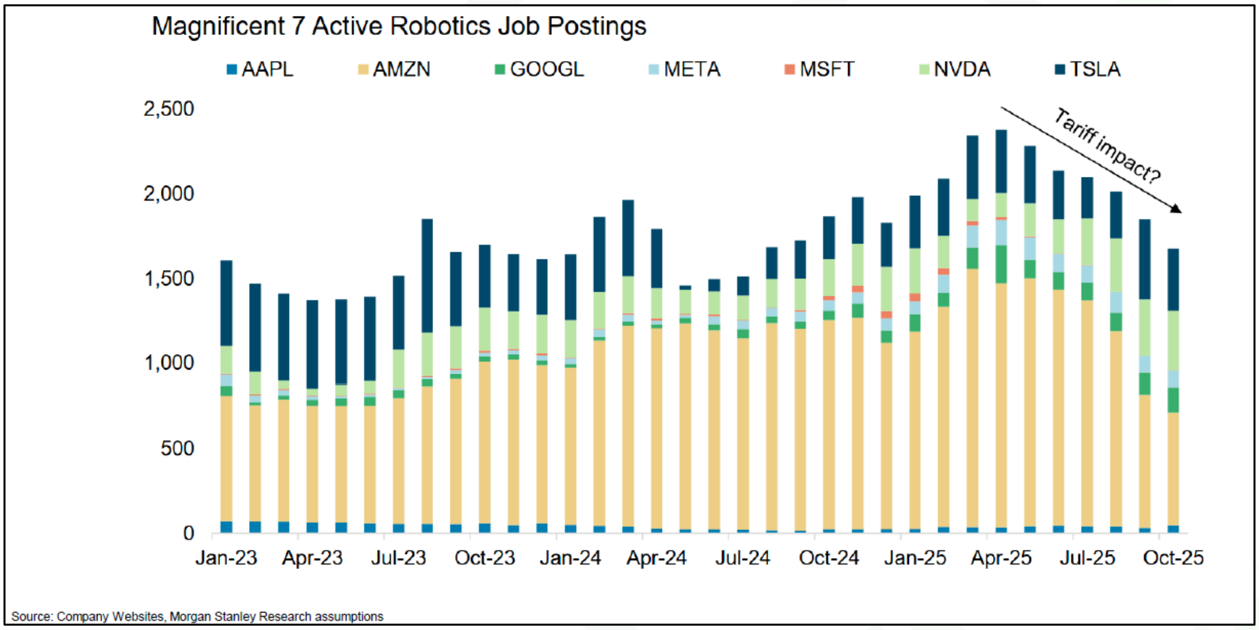
Foundational Memo V: Robotics

Robotics represents the next, and one of the most exciting, tectonic shifts in the evolution of technology: the migration of intelligence from the digital world into the physical one. It is not a cyclical story, nor a narrow automation story, but a transformative general-purpose technology that sits at the intersection of energy, mobility, artificial intelligence, infrastructure and manufacturing.

As with prior tectonic shifts - electrification, computing, the internet - adoption around robotics will be uneven and nonlinear. But the direction is clear, and the impact will be transformative.

Intelligence is becoming embodied, mobile, and scalable. One of the strongest indicators of the transformative platform shift ahead is the behavior of global corporate leaders such as Google, Meta, Apple – all of which are aggressively hiring robotics talent to position for shift into physical AI.

