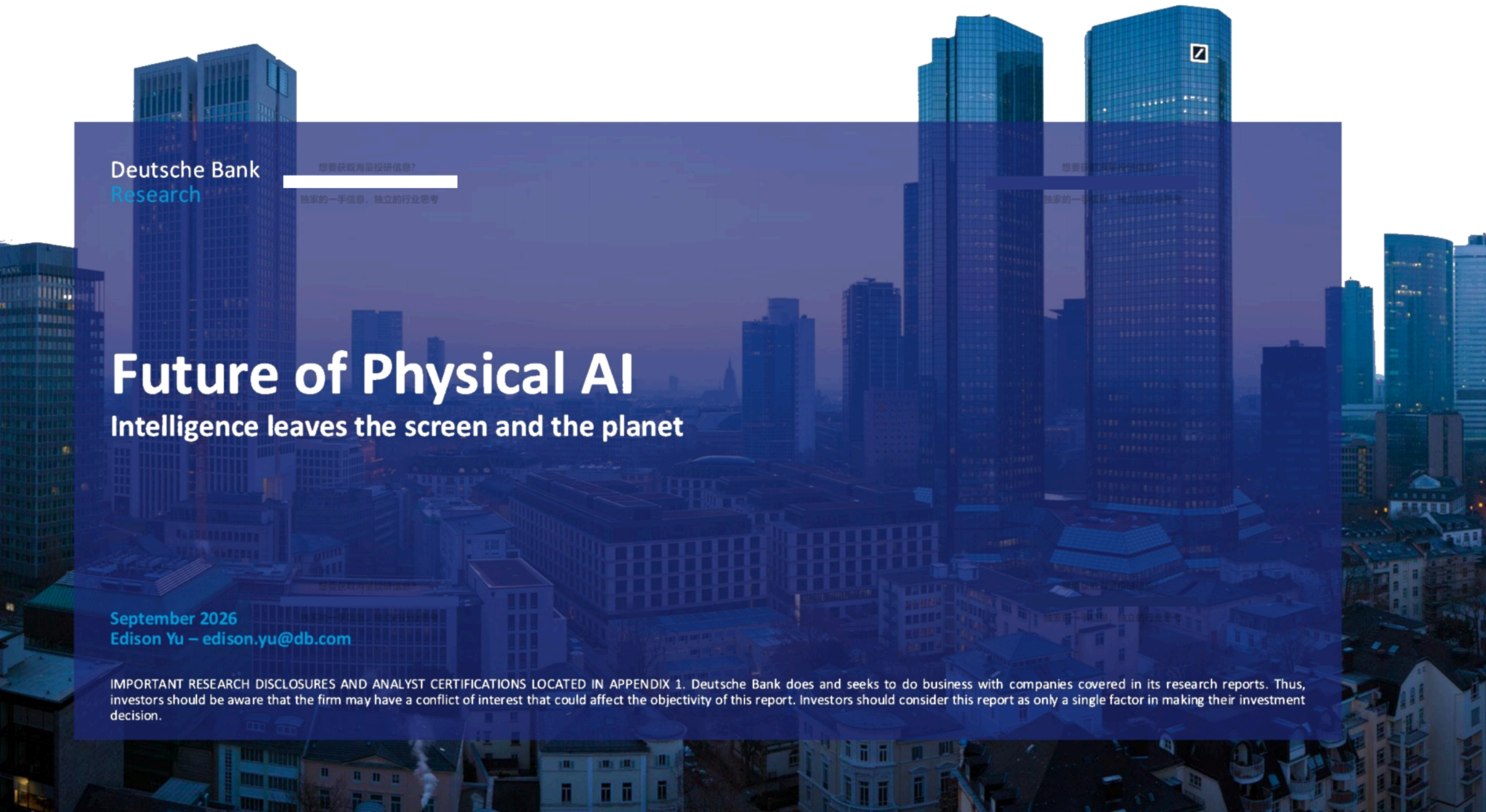


Deutsche Bank
Research

Future of Physical AI

Intelligence leaves the screen and the planet

September 2026
Edison Yu – edison.yu@db.com

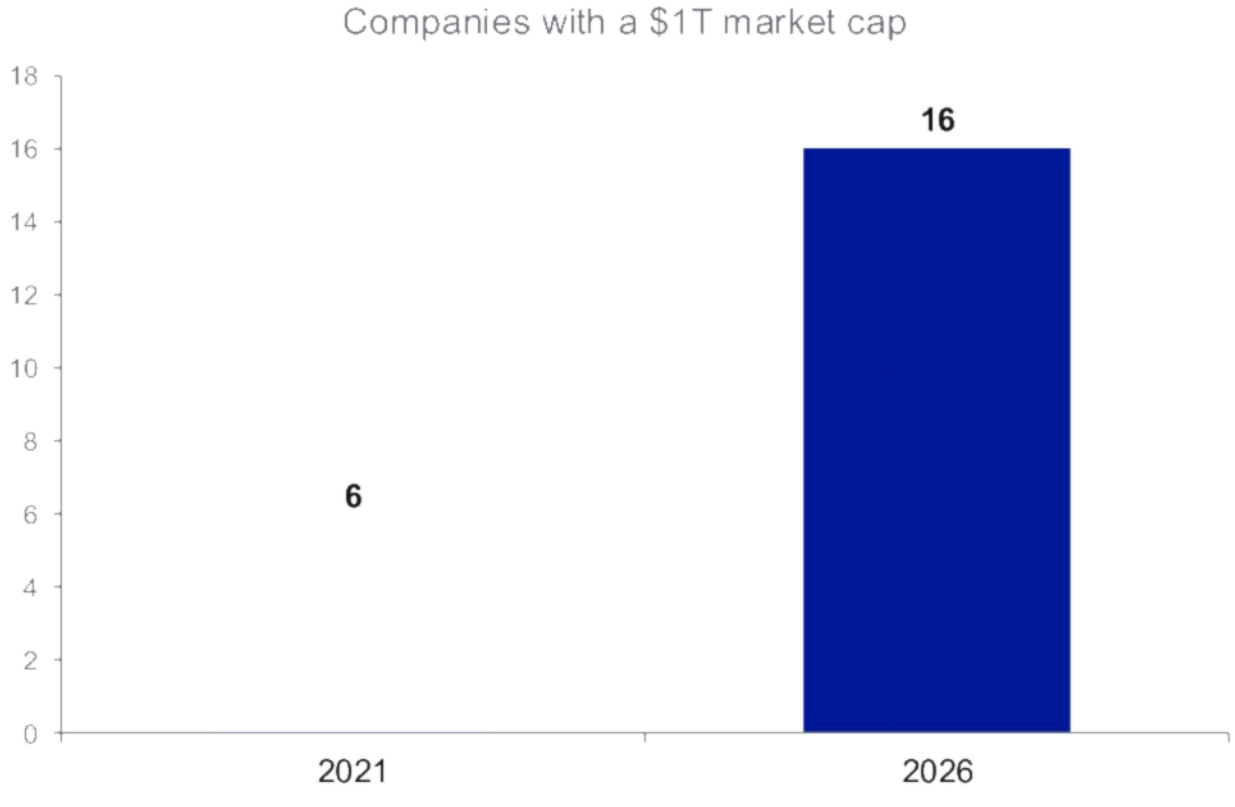
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01

State of the markets

Big numbers + big ambitions

