CHINA AI ROBOTICS

Expert call on Frontier Foundation Models in Physical AI & Embodied Robotics

Jacqueline Du
+852-2978-1785 ;
jacqueline.du@gs.com
Goldman Sachs (Asia) L.L.C.

Ronald Keung, CFA
+852-2978-0856
ronald.keung@gs.com
Goldman Sachs (Asia) L.L.C.

As frontier LLMs expand into physical AI, their emergent zero-shot generalization capabilities increasingly position them to operate as the centralized cognitive 'brain' for embodied robotics. On 28 Oct, we hosted a Robotics Algorithm Engineer at a top-tier AI research institution, currently focused on embodied VLM/VLA algorithms and with prior experience in 3D reconstruction and spatial interaction, for an expert call with investors.

Key implications in our view post the expert call:

- **An acceleration rather than an overnight inflection:** Future advancements in high-precision 3D perception and low-latency processing are unlocking significant leaps in zero-shot and few-shot generalization for frontier foundation models which is bridging the gap toward commercial viability and accelerating real-world deployment schedules.
- **Shifting moats toward edge and hardware integration:** Because frontier AI laboratories face non-trivial barriers when descending into embedded hardware and on-device execution layers, some robotics OEMs must reposition their moats. Long-term competitive differentiation will increasingly center on rapid edge-model deployment, robust compute optimization, and seamless hardware-software co-design.
- **Upstream data infrastructure as near-term beneficiaries:** As physical AI scales, surging demand for multimodal real-world interaction data positions collection and sensing hardware—particularly advanced 3D spatial sensors and high-resolution tactile arrays—as prime near-term beneficiaries, with data fidelity remaining the critical operational bottleneck.
- **Not just about Humanoids but also Industrial Automation & Cobots:** While bipedal humanoids command public mindshare, the potential combination of foundation models with collaborative robots (cobots) and brownfield industrial automation could also represent more practical factory solutions that requires precision and reliability.

Stock ideas: Prefer attractively valued supply chain stocks with solid fundamentals and AI robotics upside: Buy Inovance on its positioning across

Goldman Sachs does and seeks to do business with companies covered in its research reports. As a result, investors should be aware that the firm may have a conflict of interest that could affect the objectivity of this report. Investors should consider this report as only a single factor in making their investment decision. For Reg AC certification and other important disclosures, see the Disclosure Appendix, or go to www.gs.com/research/hedge.html. Analysts employed by non-US affiliates are not registered/qualified as research analysts with FINRA in the U.S.

humanoid components/modules and AI-enabled automation hardware with sensing/data-collection capabilities, supported by its broader strengths in industrial automation and motion control. **Buy Sanhua-H** on potential actuator-assembly exposure to North American robot customers, alongside its core leadership in global EV thermal management and HVAC components. **Buy Shuanghuan** on its precision-gear leadership and expanding exposure to humanoid/AI robotics, with AI robotics revenue expected to more than double to Rmb400-500mn in 2027E. **We stay Neutral on Sanhua-A and LeaderDrive mainly on valuation;** for Sanhua-A, we prefer Sanhua-H given the H-share valuation discount, while for LeaderDrive we remain positive on harmonic reduction-gear TAM expansion across humanoid/service and industrial robots but see valuation as limiting upside.

The author would like to thank Zhou Li, Hao Chen, Zhihan Ye, and Junfang Zhang for their contributions to this report.