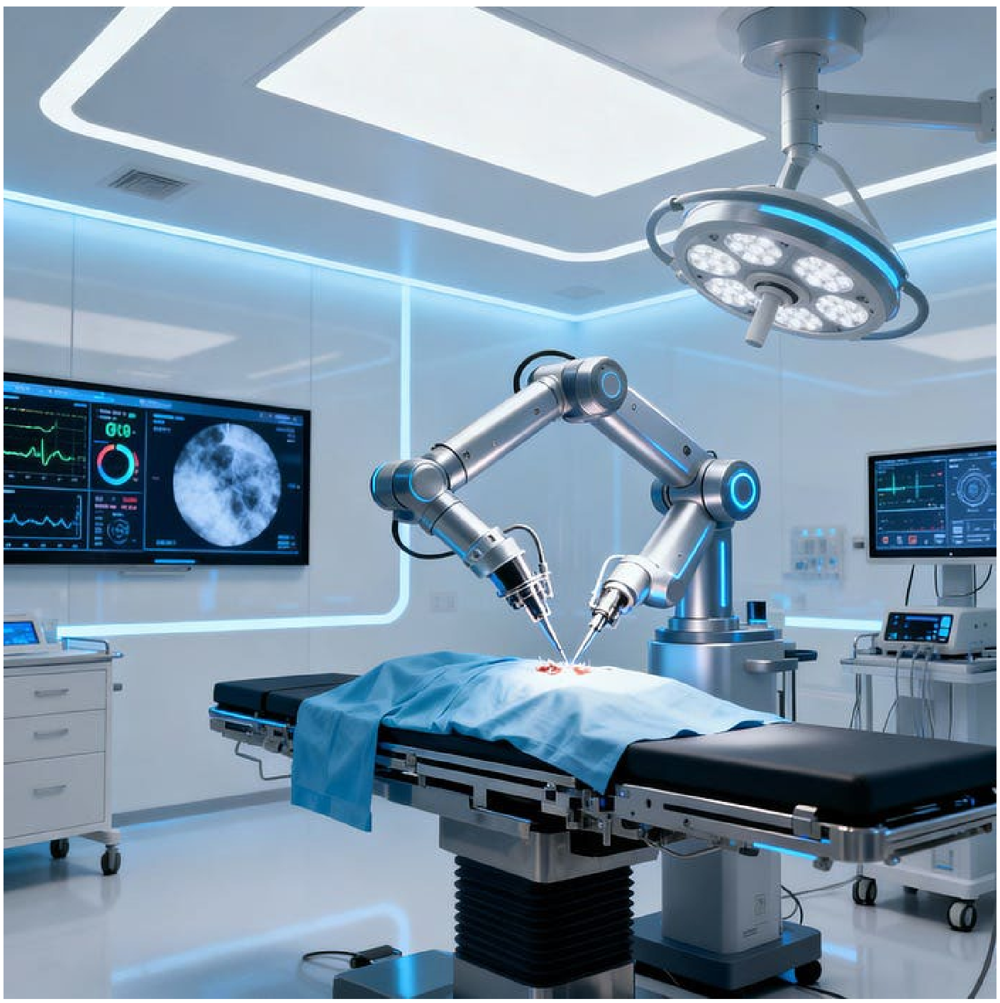


What's Changing?

Robotics has been discussed for decades. What makes this moment different is the acceleration of forces that are structural, economic, and already in motion.

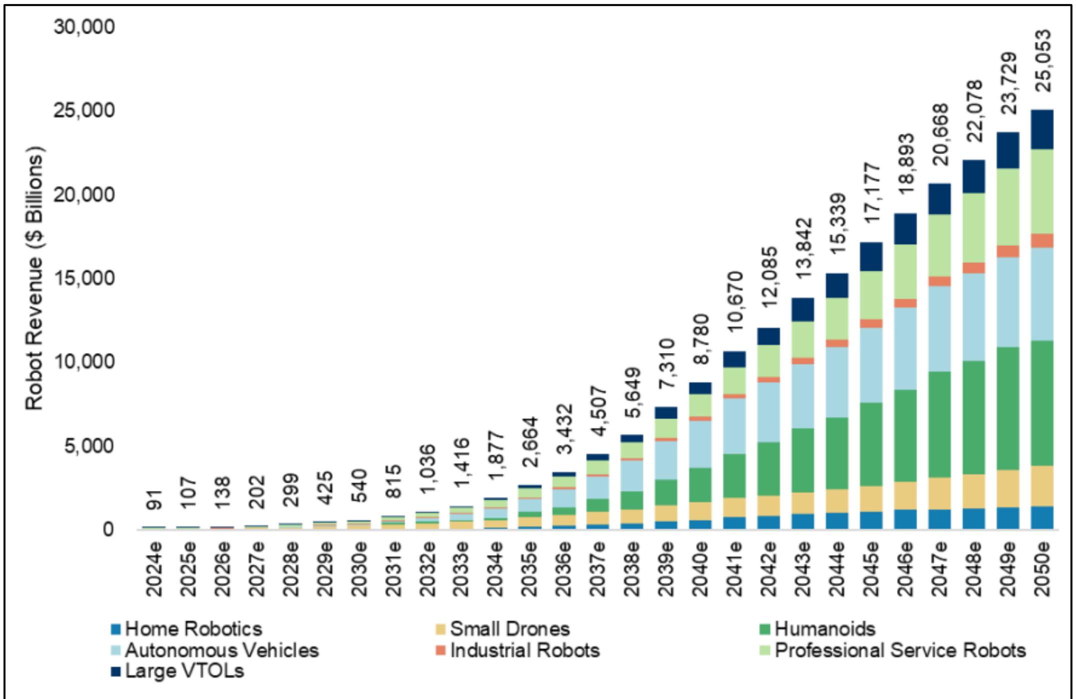
Today, the economics of the underlying technologies driving the explosion in robotics have crossed a critical threshold. When the fully loaded costs of human labor - recruitment, training, turnover, downtime, safety, insurance, and variability - are compared to robotic total cost of ownership, parity has been reached or surpassed in many tasks, turning automation into a rational capital allocation decision rather than an experiment.