The $1T club has more than doubled in five years



Source: Deutsche Bank, Bloomberg Finance LP

6

Sep 2021: Apple, Microsoft, Alphabet, Amazon, Saudi Aramco, Meta

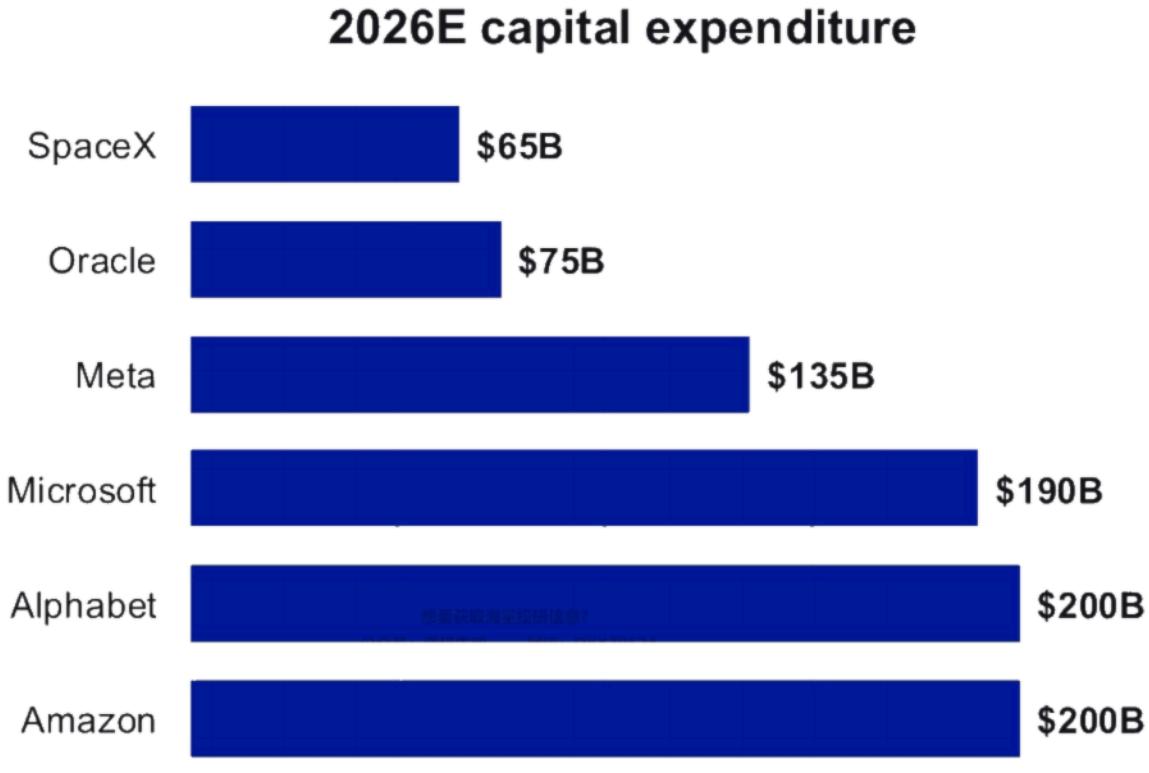
16

Sep 2026 adds: Nvidia, Broadcom, TSMC, Samsung, SK Hynix, Micron, AMD, Tesla, Berkshire Hathaway, SpaceX