Key discussion topics on the expert call

1. Frontier Foundation Model Capabilities and Architectural Evolution

- **Step-change in task generalization:** The primary breakthrough in latest-generation frontier foundation models is their transition beyond narrow "out-of-domain" (OOD) adaptability—such as varying an object's color, texture, or basic geometry—toward true zero-shot and few-shot task generalization. Models can increasingly be deployed across novel environments and unstructured conditions without requiring scenario-specific fine-tuning.
- **Three critical engineering bottlenecks:**
  a. *Spatial 3D perception:* While depth representations have matured materially, current spatial fidelity remains insufficient for millimeter-level physical interactions, causing closed-loop execution to suffer from repeated trial-and-error cycles.
  b. *Inference latency:* End-to-end execution frequencies remain too slow for real-time dynamic stabilization, high-speed manipulation, and microsecond-level reflexive recovery.
  c. *Inference economics:* Widespread commercial deployment requires progressive model distillation, transferring high-level physical reasoning and spatial awareness from frontier-scale clusters down into optimized, parameter-efficient edge models.
- **The System 2 vs. System 1/0 architectural division:**
  - **Supervisory role of System 2:** High-level models operate primarily as a cognitive supervisor—either outputting waypoint and semantic action primitives directly to System 1 or monitoring and correcting System 1 trajectories in real time.
  - **Frontier labs gated from low-level control:** Frontier AI laboratories are unlikely to descend into System 1 (reflexive motion planning) or System 0 (microsecond actuator torque control) in the near term. Physical embodiment

presents distinct electromechanical dynamics, hardware-specific kinematics, and protracted iteration cycles involving real-world stress testing, physical component fatigue, and mechanical repairs. These hardware constraints contrast sharply with the hyper-accelerated, software-only evaluation cycles of digital large language models (LLMs), making direct System 0-level control a less natural extension for pure software labs.

2. Strategic implications for the robotics ecosystem

- **The generalization vs. precision trade-off:** Commercial robotics currently faces a structural divide: systems achieve either high generalization across unstructured domains or near-100% deterministic precision within rigid silos, but rarely both. Because mission-critical industrial manufacturing demands six-sigma reliability and microsecond repeatability, industrial robotics will continue to rely on domain-specific datasets and deterministic kinematics. Conversely, frontier foundation models unlock variable, non-standardized commercial, logistics, and domestic service environments where adaptability outweighs sub-millimeter precision.
- **Repositioning OEM moats around hardware abstraction:** With frontier foundation models establishing third-party cognitive dominance, the primary defensible moat for robotics OEMs shifts downward toward System 1/0 execution. Long-term differentiation depends on developing robust real-time control operating systems, safety compliance architectures, and standardized API/SDK abstraction layers that enable external foundation models to command the underlying hardware seamlessly.
- **Geopolitical and supply chain dynamics:** Overseas leadership at the frontier foundation-model layer does not inherently displace domestic or Chinese embodied-AI hardware players. Once a viable cognitive architecture is proven, OEMs that excel in precision mechatronics, high-yield manufacturing, and System 1 motion integration can capture significant terminal value, even if the high-level cognitive "brain" is sourced from third-party foundation model providers.

3. Industry maturity: "ChatGPT moment" vs. accelerated evolution

- **An acceleration rather than an overnight inflection:** Rather than representing an instantaneous operational tipping point, frontier models function as a powerful catalyst. By solving generalized semantic scene understanding and broad task planning, they pull forward the commercialization timeline for complex, unstructured domains (most notably domestic home assistance and high-variability logistics) that were previously deprioritized or confined to scripted demonstrations.
- **Benchmarking against Autonomous Driving (AD):**
  - *Maturity Phase:* When measured against safety-critical, produ
    reliability metrics, general-purpose robotics manipulation rer
    tracking closer to pre-2015 or roughly 2017–2018 stage auto
    development.
  - *Velocity of Progress:* However, the compounding rate of techni



projected to track at **2x to 4x the historical AD velocity**. The emergence of generalized foundation models allows physical AI to bypass years of siloed heuristic programming, establishing a credible transfer-learning curve that dramatically accelerates real-world deployment schedules.

