Robotics

Figures current as of October 2026

The machine that moves: what it is made of and how it is controlled, the sixty years in which it mastered the factory and failed at the kitchen, the AI turn that lets it learn, the robots already at work in factories, warehouses, and streets, the humanoids and the bet on the general form, the cheap drone's remaking of war, and the arguments over productivity, jobs, and China, with the arithmetic worked at each step.

MODULE 1 — Foundations

Goal: Set the vocabulary and the standard of evidence.

What a robot is, the kinds of robots and where each stands, the terms that recur, and the difference between a demonstration and a deployment.

MODULE 2 — The History

Goal: Trace sixty years of the factory and the failure at the kitchen.

Unimate on a General Motors line in 1961, Japan's rise, the Roomba, DARPA's challenges, the warehouse and the car, the AI turn, and Moravec's paradox, the reason a machine that welds a car body could not fold a towel.

MODULE 3 — The Machine

Goal: Understand what a robot is made of.

Actuators and the gears behind them, the hand problem and the surgical robots that solved a version of it, sensors, power, and the control stack from the motor loop to the task, with a humanoid's hardware costs worked.

MODULE 4 — The AI Turn

Goal: Understand how a robot learns instead of being programmed.

Imitation from teleoperation, reinforcement in simulation, the vision-language-action models of 2026 and who builds them, the data problem, and what the learned policies can and cannot yet do.

MODULE 5 — Factories and Warehouses

Goal: Read the automation that already works.

The five million industrial robots and where they are, China's share and its own makers, the collaborative robots, Amazon's million, and a line's payback in Ohio and Shenzhen, worked.

MODULE 6 — Autonomous Vehicles

Goal: Read the largest deployment of robots among the public.

Waymo's fourteen markets, Tesla's camera-only bet, Baidu's and China's fleets, Zoox's exemption, the driverless trucks, the safety record against the human one, and a robotaxi's costs per ride, worked.

MODULE 7 — Humanoids

Goal: Weigh the bet on the general form.

The shipments and where they went, the makers from AgiBot and Unitree to Figure, Tesla, and Boston Dynamics, the listings, and the cases for and against the form, with the evidence.

MODULE 8 — Drones and the Military

Goal: Understand the cheap drone's war and the autonomy line.

Ukraine's drones and interceptors, the Iran war's interceptor shortage, the sea drones, the American programs, the autonomous-weapons argument with the evidence, and the civil drone rules.

MODULE 9 — The Arguments, and What to Watch

Goal: Weigh the cases and name the dates.

The physical-AI thesis, jobs, and China, each made as its advocates make it and then weighed; the contradictions no single module states; a dated watch list; and the last word.

The State of the Art, as of October 2026

The Leading Robots, Their Makers, and When They Shipped

This table is the course's reference point: the most advanced or most widely deployed robot in each part of the field as of October 8, 2026, who makes it, when it shipped, and the module that explains it. A few terms recur. A humanoid is a robot built in the shape of a person, a cobot is an arm designed to work beside people without a safety cage, and a robotaxi is a car that carries paying passengers with no one at the wheel. A foundation model is a large AI model trained on broad data and then adapted to many tasks, the kind that now controls the newest robots.

Category	Leading product	Maker	Shipped or status	Module
Industrial arms	The makers' arm families; China's domestic arms	Fanuc and Yaskawa (Japan); ABB (Switzerland); KUKA (Germany, owned by China's Midea); Estun and Inovance (China)	In continuous production	5
Collaborative arms (cobots)	The UR series; Fanuc's CRX; AUBO, JAKA, and Dobot arms	Universal Robots (Teradyne); Fanuc; Chinese makers	In continuous production	5
Warehouse systems	Proteus, Sequoia, and Vulcan robots coordinated by the DeepFleet model	Amazon	Vulcan May 2025; DeepFleet June 2025	5
Surgical system	da Vinci 5	Intuitive Surgical	Cleared in the United States in March 2024	3
Robotaxi, United States	The sixth-generation Waymo Driver on the Zeekr-built Ojai van	Waymo (Alphabet)	In paid service in 2026	6
Robotaxi, camera-only	Tesla's Robotaxi service on the Model Y; the Cybercab	Tesla	Rides without a safety monitor from January 22, 2026; Cybercab public rides from September 4, 2026	6
Robotaxi, China	Apollo Go on the RT6	Baidu	RT6 in service since 2024	6
Purpose-built robotaxi	The Zoox vehicle, with no steering wheel or pedals	Zoox (Amazon)	Paid rides from August 10, 2026	6
Driverless trucks	The Aurora Driver on heavy trucks	Aurora	Driverless since May 2025	6
Industrial humanoid	Atlas, production version	Boston Dynamics (Hyundai)	Unveiled at CES, January 2026	7
Volume humanoids	Yuanzheng A2, Lingxi X2, Genie G2; the G1, R1, and H2	AgiBot; Unitree	Unitree's G1 2024 and R1 July 2025; H2 unveiled October 2025	7
American humanoids	Figure 03; Digit; Apollo; Optimus	Figure AI; Agility Robotics; Apptronik; Tesla	Figure 03 October 2025; Optimus V3 not yet unveiled	7
Home humanoid	NEO	1X	Preorders from October 28, 2025; deliveries promised for 2026	7
Robot foundation models	Gemini Robotics 2; π0.7; Helix 02; GR00T N1.7	Google DeepMind; Physical Intelligence; Figure AI; Nvidia	Gemini Robotics 2 July 30, 2026; π0.7 April 16, 2026; Helix 02 and GR00T N1.7 in 2026	4