+10

7 out of 10 are semis; of the other 3, Tesla & SpaceX work on AI

Capex supercycle fueling the market and economy



Source: Company Reports, Deutsche Bank Research; ZGC & Co

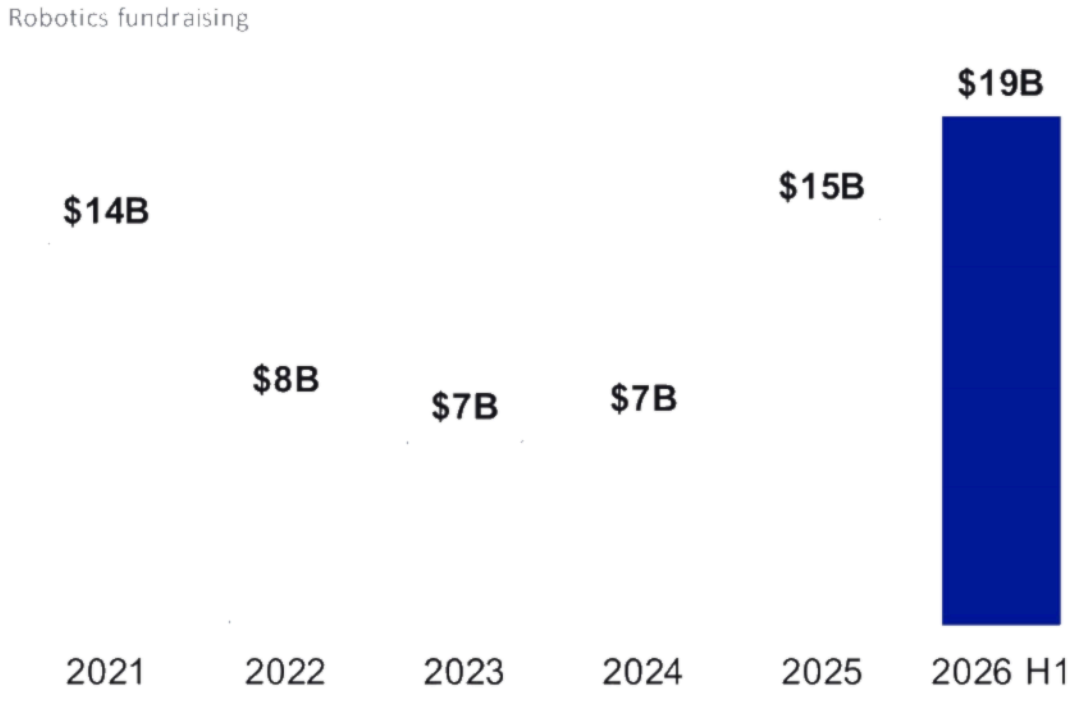
$865B this year

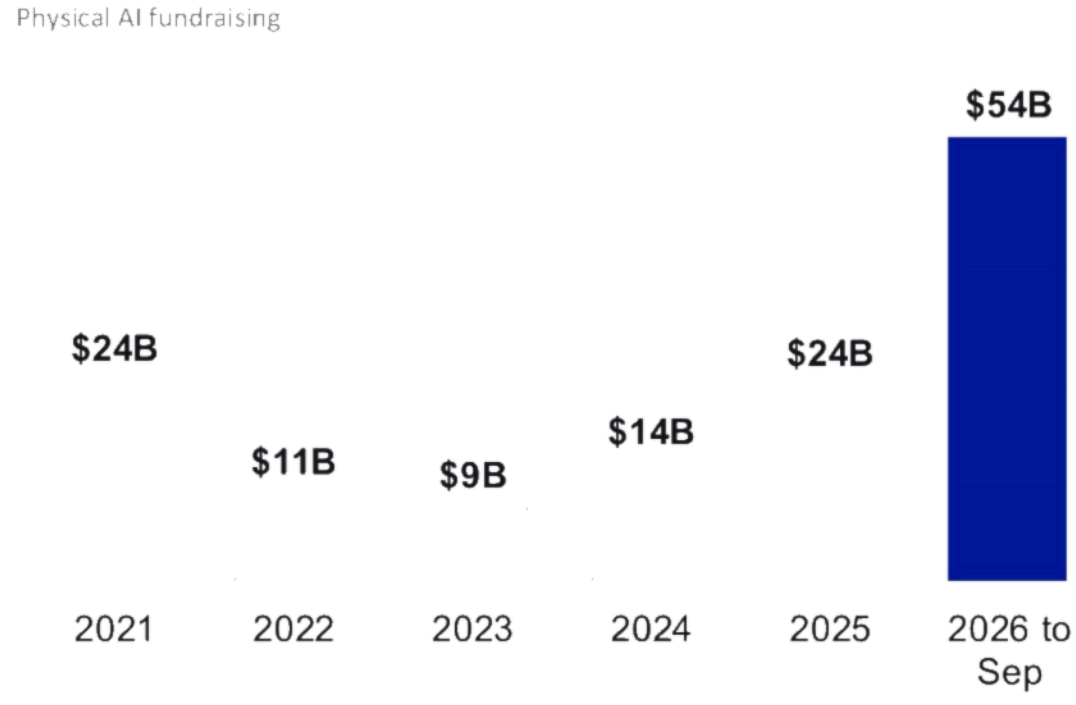
Combined 2026 capex: Amazon, Microsoft, Alphabet, Meta, Oracle, SpaceX