4. Resolving the physical data bottleneck

- **The dimensionality challenge:** Unlike autonomous vehicles—which operate primarily within a constrained planar manifold (steering, throttle, braking)—dexterous manipulation entails dozens of mechanical degrees of freedom, continuous contact dynamics, shear forces, and tactile feedback loops. Consequently, embodied AI will likely require an estimated **10 million hours** of high-quality, multi-modal interaction data to reach generalized production thresholds, rather than passive or noisy recordings.
- **Relative evaluation of data collection modalities:**
  - **Egocentric video (Ego):** Highly effective for high-level semantic task understanding and user intent modeling, but inherently limited by a lack of physical interaction dynamics, forces, and contact physics.
  - **Physics simulation (Sim-to-Real):** Offers rapid volumetric scaling for gross trajectories and kinematic path planning, but suffers from a persistent "reality gap" in contact friction, material deformation, and compliance, making it useful only when calibrated to physical transfer.
  - **Homomorphic dexterous Universal Manipulation Interface (UMI):** Represents the highest strategic value for manipulation policies. By capturing action data directly at the physical hand-object interface without requiring a full, costly teleoperated robot rig, it enables portable, scalable data acquisition with high fidelity.
- **The imperative for tactile integration:** Millimeter-level precision cannot be resolved via 3D vision alone due to visual occlusions, depth ambiguity, and sensor noise during close physical contact. The industry's most viable data-collection vector is a **homomorphic dexterous-hand UMI system augmented with high-resolution tactile sensing**, using direct touch telemetry to bridge the precision gap that vision leaves behind.

Appendix

Based on the expert's framework from the call, robotic intelligence can be organized as a three-layer architecture, moving from the high-level "brain" down to the physical robot control. At each step down the stack, the system operates closer to real-world execution, and the required frequency of action and external-feedback processing increases.

- **System 2** is the high-level reasoning layer, responsible for task understanding and planning. It serves as the robot's "brain."
- **System 1** translates high-level intent into executable action policies or trajectories.

In the expert's framing, many VLA/VLM-based "embodied brain" systems promoted by robotics companies are better understood as System 1 rather than pure System 2, because they combine perception, decision-making, and control.

- **System 0** sits closest to the robot body and handles high-frequency execution, low-level control, and fast physical feedback loops, including force and tactile feedback.

Exhibit 1: Robot intelligence in a 3-layered (System 2/System 1/System 0) architecture

