Thematic

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Robotics and The Rare Earth Bottleneck

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EXECUTIVE SUMMARY

The Robotics industry is entering a transformative era, driven by exponential advances in artificial intelligence and hardware capabilities. From traditional industrial arms on factory floors to next-generation humanoid machines capable of perception, reasoning, and mobility, robots are now becoming a central pillar of global automation. The global robotics market was valued at $74.12 billion in 2024,[1] with over 541,321 new industrial units installed globally,[2] a figure expected to rise as labour shortages, cost pressures, and demand for 24/7 precision operations increase. Meanwhile, the humanoid robotics segment is attracting significant interest and capital, with Morgan Stanley forecasting total humanoid revenue could exceed $1 trillion by 2050 in the United States (U.S.) alone.[3]

However, behind the sleek hardware and AI-enabled autonomy lies a critical bottleneck: materials.

Advanced robots, particularly humanoids, rely on rare earth magnets, especially Neodymium-Iron-Boron (NdFeB), to power compact, high-torque electric motors. Each humanoid robot may require several kilograms of these magnets, and as production scales, the demand for rare earth elements will surge. China currently controls 91% of refined rare earth production,[4] creating an acute geopolitical and supply chain risk. Recent export controls by Beijing have already triggered major disruptions across automotive and robotics industries, highlighting the fragility of this dependency.

This note explores both sides of the robotics opportunity: the explosive potential of humanoid and industrial automation, and the rare earth material bottleneck that could constrain it. We highlight MP Materials as a strategic U.S. solution to this problem. As the largest rare earth miner in the Western Hemisphere and the only U.S. company building a fully integrated mine-to-magnet supply chain, MP is now backed by the U.S. Department of Defense and scaling aggressively. Its vertical model offers rare geopolitical insulation and direct leverage to a multi-decade capex cycle in critical materials.

For broader exposure, we also recommend the VanEck Rare Earths & Strategic Materials UCITS ETF, which provides diversified access across the entire value chain, from upstream miners to downstream refiners and magnet manufacturers. With 69.55% of holdings outside China,[5] it is positioned to benefit from price squeezes triggered by China's monopoly, the ETF is an efficient vehicle for gaining strategic exposure to the global scramble for rare earth dominance, an issue now inextricably linked with the future of robotics.

[1] https://www.marketresearchfuture.com/reports/robotics-market-4732#:~:text=Robotics%20Market%20Size%20in%202023,2024%2D2032):%2018.4%25.
[2] https://ifr.org/ifr-press-releases/news/record-of-4-million-robots-working-in-factories-worldwide
[3] https://advisor.morganstanley.com/john.howard/documents/field/j/jo/john-howard/The_Humanoid_100_-_Mapping_the_Humanoid_Robot_Value_Chain.pdf
[4] https://www.iea.org/topics/critical-minerals
[5] https://www.vaneck.com/uk/en/investments/rare-earth-etf/portfolio/