$500B

US telecom capex 1996–2000 inflation adjusted, mostly long-haul fiber, 85–95% of which was still unlit four years after the bust

Physical AI is in early innings; capital just starting to flow





Largest humanoid rounds: Figure $1bn (Sep 2025) · Skild AI $1.4bn (Jan 2026) · NEURA up to $1.4bn (Jun 2026) · Apptronik $935m

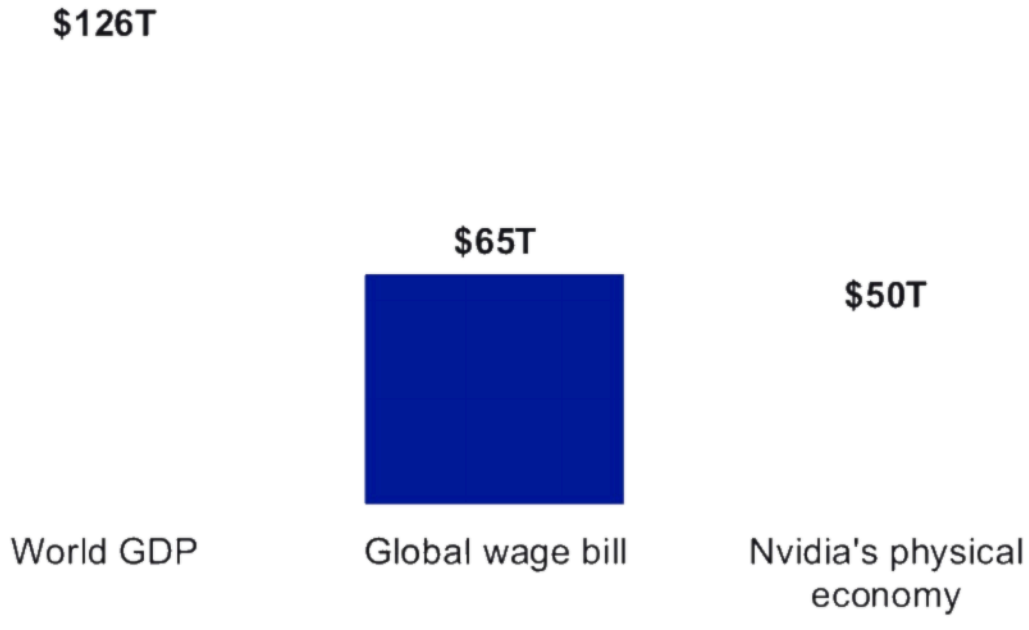
Source: Crunchbase, Company Reports, Dealroom, Deutsche Bank Research

02

Intelligence wants to leave the screen

From tokens to torque

Reshaping the physical economy with AI



MACHINES

Robotaxis, humanoids, warehouse robots, drones, surgical systems. Capital-intensive, and the layer where labor is actually replaced.

COMPUTE

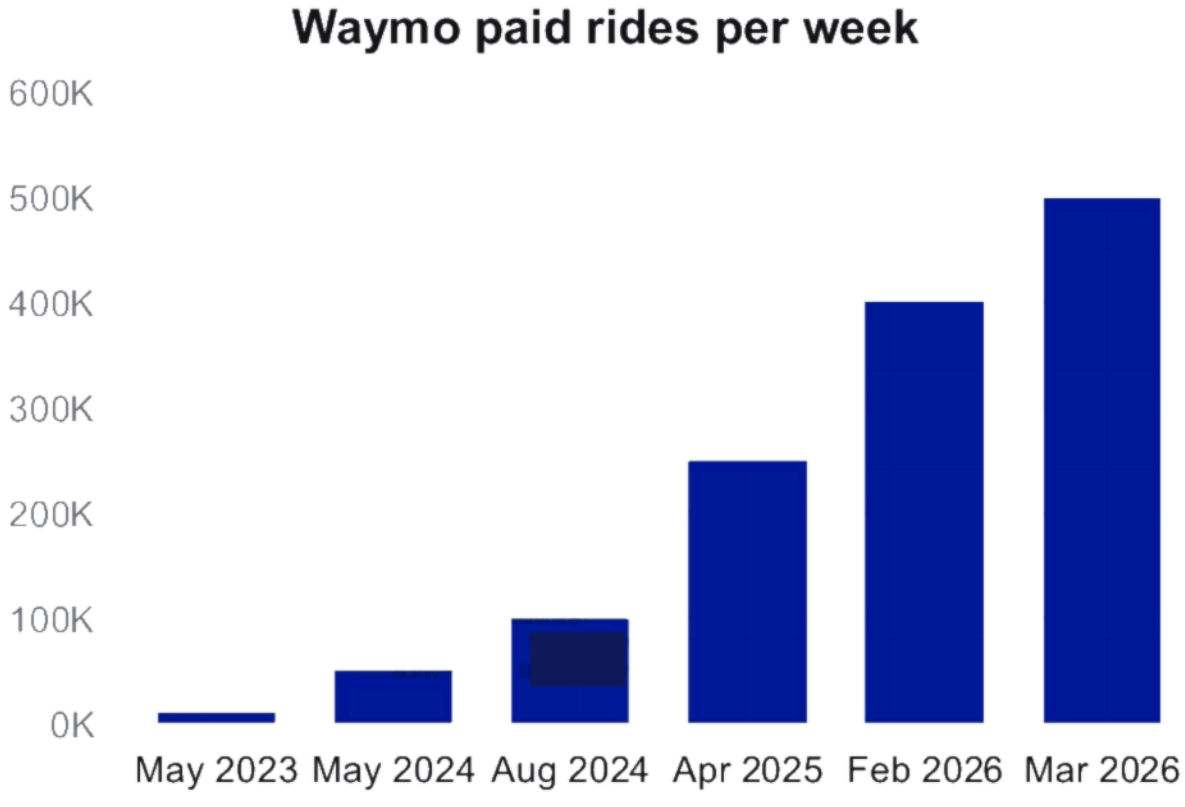
GPU, CPU, or ASIC chips on the edge.

