs, the upgrade enhances the robot's full-body motion control.
Aug 2024	Norway & US	1X Technologies	NEO Beta	NEO can walk, jog, climb stairs, and navigate space naturally. A prototype of its bipedal humanoid designed for home use.
Aug 2024	China	RobotEra (星动纪元)	STAR1	Features 55 degrees of freedom (DOF). The maximum joint torque reaches 400Nm, and it also has high-speed performance, with a maximum speed up to 25rad/s.
Aug 2024	China	AgiBot (智元机器人)	Yuanzheng A2 (远征A2); Lingxi X1 (灵犀X1)	40+ degrees of freedom and two-hour battery life
Aug 2024	China	DEEP Robotics (云深处)	Dr.01	DEEP Robotics is known for robot dogs. Launched first humanoid in August 2024
Aug 2024	US	Figure	Figure 02	Figure 02 brings together the dexterity of the human form and cutting edge AI to go beyond single-function robots and lend support across manufacturing, logistics, warehousing and retail.
Jul 2024	Germany	NEURA Robotics	4NE-1	NEURA was given early access to Nvidia's humanoid development and deployment tools.
Jun 2024	China	Galbot (银河通用)	G1	General-purpose humanoid robot.
May 2024	China	Unitree Robotics (宇树科技)	Unitree G1	Unitree G1 is priced at only Rmb99,000.
May 2024	China	Chery (奇瑞汽车) & Aimoga	Mornine	Mornine is equipped with large language model (LLM), which means that Mornine is able to answer questions and could act as a guide, a salesperson, a receptionist, etc.
Apr 2024	Israel	Mentee Robotics	MenteeBot	MenteeBot is set to launch on the market in 1Q25 and can be used for activities in both private households and warehouses.
Jan 2024	China	LimX Dynamics (逐际动力)	CL-1	LimX has received fundings from companies including Lenovo. It released a video of testing its humanoid robot CL-1 in January 2024.

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Source: Deutsche Bank, company data

Key humanoid robot OEMs (3) – Started in Japan but now dominated by the US and China

Timeline of humanoid robot model launch by key OEMs (2)

Time	HQ	Company	Robot	Details and tasks
2023	China	UBTECH (优必选)	Walker S	Ubtech first launched its humanoid robot Walker in 2016, Walker Gen 1 in 2018, Walker Gen 2 in 2019, Walker X in 2021 and Walker S in 2023.
Dec 2023	China	Leju Robotics (乐聚机器人)	Kuavo (夸父)	Leju and Huawei Cloud signed strategic partnership agreement in March 2024 to collaborate in large model and humanoid robot fields.
Dec 2023	US	Tesla	Optimus Gen 2	A video was released showing Optimus Gen 2 picking up delicate objects such as an egg. Improvements also include 30% walk speed boost, 10kg weight reduction.
Oct 2023	China	XPeng (小鹏)	PX5	XPeng plans to first test PX5 in its factories and sales stores.
Oct 2023	US	Figure	Figure 01	Founded in 2022, Figure is partnering with OpenAI for AI models and Microsoft's Azure for AI infrastructure, training and storage. Figure has received fundings from Jeff Bezos, OpenAI, Nvidia, and Microsoft.
Aug 2023	China	Unitree Robotics (宇树科技)	Unitree H1	Unitree H1 is the first full-size general-purpose humanoid robot that can run in China.
Aug 2023	China	AgiBot (智元机器人)	Yuanzheng A1 (远征A1)	AGIBOT was established in February 2023 and launched its humanoid robot Yuanzheng A1 in August 2023.
Aug 2023	US	Apptronik	Apollo	Apollo is a humanoid robot built to work alongside people in environments designed for people.
Jul 2023	China	Fourier Intelligence (傅利叶智能)	GR-1	Founded in 2015, Fourier launched GR-1 general-purpose humanoid robot in 2023.
Mar 2023	US	UCLA & RoMeLa	ARTEMIS	ARTEMIS (Advanced Robotic Technology for Enhanced Mobility and Improved Stability) is a general-purpose humanoid robot that focuses on bipedal locomotion, particularly on uneven terrains.
2023	Norway & US	1X Technologies	EVE	EVE is a smart working android.
Sep 2022	US	Tesla	Optimus Gen 1	Tesla unveiled its Optimus humanoid robot at its AI Day 2022.
Aug 2022	China	Xiaomi (小米科技)	CyberOne (铁大)	In addition to the humanoid robot CyberOne, Xiaomi also manufactures four-legged robot CyberDog.
Dec 2021	UK	Engineered Arts	Ameca	Ameca is designed specifically as a platform for development into future robotics technologies. The first video of A 2021.
2021	Japan	Toyota Research Institute (TRI)	Busboy	Busboy can tackle domestic chores like clearing tables and wiping down countertops and other surfaces.
2020	Germany	Karlsruhe Institute of Technology (KIT)	ARMAR-6	ARMAR-6 is a collaborative humanoid assistant robot for industrial environments.
2019	Spain	Macco Robotics	KIME	KIME features a robotic head and torso and has two articulating arms that can be used to grab and dispense bevera
2019	US	Agility Robotics	Digit	Digit is a mobile manipulation robot that provides a wide work envelope and payload ranges typical for warehousir
2017	Japan	Toyota Research Institute (TRI)	T-HR3	T-HR3 is Toyota's third generation humanoid robot and is a humanoid robot capable of flexible movements that mi r.
2017	US	Agility Robotics	Cassie	Launched in mid 2017, Cassie is a dynamic bipedal robot by Agility Robotics, a spin-off of Oregon State University
2016	US	Boston Dynamics	Spot	The four-legged Spot was revealed in June 2016 and became commercial available in 2019.
2014 - 2021	Japan	Softbank	Pepper	Pepper is a semi-humanoid robot, designed with the ability to read emotions. Reuters reported that SoftBank disc
2013 & 2024	US	Boston Dynamics	Atlas	Atlas was unveiled to the public in July 2013. In April 2024, the hydraulic version of Atlas was retired and replaced
2005	UK	Engineered Arts	RoboThespian	RoboThespian is a robotic actor and features an actuated upper body, arms, fingers, head and jaw designed to mim
2000 - 2018	Japan	Honda	ASIMO	ASIMO was created in 2000. Honda discontinued the commercial development of ASIMO in 2018.
1972	Japan	Waseda University	WABOT-1	The WABOT-1 was the first full-scale anthropomorphic robot developed in the world.



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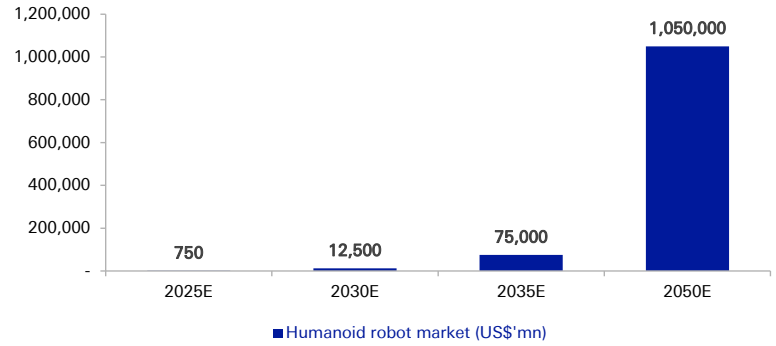

Humanoid robot market forecast and supply chain (actuator-focused)

Sizing the humanoid robot market – US$75bn market by 2035E and US$1tn by 2050E

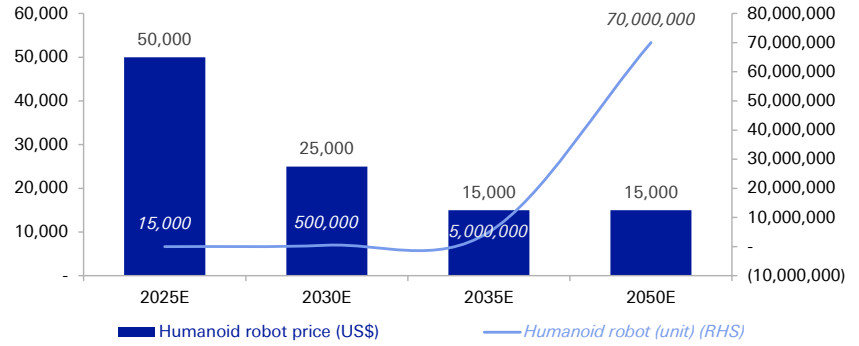
We increase our forecast for humanoid robot market to **US$750mn/US$12.5bn/US$75bn** for **2025/2030/2035**, roughly doubling our previous forecast. By **2050**. we believe the humanoid robot market could reach **US$1tn**.

- **Volume:** We now forecast **15k/500k/5mn/70mn units** of humanoid produced in **2025/2030/2035/2050**. We estimate "**a few thousands**" of humanoids were produced **in 2024**, and this should rise significantly based on humanoid OEMs' production plans led by Tesla, Figure and Agility (details on slide 7). In the long term, we sense check our 2050 forecast against the passenger vehicle and traditional industrial robot penetration among households. If we apply **55-90% humanoid penetration among households** in China, the US and Europe (inline with passenger vehicle penetration) and **8-10% humanoid penetration among manufacturing and hospitality** sectors (details are on next slide), this would translate to **~560mn units of humanoid stock by 2050**, implying **~70mn units of humanoid sales** per annum. We think there is **upside room** as **humanoids** are **more general purpose than vehicles** and Elon Musk estimates 1,000x more uses for humanoids than cars, although the training needed for humanoids are at least 10x vs cars;
- **Price:** We forecast the unit price per humanoid of **US$50k/US$25k/US$15k/US$15k** in **2025/2030/2035/2050**, dropping faster than our previous expectation in the initial ten years considering the accelerating production ramp-up and the resultant economy of scale. For reference, **Elon Musk** talked about **selling** Optimus **at US$20,000-30,000** and the **cost** could go to **US$10,000** at very high scale. For 2035-50, we expect the price to stay flattish as inflation balances out the cost reduction from further mass production.

Humanoid robot market to reach US$75bn by 2035 and US$1tn by 2050



We forecast 5mn/70mn units of humanoids selling at US$15k by 2035/50



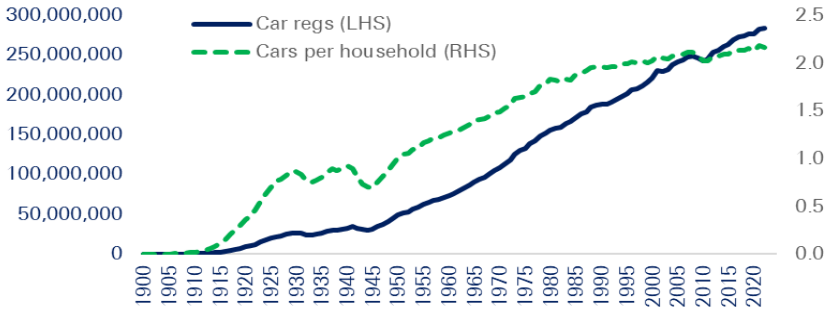
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Source: Deutsche Bank estimates

Humanoid adoption curve and penetration vs vehicles and traditional industrial robots

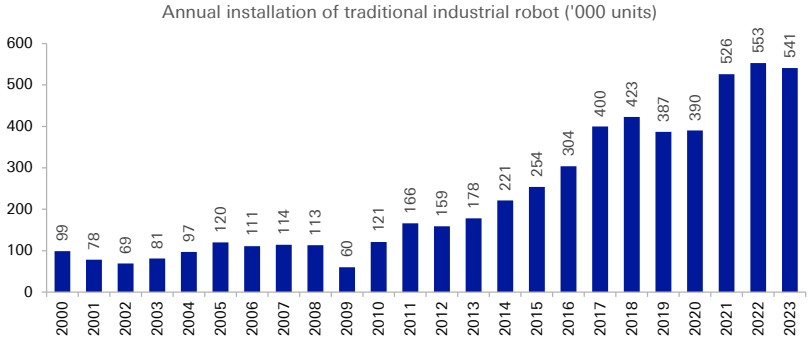
Humanoid penetration vs automobile and traditional industrial robots