The favorable economics indicated by sustained cost declines, combined with the technological reliability and convergence of semiconductors, sensors, motors, power electronics, and batteries - is making physical AI viable as the technologies expand across multiple industries and geographies.



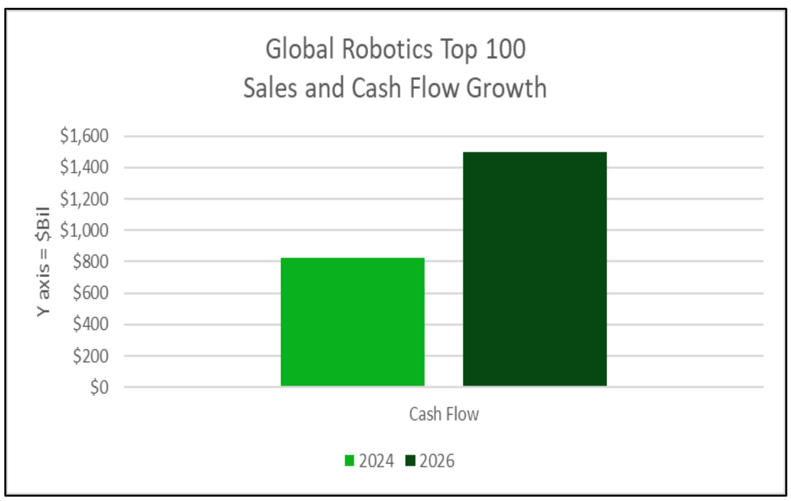
The Scale of the Opportunity

What has long been promised is now becoming investable. Even partial penetration of "traditional" industries will create multi-trillion dollar outcomes as the economy undergoes a structural re-architecture of global labor and production. Industry estimates see as much as $500B in hardware sales by 2030; $9T by 2040, and as much as $25T by 2050.



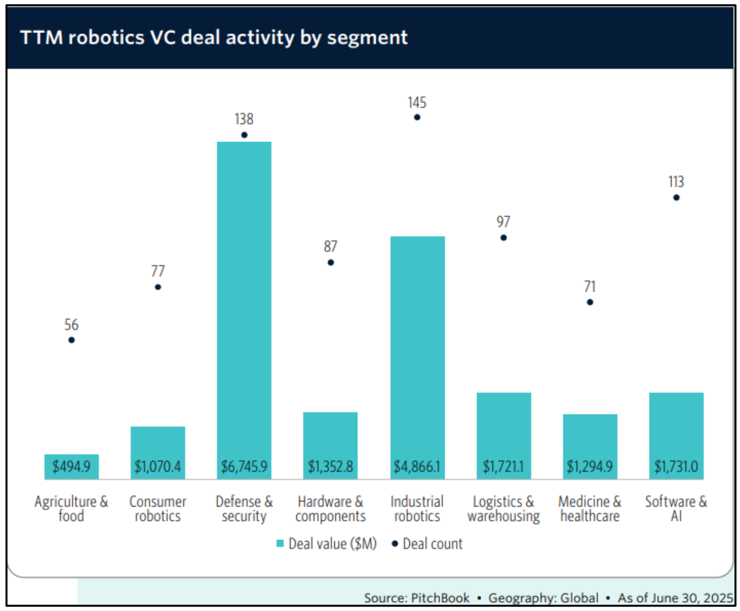
Source: Morgan Stanley Research estimates

Over the next two years, the financial impact at key robotics companies will be quite dramatic. A list of 100 publicly traded humanoid/robotics companies from 13 different countries will see aggregate revenues jump 30% over the next two years from 2024 levels, while aggregated cash flow will jump by 82%[1] for the same 100 stocks, evidence of the accelerating build-out of the robotics sub-sectors.



[1] Notably, cash flow growth for this group grows even faster, at 95%, if Mag-7 names are excluded.

Evidence of strong and sustained investment in robotics also comes from venture capital funding, which Pitchbook indicates robotics jumped to $8.8B in the 2Q'25, a 170% quarter over quarter increase 263% year over year increase, with reshoring and labor shortages driving record robot density, which is currently at 162 robots per 10,000 workers globally, with China at 470 and the US at 295.



Even conservative scenarios suggest meaningful scale of humanoid robots, ranging from early deployments in factories and warehouses for dexterous, human-adjacent tasks (already in place) to medium-term adoption across logistics, maintenance, healthcare support, and services (pilots in place).