FOUNDATION MODELS

Nvidia Cosmos, World Labs Atlas/Marble, Tesla FSD, and more.

Source: Company Presentations, Deutsche Bank Research, IMF

Robotaxi is first real deployment and ramping up



Waymo

14 metros · 4,000 AVs · >500K paid rides/week · 200M cumulative autonomous miles · targeting 1M rides/week

Tesla

Cybercab commercial service opened in Austin on Sep 3 with no steering wheel or pedals

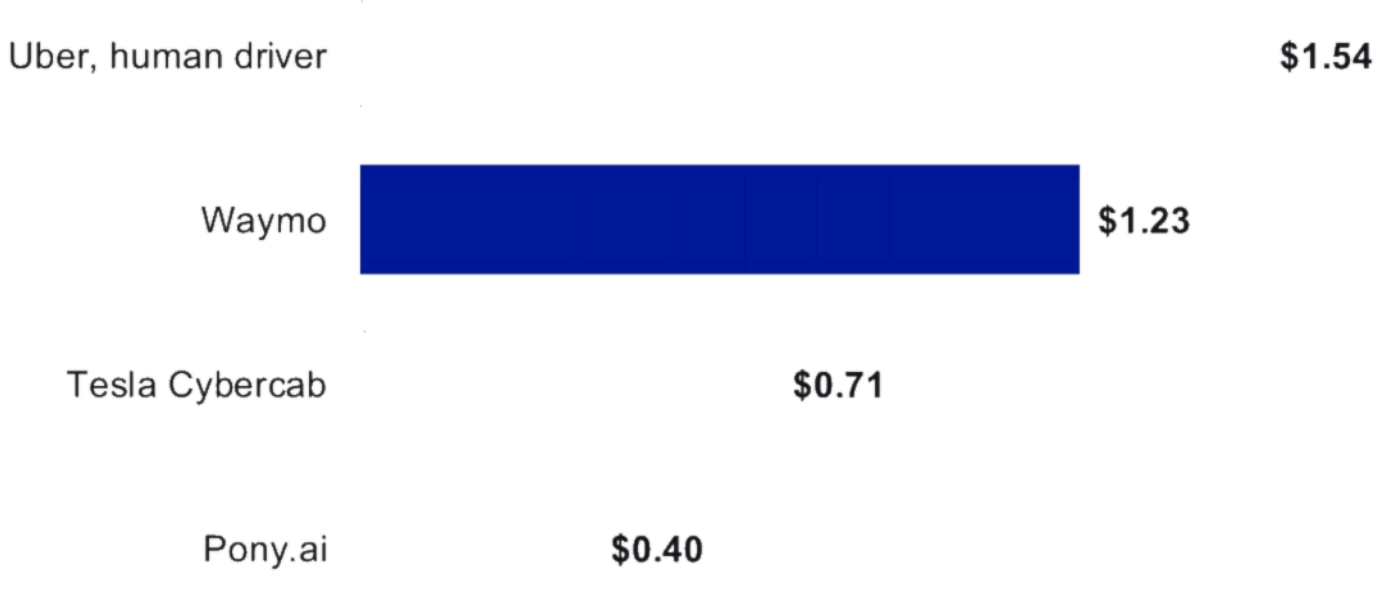
Pony.ai

~2,000 AVs· paid service in Beijing, Shanghai, Guangzhou and Shenzhen

Source: Bloomberg Finance LP, Company Reports, Deutsche Bank Research

Economics compelling even before full optimization

All-in cost to deliver one vehicle-mile



WAYMO COST PER VEHICLE-MILE

Depreciation, $105k over 175k mi	**$0.60**
Remote assistance, 1 per 20 cars	**$0.09**
Depot, cleaning, maintenance	**$0.26**
Insurance and liability	**$0.23**
Energy, 0.3 kWh per mile	**$0.05**
Total	**$1.23**

Source: Company Reports, Deutsche Bank Research

Labor shortages lead to inflation and industrial bottlenecks

321k

projected net migration to mid-2026, down from 2.7M in 2024

11,200

baby boomers reaching retirement age every day

1.9M

manufacturing roles projected unfilled by 2033



Why the squeeze compounds

Labor force growth is near zero this year.
Breakeven hiring is under 10,000 jobs a month, the lowest in 65 years.