	China	US	Europe	Total (Global for industrial robot)
Reference: Passenger vehicle (PV) (2024)				
Passenger vehicle stock unit (mn)	353	240	256	849
PV penetration of households	*71%*	*181%*	*128%*	*103%*
Passenger vehicle sales unit (mn)	28	16	17	60
Stock-to-sales ratio	*12.8x*	*15.1x*	*15.1x*	*14.1x*
Reference: Industrial robot (2023) from IFR				
Industrial robot stock unit ('000)	1,755	382	728	4,282
Industrial robot penetration	*4.7%*	*3.0%*	*2.2%*	*1.7%*
Industrial robot sales unit ('000)	276	38	92	541
Stock-to-sales ratio	*6.4x*	*10.2x*	*7.9x*	*7.9x*
Humanoid robot market potential by 2050				
Yearly salary (US$)				
Manufacturing	13,342	43,873		
Hospitality	7,386	37,510		
1) Manufacturing				
Manufacturing labour (million)	37	13	32	82
Humanoid penetration %	*10%*	*10%*	*8%*	
Humanoids stock unit (million)	3.7	1.3	2.6	7.6
2) Hospitality				
Hospitality labour (million)	26	17	10	52
Humanoid penetration %	*10%*	*10%*	*8%*	
Humanoids stock unit (million)	2.6	1.7	0.8	5.0
2) Households				
No of households (million)	494	133	200	827
Humanoid penetration %	*65%*	*90%*	*55%*	
Humanoids stock unit (million)	321.2	119.3	110.0	550.5
Humanoids total stock unit (million)	**327**	**122**	**113**	**563**
Humanoids annual sales unit (million)	**41**	**15**	**14**	**70**
Stock-to-sales ratio	*8.0x*	*8.0x*	*8.0x*	

Automobile adoption in the US during early 1900s was surprisingly rapid



The adoption curve of traditional industrial robot was slow during 2000-10 but accelerated post 2009; China was the main growth driver



Source: Deutsche Bank estimates, National Bureau of Statistics, US Bureau of Labour Statistics, Eurostat, IFR, US Federal Highway Administration (FHWA)

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Configuration of humanoid robots

Robot OEM	Tesla	Figure	Agility Robotics	UBTECH	Unitree
Robot	**Optimus**	**Figure**	**Digit**	**Walker S1**	**G1**
Appearance					
Launch date	Gen 1: Sep 2023 Gen 2: Dec 2023	Figure 01: Oct 2023 Figure 02: Aug 2024	2019	Oct 2024	G1: May 2024 H1: Aug 2023
Body part					
Power	Electric	Electric	Electric	Electric	Electric
Height	Gen 1: 5'8'' (173cm)	5'6'' (168cm)	5'9'' (175cm)	172cm	130cm
Weight	Gen 1: 125 lb (57kg)	Figure 02: 70kg	140 pounds (65kg)	76kg	35kg
Speed	n.a.	Figure 02: 1.2m/s	1.5m/s	n.a.	2m/s
Payload	n.a.	Figure 02: 20kg	35 lbs (15.9kg)	15kg	n.a.
Runtime	n.a.	Figure 02: 5 hours	Up to 8 hours	n.a.	About 2 hours
Battery	n.a.	Figure 02: 2.25KWh	n.a.	n.a.	n.a.
Degree of freedom (DoF):					
Per hand	Gen 1: 11 DoF (6 actuators) Gen 2: 11 DoF Gen 3: 22 DoF	Figure 01: 6 DoF Figure 02: 16 DoF	n.a.	n.a.	7-9 DoF
Per arm	Gen 1: 6 DoF	Figure 01: 7 DoF	4 DoF	n.a.	5 DoF
Neck	Gen 1&2: 2 DoF	Figure 01: 0 DoF	n.a.	n.a.	n.a.
Per leg	Gen 1: 6 DoF	Figure 01: 6 DoF	n.a.	n.a.	6 DoF
Torso	Gen 1: 2 DoF	Figure 01: 3 DoF	n.a.	n.a.	1-3 DoF
Total DoF	**Gen 1: 50 DoF (28 structural actuators)**	**Figure 01: 41 DoF**	**n.a.**	**n.a.**	**23-43 DoF**
Sensing	Hand tactile and force sensors; Foot force/torque sensing	n.a.	n.a.	n.a.	n.a.
Camera	2D cameras	Figure 02: 6 cameras	n.a.	3D camera	Depth camera + 3D LiDAR
Brain part					
Chip	Tesla SOC	NVIDIA	n.a.	n.a.	Undisclosed vendor; NVIDIA Jetson Orin (for high computing); Rockchip (瑞芯微) (for robot dog)
AI	FSD computer	OpenAI (Figure exited the agreement in Feb 2025)	n.a.	n.a.	n.a.

In the figure on the lefthand side, we show the **configuration** of a selection of humanoid robots from OEMs from the US and China. The **hardware (body)** and **software (brain)** parts of humanoid robots consist of more components than we have listed, such as battery, sensors, "skin", chips, and software for purposes such as large language model (LLM) and motion simulation.

In this report, we focus on the **actuator** component, as actuators are the most relevant to the companies for our APAC Industrials coverage.

An **actuator** is a device that converts energy into physical motions (mostly rotary or linear or back-and-forth sway). For robots, **degree of freedom (DoF)** refers to the number of movable joints.

Compared to traditional industrial robots that typically come with only one "arm" of 3-6 degrees of freedom, humanoid robots have a full body with 40+ degrees of freedom – for comparison, a human body has 200+ degrees of freedom.

As degree of freedom is enabled by actuators, this means that **humanoid robots are equipped with 6-10x more actuators than traditional industrial robots**, pointing to potential for an exponentially larger market for robot actuators.

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Source: Deutsche Bank, company data

Actuator architecture of Tesla Optimus (1) – Rotary and linear actuators

As **Tesla** is one of the leading humanoid OEMs and has the most ambitious production plan, we use Tesla's actuator architecture to demonstrate the design and the related actuator components.

The current design of Optimus Gen2 (the latest launched version – Gen3 is to be launched soon) is made up of **28 structural actuators**, of which 14 are **rotary actuators** for torso, shoulders and wrists, and 14 are **linear actuators** for arms and legs:

- **Rotary actuator:** consists of a motor (in our view, most likely a frameless torque motor, as it is more compact and can generate high torque – in comparison, common traditional industrial robot arms use servo motors), an angular contact ball bearing, a mechanical clutch, a strain wave gearing, a cross roller bearing and sensors for position and torque;
- **Linear actuator:** consists of a motor (in our view, most likely also a frameless torque motor), an inverted roller screw, planetary rollers, a ball bearing, a four-point contact bearing, a stator and sensors for force and position.

The design of actuators is consistently evolving. Tesla and other humanoid OEMs could come up with new designs made up of different components in the future models.

28 structural actuators for Tesla's Optimus

	Rotary	Linear	Total
Arm (*2)		3	**6**
Wrist (*2)	1		**2**
Shoulder (*2)	3		**6**
Leg (*2)		4	**8**
Torso / Waist / Pelvis (*2)	3		**6**
Total	**14**	**14**	**28**

Components within a rotary actuator

Shape	Actuator
	Rotary actuator:
	Frameless torque motor (无框力矩电机) High speed: Angular contact ball bearing (角接触球轴承) Mechnical clutch (机械离合器) Low speed: Strain wave gearing (谐波减速器) Cross roller bearing (交叉滚子/滚柱轴承) Sensors: Input & Output position sensor (位置传感器/编码器) Non-contact torque sensor (非接触式力矩传感器)

Components within a linear actuator

Shape	Actuator
	Linear actuator:
	Frameless torque motor (无框力矩电机) High speed: Inverted roller screw (反向滚柱丝杠) Planetary roller (行星滚柱丝杠) Low speed: Ball bearing (球轴承) 4-Point contact bearing (四点接触球轴承) Stator (定子) Sensors: Force sensor (力传感器) Position sensor (位置传感器/编码器)

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Source: Deutsche Bank, company data

Actuator architecture of Tesla Optimus (2) – Design of dexterous hand evolving

Dexterous hand is the most complicated actuator for humanoids. While the design of structural actuators are broadly similar across humanoids, the **design of dexterous hand varies** and is evolving very fast due to the inherent complexity given the large number of degrees of freedom (DoF) per hand – human hand（excluding wrist) has 21 DoF, and **Tesla** has increased the DoF from 11 for Optimus Gen1 and Gen2 to **22 DoF for Gen3** (Gen3 has another 3 DoF on the wrist/forearm).

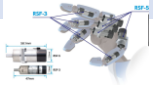
For Tesla's Optimus **Gen1**, Tesla used worm- and tendon-based structure for the hand. While the full body details of Gen3 are not yet released, Tesla showcased the dexterous hand for Gen3 in October 2024 at the "We. Robot" event. Our understanding is that the design for hands for **Gen3** is meaningfully different – in addition to doubling the DoF to 22, Tesla appears to have moved motors to the forearm and replaced the worm drives with **micro screws** (unclear which screws are used, but we think likely roller screws for high precision and high payload). This design change **increases exponentially the number of actuators** (from 6 to 17-20 per hand) and **the use of screws** (from 14 to up to 48) for Tesla.

We note that the design of dexterous hand actuators varies by robot OEM and component supplier. For example, **Harmonic Drive** showed its design for dexterous hand actuators in May 2024. As Harmonic excels at harmonic reducers (i.e., strain wave gears), it has introduced the **super-mini RSF actuator series**, consisting of Harmonic' reducer, a servo motor, encoders and an optional brake. For the RSF-3 actuator used for fingertips, its length is only **47mm**, with diameter of **13mm**. For the RSF-5 actuator used for finger roots, its length is 58.1mm, with a diameter of 22mm. However, because of the **high cost**, we do not think the design is widely adopted yet.