SPECIALISED ROBOTS

Industrial Robots

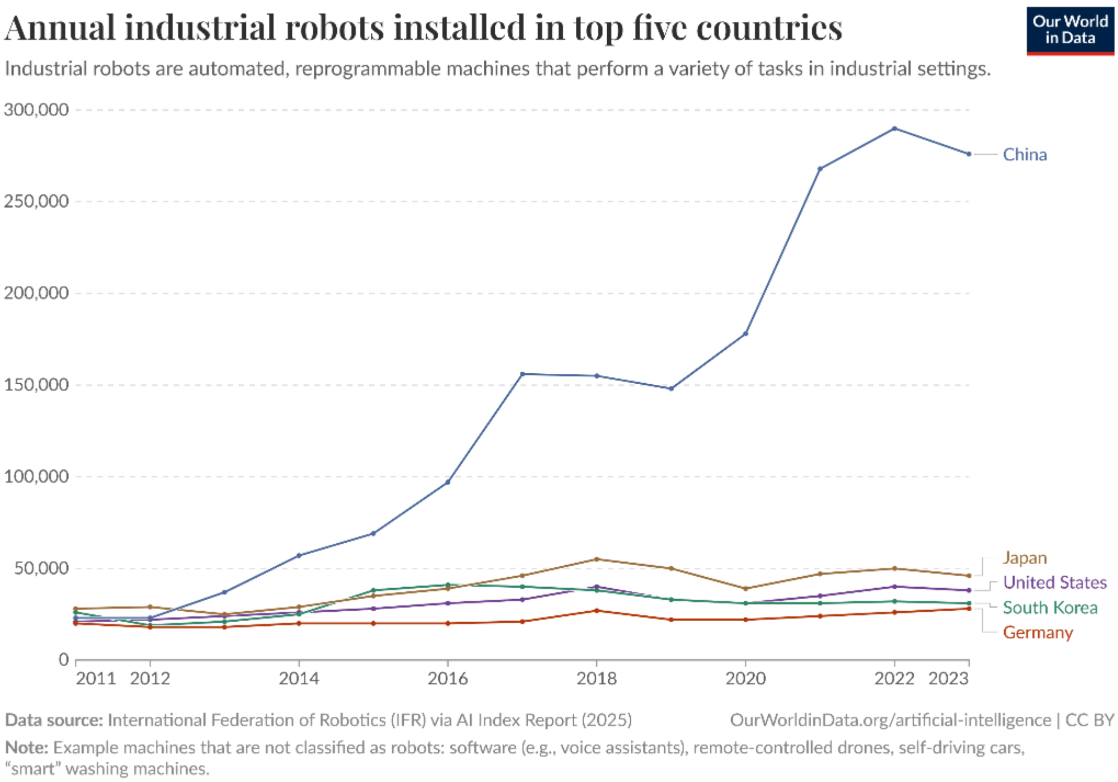
Industrial robots are the classic mechanised arms and machines working on factory floors. Typically stationary, multi-axis robotic arms, they perform repetitive or dangerous manufacturing tasks such as welding, painting, assembly, material handling, and machine tending. These robots are built for speed, precision, and endurance, often handling heavy payloads, or operating in hazardous conditions to augment or replace human labour in production lines.

Source: Wevolver

The automotive industry was an early adopter and remains a dominant user, accounting for 25% of the robots installed in 2023, followed by the electronics industry (23%).[6] Other sectors include metals, plastics, and food processing. After decades of use, industrial robotics is a mature but growing segment.

The global industrial robotics market reached about $42 billion in 2023 and is expected to grow at a CAGR of 15.2% as automation spreads.[7] In 2023, factories worldwide installed ~541,000 new industrial robots and the operational stock of industrial robots hit a record ~4.3 million units in 2023, almost triple a decade earlier.[8] Even as newer segments grow faster, industrial robots will likely remain the largest revenue segment through this decade. Growth drivers include rising labour costs, demand for high precision and uptime, and improved robot capabilities.

[6] https://ifr.org/img/worldrobotics/Executive_Summary_WR_2024_Industrial_Robots.pdf
[7] https://statzon.com/insights/global-industrial-robot-market
[8] https://ifr.org/ifr-press-releases/news/record-of-4-million-robots-working-in-factories-worldwide



Source: Our World in Data

Notably, Asia leads in adoption, accounting for 70% of all new robot installation in 2023 (China alone installed ~276,000 units in 2023, 51% of global).[9] China's industrial robot market has been growing ~5–10% annually and now installs more robots each year than the next four countries combined.[10] Major industrial nations like Japan, Germany, South Korea, and the U.S. are all adopters, though China's scale is unmatched.

Medical robots

Medical robots range from surgical robots in operating rooms to rehabilitation robots, diagnostic robots, and hospital automations. The flagship application is robot assisted surgery. Surgical robotic systems (the da Vinci system by Intuitive Surgical) enable minimally invasive surgeries with enhanced precision and control. These systems typically involve robotic arms manipulated by a surgeon at a console, translating the surgeon's hand movements into tiny instrument motions inside the patient. They offer benefits like finer motion scaling, tremor elimination, and 3D high-definition visualization, allowing complex procedures through small incisions.