Category	Leading product	Maker	Shipped or status	Module
Robot computer	Jetson AGX Thor	Nvidia	Generally available August 25, 2025	3
Interceptor drone	Sting	Wild Hornets (Ukraine)	In mass production since 2025	8
Sea drone	Magura V5	Ukraine's military intelligence agency (HUR)	In combat since 2023	8
Delivery drones	Wing; Zipline	Alphabet; Zipline	Delivering for Walmart in four states in 2026	8

Company announcements, regulators, and press reports.

Who's Who

The Companies, Agencies, and Research Bodies This Course Names

Name	What it is	Based in
1X	Maker of the NEO home humanoid	US (founded in Norway)
ABB	Engineering group; maker of industrial arms	Switzerland
AgiBot	Humanoid maker; maker of the Yuanzheng, Lingxi, and Genie robots and the AgiBot World dataset	China
Agility Robotics	Maker of the Digit warehouse humanoid	US
Airbus	Aircraft maker	Europe
Alphabet (Google)	Google's parent; owns Waymo, Wing, and Google DeepMind	US
Amazon	Retailer; owns Zoox	US
Apptronik	Maker of the Apollo humanoid	US
AUBO, JAKA, and Dobot	Makers of collaborative arms	China
Aurora	Maker of the Aurora Driver for heavy trucks	US
Baidu	Search company; operator of the Apollo Go robotaxi service	China
Bank of America and Morgan Stanley	Banks whose research estimates what humanoids cost to build	US
BMW	Carmaker	Germany
Boston Dynamics	Maker of the Atlas humanoid; owned by Hyundai	US
BYD and Geely	Carmakers; Geely owns Zeekr	China
Center for Strategic and International Studies (CSIS)	Research institute	US
Churchill Capital Corp XI	Listed shell company merging with Agility Robotics	US
Commerce Department	US department that runs the national-security trade investigations under Section 232	US
Congressional Research Service	Congress's research agency	US
Convention on Certain Conventional Weapons (CCW)	UN treaty framework in Geneva, where an expert group is drafting elements of a possible instrument on autonomous weapons	International
Counterpoint Research, IDC, Omdia, and Smart Analytics Global	Market-research firms that track humanoid shipments	International
Cruise	General Motors' former robotaxi company	US
DARPA (Defense Advanced Research Projects Agency)	The Pentagon's research agency; ran the self-driving and robotics challenges	US
Defense Autonomous Warfare Group	Special Operations Command unit for autonomous systems	US
DJI	Civil-drone maker	China
Efort, Estun, Inovance, and Siasun	Makers of industrial arms	China
Engine AI, Galbot, and Leju Robotics	Humanoid makers	China
Fanuc and Yaskawa	Makers of industrial arms and controls	Japan
Federal Aviation Administration (FAA)	US aviation regulator; registers drones and writes their flight rules	US
Federal Communications Commission (FCC)	US communications regulator; keeps the Covered List of barred equipment	US
Figure AI	Maker of the Figure humanoids and the Helix models	US

Name	What it is	Based in
Foxconn	Electronics manufacturer	Taiwan
General Motors	Carmaker	US
Google DeepMind	Alphabet's AI lab; maker of the Gemini Robotics models	Britain
GXO	Logistics company	US
Harmonic Drive Systems and Leaderdrive	Makers of strain-wave reducers for robot joints	Japan; China
Honda	Carmaker; built the ASIMO humanoid	Japan
HUR	Ukraine's military intelligence agency; operator of the Magura sea drones	Ukraine
Hyundai	Carmaker; owner of Boston Dynamics	South Korea
Institute for Science and International Security	Research institute	US
International Committee of the Red Cross (ICRC)	Humanitarian body and guardian of the laws of war	Switzerland
International Federation of Robotics (IFR)	Industry body; publishes the annual World Robotics count	Germany
Intuitive Surgical	Maker of the da Vinci surgical robots	US
iRobot	Maker of the Roomba	US
Jabil	Manufacturing-services company	US
Joint Interagency Task Force 401	US military task force against small drones	US
Kawasaki	Maker of industrial robots	Japan
Kiva Systems	Maker of warehouse robots; bought by Amazon	US
KUKA	Maker of industrial arms; owned by Midea	Germany
Lockheed Martin	Defense company; maker of the Patriot PAC-3 MSE interceptor	US
Mercado Libre	E-commerce company	Latin America
Mercedes-Benz	Carmaker	Germany
National Highway Traffic Safety Administration (NHTSA)	US vehicle-safety regulator	US
National Transportation Safety Board (NTSB)	US crash investigator; it cannot fine or regulate	US
Nvidia	Chip company; maker of the Jetson Thor robot computer and the GR00T models	US
Ocado	Grocery-automation company	Britain
Physical Intelligence	AI lab; maker of the π robot models	US
PitchBook	Data firm that tracks venture investment	US
Pony.ai	Robotaxi company	China
Schaeffler	Industrial supplier	Germany
Skild AI	AI lab; maker of the Skild Brain and S1 robot models	US
SoftBank	Investment group	Japan
Tesla	Carmaker; maker of the Optimus humanoid, the Cybercab, and the Robotaxi service	US
Toyota	Carmaker	Japan
Uber and Lyft	Ride-hailing companies and robotaxi partners	US
UBTech	Humanoid maker; maker of the Walker S2	China