Design of dexterous hand: Tesla Optimus Gen1 (LHS); Gen3 (middle); Harmonic Drive (RHS)

Shape	Actuator
 	**Hand actuator for Gen1 (6 per hand):** Coreless motor (空心杯电机) Planetary reducer (行星减速器) Servo drive (伺服驱动器) Encoder (编码器) Worm drive (蜗轮蜗杆传动) Tendon (腱绳) Sensors for hand tactile and force (触觉传感器、力传感器)

Shape	Actuator
	**Hand actuator for Gen3 (17-20 per hand):** Motor (电机): unclear which type Reducer: maybe and unclear Micro screw (微型丝杠): likely planetary roller screw (行星滚柱丝杠) and ballscrews (滚珠丝杠) Tendon (腱绳) Servo drive (伺服驱动器) Encoder (编码器) Sensors for hand tactile and force (触觉传感器、力传感器)

Shape	Actuator
	**Hand actuator:** Harmonic Drive® precision gear Brushless servo motor (无刷伺服电机) Encoder (编码器) Brake (optional) (制动器)

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Cost breakdown of humanoid robots

Component	Low cost scenario (2025)					High cost scenario (2025)				
	Cost per unit		Quantity per robot	Cost per robot		Cost per unit		Quantity per robot	Cost per robot	
	Rmb	US$		Rmb	US$	Rmb	US$		Rmb	US$
Frameless torque motor (无框力矩电机)	600	83	14	8,400	1,155	1,200	165	14	16,800	2,311
Strain wave gearing (谐波减速器)	1,000	138	14	14,000	1,926	2,000	275	14	28,000	3,851
6-axis torque sensor (六维力矩传感器)	8,000	1,100	4	32,000	4,402	10,000	1,376	4	40,000	5,502
1-axis / 3-axis torque sensor	500	69	10	5,000	688	800	110	10	8,000	1,100
Sensor / Encoder	200	28	14	2,800	385	300	41	14	4,200	578
Bearings	300	41	14	4,200	578	500	69	14	7,000	963
Others	800	110	14	11,200	1,541	800	110	14	11,200	1,541
Rotary actuator per unit cost				**5,543**	**762**				**8,229**	**1,132**
Rotary actuator total			**14**	**77,600**	**10,674**			**14**	**115,200**	**15,846**
% of total huamnoid robot				**39%**	**39%**				**24%**	**24%**
Frameless torque motor (无框力矩电机)	600	83	14	8,400	1,155	1,200	165	14	16,800	2,311
Planetary roller screw (行星滚柱丝杠)	2,000	275	10	20,000	2,751	5,000	688	10	50,000	6,878
Lead screw (梯形丝杠)	1,000	138	4	4,000	550	300	41	4	1,200	165
Force sensor	500	69	14	7,000	963	800	110	14	11,200	1,541
Encoder	200	28	14	2,800	385	300	41	14	4,200	578
Bearings	300	41	14	4,200	578	500	69	14	7,000	963
Others	800	110	14	11,200	1,541	800	110	14	11,200	1,541
Linear actuator per unit cost				**4,114**	**566**				**7,257**	**998**
Linear actuator total			**14**	**57,600**	**7,923**			**14**	**101,600**	**13,975**
% of total huamnoid robot				**29%**	**29%**				**21%**	**21%**
Coreless motor (空心杯电机)	800	110	12	9,600	1,320	1,200	165	34	40,800	5,612
Planetary reducer (行星减速器)	300	41	12	3,600	495	-	-	-	-	-
Micro planetary roller screw (行星滚柱丝杠)	-	-	-	-	-	2,000	275	34	68,000	9,354
Encoder (编码器)	200	28	12	2,400	330	300	41	34	10,200	1,403
Sensors for tactile and force (触觉、力传感器)	2,000	275	10	20,000	2,751	3,000	413	34	102,000	14,030
Others	300	41	12	3,600	495	500	69	34	17,000	2,338
Dexterous hand per unit cost				**19,600**	**2,696**				**119,000**	**16,369**
Dexterous hand total			**2**	**39,200**	**5,392**			**2**	**238,000**	**32,737**
% of total huamnoid robot				**20%**	**20%**				**49%**	**49%**
Inertial measurement unit (IMU; 惯性传感器)	1,500	206	2	3,000	413	2,500	344	2	5,000	688
Battery pack	1,000	138	1	1,000	138	1,500	206	1	1,500	206
FSD chip	10,000	1,376	1	10,000	1,376	10,000	1,376	1	10,000	1,376
Others (body parts, cameras, etc.)	10,000	1,376	1	10,000	1,376	15,000	2,063	1	15,000	2,063
Humanoid robot total				**198,400**	**27,290**				**486,300**	**66,891**

In the figure on the left-hand side, we show our cost breakdown estimates for humanoid robots, based on the disclosure from Tesla's Optimus and our estimates.

Based on our estimation, the low-cost model of humanoids cost close to **Rmb200,000/ US$27,000 per unit**. The high-cost model could cost about as high as close to **Rmb500,000/ US$67,000**.

We note that the humanoid robot space is evolving fast, with frequent hardware revisions, which could affect the components used and the associated cost.

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Source: Deutsche Bank estimates

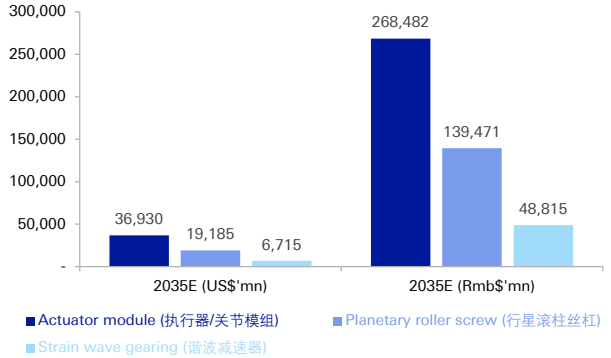
Market size of key components

	Unit	2025E	2030E	2035E	2050E	25/30 CAGR	30/35 CAGR	35/50 CAGR
Humanoid robot volume	Unit	15,000	500,000	5,000,000	70,000,000	102%	58%	19%
Humanoid robot price	US$	50,000	25,000	15,000	15,000	-13%	-10%	0%
Humanoid robot market	**US$'mn**	**750**	**12,500**	**75,000**	**1,050,000**	**76%**	**43%**	**19%**
Humanoid robot price	Rmb	363,500	181,750	109,050	109,050	-13%	-10%	0%
Humanoid robot market	**Rmb'mn**	**5,453**	**90,875**	**545,250**	**7,633,500**	**76%**	**43%**	**19%**
Planetary roller screw (行星滚柱丝杠)								
Unit per humanoid robot	Unit	14	27	40	40			
Planetary roller screw total unit demand	Unit	210,000	13,500,000	200,000,000	2,800,000,000			
Planetary roller screw price	US$	275	162	96	96	-10%	-10%	0%
Planetary roller screw per robot	US$	3,851	4,386	3,837	3,837	3%	-3%	0%
Planetary roller screw market for humanoid robot	**US$'mn**	**58**	**2,193**	**19,185**	**268,583**	**107%**	**54%**	**19%**
% of total humanoid robot market	%	8%	18%	26%	26%			
Planetary roller screw price	Rmb	2,000	1,181	697	697	-10%	-10%	0%
Planetary roller screw per robot	Rmb	28,000	31,886	27,894	27,894	3%	-3%	0%
Planetary roller screw market for humanoid robot	**Rmb'mn**	**420**	**15,943**	**139,471**	**1,952,599**	**107%**	**54%**	**19%**
% of total humanoid robot market	%	8%	18%	26%	26%			
Strain wave gearing (谐波减速器)								
Base case:								
Unit per humanoid robot	Unit	14	14	14	14			
Strain wave gearing total unit demand	Unit	210,000	7,000,000	70,000,000	980,000,000			
Strain wave gearing price	US$	275	162	96	96	-10%	-10%	0%
Strain wave gearing per robot	US$	3,851	2,274	1,343	1,343	-10%	-10%	0%
Strain wave gearing market for humanoid robot	**US$'mn**	**58**	**1,137**	**6,715**	**94,004**	**81%**	**43%**	**19%**
% of total humanoid robot market	%	8%	9%	9%	9%			
Strain wave gearing price	Rmb	2,000	1,181	697	697	-10%	-10%	0%
Strain wave gearing per robot	Rmb	28,000	16,534	9,763	9,763	-10%	-10%	0%
Strain wave gearing market for humanoid robot	**Rmb'mn**	**420**	**8,267**	**48,815**	**683,410**	**81%**	**43%**	**19%**
% of total humanoid robot market	%	8%	9%	9%	9%			
Actuator module (执行器/关节模组)								
Base case:								
Unit per humanoid robot	Unit	28	28	28	28			
Actuator module total unit demand	Unit	420,000	14,000,000	140,000,000	1,960,000,000			
Actuator module price	US$	757	447	264	264	-10%	-10%	0%
Actuator module per robot	US$	21,183	12,508	7,386	7,386	-10%	-10%	0%
Actuator module market for humanoid robot	**US$'mn**	**318**	**6,254**	**36,930**	**517,023**	**81%**	**43%**	**19%**
% of total humanoid robot market	%	42%	50%	49%	49%			
Actuator module price	Rmb	5,500	3,248	1,918	1,918	-10%	-10%	0%
Actuator module per robot	Rmb	154,000	90,935	53,696	53,696	-10%	-10%	0%
Actuator module market for humanoid robot	**Rmb'mn**	**2,310**	**45,468**	**268,482**	**3,758,754**	**81%**	**43%**	**19%**
% of total humanoid robot market	%	42%	50%	49%	49%			
RV reducer (RV减速器)								
Blue sky:								
Unit per humanoid robot	Unit	4	4	4	4			
RV reducer price	US$	413	244	144	144	-10%	-10%	0%
RV reducer per robot	US$	1,651	975	576	576	-10%	-10%	0%
RV reducer market for humanoid robot	**US$'mn**	**25**	**487**	**2,878**	**40,287**	**81%**	**43%**	**19%**
% of total humanoid robot market	%	3%	4%	4%	4%			
RV reducer price	Rmb	3,000	1,771	1,046	1,046	-10%	-10%	0%
RV reducer per robot	Rmb	12,000	7,086	4,184	4,184	-10%	-10%	0%
RV reducer market for humanoid robot	**Rmb'mn**	**180**	**3,543**	**20,921**	**292,890**	**81%**	**43%**	**19%**
% of total humanoid robot market	%	3%	4%	4%	4%			

We focus on the key components that are relevant to our coverage.

We forecast the market size to the highest for **actuator modules** due to the high unit cost as an actuator integrates many components. We believe the TAM for **planetary roller screws** is larger than **strain wave gears**, as we assume higher number of planetary roller screw per robot (40 units comprising of 14 for structural actuators and another 16 for dexterous hands – we assume 8 screws per hand to leave some room for upside vs Tesla's Gen3 model that has 17-20 per hand).

Market size of key components by 2035



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Source: Deutsche Bank estimates

Potential suppliers for humanoid robot components relevant to our automation coverage

Entry barrier	Component	Manufacturers	
		China	Overseas
High	Dexterous hand (灵巧手)	- Moons' Electric (鸣志电器) (listed) - Zhaowei Machinery (兆威机电) (listed)	- **Shadow Robot** (UK) (private) - **DLR** (Germany) (private)
	Planetary roller screw (行星滚柱丝杠)	- Seenpin Electromechanical Transmission (新剑传动) (listed) - XCC Group (五洲新春) (listed) - BST (贝斯特) (listed) - Hengli Hydraulic (恒立液压) (listed) - Shuanglin Auto Parts (双林股份) (listed) - Qinchuan Machine Tool (秦川机床) (listed) - Nanjing Technology and Equipment Manufacturing (南京工艺装备制造) (private) - UTech (优仕特) (Taiwan) (private) - Zhenyu Technology (震裕科技) (listed) - DINGS'Intelligent Control (鼎智科技) (listed) - Beite Technology (北特科技) (listed)	- **Ewellix** (Sweden): was under **SKF**, but was carved out and acquired by **Schaeffler** in 2023 - **Schaeffler** (Germany) (listed) - **GSA** / Gewinde Ziegler AG (Switzerland) (private) - **Rollvis** (Switzerland) (private) - **Bosch Rexroth** (Germany) (private)
	Strain wave gearing (谐波减速器)	- Leaderdrive (绿的谐波) (listed) - Sling Automobile Bearing (斯菱股份) (listed) - Laifual (来福谐波) (private) - Fbrobot (福德机器人) (listed) - Han's Motion (大族精密) (sold by Han's Laser) - Fine Motion Robot Technology (环动科技) (under Shuanghuan Driveline which is listed) - Reach Machinery (瑞迪智驱) (listed) - TC Drive (同川精密) (private) - Haozhi Industrial (昊志机电) (listed) - Guomao Reducer (国茂股份) (listed) - Hiwin (上银科技) (Taiwan) (listed)	- **Harmonic Drive Systems** (Japan) (listed) - **Nidec-Shimpo** (Japan): acquired by **Nidec** (Nidec is listed) - **Cone Drive** (US): acquired by **Timken** (Timken is listed) - **igus** (Germany) (private)
	Actuator integrator (执行机集成商)	- Sanhua Intelligence Control (三花智控) - Tuopu Group (拓普集团)	- **Bosch** (Germany) (private)
	Planetary reducer (行星减速器)	- Everwin Precision (长盈精密) (listed) - FORE Intelligent Tech (丰立智能) (listed) - Kofon (科峰智能) (private) - Newstart (纽氏达特) (private) - Apex Dynamics (精锐科技) (Taiwan) (listed) - ZhongDa Leader (中大力德) (listed) - Li Ming (利茗) (Taiwan) (private)	- **Nidec-Shimpo** (Japan): acquired by Nidec (Nidec is listed) - **Neugart** (Germany) (private) - **WITTENSTEIN** (Germany) (private) - **SEW Eurodrive** (Germany) (private) - **STOBER** (Germany) (private) - **Bonfiglioli** (Italy) (private) - **Sumitomo** (Japan) (listed)
	Coreless motor (空心杯电机)	- Moons' Electric (鸣志电器) (listed) - DINGS'Intelligent Control (鼎智科技) (listed) - Topband (拓邦股份) (listed) - Veichi Electric (伟创电气) (listed) - HCFA (禾川科技) (listed) - Zhaowei Machinery & Electronics (兆威机电) (listed) - Leadshine (雷赛智能) (listed)	- **Maxon** (Switzerland) (private) - **FAULHABER** Drive Systems (Germany) (private) - **Nidec** (Japan) (listed) - **Portescap** (Switzerland) (acquired by Regal Rexnord which is listed) - **Orbray** (Japan) (private)
Low	Frameless torque motor (无框力矩电机)	- Kinco (步科股份) (listed) - Haozhi Industrial (昊志机电) (listed) - HCFA (禾川科技) (listed) - Leadshine (雷赛智能) (listed)	- **Kollmorgen** (US) (private) - **Allied Motion** (US) (listed) - **Parker Hannifin** (US) (listed) - **Nidec** (Japan) (listed) - **Aerotech** (US) (private)