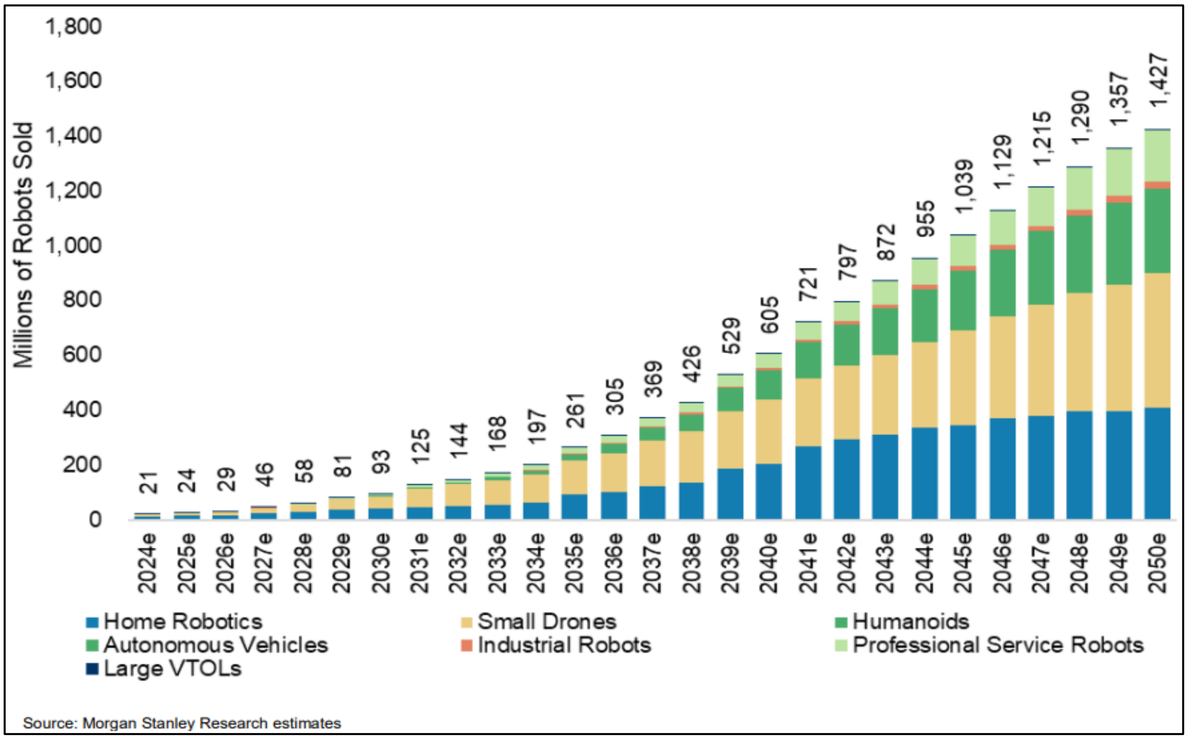
Among the most interesting areas for advanced humanoid robots to operate in are special operations such as "dangerous, dirty and dull" (3D) tasks, considering the associated fatality rate and people's low willingness in doing such jobs thus customers' likely willingness to pay a higher price than typical manufacturing work.

	Humanoid robot demand from labor force substitution (k units)					
	at 5% substitution rate		at 10% substitution rate		at 15% substitution rate	
	Global ex. China	China	Global ex. China	China	Global ex. China	China
Special operations	**500**	**213**	**1,000**	**426**	**1,499**	**639**
Disaster rescue	*70*	*19*	*140*	*38*	*211*	*58*
Nuclear reactor maintenance	*9*	*2*	*18*	*3*	*26*	*5*
Coal mining	*384*	*130*	*769*	*260*	*1,153*	*390*
Hazardous chemical industry	*36*	*62*	*73*	*125*	*109*	*187*
Auto manufacturing	**215**	**219**	**430**	**437**	**645**	**656**
Total	**715**	**431**	**1,430**	**863**	**2,145**	**1,294**

Source: US Bureau of Labor Statistics, Statista, DATAUSA, The World Bank, ACEA, NBS, World Nuclear Association, IAEA, heneng.net, Goldman Sachs Global Investment Research

Humanoid robots, whether they arrive sooner or later, will accelerate investment across investment opportunities in enabling layers: computing power, sensors, actuation, energy, safety, and fleet software.

The staggering needs to support this growth are highlighted by a few statistics from Morgan Stanley's Global Robotics Outlook Model (GROM). Should global robot sales growing from 24 million today to 1.4 billion by 2050.