Name	What it is	Based in
United Nations General Assembly	Votes on resolutions on autonomous weapons	International
Unitree	Maker of humanoid and four-legged robots	China
Universal Robots	Maker of the UR collaborative arms; owned by Teradyne	Denmark
Verne	Robotaxi operator	Croatia
Walmart	Retailer	US
Waymo	Alphabet's robotaxi company	US
Wild Hornets	Maker of the Sting interceptor drone	Ukraine
Wing and Zipline	Drone-delivery companies; Wing is owned by Alphabet	US
Xpeng	Electric-car maker; builder of the IRON humanoid	China
Zoox	Amazon's robotaxi company	US

Organizations grouped in one row share a role. Figures and dates are in the modules.

Module 1 — Foundations

The Vocabulary and the Standard of Evidence

Recommended Reading / Reference

Book: Daniela Rus and Gregory Mone, *The Heart and the Chip: Our Bright Future with Robots*

Reference: The International Federation of Robotics (IFR), *World Robotics*, the annual count of the world's industrial robots, published each September

1a. What a Robot Is

A robot is a machine that senses its surroundings, decides what to do, and acts on the physical world without a person directing each motion. That definition separates it from a tool, which a person moves, from an ordinary machine, which repeats a fixed motion, and from a computer, which acts only on information. The industrial arm bolted to a factory floor, the vacuum that maps a living room, the car that drives itself, the drone that finds its target, and the humanoid that walks are all robots by that definition. They differ in the three things it names: how much they sense, how much they decide, and how much they can do with their bodies. For sixty years the answer to all three was 'little' (Module 2). The field's history is the widening of those three capacities, and the reason 2022-26 is a turning point is that the deciding, the part that lagged, is being handed to learned models (Module 4). That change lets a machine act in a world it was not programmed for, which is what the factory arm could never do.

1b. The Kinds

Kind	What it does	Module
Industrial arms	Weld, paint, assemble, and move parts along a programmed path, usually inside a cage	5
Collaborative arms	Work beside people at lower speed and force	5
Mobile warehouse robots	Carry shelves and totes to people, sort parcels, and pick items from bins	5
Surgical robots	Move instruments under a surgeon's control	3
Autonomous vehicles	Drive passengers and freight without a driver	6
Humanoids	Walk and use two arms and hands in spaces built for people	7
Drones	Fly, find targets, strike, intercept, inspect, and deliver	8
Consumer robots	Vacuum, mow, and clean pools, one task each	2

1c. The Vocabulary

Term	Meaning	Where it matters
Degrees of freedom	The number of independent motions a machine can make: six for an arm that can reach any point at any angle, and dozens for a humanoid	Each degree is a motor, a sensor, and a control problem
Actuator	The motor and gearing that move a joint	Sets the cost, strength, and precision of the machine (Module 3)
End effector	The tool at the end of an arm: a gripper, a welder, a suction cup, or a hand	The hand problem (Module 3)
Kinematics and dynamics	The geometry of a motion, and the forces behind it	The mathematics every controller solves
Teleoperation	A person controlling a robot remotely	Surgery (Module 3) and training data (Module 4)
Simulation and sim-to-real	Training a robot's controller in a physics simulator and transferring it to the real machine	Learned walking (Module 4)
Policy	The learned function that maps what a robot senses to what it does	The unit of progress in the AI turn
Vision-language-action (VLA) model	A large AI model that takes camera images and a written instruction and outputs motor commands	The robot models of 2026 (Module 4)
Autonomy levels	For vehicles, Level 0 (no automation) to Level 5 (drives anywhere, no driver); Level 4 is driverless within a defined area	The scale behind every robotaxi claim (Module 6)
Embodied AI, physical AI	The industry's terms for AI models that control bodies	The thesis argued in Module 9

1d. Demonstration and Deployment

Robotics is a field in which the demonstration and the deployment are years apart and constantly confused. A video of a humanoid folding laundry is not a laundry-folding robot, a robotaxi in one city is not a robotaxi everywhere, and a company's production target is not a production count. The course therefore uses the deployed numbers where they exist, from the IFR, the regulators' filings, and audited company disclosures, and marks a company's own figures as its claims. Demonstrations are called demonstrations, and the test applied throughout is the one a buyer applies: what fraction of the time the machine succeeds, at what cost, and who counted. On the contested questions, the humanoid bet, autonomous weapons, and the jobs, each side's case is made as its advocates make it before the evidence is weighed.

Module 1 Key Points

Foundations

• A robot senses, decides, and acts on the physical world without a person directing each motion; the deciding is what is now changing.

• The kinds run from caged factory arms and cobots to warehouse fleets, surgical robots, robotaxis, humanoids, drones, and single-task consumer machines.