On this slide, we list potential suppliers for the key components. We have highlighted companies in our APAC Industrials coverage in the colour red.

The lists are not exhaustive and are based on company disclosure and our channel checks. We expect the lists to change as humanoid OEMs are constantly updating their design and production plan, which affects the supply chain decisions.

Potential suppliers for humanoid OEMs

Tesla	Figure	Huawei	Others
Integrator: - Sanhua (三花智控) (listed) - Tuopu Group (拓普集团) (listed) **Screw:** - **Schaeffler** (Germany) (listed) - Seenpin Electromechanical Transmission (新剑传动) (listed) - Beite Technology (北特科技) (listed) **Gear:** - **Harmonic Drive Systems** (Japan) (listed) - Leaderdrive (绿的谐波) (listed) - Everwin Precision (长盈精密) (listed) **Motor:** - Moons' Electric (鸣志电器) (listed) - **Maxon** (Switzerland) (private)	**Gear & Bearing:** - Everwin Precision (长盈精密) (listed) - **Gear:** - Leaderdrive (绿的谐波) (listed) - Moons' Electric (鸣志电器) (listed) - Zhaowei Machinery (兆威机电) (listed)	**Huawei embodied partners** (16 in total): - Leju Robotics (乐聚机器人) - Zhaowei Machinery and Electronic (兆威机电) (listed) - Hans Robot (大族机器人) - Moying Robotics (墨影科技) - Topstar (拓斯达) (listed) - X-Square Robot (自变量机器人) - Hualong Xunda Information Technology (华龙迅达) - Huacheng Industrial Control (华成工控) - Zhongjian Technology (中坚科技) (listed) - EFORT (埃夫特) (listed) - Digit Technology (数字华夏) - BrainCo (强脑科技) - ORCAS Robot (佛山奥卡机器人) - Hechuan Humanoid Robot (禾川人形) - Chinasoft International (北京中软国际教育) - Chuangxin Lezhi Informational Technology (北京创新乐知网络技术有限公司)	**For Unitree:** - Changsheng (长盛轴承) (listed) for bearings for robot dogs - ZhongDa Leader (中大力德) (listed) for planetary reducers for robot dogs **For NVIDIA:** - Hota Industrial (和大) (listed) - Main Drive (盟英) under (Mirle Automation) 盟立 (listed) - Hiwin (上银科技) (listed) - Ace Pillar (罗升) (listed) - Chieftek Precision (直得) (listed) - Solomon Technology (所罗门) (listed)

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Source: Deutsche Bank, company data, Economic Daily News



Stock picks

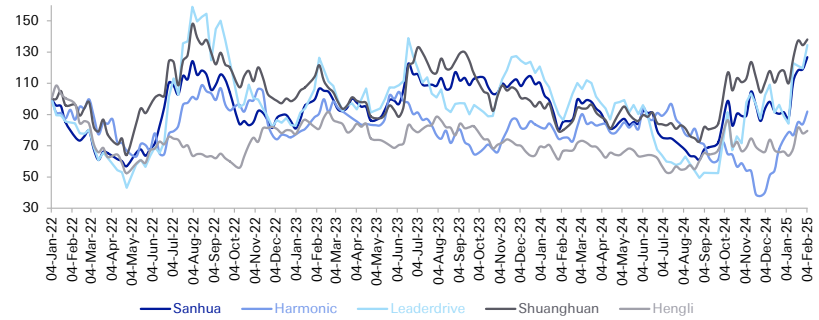
APAC Industrials: Humanoid has been an investment theme in China since mid-2022

Investors in China have been watching the humanoid development closely since 2022. The news flows and sentiment have driven **multiple rounds of share price outperformance** of relevant names in our APAC Industrials coverage, as shown in the figures on the right-hand side and below.

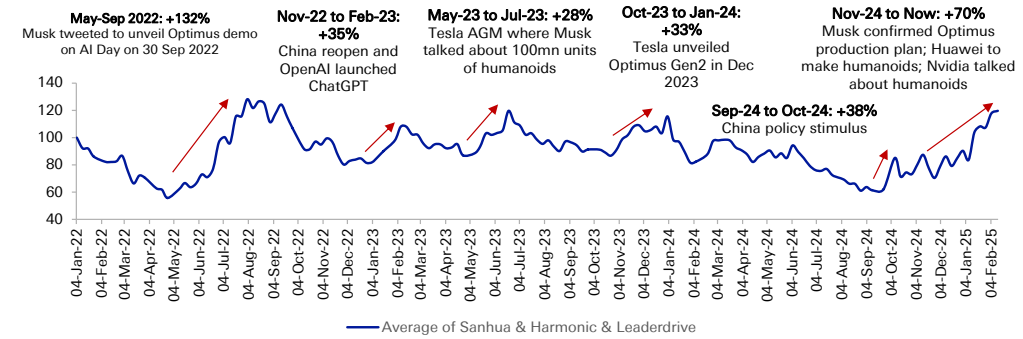
In our APAC Industrial coverage, **Sanhua**, **Leaderdrive** and **Harmonic** are the most sensitive to humanoid sentiment as they are believed by the market to have entered the supply chain for **Tesla humanoids** with high certainty. **Sanhua**'s share price has almost recovered back to the historical high level in February 2025. **Shuanghuan** and **Hengli** as well as **Hiwin** are also potential humanoid component suppliers, and therefore benefited from the sentiment too.

We feel that **excitement** about and the **attention** on humanoid since late 2024 have been **the strongest and the broadest** among all the rounds we have seen.

Indexed share price performance (Jan 2022 = 100) of the most relevant humanoid names in our APAC Industrials coverage



Timeline of humanoid impact on share price of relevant APAC Industrial names



Share price performance details

	Stock price % changes during					
	May-Sep 2022	Nov-22 to Feb-23	May-23 to Jul-23	Oct-23 to Jan-24	Sep-24 to Oct-24	Nov-24 to Now
Most relevant humanoid names						
Sanhua	103%	29%	34%	7%	43%	47%
Harmonic	60%	30%	8%	20%	4%	167%
Leaderdrive	248%	45%	40%	36%	74%	51%
Shuanghuan	102%	11%	39%	6%	45%	31%
Hengli	24%	7%	8%	2%	34%	18%
Hiwin	-8%	32%	6%	18%	10%	45%
Others relevant humanoid names						
Supcon	34%	0%	-1%	10%	57%	25%
Estun	63%	16%	22%	-3%	40%	19%
Inovance	21%	7%	3%	0%	72%	14%
THK	10%	5%	-3%	3%	1%	3%
Yaskawa	6%	14%	16%	14%	9%	6%
Index						
CSI 300 Index	9%	8%	-3%	-3%	33%	2%
Nikkei 225	7%	-2%	14%	9%	8%	1%
Taiwan Index	-11%	6%	10%	9%	7%	3%

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Source: Deutsche Bank, Bloomberg Finance LP

APAC Industrials: Engagement of our coverage in humanoid

We provide the details on how our APAC Industrials coverage is engaged in the humanoid robot market.

We consider **Sanhua**, **Harmonic Drive**, **Leaderdrive**, **Shuanghuan** and **Hengli** as the most relevant as their engagement is direct as component suppliers with relatively higher possibility of entering the humanoid robot supply chain. **Hiwin** is rising as a potential humanoid robot component supplier – Hiwin is already a supplier for robot dogs for **Boston Dynamics** and more recently in December 2024, Hengli's CEO mentioned that they are in talks with all major humanoid OEMs globally.

Supcon and **Estun** have invested in humanoid robot OEMs. **Inovance** is developing humanoid components. **THK** and **Yaskawa** both manufacture components that could potentially be used in humanoids.

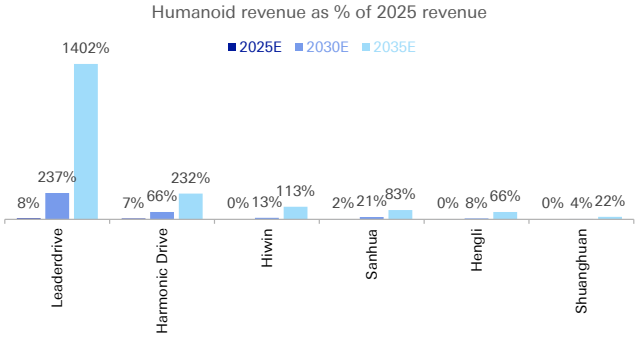
Engagement details of our APAC Industrials coverage in humanoid

Company	Humanoid engagement details
Most relevant names	
Sanhua	Sanhua is the **thermal management** system provider for **Tesla's EVs**. Sanhua has been in talks with Tesla early on about humanoids, and is widely believed by the market to become an **actuator integrator** for Tesla's humanoids. Sanhua has a partnership with **Leaderdrive**.
Harmonic	Harmonic is the global leading manufacturer of **strain wave reducers**. Harmonic mentioned that they have **already received orders for humanoids**, and guided in late 2023 for sales of ¥3.4bn (US$22mn) from humanoid robot reducers in FY3/25E, although the company subsequently pointed to delays.
Leaderdrive	Leaderdrive is the leading manufacturer of **strain wave reducers** in China. Leaderdrive guided for more than **10% revenue from humanoids** in 4Q24E. Leaderdrive is in talks with both **domestic and overseas humanoid OEMs**.
Shuanghuan	Shuanghuan is the top 2 RV reducer manufacturer and is the top 10 harmonic reducer manufacturer in China. Shuanghuan supplies **auto gears for Tesla's EVs**. Shuanghuan is in talks with Tesla to design the **next generation reducers for humanoids**.
Hengli	Hengli is the leading manufacturer of hydraulic cylinders and pumps for excavators in China. The company is expanding in the **linear product** market with a high-quality team. Hengli has **sent samples of screws and actuators to Tesla** in late 2024 and early 2025.
Hiwin	Hiwin have supplied **ball screws** for **robot dogs** for **Boston Dynamics** for 4-5 years. Hiwin is in talks with robot OEMs from US and Japan to supply strain wave reducers and screws. Business Weekly in Taiwan reported in December 2024 that **Nvidia** is looking to build a humanoid robot team in Taiwan, and Hiwin was reportedly one of the partners Nvidia has talked to. Hiwin's CEO confirmed in late December that Hiwin is in talks with **all the major humanoid OEMs globally**.
Relevant names	
Supcon	Supcon **invested in Zhejiang Humanoid Robot** Innovation Centre (浙江人形机器人创新中心有限公司) in 2024. Zhejiang Humanoid Robot Innovation Centre launched their first humanoid robot in March 2024. We view Supcon as advanced in **Industrial AI** as it launched an industrial AI model TPT (time-series pre-trained transformer) in 2024 with more products to be launched in 2025.
Estun	Estun **invested in humanoid robot** company Codroid (酷卓). Codroid launched humanoid robot CORDOID 01 in 2024.
Inovance	Inovance is **developing components for humanoids** such as sensors, control and drive systems.
THK	THK launched a **humanoid robot** what it claims to be the world's **fastest** at 3.5m/s in June 2024. THK is a leading manufacturer of **screws** which we think could be potentially used for humanoids.
Yaskawa	Yaskawa is a leading manufacturer globally of **servomotors** which we think could be potentially used for humanoids.