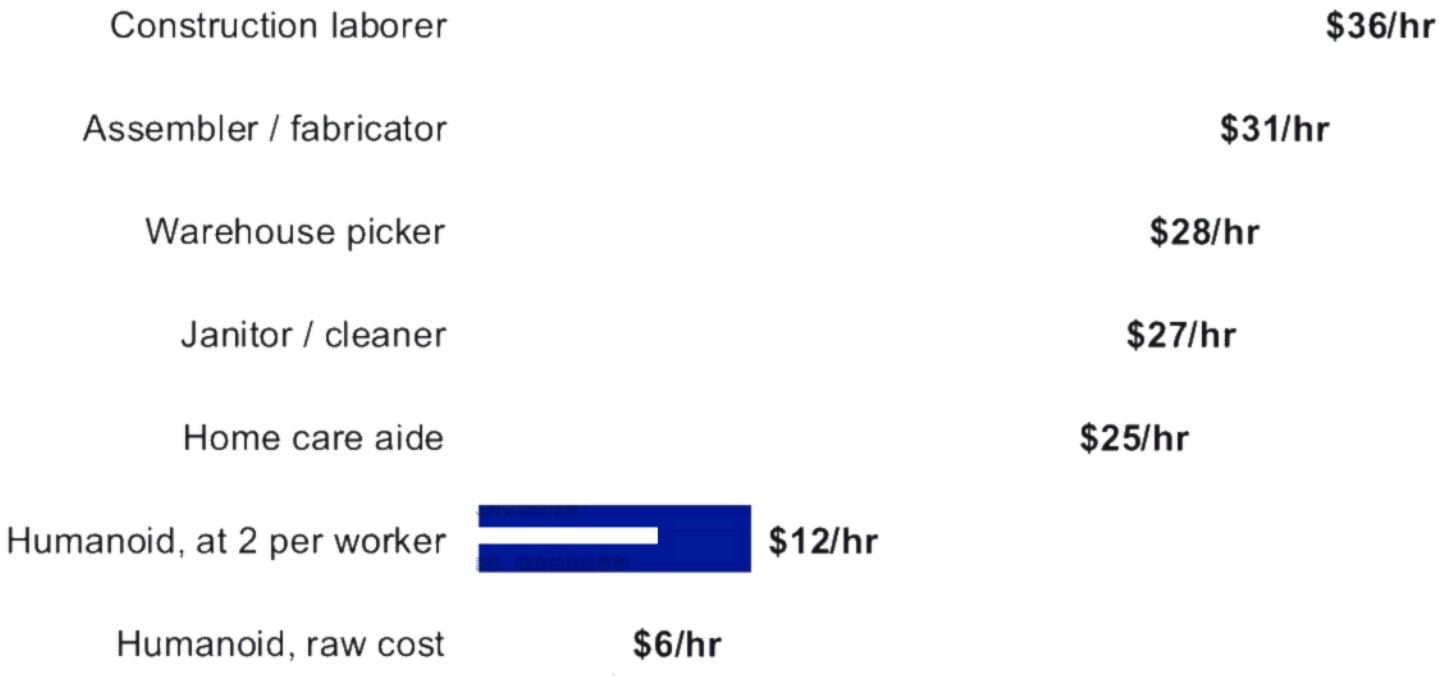
Fertility has been below replacement since 2008.
At 1.6 births, the native-born workforce shrinks without migration.

Reshoring needs people, not just plants.
Manufacturers rank skilled workers above tariffs as the binding constraint.

Source: Deutsche Bank, US Census Bureau; Federal Reserve; Deloitte and the Manufacturing Institute; Reshoring Initiative.