• Autonomy levels run from 0 to 5; Level 4 means driverless within a defined area, and Level 5 driverless anywhere.

• A policy is the learned map from sensing to action; a vision-language-action model turns images and an instruction into motor commands.

• The course's test of any robot: what fraction of the time it succeeds, at what cost, and who counted.

Module 1 Quiz

Check Your Understanding

1. What separates a robot from an ordinary machine, in the module's definition?

A) A robot is programmed by a computer rather than by hand.

B) A robot has an electric motor rather than a mechanical drive.

C) A robot senses its surroundings and decides how to act, where an ordinary machine repeats a fixed motion.

D) A robot can move from place to place, while a machine stays put.

2. Why is 2022-26 a turning point, according to the module?

A) Robot arms finally became cheap enough for small factories to buy them.

B) Governments began paying companies to replace workers with machines in their plants.

C) The deciding is being handed to learned models.

D) Sensors became cheap.

3. What does Level 4 autonomy mean?

A) Driverless anywhere a person can drive

B) Driver assistance with a person watching

C) Driverless on highways, with a person ready to take over

D) Driverless within a defined area

4. What is a policy, in the AI sense?

A) A government rule on where robots may operate

B) A learned map from sensing to action

C) An insurance contract for a fleet of robots, priced per mile driven

D) A company's safety rules for operators working beside cobots on the floor

5. How many degrees of freedom does an arm need to reach any point at any angle?

A) Six joints

B) Three, one for each axis of space

C) Two

D) Twelve, counting each motor and gear separately

Module 2 — The History

Sixty Years of the Factory, and the Failure at the Kitchen

Recommended Reading / Reference

Book: Rodney Brooks, *Flesh and Machines: How Robots Will Change Us*

Reference: The Association for Advancing Automation (A3), the industry's historical record of the Unimate and its successors

2a. The Eras

Era	Years	What happened	What it established
Unimate	1959-1975	George Devol's and Joseph Engelberger's hydraulic arm goes to work at General Motors' die-casting plant in Ewing Township, New Jersey, in 1961, after a prototype in 1959; Kawasaki licenses it in 1968-69 and builds Japan's first robot	The industrial arm: a programmed path, repeated, in a cage, with the car plant as its home market
Japan's rise	1975-1995	Fanuc, Yaskawa, and the Japanese carmakers make the arm electric, precise, and cheap; the SCARA arm (1978) speeds electronics assembly; Japan holds about half the world's robots by 1990	The four families that still lead, Fanuc, ABB, Yaskawa, and KUKA, and the manufacturing model
The research decades	1985-2010	Rodney Brooks's insect-like robots and the argument that intelligence needs a body; Honda's ASIMO walks (2000); the Roomba sells millions by doing one thing (2002); DARPA's Grand Challenges (2004-07) produce the self-driving car	Consumer robots as single-purpose appliances, and autonomy as a research prize
The autonomy decade	2009-2022	Google's self-driving project starts (2009) and becomes Waymo; Amazon buys Kiva Systems for $775 million (2012) and fills its warehouses; Universal Robots sells the first collaborative arms; the DARPA Robotics Challenge (2015) shows humanoids falling over while opening doors	The warehouse and the car as the new frontiers, and the humanoid as a joke
The AI turn	2022-2026	Tesla shows its first Optimus prototype (2022); the vision-language-action models arrive (2023-26); robotaxis become a business and humanoids a product	The learned policy (Modules 4, 6, and 7)

2b. Moravec's Paradox

The history has one lesson, named in 1988 by the roboticist Hans Moravec and argued in the same decade by Rodney Brooks and Marvin Minsky. The things that are hard for people, such as arithmetic, chess, and welding the same seam a thousand times, are easy for machines. The things that are easy for people, such as walking across a cluttered floor, picking up an egg, and folding a towel, are among the hardest problems in engineering. The reason is what evolution optimized. A person's motor and perceptual skills were refined over hundreds of millions of years and run without conscious effort, while abstract reasoning is a recent and thin layer, so a machine built to calculate and then asked to move is working against the grain of what it was built for. The sixty-year record is the paradox in practice: the arm that mastered the car body could not clear a table. What is different since 2022 is that the learned models attack the paradox from the other side. Instead of programming the motion, they learn it from millions of examples of people and machines moving, which is roughly how evolution solved it. Whether that method reaches the kitchen is the question of Modules 4 and 7, and that it has begun to is why the humanoid is no longer a joke.

Module 2 Key Points

The History

• The industrial arm began at a General Motors plant in 1961 as a programmed path in a cage; Japan made it cheap and precise.

• Four families, Fanuc, ABB, Yaskawa, and KUKA, have led for forty years, and the car plant was the home market.

• The Roomba sold millions by doing one thing, DARPA's challenges produced the self-driving car, and the 2015 humanoids fell over opening doors.

• Moravec's paradox: what is hard for people is easy for machines, and what is easy for people, like walking and folding, is hard.

• The AI turn attacks the paradox from evolution's side, learning motion from millions of examples instead of programming it.