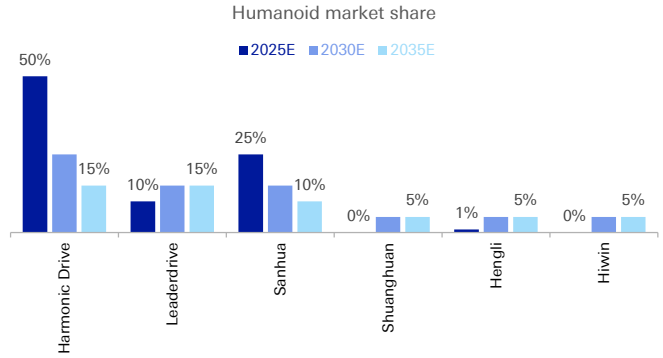
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Source: Deutsche Bank, company data

APAC Industrials: Humanoids to become a significant revenue stream by 2030-35

Humanoid could contribute tremendously to the revenue for Leaderdrive, Harmonic Drive, Sanhua and Hengli



Our assumption of humanoid market share by company



Our detailed calculation of humanoid robot contribution by company

	2025 revenue Local currency (mn)	2025 revenue In Rmb'mn	Humanoid revenue (Rmb'mn) 2025E	2030E	2035E	Humanoid as % of 2025 revenue 2025E	2030E	2035E	Humanoid market share 2025E	2030E	2035E	2035E P/E	2035E NPM
Sanhua	32,540	32,540	578	6,820	26,848	2%	21%	83%	25%	15%	10%	30x	10%
Harmonic Drive	65,895	3,168	211	2,078	7,363	7%	66%	232%	50%	25%	15%	25x	13%
Leaderdrive	522	522	42	1,240	7,322	8%	237%	1402%	10%	15%	15%	30x	20%
Shuanghuan	11,021	11,021	0	413	2,441	0%	4%	22%	0%	5%	5%	25x	15%
Hengli	10,620	10,620	4	797	6,974	0%	8%	66%	1%	5%	5%	25x	15%
Hiwin	27,600	6,147	0	797	6,974	0%	13%	113%	0%	5%	5%	25x	10%

As it is still early days for humanoids with minimal penetration, we look to the longer term (2035) to assess the revenue contribution and profit to our coverage.

Humanoid revenue should remain **small** in **2025** for most companies, except 7-8% for **Leaderdrive** and **Harmonic Drive**.

However, we believe humanoids could become a significant revenue stream for the companies by 2035. Our calculation shows that humanoid should contribute the most to **Leaderdrive** revenue and could lift its revenue by more than 10x by 2035. This is followed by meaningful contributions to **Harmonic Drive**, **Hiwin**, **Sanhua** and **Hengli**.

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Source: Deutsche Bank estimates

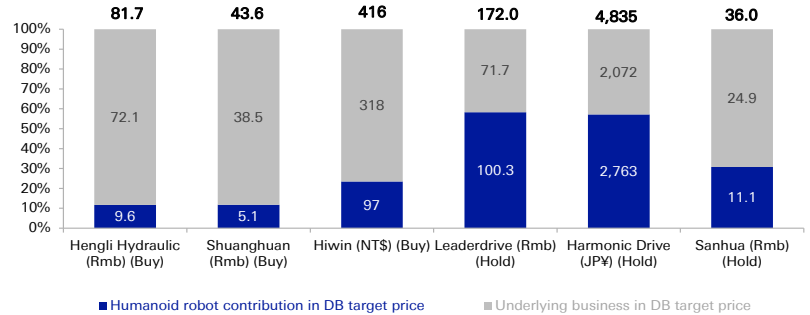
APAC Industrials: Expensive multiples of humanoid names on rapid growth potential

Valuation multiples are high for humanoid-related names in our APAC Industrials coverage, especially for **Leaderdrive** and **Harmonic** Drive, as shown in the figures below.

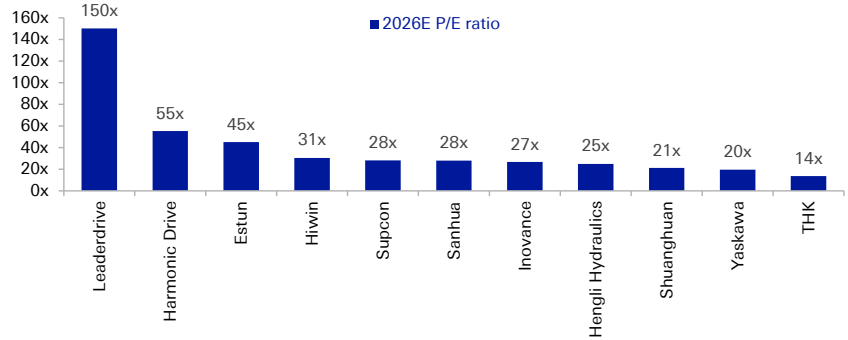
However, as explained on the prior slide, we calculate humanoid could contribute significantly to the companies' revenue in the future years (2030 and beyond). As the revenue significance of humanoid in 2025/26 is small, we do not feel that 2026 multiples are good representatives of the long-term opportunity. We therefore look to **humanoid contribution revenue forecast to 2035** and discount it back to calculate valuation for humanoid for the companies.

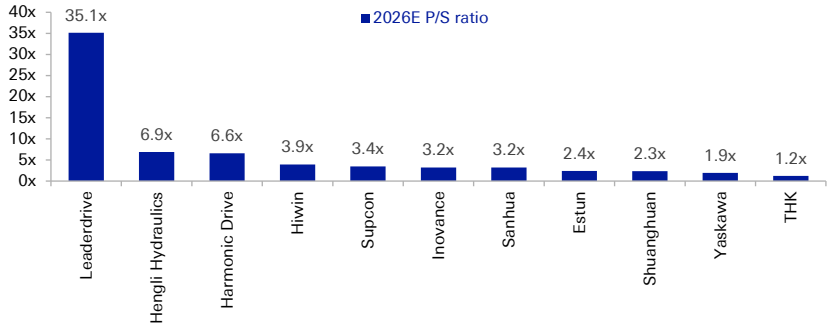
We show the breakdown of humanoid robot contribution in our target price on the right-hand side chart. We expect humanoid robot to account for about 60% of value for both **Harmonic Drive** and **Leaderdrive** as they show the highest revenue upside from humanoid. Humanoid should also contribute meaningfully for **Sanhua** and **Hiwin**, per our calculation.

Target price breakdown of humanoid-related names



Multiples are expensive for many of the humanoid-related names, especially Leaderdrive and Harmonic Drive





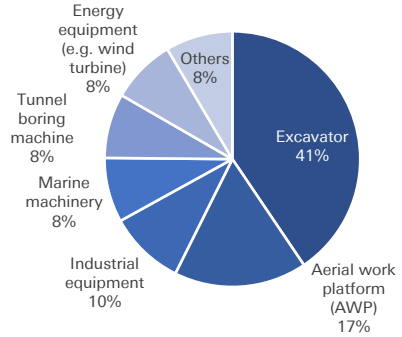
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Source: Deutsche Bank estimates, company data

APAC Industrials: Hengli Hydraulic (601100.SS): Buy, TP Rmb81.7

Investment thesis:

- Large upside potential from **humanoid** for Hengli from (1) the use of **screws** in dexterous hand from zero to 17-22 per hand, increasing total screws used per humanoid **from 14 to up to 48**; and (2) **higher ASP** opportunity of 2-3x as Hengli has sent samples for not only screws but also **integrated actuators**;
- **Excavator sales** (41% of Hengli's sales) have **bottomed out** with room for growth – China domestic demand is off a low base as 2024 was 1/3 of the peak level in 2020; Chinese excavator OEMs still aim to gain share in the overseas market;
- Hengli has built a high-quality team (many from **THK**) for **linear products** with high growth potential for this new business – we forecast the business to grow from Rmb50mn in 2024E to Rmb750mn in 2026, accounting for 6% of group sales.

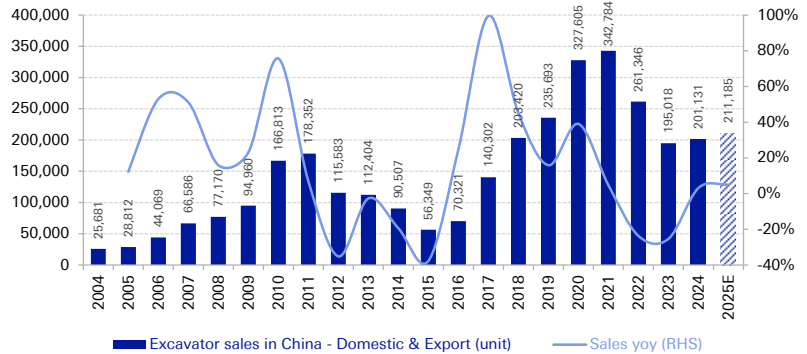
End-market breakdown for Hengli (2023)



Humanoid robot contribution calculation for Hengli

	Unit	2025E	2030E	2035E	2050E	25/30 CAGR	30/35 CAGR	35/50 CAGR
Humanoid robot	Unit	15,000	500,000	5,000,000	70,000,000	102%	58%	19%
Unit per humanoid robot	Unit	14	27	40	40			
Planetary roller screw total unit demand	Unit	210,000	13,500,000	200,000,000	2,800,000,000			
Planetary roller screw price	Rmb	2,000	1,181	697	697	-10%	-10%	0%
Planetary roller screw per robot	Rmb	28,000	31,886	27,894	27,894	3%	-3%	0%
Planetary roller screw market for humanoid robot	**Rmb'mn**	**420**	**15,943**	**139,471**	**1,952,599**	**107%**	**54%**	**19%**
% of total humanoid robot market	%	8%	18%	26%	26%			
Market share of Hengli	%	1%	5%	5%	5%			
Planetary roller screw total unit demand for Hengli	Unit	2,100	675,000	10,000,000	140,000,000			
Sales for Hengli from humanoid robot	**Rmb'mn**	**4**	**797**	**6,974**	**97,630**			
Net profit for Hengli from humanoid robot	Rmb'mn	1	120	1,046	14,644			
Net profit margin	%	15%	15%	15%	15%			
Number of shares outstanding (NOSH)	mn	1,343	1,343	1,343	1,343			
EPS for Hengli from humanoid robot	**Rmb**	**0.00**	**0.09**	**0.78**	**10.90**			
Valuation for humanoid robot								
2035E P/E	Times	25x						
WACC	%	7.4%						
Share price for Hengli from humanoid robot for 2025	**Rmb**	**9.8**						