In order to sell 1.4 billion robot sales per year, Morgan Stanley estimates industry needs to massively scale the following:

- Cameras: A 95-fold increase to in cameras to US$277B in content;
- Motors and Bearings: A 260-fold increase in motors (27 billion units worth $2.5T) and a 200-fold increase in bearings (41 billion units);
- Compute (i.e. the "brain"): A 40,000 increase in edge computing capacity (12.5 million ExaFLOPS worth $1.5T).

Robotics represents the embodiment of intelligence: machines that can perceive, decide, and act in real environments. Monetarily, the robot itself is only the surface layer. Considerable monetization will accrue in software, fleet orchestration, data, and recurring services - mirroring the evolution of mobility into software-defined vehicles.

Key Investment Areas

We see accelerating returns from the robotics opportunity as they increasingly touch nearly every physical industry, are soon be built into our everyday infrastructure, and as long-lived, learning, assets, reshape our world in exciting new ways.

Downstream Services and Autonomy-Enabled Ecosystems

Autonomous vehicles represent robotics operating in the most demanding conditions: public, regulated, safety-critical environments. This makes them a bellwether for the broader robotics transition.

Uber is a prime example of a company exceptionally well positioned to benefit from the fleet-based, service oriented platforms being built in the modern robotics landscape. Uber already owns the hardest, most defensible layer of the stack: global demand aggregation, marketplace liquidity, and operational infrastructure.

Unlike OEMs or AV developers that must create demand and city-level operations from scratch, Uber can plug autonomous fleets directly into an existing, high-frequency marketplace with hundreds of millions of users, lowering unit economics from day one. As public comfort with driverless rides increases and competitors retreat or stall, Uber's platform becomes the natural commercialization layer for autonomy—positioning it to capture a disproportionate share of value as mobility shifts from human-driven to software-defined.

Robotics Semiconductors

Physical AI demands low-latency, energy-efficient compute. Semiconductor content in advanced robots and humanoids is projected to grow rapidly, becoming a major share of system value.

Companies like Horizon Robotics are exceptionally well positioned at the heart of the edge compute and robotics semiconductor opportunity, designing energy-efficient, low-latency AI SoCs that power perception, planning, and control directly at the edge in autonomous driving and intelligent vehicles. Rather than competing in sensors or full-stack perception software, Horizon provides the computing substrate that increasingly captures a growing share of system value as autonomy and robotics scale. Its chips are deeply optimized for perception and sensor-fusion workloads, but this serves as an application focus that reinforces its core advantage: executing complex, real-time AI on-device under strict automotive power, cost, and safety constraints—precisely where demand and value creation are accelerating.

Critical Minerals

Critical minerals - lithium, cobalt, nickel, copper, and especially rare earth elements (REEs) - are foundational to the robotics industry. Additionally, rare earth magnets provide superior magnetic energy density, high torque, and resistance to demagnetization, making them indispensable for compact and powerful robotic designs. Over 95% of motors in humanoid robots use rare earth magnets with each unit using as much as 2-4 kilograms of these materials – more than an electric vehicle. Additionally and importantly, critical minerals also support the batteries and power systems used in numerous robotic designs. A company like MP Materials, with its strengthening strategic supply chain independence, stands at the forefront of supplying critical materials for the surge in global robotics.

Additional Areas of Focus

Perception and Sensor Fusion

Object detection is foundational to robotic autonomy, and companies are relying on sophisticated sensor combinations, with vision, depth, LiDAR/radar, and tactile sensing foundational for operating in unstructured environments. As robots move closer to people, sensing reliability becomes mission-critical.

Actuation and Power Systems

Motor control remains a core component of robotics systems. Precision motors, drives, reducers, and batteries differentiate robots that can safely and effectively interact with the physical world. Key challenges in motor control include the demand for real-time control, power efficiency, and precision.

Risks

The robotics transition is powerful but not frictionless. Key risks include simulation-to-reality gaps, where models fail outside controlled conditions; safety and trust concerns, especially in human-adjacent environments; regulatory fragmentation that can slow deployment across regions; cybersecurity threats, given the physical consequences of system compromise; and operational complexity, particularly at fleet scale.

For investors, one critical distinction to analyze will be not whether these risks exist, but which companies treat them as core challenges (optimal) or simply edge cases (sub-optimal, risky).

Conclusion

For the world, robotics represents a complete re-architecture of physical work—one that compounds like software, scales like infrastructure, and reshapes cost structures across the global economy.

For investors, robotics represents a convergence of technologies, recognized but not fully appreciated by the markets, which is setting up outstanding investment opportunities for investors who understand their generational impact.