Module 2 Quiz

Check Your Understanding

1. Where did the first industrial robot go to work?

A) At a Toyota plant in Japan, welding car bodies for the home market.
B) At a Ford plant in Michigan, painting bodies on the Model T's successor line.
C) At NASA's Houston laboratory, handling the lunar rock samples.
D) At a General Motors die-casting plant in New Jersey.

2. What is Moravec's paradox?

A) That robots cost less than the workers they replace
B) That AI can reason but cannot see
C) That Japan's early lead in robots would not last
D) That what is hard for people is easy for machines, and what is easy for people is among the hardest problems in engineering

3. When did Amazon buy Kiva Systems, and for how much?

A) 2012, $775 million
B) 2009, about $90 million in stock
C) 2016, $1.2 billion in cash
D) 2019, $2 billion in stock

4. When did Honda's ASIMO first walk in public, and when did the Roomba go on sale?

A) 2000 and 2002, two years apart
B) 1997 and 2000
C) In 2005 and 2010
D) 1990 and 1995, at the height of Japan's rise

5. Why did the Roomba succeed where general-purpose robots failed?

A) It was humanoid in form, so it fitted the home.
B) It used AI to plan its route through every room.
C) It was the cheapest robot ever sold, at under $50, which put it in millions of homes.
D) It did one thing.

Module 3 — The Machine

What a Robot Is Made Of

Recommended Reading / Reference

Book: John J. Craig, *Introduction to Robotics: Mechanics and Control*, the standard textbook

Reference: Intuitive Surgical's quarterly reports, the public record of the most widely used surgical robot

3a. The Parts

Part	What it does	The engineering	The cost and the constraint
Actuators	Move each joint	Electric motors with gearing: strain-wave (harmonic) drives for precision, planetary gears for strength, cycloidal and quasi-direct drives for both, and roller screws for linear joints; hydraulics, used in Boston Dynamics' old Atlas, abandoned for leaks and weight	The largest cost: 56% of a humanoid's parts bill, by Morgan Stanley's estimate; roller screws $1,350-2,700 each; Chinese strain-wave reducers 30-50% cheaper than Japanese ones, with Japan's Harmonic Drive Systems and China's Leaderdrive making most of them
The hand	Grasp and manipulate	The unsolved problem: a human hand has about 27 degrees of freedom and thousands of touch receptors, the industrial gripper has two fingers or a suction cup, and the newest robot hands have 16-22 degrees of freedom and are fragile and expensive	Manipulation is where most tasks fail; the surgical robot solved a version by putting a surgeon's hands on its instruments: 11,710 da Vinci systems installed at June 30, 2026, about 3 million procedures a year, each run by a surgeon
Sensors	Perceive	Cameras, cheap and rich in information; lidar, a laser range-finder that measures depth directly (the two bets of Module 6); radar; force and torque sensors in the joints; tactile skins, mostly in research; inertial units for balance	Vision is cheap and the AI models made it useful, lidar fell from about $75,000 a unit in 2007 to a few hundred dollars for Chinese car units, and touch is the missing sense
Power	Run for hours	Lithium batteries at 250-300 watt-hours per kilogram; a humanoid carries 1-2 kilowatt-hours	Two to five hours a charge, which is why factory arms are plugged in and the newest humanoids swap their own batteries
Compute	Think	An onboard computer runs perception and the policy 5-100 times a second, and training happens in data centers; Nvidia's Jetson AGX Thor sells as a $3,499 developer kit and a $2,999 module	Cheap and improving; the least constraining part
Structure	Hold together	Aluminum and carbon fiber; most humanoids weigh 35-90 kilograms, and industrial arms carry payloads from 5 to more than 2,000 kilograms	Weight against strength against cost

3b. The Control Stack

A robot's control runs in layers at different speeds. At the bottom is the motor loop, a thousand times a second, which holds each joint at the angle and torque commanded and has worked reliably since the 1980s. Above it is the whole-body controller, about a hundred times a second, which solves the physics of the whole machine so that a humanoid stays balanced when it lifts a box or a car stays on the road when it brakes. Boston Dynamics spent thirty years on that layer, and learned models are now replacing it. Above

that is the planner, a few times a second, which decides where to move and in what order, and which was hand-coded until it became the learned policy of Module 4. At the top is the task, 'unload this truck' or 'drive to this address', which used to be a program and is now given as an instruction to the models of Module 4. The AI turn replaces the middle layers with learning, and its limit is the bottom one. No model fixes the hardware in the table, which is why it is the floor under everything the next module describes.