Excavator sales in China have bottomed out



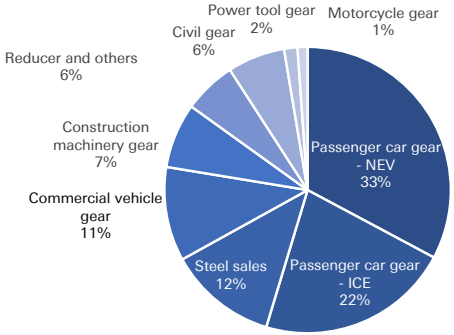
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Source: Deutsche Bank estimates, company data, Wind

APAC Industrials: Shuanghuan Driveline (002472.SZ): Buy, TP Rmb43.6

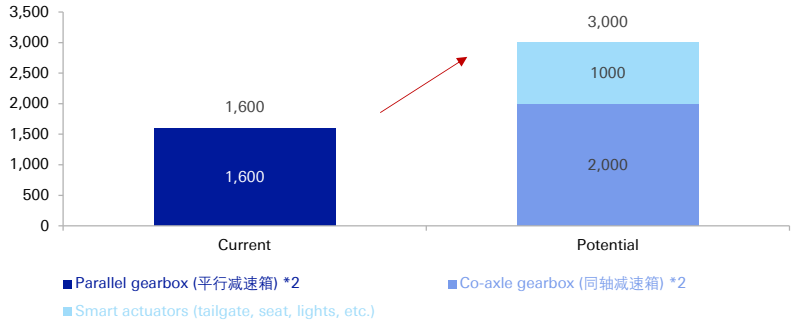
Investment thesis:

- **Higher ASP** per passenger vehicle opportunity from increasing orders for co-axle gearboxes and additional smart actuators, adding to ASP potential of Rmb3,000 per EV, almost doubling Rmb1,600 previously;
- Growth prospects from **new businesses** including reducers for traditional robots and humanoid robots as well as for industrial equipment, and smart actuators for robot vacuum cleaners, drones and eBikes. We note Shuanghuan supplies EV gears to **Tesla** and is co-developing a next-generation of reducers for humanoids;
- **Overseas expansion** potential with good reception from European and Japanese customers (Schaeffler, Valeo, Toyota, Stellantis, BMW, Audi) and the new factory in Hungary;

End-market breakdown for Shuanghuan (1H24)



Room for meaningful ASP growth per vehicle



Humanoid robot contribution calculation for Shuanghuan

	Unit	2025E	2030E	2035E	2050E	25/30 CAGR	30/35 CAGR	35/50 CAGR
Humanoid robot	Unit	15,000	500,000	5,000,000	70,000,000	102%	58%	19%
Unit per humanoid robot	Unit	14	14	14	14			
Strain wave gearing total unit demand	Unit	210,000	7,000,000	70,000,000	980,000,000			
Strain wave gearing price	Rmb	2,000	1,181	697	697	-10%	-10%	0%
Strain wave gearing per robot	Rmb	28,000	16,534	9,763	9,763	-10%	-10%	0%
Strain wave gearing market for humanoid robot	**Rmb'mn**	**420**	**8,267**	**48,815**	**683,410**	**81%**	**43%**	**19%**
% of total humanoid robot market	%	8%	9%	9%	9%			
Market share of Shuanghuan	%	0%	5%	5%	5%			
Strain wave gearing total unit demand for Shuanghuan	Unit	-	350,000	3,500,000	49,000,000			
Sales for Shuanghuan from humanoid robot	**Rmb'mn**	**-**	**413**	**2,441**	**34,170**			
Net profit for Shuanghuan from humanoid robot	Rmb'mn	-	62	366	5,126			
Net profit margin	%	15%	15%	15%	15%			
Number of shares outstanding (NOSH)	mn	841	841	841	841			
EPS for Shuanghuan from humanoid robot	**Rmb**	**-**	**0.07**	**0.44**	**6.09**			
Valuation for humanoid robot								
2035E P/E	Times	25x						
WACC	%	7.8%						
Share price for Shuanghuan from humanoid robot for 2025	**Rmb**	**5.1**						

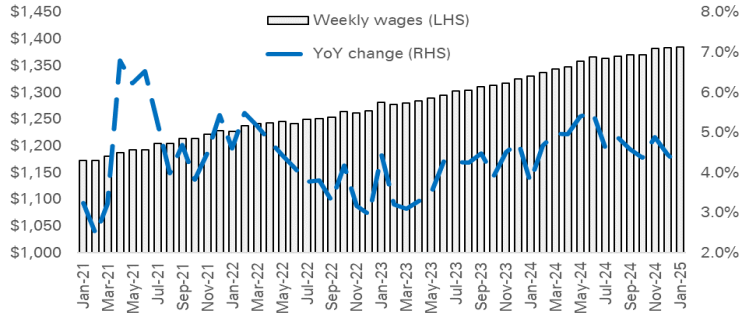
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Source: Deutsche Bank, company data

US Autos & Mobility: Tesla (TSLA): Buy, TP $420

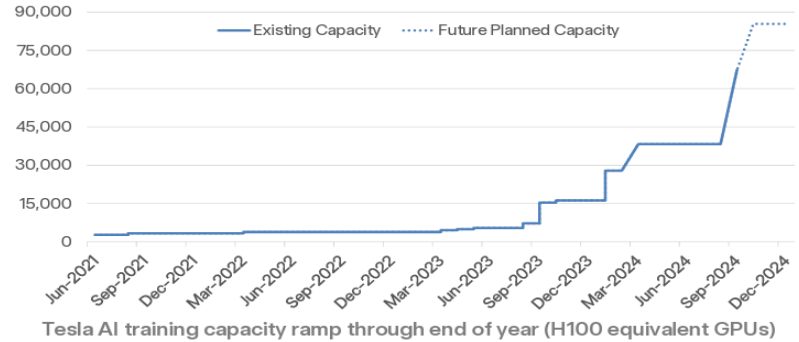
Investment thesis:

- We view Tesla as a technology platform reshaping multiple industries, deserving of a unique type of valuation. Tesla structurally already has a big lead in BEVs especially as it relates to scale/cost and commands outsized brand value globally. Long term, Tesla is an emerging leader in autonomous driving (robotaxi) and humanoid robots (Optimus), in our view, which represent some of the most clear+lucrative applications of real-world end-to-end AI;
- Currently, Optimus is being trained by data sets generated through teleoperation and videos of itself performing tasks paired with motor/actuator data to map out framework that can align with human movement. After the compatibility is fully mapped out, Optimus should be able to train/learn by watching videos of humans performing tasks in a "DIY" type of manner, similar to how FSD learns from human driving.

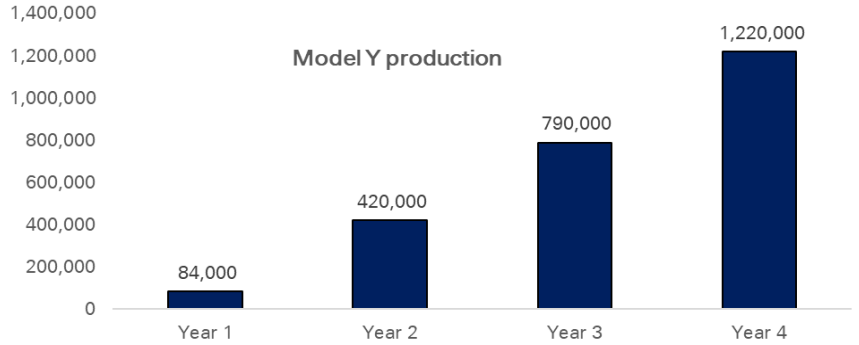
High wages in US manufacturing suggest large savings potential



Model training can leverage existing E2E AI infrastructure



Unique ability to scale up production and supply chain quickly



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Source: Deutsche Bank, company data



Appendix

Humanoid robot is a new addition to the robot industry (1)

The International Federation of Robotics (IFR) divides robots into two types — **industrial robots** (including traditional industrial robots and collaborative robots) and **service robots**. According to the IFR, annual installation of **industrial robots** reached 541,000 units in 2023 with an installed base of 4.3mn units. For **service robots**, annual installation was 205,000 units in 2023 for professional service robots, 6,200 units for medical robots and 4.1mn units for consumer service robots.

Humanoid robots come with greater human-like dexterity, involving more advanced sensing and AI capabilities. Therefore, in our view, humanoid robots could be used for general purposes, and they could act as both industrial robots in manufacturing factories (for tasks such as picking and sorting) and service robots (for human interactions). The development of the humanoid robot can be traced back to **as early as the 1970s**, when Waseda University in Japan invented WABOT-1, the first full-scale anthropomorphic robot developed in the world. In recent years, humanoid robots came under the spotlight of investors when **Elon Musk mentioned in August 2021, at Tesla's first AI Day**, that Tesla was working on a humanoid robot with the goal of building a prototype in 2022. At Tesla's **second AI Day in September 2022**, the humanoid robot, **Optimus, was unveiled**.

The pace of humanoid robot development **has accelerated** in recent years, driven, in our view, by **the fast development of artificial intelligence (AI)**, as the integration of AI enables humanoid robots to interpret and respond to complex commands and scenarios, mimicking human-like behaviour by leveraging advanced language and vision models, powered by AI. For example, Elon Musk sees **electric vehicles (EVs) as robots on wheels**, and Tesla's humanoid robot, Optimus, shares the same "brain" as Tesla EVs, and Tesla uses its computer vision video processing and recognition system, Dojo, for both its EVs and Optimus. The humanoid robot, **Figure 01**, from Figure is equipped with high-level visual and language intelligence from OpenAI models, enabling it to have full conversations with people.

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Humanoid robot is a new addition to the robot industry (2)

Type	Industrial robot		Service robot	Humanoid robot
	Traditional industrial robot	Collaborative robot (Cobot)		
Definition	Industrial robots are heavy-duty machines designed to automate the manufacturing process	Cobots are intended for direct human-robot interaction within a shared space, or where humans and robots are in close proximity		Humanoid robots are robots designed to resemble humans in appearance and behaviour
Capability	- Material handling - Assembly - Welding - Painting & Coating - Quality inspection - Picking, sorting and packing	- Assembly (part selection, dispensing of adhesive, fastening of screws, etc.) - Machine tending - Material handling - Quality inspection - Welding	Service robots are robots in personal use or professional use that performs useful tasks for humans or equipment. Service robots include **consumer service robots** (domestic cleaning robots, automated wheelchairs, and social interaction robots), and **professional service robots** (cleaning robots for public places, delivery robots, fire-fighting robots, rehabilitation robots and surgery robots in hospitals, as well as autonomous mobile robots (AMR))	- Moving / walking - Interact with humans
Features	- Do work in place of human beings; - Can handle heavier and larger materials than cobots; - Moves at a faster speed than cobots; - Engineers need to re-write codes for any changes; - Often needs safety cages to keep humans out of the workspace	- Do work alongside human beings; - More easily programmable than industrial robots; - Not designed for heavy manufacturing; - Usually cheaper than industrial robots		- Could perform complex actions that require human-like dexterity, such as picking up objects, walking and climbing stairs; - Able to behave like humans and interact with humans
User case	- Manufacturing factory - Warehouse	- Manufacturing factory - Agriculture - Medical - Pharma	- Transportation & logistics - Hospitality - Medical robotics - Professional cleaning - Agriculture	- Manufacturing factory - Warehouse - Entertainment - Education - Home assistance - Elderly care
Example				

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China policy on humanoid robot (1)