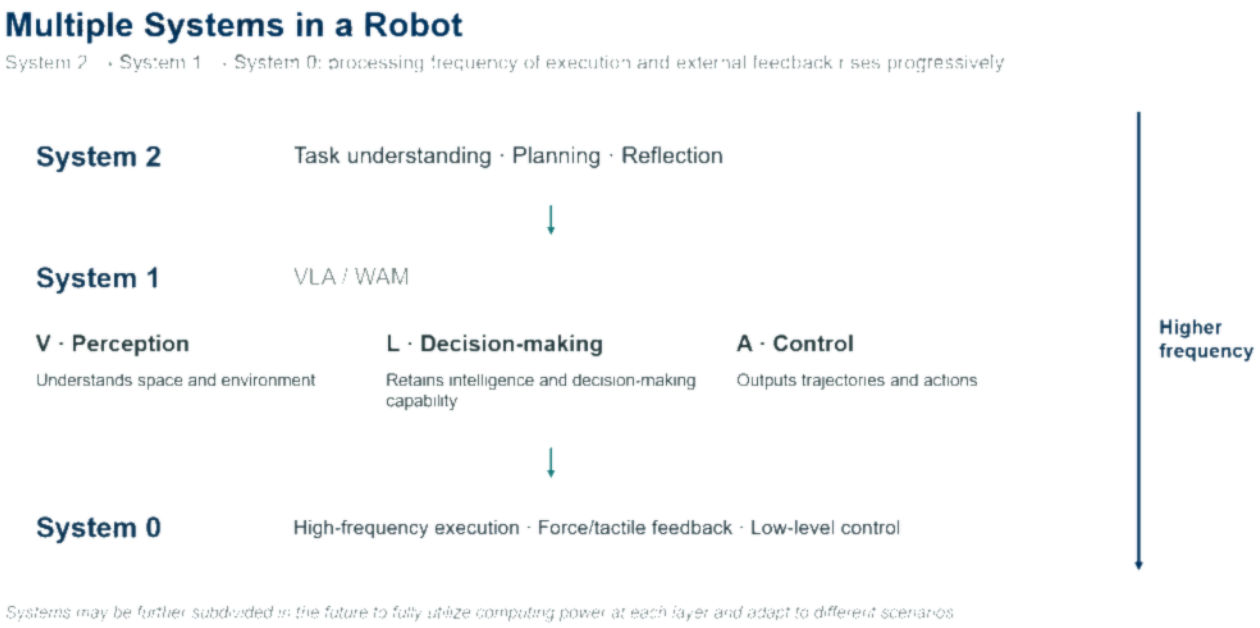
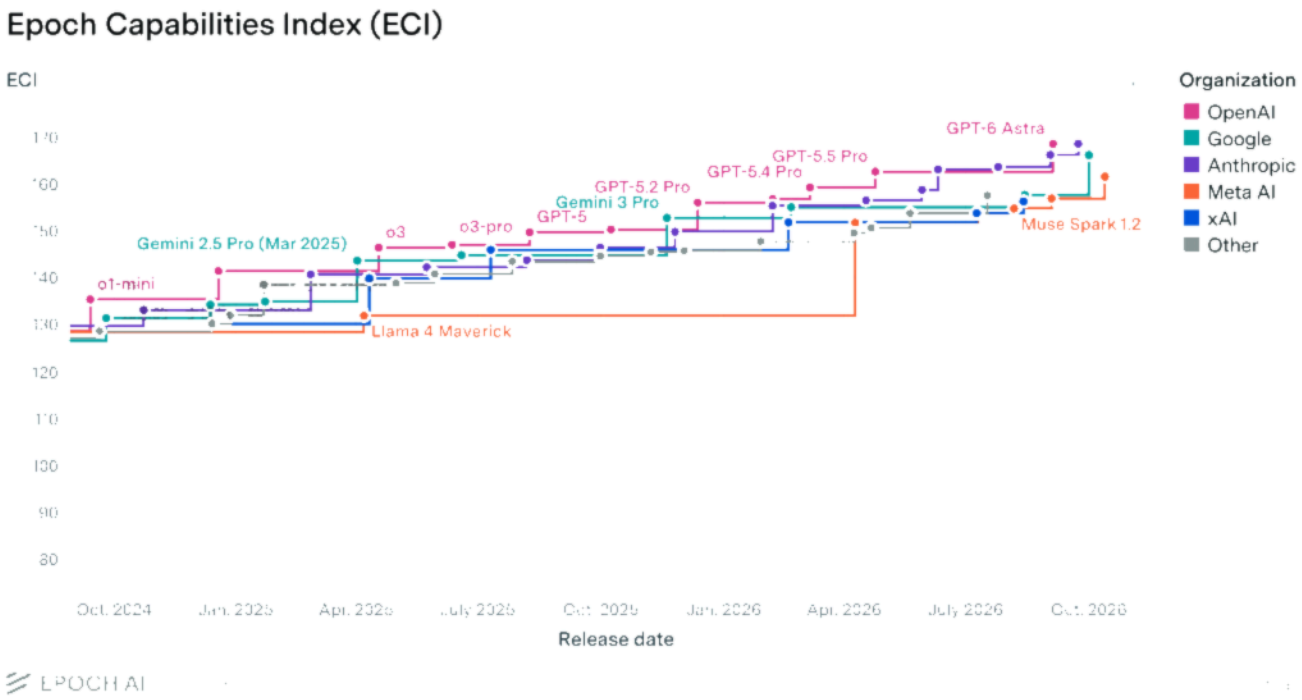


Exhibit translated from the expert's presentation.