Humanoids can help address these headwinds

Fully loaded cost per productive hour, US, 2026

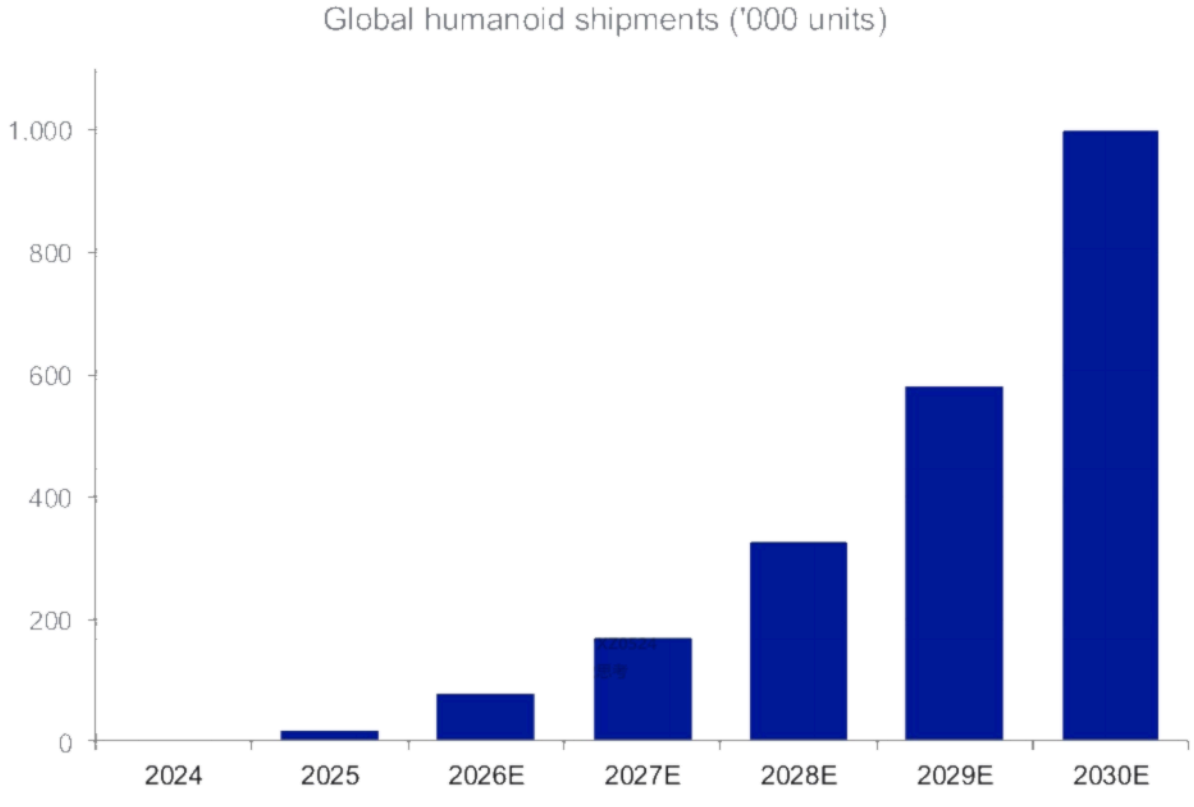


COST PER PRODUCTIVE HOUR

Depreciation, $50k over 5 years	**$1.79**
Maintenance and spares, 15%/yr	**$1.34**
Supervision, 1 tech per 10 units	**$1.52**
Fleet software, $6k/yr	**$1.07**
Energy, 1.2 kW at $0.12/kWh	**$0.14**
Raw operating cost	**$5.86**
At 2 robots per worker	**$11.72**

Source: BLS, Company Reports, Deutsche Bank Research

Humanoid shipments are running ahead of forecast this year



80k

2026E global shipments vs. prior ~50k; China built 40k+ units in 1H26 alone

70k

of those ship in China (88% share)

100mn

units by 2050E or $1.5trn market

Source: Company Reports (Unitree, Agibot), Deutsche Bank Research

03

Key obstacles

Data and supply chain

Data for training is limited; fidelity also an issue

TEXT

5,700 years

continuous human reading, the equivalent of 1T tokens

ROBOT ACTION DATA

124 days

AgiBot World, the largest open robot dataset, end to end

The unlimited source, human video, is missing what a robot has to learn

No actions

Joint angles, torques and gripper state are absent. You see the outcome, never the command that produced it.

Wrong body

A human hand is not a gripper. The camera moves, scale is unknown, and the contact happens off-screen.

No failures

Nobody uploads the attempts that went wrong, so there is no recovery behavior in the corpus to learn from.

Source: AgiBot World Colosseo (2025), Open X-Embodiment and latent-action literature.

Multiple ways to collect more data albeit with limitations

Source	Throughput	Cost per usable hour	What breaks
Teleoperation	5-50 episodes per operator-hour	$35-60	Demos transfer only partly to a new body
Simulation	Millions of episodes overnight	Under $1	Every task needs a real capture to build and validate the world
Human video	Effectively unlimited	Near zero	No joint angles, forces or recorded failures
Fleet learning	Scales with robots in the field	Rides deployment cost	Needs a deployed fleet before it starts

Teleoperation buys fidelity by the hour, so every serious programme is trying to move volume onto the cheap sources without losing fidelity.

Source: Deutsche Bank, Company reports/website (Nvidia, 1X technologies, Figure AI), Deutsche Bank Research

Solutions to addressing data bottlenecks

TELEOPERATION

Pool the demos

Train on demonstrations pooled across robot types, so a new body starts from the shared pool instead of zero. The hourly cost stays; you pay most of it once.

SHARE DEMOS

SIMULATION

Reconstruct, then multiply

Capture the real task, prove the sim matches it, then generate the variations. Recent results cover cables, packing and tight tolerances with no real training data.

CAPTURE ONCE

HUMAN VIDEO

Infer the actions

Models learn latent actions from unlabelled video, then a small labelled set anchors them to real joints. Video pretrains the policy, not just perception.

PRETRAIN FIRST

FLEET LEARNING

Start narrow

Field one repeatable task current policies already clear. Those units pay for themselves while collecting the data the next task needs.

DEPLOY FIRST

EVALUATION

Rank, don't measure

A validated sim need not match real success rates, only rank checkpoints correctly. Hardware testing is too slow to separate 90% from 92%.

VALIDATE SIM

Source: Deutsche Bank, Open X-Embodiment and RT-X

US domestic supply chain still a work in progress vs. China

- **Rare-earth magnets**

  Every joint motor needs neodymium. China refines about 90% of global supply and has already used export licensing as leverage. The US has no refining at scale, and new capacity is a multi-year build.

- **Precision reducers**

  30–40 precision joints per humanoid. Japan's Harmonic Drive leads and Chinese challengers are closing; there is no American source at scale.

- **Battery cells**

  China's CATL leads, with LG and Panasonic behind. The EV buildout has put some cell capacity on US soil, but humanoids are likely to ride an Asian cost curve for years.

Source: Company Reports, Deutsche Bank Research

04

The frontier takes us off world

AI is the true enabler of exploring the cosmos

Terrestrial data center costs may keep rising

Political opposition

Siting fights, longer interconnection queues and community mitigation take land and construction to +6% a year instead of +2%.

+6% a year

land and construction, vs +2% base

Supply bottlenecks

Transformers, switchgear and memory reprice: power and cooling +4% a year and servers +2%, against -3% and -1% in the base case.