Date	Policy
Dec-24	**Hangzhou**: "**Measures to Promote Innovation and Development of Humanoid Robot Industry**" Include humanoid robot's **complete machine**, **software algorithms** and **key components** in the scope of support for key scientific research projects, promote key technological breakthrough on humanoid robots such as "brain, cerebellum and limbs". Include humanoid robot AI General Language model in the key supported AI specilised models, and include the relevant open source algorithm platform into municipal AI open source demonstration platform. "
Dec-24	**Chongqing**: "**Measures to Support the Innovation and Development of Humanoid Robot**" Focus on major key municipal scientific and technological innovation projects such as **"storage and computing integrated" chips, high-performance end effectors, electric-driven linear joints, new sensors, and robotic operations system**, promote core technology breakthrough. Focus on vision - language - action model, world model, universal skill training framework, model compression, parameter efficient fine-tuning, simulation data engine, virtual and reality conversion, neural radiance field, occupancy network, scene flow estimation, diffusion policy, causal inference, retrieval-augmented generation, Chain-of-Thought and other embodied large model related technologies, and form a batch of industrialization results.
Dec-24	**Hangzhou**: "**Humanoid Robot Development Plan (2024-2029)**" Focus on "**the best body + the strongest brain**" to accelerate the construction of an integrated innovation system and a full industry chain ecosystem for R&D, design, manufacturing and application of humanoid robots. By **2027**, the industrial innovation system will be initially established, and the infrastructure supporting the development of humanoid robots will be basically sound; by **2029**, the industrial scale will achieve leaping growth, and the entire industry chain ecosystem and industrial clusters will be basically formed.
Dec-24	**Anhui**: **"Humanoid Robot Development Action Plan (2024-2027)"** By **2027**, the "23456" innovation system and industrial ecology of humanoid robot industry will be built, a hub for developing humanoid robot industry with great influence will be established. That is to create two industrial pilot zones in Hefei and Wuhu; build three major platforms including a provincial innovation platform for humanoid robots, a pilot verification platform, and an incubation platform; build no less than four types of domestically representative humanoid robots. Develop advantageous components such as **controllers, high-power-density and high-performance servo and motors, integrated joints, lightweight dexterous hands, and electronic skins**; launch multiple humanoid robot products for six major scenarios including **manufacturing, emergency response, trade logistics, medical health, home services, and tourism services**.
Nov-24	**Nanjing: "Action Plan for Promoting High-Quality Development of the Robot Industry (2024-2026)"** Propose to build "1+N+1" complete machine system. The first "1" said to build the leading edge of **industrial robots**. "N" indicates to enhance several **featured robot industries**. The latter "1" represents the forward-looking layout of the **humanoid robot industry**. Comprehensively promote the R&D of humanoid robot **"brain", "cerebellum", "limbs"** and other components, construct a universal complete machine platform for humanoid robots, and initially establish **small-batch production** capacity of complete machine.
Dec-24	**Shijingshan District: "Measures for Supporting the Development of the Humanoid Robot Industry (Trial)"** Focus on key technologies such as the "**brain, cerebellum, limbs, and body**" of humanoid robots, the government will provide project subsidies, maximum amount up to Rmb5mn for a single project; additional subsidies up to Rmb9mn will be provided to municipal level projects. Encourage to overcome technical problems such as **force sensors, micro-electromechanical attitude-measuring sensors, and tactile sensors**. Support various application scenarios of humanoid robots, such as **consumer finance, special applications, emergency, industrial, medical care, elderly care, logistics, commerce, construction**, etc.
Nov-24	**"AI Embodied Intelligent Data Collection Specifications"** MIIT industry standard "AI Embodied Intelligent Data Collection Specification", a project spearheaded by the National & Local Embodied Intelligent Robot Innovation Center, **standardizes the format of embodied intelligent data set collection**, so that data collected by different companies can be shared and open sourced with each other, to accelerate the "emergence" of models.
Oct-24	**"Humanoid Robot Classification and Grading Application Guidelines" "Guide for Grading the Intelligent Levels of Embodied Intelligence"** National & Local Embodied Intelligent Robot Innovation Center released the first national standards for embodied intelligence. The group standard "Humanoid Robot Classification and Grading Application Guide" guides the classification in terms of structural appearance, movement mode and intelligent model, and classifies the humanoid robots into **four technical grades from L1 to L4** in accordance with the grading elements of embodied intelligence, lower limb movement, upper limb operation, and application environment, etc. The group standard "Guidelines for Grading the Development Stages of Embodied Intelligence and Intelligence" adopts the grading principles of system functionality, autonomy and generalization, and divides **the level of intelligence from basic to advanced into five stages of G1-G5** according to the core capabilities of perception, cognition, decision-making, autonomy, etc.
Sep-24	**Zhejiang: "Humanoid Robot Industry Innovation and Development Implementation Plan (2024-2027)"** By **2027**, the annual output of humanoid robots in Zhejiang Province will reach **20,000 units**, the **core industry scale** will reach **Rmb20bn**, and the related industry scale will reach **Rmb50bn**.

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Source: Deutsche Bank, China government

China policy on humanoid robot (2)

Date	Policy
Aug-24	**Chengdu: "Robot Industry Development 3-Year Action Plan (2024-2026)"** Significantly improve the innovation capabilities of robot industry by **2026**, create 100 new robotic products, gather 100 upstream and downstream enterprises in the industry chain, and create 100 benchmark demonstration scenarios. The scale of the entire industry chain will **exceed Rmb60bn**, and it will become a national growth pole for humanoid robot R&D and manufacturing and a new hub for demonstration applications.
Jun-24	The National Development and Reform Commission (NDRC) and other departments issued a notice on "Measures to create new consumption scenarios and cultivate **new consumption growth points** ". It is proposed to intensify the development of software and hardware functions such as flexible screens, super photography, super quick charge, AI assistants, end-side large models, and cross-screen and cross-terminal interconnection to enhance the convenience of human-machine interaction. Expand the functions of smart robots in **cleaning, entertainment and leisure, elderly care and disability care, education and training, etc**., and explore the development of **humanoid robots** based on AI models.
Jan-24	Seven departments including MIIT released opinion on promoting innovation and development of future industry, mentioned breakthroughs in high-end equipments such as **humanoid robots**, quantum computers, ultra-high-speed trains, the next generation of large aircraft, green smart ships and unmanned ships.
Oct-23	MIIT issued the "**Guiding Opinions on the Innovation and Development of Humanoid Robots**" **2025 goal:** The humanoid robot innovation system is initially established, make breakthroughs in a number of key technologies such as "brain, cerebellum, and limbs", and ensure the safe and effective supply of core components. Cultivate 2-3 ecological enterprises with global influence and a number of specialized, new small and medium-sized enterprises, and create 2-3 industrial clusters. **2027 goals:** Significantly improve the technological innovation ability of humanoid robots, form a safe and reliable industrial supply chain system, and build an internationally competitive industrial ecology.
Oct-23	**Shanghai Action Plan for Promoting High-quality Innovation and Development of Smart Robot Industry (2023-2025)** **2025** goal: build three public service platforms, smart robot detection and pilot verification innovation center, **humanoid robot** manufacturing innovation center, general robot industry research institute, etc.
Jun-23	**Beijing: "Robot Industry Innovation and Development Action Plan (2023-2025)"** Provides policy guidance for the **humanoid robot** industry for the first time, and proposes to step up the layout of humanoid robots, benchmark the world's leading humanoid robot products, support enterprises and universities to carry out research and engineering of humanoid robot products and key components, accelerate the construction of Beijing humanoid robot industry innovation center, and strive to become national manufacturing innovation center. **2025 goal**: robot innovation ability greatly improves, cultivates 100 kinds of high-tech and high value-added robot products, 100 kinds of application scenarios with national promotion value, and the number of robots owned by 10,000 people reaches the world's leading level. The city's core robot industry revenue reaches more than Rmb30 billion.
May-23	**Shenzhen: "Action Plan for Accelerating the High-quality Development and High-level Application of AI in Shenzhen (2023-2024)"** Carrys out the research and development of general-purpose embodied smart robots, supports scientific research institutions and enterprises to build **more than 5 joint AI laboratories, and accelerates the establishment of Guangdong Humanoid Robot Manufacturing Innovation Center**.
May-23	**Shanghai: "3-Year Action Plan for Promoting the High-quality Development of the Manufacturing Industry (2023-2025)"** Aims at the frontier of AI technology, builds a general large model, and develops vertical fields industrial ecology, builds an international algorithm innovation base, and accelerates the innovation and development of humanoid robots.
Apr-23	**Shandong Province: "3-Year Action Plan for Improving the Innovation Capability of Manufacturing Industry (2023-2025)"** Accelerates the deployment of cutting-edge fields such as humanoid robots, metaverse, quantum technology, future networks, promote the R&D and application of 6G technology,
Jan-23	17 departments including MIIT jointly issued the **"Robot+" Application Action Plan.** **2025 goal:** Robots' penetration rate in manufacturing industry **doubles** compared with 2020. Focus on 10 key areas, break through more than 100 types of robot innovative application technologies and solutions, promote more than 200 typical application scenarios of robots with high technological level, innovative application modes and significant use, create a number of "robot +" benchmarking enterprises, and build a number of application experience centers and test verification centers.
Dec-21	"**14th Five-Year Plan for the Development of Robot Industry**": The average **annual sales growth** rate of robot industry exceed **20%;** form a group of internationally competitive leading enterprises and a large number of innovative, specialized "little giant" enterprises with strong growth; build 3-5 industrial clusters with international influence. Robots' penetration rate in manufacturing industry **doubles**.

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Source: Deutsche Bank, China government

APAC Industrials: Humanoids valuation (DCF-based) for key names

Key assumptions

	2025 revenue Local currency (mn)	2025 revenue In Rmb'mn	Humanoid revenue (Rmb'mn) 2025E	2030E	2035E	Humanoid as % of 2025 revenue 2025E	2030E	2035E	Humanoid market share 2025E	2030E	2035E	2035E P/E	2035E NPM
Sanhua	32,540	32,540	578	6,820	26,848	2%	21%	83%	25%	15%	10%	30x	10%
Harmonic Drive	65,895	3,168	211	2,078	7,363	7%	66%	232%	50%	25%	15%	25x	13%
Leaderdrive	522	522	42	1,240	7,322	8%	237%	1402%	10%	15%	15%	30x	20%
Shuanghuan	11,021	11,021	0	413	2,441	0%	4%	22%	0%	5%	5%	25x	15%
Hengli	10,620	10,620	4	797	6,974	0%	8%	66%	1%	5%	5%	25x	15%
Hiwin	27,600	6,147	0	797	6,974	0%	13%	113%	0%	5%	5%	25x	10%

Sanhua

	Unit	2025E	2030E	2035E	2050E	25/30 CAGR	30/35 CAGR	35/50 CAGR
Humanoid robot	Unit	15,000	500,000	5,000,000	70,000,000	102%	58%	19%
Unit per humanoid robot	Unit	28	28	28	28			
Actuator module total unit demand	Unit	420,000	14,000,000	140,000,000	1,960,000,000			
Actuator module price	Rmb	5,500	3,248	1,918	1,918	-10%	-10%	0%
Actuator module per robot	Rmb	154,000	90,935	53,696	53,696	-10%	-10%	0%
Actuator module market for humanoid robot	**Rmb'mn**	**2,310**	**45,468**	**268,482**	**3,758,754**	**81%**	**43%**	**19%**
% of total humanoid robot market	%	42%	50%	49%	49%			
Market share of Sanhua	%	25%	15%	10%	10%			
Actuator module total unit demand for Sanhua	Unit	105,000	2,100,000	14,000,000	196,000,000			
Sales for Sanhua from humanoid robot	**Rmb'mn**	**578**	**6,820**	**26,848**	**375,875**			
Net profit for Sanhua from humanoid robot	Rmb'mn	58	682	2,685	37,588			
Net profit margin	%	10%	10%	10%	10%			
Number of shares outstanding (NOSH)	mn	3,786	3,786	3,786	3,786			
EPS for Sanhua from humanoid robot	**Rmb**	**0.02**	**0.18**	**0.71**	**9.93**			
Valuation for humanoid robot								
2035E P/E	Times	30x						
WACC	%	7.5%						
Share price for Sanhua from humanoid robot for 2025	**Rmb**	**11.1**						