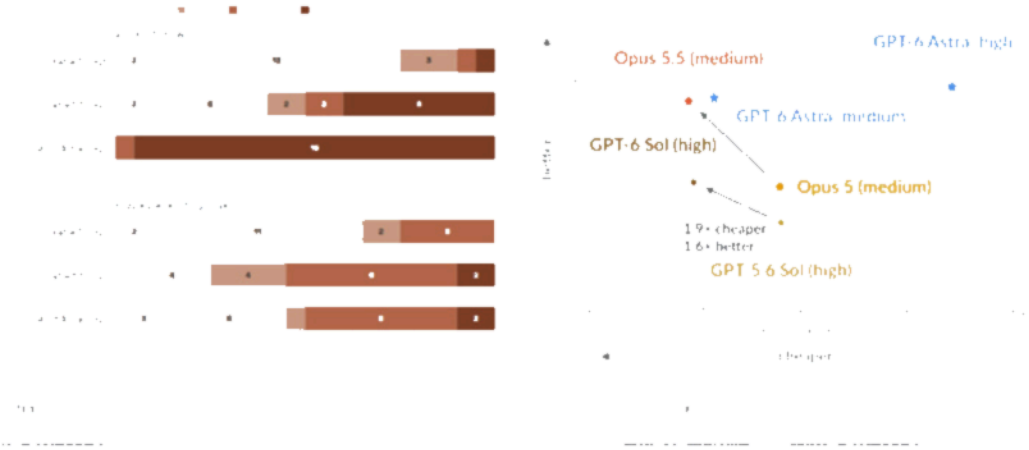
Source: Data compiled by Goldman Sachs Global Investment Research

Exhibit 2: GPT-6 Astra represents the latest step-up in OpenAI's frontier foundation-model capabilities
Epoch Capabilities Index (ECI) for frontier foundation models by organization and release date, Sep 2024-Oct 2026



Source: Epoch AI

Exhibit 3: GPT-6 Astra performance and cost across physical manipulation and robotics benchmarks



Source: Open AI Robocurve

Investment thesis, PT valuation methodology and risks

Shenzhen Inovance is a domestic leader in industrial automation. We like the company's growth outlook given: 1) although its two key products, i.e., inverter/servo already reached 25%/33% or No.1/No.1 in China as of 2025, the company still has opportunities in overseas markets; 2) we expect the company to gain market share in small/large PLC, which will serve as a building block for it to extend into digitalization and transform into

an IoT solution provider; 3) EV components continue to ramp up share on top of fast industry growth; and 4) digitalization business development with the potential to exceed our expectations. We view Inovance's major competitive moats that will underpin its resilience through cycles as: 1) industry leading R&D effectiveness with high success rates for new product lines; and, 2) a comprehensive product portfolio and end-market coverage that reinforce customers' switching costs. We view valuation as attractive given the shares are trading at around historical average multiples with a solid long-term growth and return profile; we are Buy rated.

Price Target Risks and Methodology - Shenzhen Inovance Technology Co.
Valuation methodology: Our 12-month TP of Rmb75.9 is based on a 30x 2027E P/E.

Key downside risks: 1) Slower-than-expected industrial automation market share gains; 2) Weaker-than-expected margin trends; 3) EV component segment ramp-up coming slower than expected; 4) general manufacturing capex/automation demand slowing down.

Investment Thesis - Shuanghuan Driveline
Shuanghuan Driveline is one of the largest gear manufacturers in China and one of the few capable of producing high-precision gears. We believe Shuanghuan's EV gear revenue will deliver an 18% CAGR in 2026-30E, driven by rising content value from higher co-axial gearbox penetration and market share gains in ex-China markets. In parallel, Shuanghuan is proactively developing new growth drivers in intelligent transmission gears, for which we forecast a 27% CAGR in 2026-30E, expanding applications from robotic vacuum cleaners to e-bikes and intelligent vehicles, while also conducting R&D on robotic reduction gears and cooperating with more industrial and humanoid robot OEMs on new reduction gear designs. We forecast 15%/16% firmwide revenue/net profit CAGR in 2026-30E, reflecting internal operational efficiency improvements that should offset lower margins at overseas factories in Hungary and potentially Vietnam. We are Buy rated on consistently better-than-expected margins and operational resilience, and we believe future catalysts include faster overseas passenger-vehicle gear share gains and better-than-expected GPM improvement.