Since the first FDA-approved surgical robot in 2000, surgical robots have revolutionised certain operations (e.g. prostatectomy, where the robotic approach is now standard of care). By 2023, Intuitive Surgical, A US Biotechnology company, had over 8,000 da Vinci robots installed

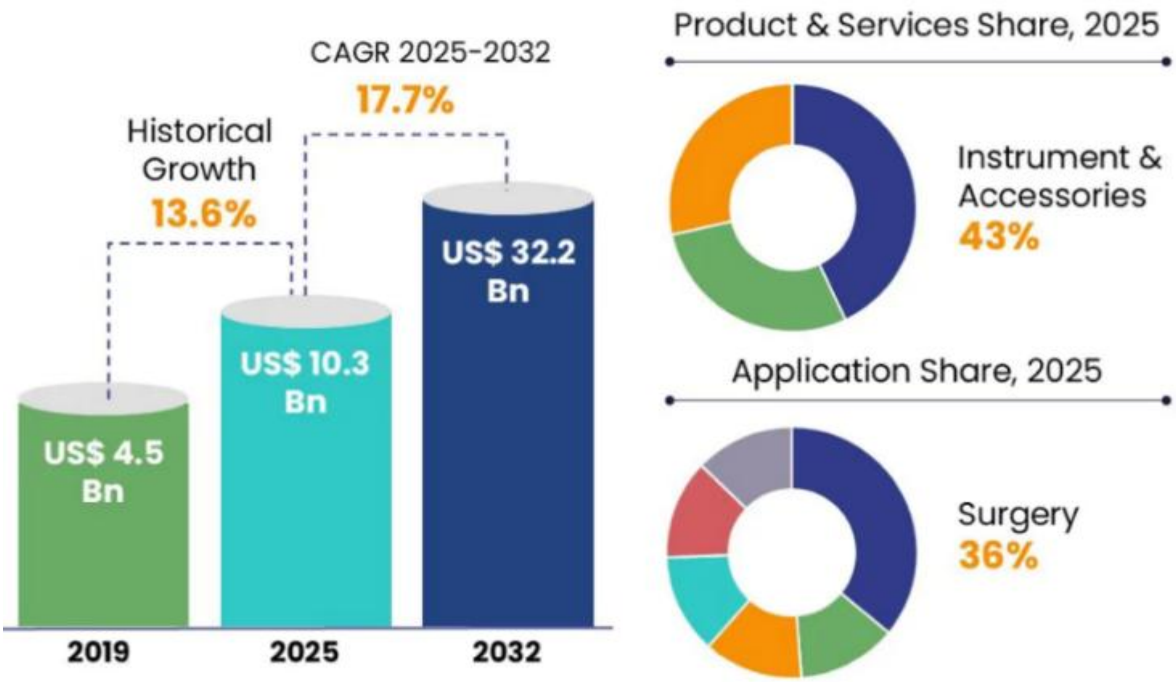
[9] https://ourworldindata.org/grapher/annual-industrial-robots-installed
[10] https://ifr.org/ifr-press-releases/news/record-of-4-million-robots-working-in-factories-worldwide

worldwide, performing ~1.5 million procedures annually.[11] Competitors have entered the field: e.g. Stryker's Mako system for orthopaedic knee and hip surgeries, Medtronic (Hugo robotic surgery platform), and Johnson & Johnson (developing the Ottava surgical robot).

Beyond surgery, medical robotics includes diagnostic robots (e.g. robotic imaging or ultrasound systems), rehabilitation robots (like exoskeleton suits that help patients regain movement in physiotherapy), telepresence robots for telemedicine consults, and hospital pharmacy robots that automate medication dispensing.