3c. A Humanoid's Hardware Costs

Worked example — What a humanoid's hardware costs, part by part

Take a general-purpose humanoid of the 2025-26 generation, 1.7 meters tall and about 60 kilograms, and build its bill of materials from the bank estimates. Bank of America's model of a typical humanoid has 30 actuators, 16 rotary and 14 linear, six-degree-of-freedom hands, and a depth camera and lidar, and it puts the bill at about $35,000 for one built mostly from Chinese parts at the end of 2025. If the actuators are 56% of that, as Morgan Stanley estimates, they come to about $20,000, or about $650 each on average. The roller screw shows why that average is hard to reach: at the table's prices, the dozen or so screws a full-size humanoid needs would alone cost $16,000-32,000, most of the actuator budget or more, which makes the screw the part the industry most needs to cheapen. The rest of the bill, about $15,000, covers the hands' small motors and sensors, six to eight cameras with an inertial unit and force sensors, an onboard computer of the Thor class, a battery pack of about 1.5 kilowatt-hours, and the structure, wiring, and assembly. The Chinese supply chain is the reason the curve is falling, because it makes the actuators and other parts more cheaply and at volume. Unitree's listing prospectus put the average cost of the humanoids it built in the first nine months of 2025, most of them smaller than this example, at CNY 62,200, about $8,700. At the other end, Hyundai was reported to put Atlas at about $140,000 a unit in early production, falling toward $30,000 above 50,000 units, and Bank of America projects $13,000-17,000 for a typical humanoid by 2030-35. Three lessons follow. A humanoid's cost is the number of actuators times their price, and both are falling. The parts that move the machine are most of its cost, and the cheapest path to a cheaper humanoid runs through the screws and reducers. And a $20,000 humanoid would cost less than a year of a factory worker's wages anywhere in the rich world.

Module 3 Key Points

The Machine

• Actuators are about half of a humanoid's parts bill, and Chinese reducers cost 30-50% less than Japanese ones.

• The hand is the unsolved problem: about 27 degrees of freedom and thousands of touch receptors against a gripper's two fingers.

• The surgical robot gives a surgeon's hands to instruments: 11,710 da Vinci systems installed by mid-2026, none autonomous.

• Control runs in layers, the motor loop, the whole-body controller, the planner, and the task, and the AI turn replaces the middle two.

• Bank of America puts a typical humanoid's parts at about $35,000, and Unitree built its smaller ones for about $8,700.

Module 3 Quiz

Check Your Understanding

1. What is the largest cost in a humanoid robot?

A) Batteries
B) The onboard computer and its software
C) The lidar and cameras
D) The actuators

2. Why is the hand the unsolved problem?

A) Because no company has funded serious work on robot hands since the 1990s.
B) Manipulation is where most tasks fail.
C) Because hands are too heavy for a humanoid's arms to carry through a full shift.
D) Because regulators require a person to approve every grasp a robot makes in a factory.

3. What does a surgical robot do?

A) Operates on its own
B) Moves instruments under a surgeon's control
C) Diagnoses patients
D) Replaces the surgeon from first cut to last stitch, with a nurse watching

4. Which layer of the control stack does no AI model fix?

A) The task
B) The whole-body controller that keeps the machine balanced
C) The planner
D) The motor loop and the hardware

5. Why are China-built humanoids so much cheaper?

A) Chinese makers use simpler software that costs less to develop.
B) Their supply chain makes actuators and other parts more cheaply and at volume.
C) The government sets a maximum retail price for robots.
D) They are smaller and lighter, with no hands, and they are sold only inside China under export rules.

Module 4 — The AI Turn

How a Robot Learns Instead of Being Programmed

Recommended Reading / Reference

Reference: UMI-Bench 1.0 (2026), the clearest outside measure of what the leading robot models can do

4a. From Programmed to Learned

Model	Maker	What it does (company claims)	Status
Gemini Robotics 2, with ER 2 and On-Device 2	Google DeepMind	Whole-body control of humanoids; five-finger dexterity, such as tying a trash bag; several robots working together; adapting to a new robot body within hours	Used by Boston Dynamics' Atlas and by Apptronik; ER 2 public through Google's AI Studio; no success rates published
π0.7	Physical Intelligence	A generalist that matched or beat the company's specialist models at espresso, box assembly, and laundry, and folded laundry on a robot it had not trained on about as well as expert teleoperators' first attempts	Still cannot run long multi-step tasks from one command
Helix 02	Figure AI	Adds a whole-body layer to Figure's two-layer model and runs on the robot's own processors; laundry folding and dishwasher loading	Runs Figure 03
GR00T N1.6 and N1.7; the Isaac GR00T reference humanoid	Nvidia	Open models for humanoids, and an open reference design built on Unitree's H2 Plus with Nvidia's Thor computer (May 2026)	Open weights; a common base for smaller makers
Skild Brain and S1	Skild AI	One model for many robot bodies; S1, which Skild says learns a task from a single video	More than $100 million of annual recurring revenue claimed, mostly from robot arms
Tesla's end-to-end network	Tesla	One neural network shared with its driving software, trained on human video and teleoperation	Elon Musk has said current Optimus demonstrations are preprogrammed or teleoperated

Company claims and announcements. The first vision-language-action models, Google's RT-2 (2023), Physical Intelligence's π0 (2024), and Figure's first Helix (2025), have been superseded.

For sixty years a robot did what an engineer wrote: a path of joint angles, a set of rules for when to stop, and a program for each task and each product. A line that changed models had its robots reprogrammed by hand, and a robot in an unstructured place, such as a home, a hospital, or a farm, had no program that could cover it. The AI turn replaces the program with a policy learned from data, in three methods that arrived in sequence. In imitation learning, a person teleoperates the robot through a task again and again, and the recordings train a model to map what the cameras see to what the motors should do. That method is behind most of the 2024-26 demonstrations, from folding laundry to loading dishwashers, and it is why the humanoid companies run teams of teleoperators. In reinforcement learning in simulation, a physics engine runs the robot through the equivalent of years of trial and error in hours, rewarding it for walking without falling, and the resulting controller transfers to the real machine. That method gave the humanoids their legs. The third method is the vision-language-action model, a large model trained on internet images and text and

then fine-tuned on robot data, which takes a camera image and a sentence such as 'put the cup in the sink' and outputs motor commands. It is the reason a robot can now be told what to do rather than programmed to do it, and the leading ones are in the table.