Harmonic Drive Systems

	Unit	2025E	2030E	2035E	2050E	25/30 CAGR	30/35 CAGR	35/50 CAGR
Humanoid robot	Unit	15,000	500,000	5,000,000	70,000,000	102%	58%	19%
Unit per humanoid robot	Unit	14	14	14	14			
Strain wave gearing total unit demand	Unit	210,000	7,000,000	70,000,000	980,000,000			
Strain wave gearing price	US$	275	162	96	96	-10%	-10%	0%
Strain wave gearing per robot	US$	3,851	2,274	1,343	1,343	-10%	-10%	0%
Strain wave gearing market for humanoid robot	**US$'mn**	**58**	**1,137**	**6,715**	**94,004**	**81%**	**43%**	**19%**
% of total humanoid robot market	%	8%	9%	9%	9%			
Market share of Harmonic Drive	%	50%	25%	15%	15%			
Strain wave gearing total unit demand for Harmonic Drive	Unit	105,000	1,750,000	10,500,000	147,000,000			
Sales for Harmonic Drive from humanoid robot	**US$'mn**	**29**	**284**	**1,007**	**14,101**			
Net profit for Harmonic Drive from humanoid robot	US$'mn	4	37	131	1,833			
Net profit margin	%	13%	13%	13%	13%			
Number of shares outstanding (NOSH)	mn	95	95	95	95			
EPS for Harmonic Drive from humanoid robot	**US$**	**0.04**	**0.39**	**1.38**	**19.29**			
Valuation for humanoid robot								
2035E P/E	Times	25x						
WACC	%	7.6%						
Share price for Harmonic Drive from humanoid robot for 2025	US$	17.8						
Share price for Harmonic Drive from humanoid robot for 2025	**Yen**	**2,763**						

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Source: Deutsche Bank estimates

APAC Industrials: Humanoids valuation (DCF-based) for key names

Leaderdrive

	Unit	2025E	2030E	2035E	2050E	25/30 CAGR	30/35 CAGR	35/50 CAGR
Humanoid robot	Unit	15,000	500,000	5,000,000	70,000,000	102%	58%	19%
Unit per humanoid robot	Unit	14	14	14	14			
Strain wave gearing total unit demand	Unit	210,000	7,000,000	70,000,000	980,000,000			
Strain wave gearing price	Rmb	2,000	1,181	697	697	-10%	-10%	0%
Strain wave gearing per robot	Rmb	28,000	16,534	9,763	9,763	-10%	-10%	0%
Strain wave gearing market for humanoid robot	**Rmb'mn**	**420**	**8,267**	**48,815**	**683,410**	**81%**	**43%**	**19%**
% of total humanoid robot market	%	8%	9%	9%	9%			
Market share of Leaderdrive	%	10%	15%	15%	15%			
Strain wave gearing total unit demand for Leaderdrive	Unit	21,000	1,050,000	10,500,000	147,000,000			
Sales for Leaderdrive from humanoid robot	**Rmb'mn**	**42**	**1,240**	**7,322**	**102,611**			
Net profit for Leaderdrive from humanoid robot	Rmb'mn	8	248	1,494	20,912			
Net profit margin	%	20%	20%	20%	20%			
Number of shares outstanding (NOSH)	mn	183	183	183	183			
EPS for Leaderdrive from humanoid robot	**Rmb**	**0.05**	**1.35**	**8.15**	**114.14**			
Valuation for humanoid robot								
2035E P/E	Times	30x						
WACC	%	10.4%						
Share price for Leaderdrive from humanoid robot for 2025	**Rmb**	**100.3**						

Hengli Hydraulic

	Unit	2025E	2030E	2035E	2050E	25/30 CAGR	30/35 CAGR	35/50 CAGR
Humanoid robot	Unit	15,000	500,000	5,000,000	70,000,000	102%	58%	19%
Unit per humanoid robot	Unit	14	14	27	40	40		
Planetary roller screw total unit demand	Unit	210,000	13,500,000	200,000,000	2,800,000,000			
Planetary roller screw price	Rmb	2,000	1,181	697	697	-10%	-10%	0%
Planetary roller screw per robot	Rmb	28,000	31,886	27,894	27,894	3%	-3%	0%
Planetary roller screw market for humanoid robot	**Rmb'mn**	**420**	**15,943**	**139,471**	**1,952,599**	**107%**	**54%**	**19%**
% of total humanoid robot market	%	8%	18%	26%	26%			
Market share of Hengli	%	1%	5%	5%	5%			
Planetary roller screw total unit demand for Hengli	Unit	2,100	675,000	10,000,000	140,000,000			
Sales for Hengli from humanoid robot	**Rmb'mn**	**4**	**797**	**6,974**	**97,630**			
Net profit for Hengli from humanoid robot	Rmb'mn	1	120	1,046	14,644			
Net profit margin	%	15%	15%	15%	15%			
Number of shares outstanding (NOSH)	mn	1,343	1,343	1,343	1,343			
EPS for Hengli from humanoid robot	**Rmb**	**0.00**	**0.09**	**0.78**	**10.90**			
Valuation for humanoid robot								
2035E P/E	Times	25x						
WACC	%	7.4%						
Share price for Hengli from humanoid robot for 2025	**Rmb**	**9.6**						

Shuanghuan

	Unit	2025E	2030E	2035E	2050E	25/30 CAGR	30/35 CAGR	35/50 CAGR
Humanoid robot	Unit	15,000	500,000	5,000,000	70,000,000	102%	58%	19%
Unit per humanoid robot	Unit	14	14	14	14			
Strain wave gearing total unit demand	Unit	210,000	7,000,000	70,000,000	980,000,000			
Strain wave gearing price	Rmb	2,000	1,181	697	697	-10%	-10%	0%
Strain wave gearing per robot	Rmb	28,000	16,534	9,763	9,763	-10%	-10%	0%
Strain wave gearing market for humanoid robot	**Rmb'mn**	**420**	**8,267**	**48,815**	**683,410**	**81%**	**43%**	**19%**
% of total humanoid robot market	%	8%	9%	9%	9%			
Market share of Shuanghuan	%	0%	5%	5%	5%			
Strain wave gearing total unit demand for Shuanghuan	Unit	-	350,000	3,500,000	49,000,000			
Sales for Shuanghuan from humanoid robot	**Rmb'mn**	**-**	**413**	**2,441**	**34,170**			
Net profit for Shuanghuan from humanoid robot	Rmb'mn	-	62	366	5,126			
Net profit margin	%	15%	15%	15%	15%			
Number of shares outstanding (NOSH)	mn	841	841	841	841			
EPS for Shuanghuan from humanoid robot	**Rmb**	**-**	**0.07**	**0.44**	**6.09**			
Valuation for humanoid robot								
2035E P/E	Times	25x						
WACC	%	7.8%						
Share price for Shuanghuan from humanoid robot for 2025	**Rmb**	**5.1**						

Hiwin

	Unit	2025E	2030E	2035E	2050E	25/30 CAGR	30/35 CAGR	35/50 CAGR
Humanoid robot	Unit	15,000	500,000	5,000,000	70,000,000	102%	58%	19%
Unit per humanoid robot	Unit	14	14	14	14			
Strain wave gearing total unit demand	Unit	210,000	7,000,000	70,000,000	980,000,000			
Strain wave gearing price	Rmb	2,000	1,181	697	697	-10%	-10%	0%
Strain wave gearing per robot	Rmb	28,000	16,534	9,763	9,763	-10%	-10%	0%
Strain wave gearing market for humanoid robot	**Rmb'mn**	**420**	**8,267**	**48,815**	**683,410**	**81%**	**43%**	**19%**
% of total humanoid robot market	%	8%	9%	9%	9%			
Unit per humanoid robot	Unit	14	27	40	40			
Planetary roller screw total unit demand	Unit	210,000	13,500,000	200,000,000	2,800,000,000			
Planetary roller screw price	Rmb	2,000	1,181	697	697	-10%	-10%	0%
Planetary roller screw per robot	Rmb	28,000	31,886	27,894	27,894	3%	-3%	0%
Planetary roller screw market for humanoid robot	**Rmb'mn**	**420**	**15,943**	**139,471**	**1,952,599**	**107%**	**54%**	**19%**
% of total humanoid robot market	%	8%	18%	26%	26%			
Market share of HIWIN for strain wave gearing price	%	0%	0%	0%	0%			
Strain wave gearing total unit demand for Hiwin	Unit	-	-	-	-			
Market share of HIWIN for planetary roller screw	%	0%	5%	5%	5%			
Planetary roller screw total unit demand for Hiwin	Unit	-	-	-	-			
Sales for HIWIN from humanoid robot	**Rmb'mn**	**-**	**797**	**6,974**	**97,630**			
Net profit for HIWIN from humanoid robot	Rmb'mn	-	80	697	9,763			
Net profit margin	%	10%	10%	10%	10%			
Number of shares outstanding (NOSH)	mn	354	354	354	354			
EPS for HIWIN from humanoid robot	**Rmb**	**-**	**0.22**	**1.97**	**27.54**			
Valuation for humanoid robot								
2035E P/E	Times	25x						
WACC	%	8.3%						
Share price for HIWIN from humanoid robot for 2025	Rmb	22.2						
Share price for HIWIN from humanoid robot for 2025	**NT$**	**97**						

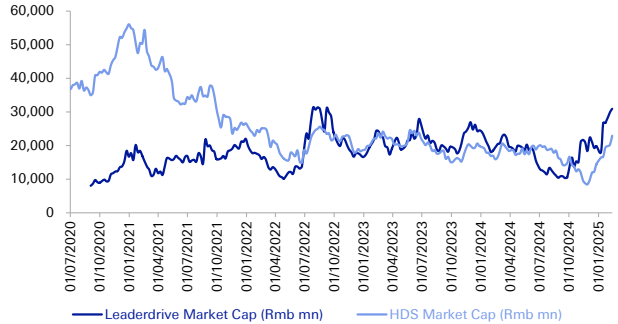
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Source: Deutsche Bank estimates

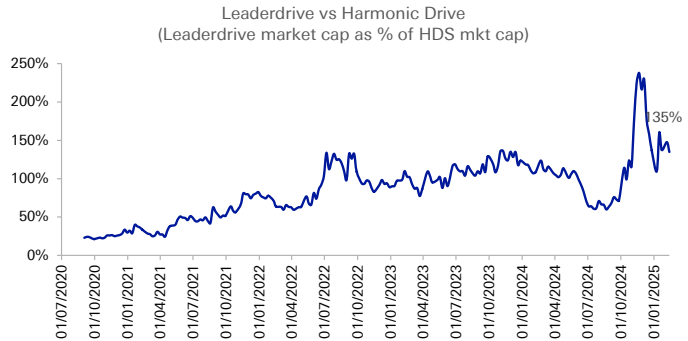
Leaderdrive vs Harmonic Drive

Reducer capacity ramp-up plan: Leaderdrive's capacity to grow from 30% of that of HDS in 2024, to 70% by 2027

Company	Year	Capacity (units / year)	Note
Leaderdrive	**2024**	590,000	500k units added in late 2023. To add 1mn by 2027
	2027	1,590,000	To add 1m units by 2027
Harmonic Drive	**2024**	1,980,000	Increased from 808k in 2018 to 1.98mn in 2022
	2025	2,021,640	To increase slightly by March 2025
	2026	2,240,040	To further increase by March 2026

Leaderdrive is trading at a 35% premium to Harmonic Drive





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Source: Deutsche Bank, company data, Bloomberg Finance LP

Link to previous reports

Humanoid robot sector reports

- **Expert Call:** Rise of the Humanoid Robots (Part 1) – 11 Feb 2025
- **Newsletter:** Figure to unveil "something never seen" in 30 days – 10 Feb 2025
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Appendix 1
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*Other information available upon request

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