The medical robotics market is on a strong growth trajectory, driven by aging populations, technological advances, and an increasing physician acceptance as clinical benefits are demonstrated. The global medical robots' market is projected to increase from $10.3 billion in 2025 to $32.2 billion by 2032.[12] It's worth noting that regulatory approvals and clinical evidence are critical to their adoption and success. Medical robots face high safety/efficacy bars from regulators (FDA, etc.), and hospitals only invest if there's clear benefit. Another key issue is public trust, with only 42% of the UK population saying they would allow robotic surgery[13]

Medical Market Outlook (USD)



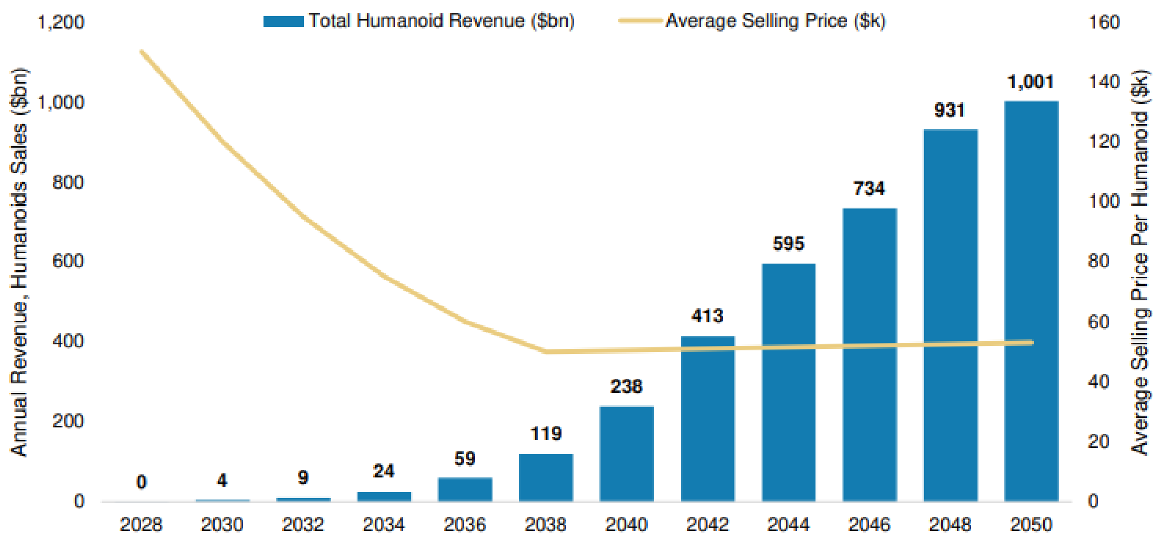
Source: Persistence Market Research

[11] https://www.guoncologynow.com/post/emerging-robotic-platforms-foster-competition-encourage-innovation
[12] https://www.persistencemarketresearch.com/market-research/medical-robots-market.asp
[13] https://www.health.org.uk/reports-and-analysis/analysis/how-does-the-public-feel-about-health-technologies-and-data

HUMANOID ROBOTS

Humanoid robots, human-shaped machines designed for general-purpose tasks, are rapidly emerging as a new frontier in advanced automation. Companies like Tesla, Figure AI, Agility Robotics, and others are racing to commercialise humanoid robots capable of working in factories, warehouses, and eventually homes. Market projections reflect the growing enthusiasm: Morgan Stanley forecasts that the U.S. humanoid robot market alone could generate $24 billion in revenue by 2035, $238 billion by 2040, and a staggering $1 trillion by 2050.[14] Elon Musk has even suggested that 10 billion humanoid robots could be operating by 2040, implying a world where robots eventually outnumber humans.[15]

US Humanoids Market, Total Revenue (USD billions)



Source: Morgan Stanley

While Musk's projections may seem exaggerated, achieving such numbers would demand an immense scale of production and material supply. Nonetheless, the broader trend is unmistakable: humanoid robotics is rapidly gaining momentum, driven by recent advances in AI and hardware that are accelerating investment across the sector. For years, machine learning remained largely confined to digital software loops. But the rise of large language models (LLMs) and generative AI (GenAI) has pushed artificial intelligence into the physical world. Multi-modal models (MMMs), which combine vision, language, and motion, are enabling robots to learn through natural language, imitation, and simulation. This shift is shortening the R&D cycle dramatically: robots can now be trained virtually, tested in synthetic environments, and improved continuously through feedback loops.