4b. The Data Problem

The language models learned from the internet, trillions of words that people had already written, and there is no internet of movement: no archive of billions of examples of hands picking up objects, recorded with the joint angles and forces a model needs. The robotics companies are building one by three routes, each with a cost. Teleoperation has people in motion-capture suits or with controllers drive robots through tasks, a slow and expensive way to collect data, which is why the humanoid makers run data-collection halls. Simulation generates unlimited data cheaply, but the 'sim-to-real gap', the difference between the engine's world and the real one in friction, deformation, and light, is why a policy that works in simulation can fail on a wet floor. Learning from video, the billions of hours of people doing things online, lacks the joint data, which the models can partly infer, and it is the approach Tesla's camera-only bet rests on. The scale is now counted in hours rather than examples. The largest open datasets hold about 3,000 hours of robot data, as in AgiBot World's million recorded trajectories, while Skild AI says its S1 model was pretrained on about 100,000 hours, still a sliver of what the language models had.

4c. What the Policies Can and Cannot Do

Can, in 2026	Cannot yet
Walk on flat and rough ground, stairs, and rubble; recover from pushes; run	Work a full shift on one battery
Pick and place known objects from bins; sort, pack, and palletize	Handle unknown, soft, or delicate objects reliably: the egg, the cable, the towel
Follow a spoken instruction for a task the model has seen examples of	Do a task it has not seen, in a room it has not seen, at a useful success rate
Learn a new pick-and-place task from a few hundred demonstrations	Learn from a single demonstration, as a person does
Work beside people in a factory cell	Work in a home, with children, pets, and clutter, without supervision

The field's honest measure is the success rate, because a policy that succeeds 80% of the time is a demonstration and one that succeeds 99.9% of the time is a product. The independent evidence is sobering. In UMI-Bench 1.0, published in 2026 by a group of Chinese and European universities and labs, the leading generalist models fully completed ten real-world tabletop tasks between 0% and 58% of the time, two of the tasks defeated every model, and scores fell by about 20 points when the objects and layouts were new. Policies trained for one task in a fixed setting do much better, and that is how the deployments of Module 7 work. The gap between the two is the subject's constant: the models generalize better than anyone expected in 2022 and worse than a person, and most manipulation still sits between the demonstration and the product.

4d. The Money Behind the Models

The AI turn has drawn the largest wave of robotics investment in history, though its size depends on what is counted. PitchBook's count, as others have reported it, put venture investment in robotics and 'physical AI' at about $27.6 billion across 1,009 deals in 2025, double its 2024 figure, with humanoid makers alone raising about $6.1 billion, while trackers that count robotics companies only report closer to $10 billion. The money is concentrated in the model builders. Physical Intelligence was valued at about $11 billion in corporate filings of May 2026, and Skild AI at more than $14 billion after its January round, valuations set far ahead of either company's revenue. The investors' bet is the 'physical AI' thesis weighed in Module 9.

Module 4 Key Points

The AI Turn

• The AI turn replaces the program with a learned policy, by imitation of teleoperators, reinforcement in simulation, and vision-language-action models.

• Reinforcement in simulation gave the humanoids their legs; imitation gave them the demonstrations; the language models let them take instructions.

• There is no internet of movement: open robot datasets hold about 3,000 hours, and Skild AI claims about 100,000.

• In an independent 2026 benchmark the leading generalist models fully completed real tasks 0-58% of the time.

• Investors valued Physical Intelligence at about $11 billion and Skild AI above $14 billion, far ahead of their revenue.

Module 4 Quiz

Check Your Understanding

1. What are the three methods by which a robot learns a policy?

A) Programming, testing, and deployment by engineers
B) Cameras, lidar, and radar
C) Imitation from teleoperation, reinforcement in simulation, and vision-language-action models
D) Hydraulics, electrics, and pneumatics

2. What is the data problem?

A) Robots store too much data
B) No internet of movement
C) Slow cameras
D) Data centers are too far from the factories

3. Why do humanoid makers run teams of teleoperators?

A) The law requires it.
B) Teleoperation produces the training data the models learn from.
C) Their robots cannot move alone.
D) Customers pay extra for a robot that a person drives from a remote center.

4. In UMI-Bench 1.0, how often did the leading generalist models fully complete the tasks?

A) About 90% of the time
B) More than 99% of the time
C) About 75%, the same as the companies reported
D) 0-58% of the time

5. What does the module call the field's honest measure?

A) The success rate, because a policy that works 80% of the time is a demonstration and one that works 99.9% of the time is a product.
B) The price of the robot.
C) The number of degrees of freedom.
D) The company's valuation in its latest funding round.