Price Target Risks and Methodology - Shuanghuan Driveline
Valuation and risks: Our 12-month TP of Rmb45.7 is based on 25x 2027E P/E.

Downside risks: 1) Lower-than-expected market share in NEV segment; 2) lower-than-expected new energy revenue outlook; 3) lower-than-expected industrial robot gears revenue.

Investment Thesis - Sanhua Intelligent Controls
Sanhua is a global leader in HVAC control & thermal management components. We like its growth potential in humanoid robot actuators on top of a solid market leadership position in its core business, and expect it to deliver 16%/17% revenue/net profit CAGR in 2025-30E. On the HVAC component segment, we believe the company is well positioned to deliver revenue growth above the residential HVAC industry, driven by commercial HVAC market share gain and ramp up in sensor products. On the EV thermal management segment, we believe the company's revenue growth will be driven by further global EV penetration increase and modest content value gain. In addition, we

see humanoid robots as a significant long-term technology trend, with Sanhua likely to secure a key role in the supply chain, as a high visibility actuator assembler. Catalysts include technology advancement in humanoid robot functionality, volume production for humanoid robot big customers, and further EV penetration in Europe. However, we think the market has priced in a too bullish outlook for humanoid robots compared to rather a delayed timeline of Optimus production. We are Neutral/Buy-rated on Sanhua-A/H.

Price Target Risks and Methodology - Sanhua Intelligent Controls
Valuation: Our 12m target price for Sanhua A/H is Rmb38.6/HK$40.0, based on 2030E P/E of 25X, discounted back to 2027E with a COE of 9.5%.

Sanhua-A key upside/downside risks: (1) Faster/Slower-than-expected revenue contribution from humanoid robots; (2) Better/Worse-than-expected global EV sales; (3) Better/Worse-than-expected home appliance sales.

Sanhua-H key downside risks: (1) Slower-than-expected revenue contribution from humanoid robots; (2) Worse-than-expected global EV sales; (3) Worse-than-expected home appliance sales.

Investment Thesis - Leader Harmonious Drive Systems Co.
On valuation, we are Neutral rated on LeaderDrive, the domestic leader in China's harmonic reduction gear market. We are positive on the company for its growing harmonic reduction gear TAM expansion, due to a growing set of applications both domestically and globally across industrial robots, collaborative robots (cobots), humanoid/service robots, CNC machine tools and other high-end equipment (solar/SPE/medical/aerospace). We continue to model the company to capture c.30%/c.50% market share in the global high-specs/low-to-mid-specs humanoid robot industry in the long term, supported by its competitive product quality, capacity advantage as well as early dominance, especially in the China humanoid robot market. The company is in the process of penetrating into overseas industrial robot customers, such as making volume shipments to 3 of the Big 4 international robot brands. That said, we expect a gradual decline of GPM and OPM in the next few years as management adopts defensive pricing to deter entrants and the company aggressively expands its production capacity to meet the fast-growing humanoid industry demand.

Price Target Risks and Methodology - Leader Harmonious Drive Systems Co.
Our 12-month target price for Leader Harmonious Drive Systems Co. is Rmb285.1, based on 35x 2035E P/E discounted back to 2027E with 12% CoE.

Upside/downside risks: (1) faster/lower-than-expected volume production and/or technology advancement of humanoid robots; (2) better/worse-than-expected domestic industrial/collaborative robot demand; (3) faster/lower-than-expected penetration into key robot customers (especially foreign brands); (4) more/less competition pressure from overseas and local brands.