[14] https://advisor.morganstanley.com/john.howard/documents/field/j/jo/john-howard/The_Humanoid_100_-_Mapping_the_Humanoid_Robot_Value_Chain.pdf
[15] https://www.reuters.com/technology/elon-musk-10-billion-humanoid-robots-by-2040-20k-25k-each-2024-10-29/

Humanoid robots train in a simulated version of reality called "Omniverse."

Source: Nvidia

AI's leap from the datacentre to the physical world marks a turning point. Until recently, AI could process speech, generate text, and produce images, but had little connection to motion. That's changing. Robots are becoming the physical embodiment of AI, capable not only of perceiving and reasoning, but of acting autonomously in real-world environments. This fusion of AI and robotics is blurring the lines between machines, mobile devices, and intelligent agents. As capital floods into the AI theme, humanoid hardware, once limited by mechanical and computational constraints, is now benefitting from a surge in R&D investment.

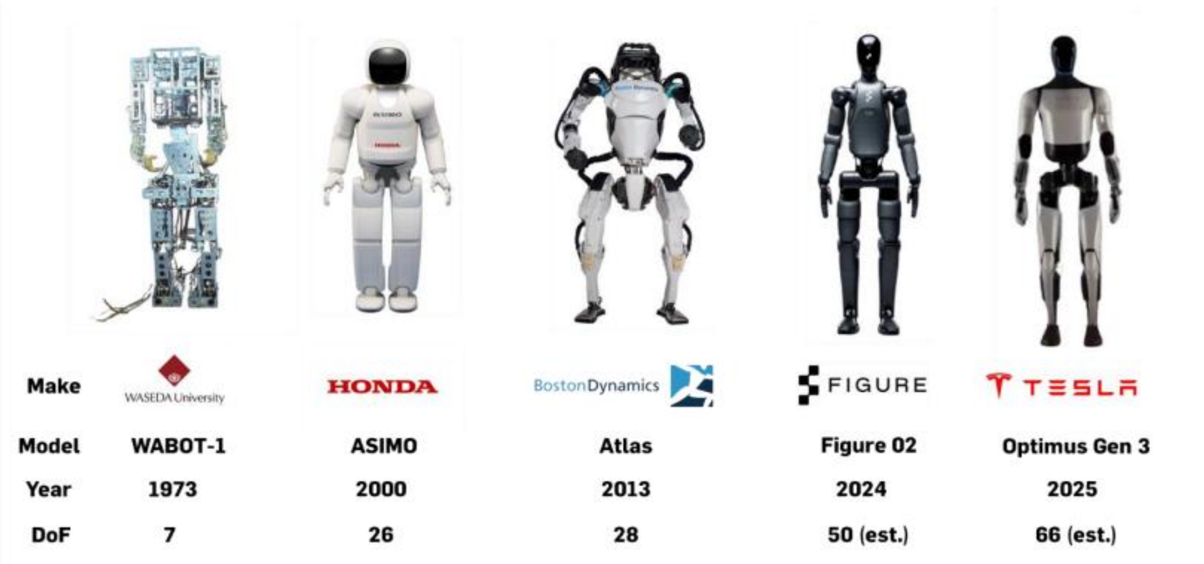
NEODYMIUM-IRON-BORON (NDFEB) PERMANENT MAGNETS

Modern robotics rely heavily on neodymium-iron-boron (NdFeB) permanent magnets in their electric motors and actuators. These are the most powerful magnets in the world and enable high torque in a compact size, essential for robot joints (and used in EV motors, wind turbines, drones, defence etc.). In a humanoid robot, nearly every limb and joint is powered by an electric motor containing NdFeB magnets, so dozens of magnets are needed per robot. As humanoid designs advance from ~25–30 degrees of freedom (DoF) to 50+, the magnet count per robot will rise accordingly. [16]

In short, if robotics are on the cusp of transforming the way humans work, live, and interact with machines, then NdFeB magnets are the linchpin that will determine whether that future can scale. The robotics opportunity is no longer speculative, it is a capital-intensive, AI-adjacent industrial evolution, but one whose trajectory is deeply intertwined with the economics and geopolitics of rare earth materials.