+4% a year

power and cooling, vs -3% base

Labor scarcity

Electrical and mechanical trades are the constraint on build speed; contractors were short about 349,000 workers entering 2026, and wages follow.

349,000

construction workers short in 2026

Source: Associated Builders and Contractors 2026, Company Reports, Deutsche Bank Research

Data centers in space

6–8x

Energy in orbit

More power per panel at dawn-dusk orbit which provides near-24/7 sunlight and 40% higher intensity

$50/kg

Starship at rapid + reuse

Vs. $1,400 on Falcon 9 today

$9/W

Satellite cost curve

Solar and radiator costs decline with scale

2030s

Parity with the ground

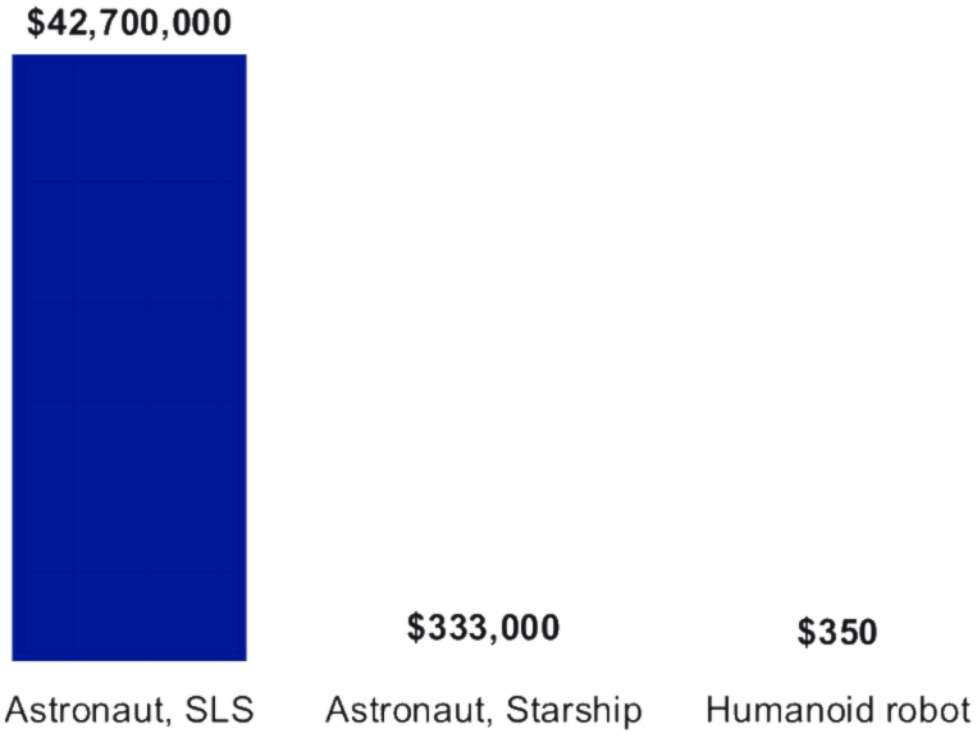
When DB estimates orbital compute matches terrestrial data centers on total cost

Orbital data centers will initially address terrestrial compute needs but naturally should enable intelligence to be scaled up off-world.

Source: Company Reports (SpaceX), Deutsche Bank Research

Labor cost is inhibitor of the space economy

Cost per productive hour on the lunar surface



Source: Company Reports (SpaceX), NASA, Deutsche Bank Research

- **An astronaut-hour costs nearly $43m**

  $4.1bn of SLS/Orion per launch over roughly 96 productive surface hours on an Artemis III profile — about $42.7m an hour, before the lander or the suits.

- **A robot-hour costs as low as ~$350**

  A $200k space-rated humanoid delivered at $50k/kg, working 12,000 hours over five years, costs about $350 an hour. Five orders of magnitude less.

- **Launch cost curve is only part of equation**

  Cost per kg to orbit has fallen by orders of magnitude. The cost of human work off Earth has not moved. Cheap tonnage only pays if something up there can work.

Vision for the lunar economy

+$24B

NASA budget now
Growing allocation toward exploration

+$100B

Moonbase infrastructure
Multi-year build out

1 launch per month

Higher frequency trips to Moon
Delivery cost to the surface will decline with volume

$260mn

Helium-3, if fusion arrives
66 kg a year at $4B a tonne, with no reactor yet to sell it to

Source: Deloitte, Deutsche Bank Research, NASA, PwC

Mars is far away and inhospitable, which should be ideal for robots

- **The Moon is the easy case**

  A 2.6-second round trip keeps an Earth operator in the loop, so the imperfect autonomy available today is already good enough for lunar work.

- **Mars rules out teleoperation entirely**

  Four to 24 minutes each way, and a launch window every 26 months. Every decision has to be made on board, which makes Mars the forcing function for the control and data problems in section three.

- **The transit itself is the hazard**

  Six to nine months each way, with galactic cosmic rays and solar particle events that no practical shield fully stops, bone and muscle loss, and no abort once committed. A machine carries none of that mass.

- **And that is why Mars favors machines**

  No return trip, no life support, no consumables clock, and a 26-month window costs a robot nothing. The base also has to be built before any crew arrive, so the first Mars workforce is robotic either way.

Source: Company Reports, Deutsche Bank Research

THE CLOSING THOUGHT

We spent thirty years building software that avoided the physical world. The return trip has started.