[16] https://www.adamasintel.com/humanoid-robots-and-the-future-of-motors-and-ndfeb-markets/

Evolution of humanoid robot models over time showing increasing DoF



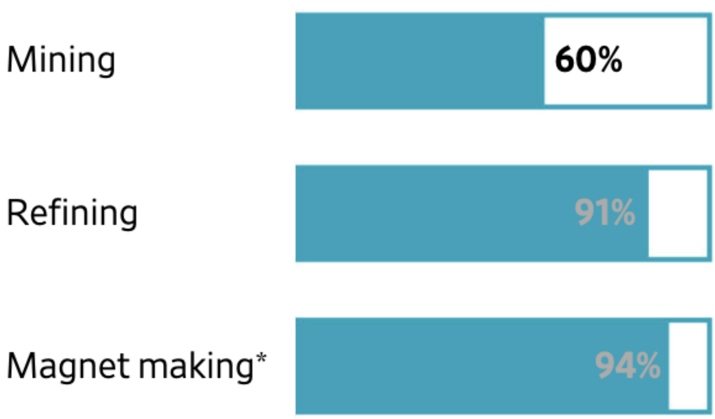
Make	WASEDA University	HONDA	BostonDynamics	FIGURE	TESLA
Model	WABOT-1	ASIMO	Atlas	Figure 02	Optimus Gen 3
Year	1973	2000	2013	2024	2025
DoF	7	26	28	50 (est.)	66 (est.)

Source: Adamas Intelligence research

CHINESE RARE EARTH BOTTLENECK

The global supply of rare earth elements and manufacture of permanent magnets is highly concentrated and increasingly exposed to geopolitical risk. China maintains a stranglehold in this market, accounting for approximately 91% of the world's refined rare earth production, 60% of rare earth mining and 94% of sintered rare earth magnets according to International Energy Agency.[17] In 2024 alone, China exported over 58,000 tonnes of rare earth permanent magnets and permanent magnet alloys.[18]

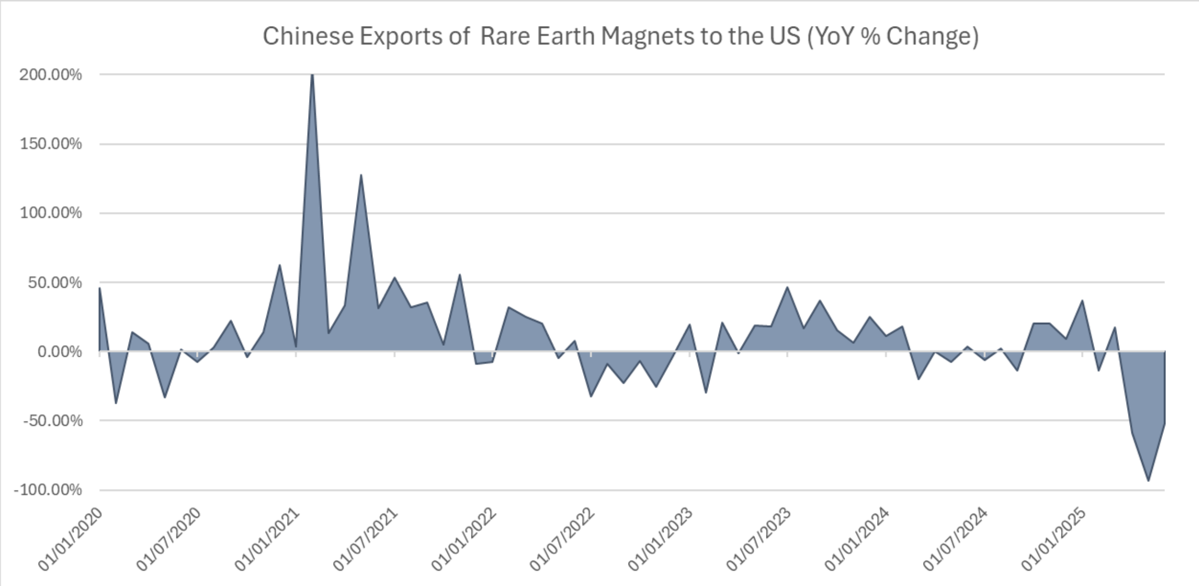
China Dominates the Rare Earth Supply Chain



Source: IEA

[17] https://www.iea.org/topics/critical-minerals
[18] https://www.adamasintel.com/record-rare-earth-magnet-exports-from-china-in-2024/

In April 2025, China imposed new export restrictions on rare earth elements, introducing a licensing regime that covers seven key materials (samarium, gadolinium, terbium, dysprosium, lutetium, scandium, and yttrium) on the grounds that they are "dual-use items" with both civilian and military applications. Although framed as a national security measure, the move was widely viewed, particularly by U.S. officials, as a retaliatory response to the Trump administration's sweeping increase in tariffs on Chinese imports just days earlier.



Source: Ocean Wall, Bloomberg

The impact on Western manufacturers was immediate and severe, exposing the fragility of the global supply chain. In May, China's exports of rare earth magnets to the U.S. dropped by 93.3% year-on-year,[19] triggering major disruptions. Ford was forced to idle its electric vehicle plant in Chicago due to magnet shortages, while German carmakers warned that continued delays could halt production altogether. Even Tesla's Optimus robot project was affected, with Elon Musk acknowledging that the magnet export licences needed from China were causing production delays. The crisis highlighted how deeply reliant the West remains on China for rare earth materials, critical components in everything from electric vehicles to advanced weaponry (for instance, an F-35 fighter jet contains around 920 pounds of rare earth magnets).[20]

This supply shock has sharpened investor focus on companies that can secure, process, or diversify rare earth supplies outside China. Among these, [redacted] has emerged as a key U.S. player, and for broader exposure, the [redacted] offers a diversified route into the supply chain.

[19] Bloomberg Data
[20] https://discoveryalert.com.au/news/japan-eu-rare-earths-partnership-2025/

GLOSSARY

Term	Definition
Humanoid Robot	A robot with a human-like form, designed to perform general-purpose tasks such as factory or warehouse work, and eventually household duties.
Industrial Robot	A stationary, multi-axis robotic system used primarily in factories for tasks like welding, painting, and assembly.
Medical Robot	A robot used in healthcare settings for surgery, rehabilitation, diagnostics, or hospital automation.
Multi-Axis Robotic Arm	A fixed robotic system with multiple rotational or linear joints, used in industrial settings for repetitive tasks such as welding or assembly.
Telepresence Robot	A mobile robot that allows a person to be virtually present in a remote location, often used in healthcare or remote office work.
Exoskeleton	A wearable robotic suit that helps users regain movement, typically used in rehabilitation or heavy industrial settings.
Robot-Assisted Surgery	Procedures performed using robotic systems like the *da Vinci* by Intuitive Surgical, where a surgeon controls robotic arms for minimally invasive operations.
Degrees of Freedom	The number of independent movements a robot joint or limb can perform.
Omniverse	A simulation platform by Nvidia where humanoid robots are trained in virtual environments to speed up development.
LLM / MMM	Large Language Models (LLMs) and Multi-Modal Models (MMMs) combine AI capabilities like vision, language, motion to enhance robotic learning
NdFeB Magnets	Neodymium-Iron-Boron magnets—the strongest permanent magnets used in robot joints, EV motors, and wind turbines. Essential for compact, high-torque motion.
Rare Earth Elements (REEs)	A group of 17 elements used in electronics, motors, and magnets. Critical for robotics but mainly processed and exported by China (94% of magnet manufacturing globally).
Neodymium-Praseodymium (NdPr)	Key rare earth materials used in high-performance magnets. MP Materials focuses on their production to supply the robotics and EV sectors.
Dual-Use Materials	Substances with both civilian and military applications (e.g. rare earths used in both EVs and defence systems), often subject to export controls.

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