Module 5 — Factories and Warehouses

The Automation That Already Works

Recommended Reading / Reference

Book: Brad Stone, *Amazon Unbound* (on the company that rebuilt the warehouse)

Reference: The IFR's *World Robotics 2026* (September 2026), the source for most of this module's industrial-robot figures

5a. The Factory

Measure	Figure	Note
Robots at work	5.08 million worldwide at the end of 2025, up 9%	More than 6 million expected by 2028
Installed in 2025	603,307, a record, up 11%; a market worth $18.6 billion	655,000 forecast for 2026
China	354,226 installed, up 20%: 59% of the world's total, more than every other country combined	Chinese makers held 55% of their home market, against about 30% in 2019-21
Other markets	United States 38,428 (up 12%, now second); Japan 36,219 (down 19%); South Korea about 30,000; Germany 24,842	The European Union about 60,500, down 11%
By industry	Electronics 23.6% of installations; cars 22.9%; metals and machinery 18%	—
Robot density, 2024	Robots per 10,000 manufacturing workers: South Korea 1,220; Singapore 818; Germany 449; Japan 446; United States 307; China 166; world average 132	—
Collaborative arms	About 12% of installations (2024, as vendors cite the IFR)	Arms cost roughly $20,000-60,000, and a full cobot cell $40,000-150,000

IFR, World Robotics 2026 and its April 2026 density release; the cobot share and prices from vendor guides.

The industrial robot is the automation that works, and the table shows where it works. China's own makers include Estun, Efort, Siasun, Inovance, and Dobot, and its 15th Five-Year Plan (2026-30) names robotics a strategic emerging industry and embodied AI an industry of the future. The density figures need one caution. On the IFR's older series China had passed Germany and Japan in robots per worker by 2023, but its April 2026 recalculation, using China's newly revised count of manufacturing workers, put it far below both, which says more about the denominator than about the robots. The industry is also changing hands. ABB agreed in October 2025 to sell its robotics business to SoftBank for $5.375 billion, a deal expected to close in mid-to-late 2026 once European, Chinese, and American regulators approve it. In Washington, the Commerce Department opened a national-security investigation of imported robots and industrial machinery in September 2025, a possible step toward tariffs, and its outcome was still pending in mid-2026. Two kinds of change run alongside the numbers. The cobot brought automation to small factories that could never afford a caged cell, and it is the market the humanoid makers are aiming at. The lights-out plant, such as Fanuc's own factories where robots build robots unattended, remains rare, because the last 10% of any line is the part that needs a person.

5b. The Warehouse

Amazon's purchase of Kiva Systems (Module 2) built the second home of robotics, in a system that inverted the warehouse: instead of people walking to shelves, the shelves, carried on wheeled drive units, come to people, who pick from them at a station. Amazon passed a million robots in mid-2025, the largest fleet in the world, and coordinates them with DeepFleet, an AI model that it says cut the fleet's travel time by 10%. The newer systems add arms that pick items from bins, such as Sparrow and Vulcan, which can feel what it grips, sortation robots, the autonomous Proteus, and humanoid trials (Module 7). The result is a warehouse that ships an order in hours with far less labor per item, and the largest source of the jobs argument of Module 9. Internal documents reported by the New York Times in October 2025 projected that automation could let Amazon avoid hiring more than 160,000 American workers by 2027 and more than 600,000 by 2033 while it doubled the number of products it sold, and set a goal of automating 75% of its operations. Amazon disputed that the documents reflected its overall hiring strategy. The goods-to-person model has spread across large retailers' warehouses and, through Ocado's grid systems, into grocery. What remains manual is picking the unknown item, the deformable bag or the loose fruit, which is the hand problem of Module 3 in an industrial setting and the task the humanoid trials are for.

5c. A Line's Payback

Worked example — A line's payback

Take a car-parts supplier in Ohio deciding whether to automate a welding and handling cell that runs three shifts with two workers a shift, and run the arithmetic. Two industrial arms cost about $60,000 each, the welding tools and fixtures $80,000, the safety fencing, conveyors, and controls $100,000, integration and programming $150,000, and training the rest, for about $500,000 installed. Running costs are about $80,000 a year: $30,000 for maintenance and consumables, $10,000 for electricity, and $40,000 for part of a technician's time. On the other side, the six workers cost $55,000 each in wages plus 30% for benefits and payroll taxes, about $430,000 a year. The cell keeps one operator per shift for loading and inspection, so the labor saving is about $215,000 a year. The cell also runs 20% faster and cuts scrap from 3% to 1%, and its consistency wins a contract the plant would otherwise have lost, worth perhaps $100,000 a year in margin. A net saving of about $235,000 a year against $500,000 installed is a payback of about two years, which the supplier's board accepts. In Shenzhen the same cell looks different. Six workers at about $12,000 a year cost $72,000, so the labor saving is about $36,000. Add perhaps $30,000 a year from the faster line and the lower scrap, subtract about $15,000 of running costs, and the cell on Chinese arms, at about $300,000 installed, pays back in about six years. That is why China automated more slowly than its wage growth alone would predict until Chinese arms became cheap, and why its installations have more than doubled since 2019. A humanoid version of the cell needs no fixtures or fencing and a fraction of the integration. In 2026 it is rented rather than bought, and Agility's investor presentation assumes about $8,500 a month per robot, so two robots cost about $204,000 a year, close to the labor they would replace, while no humanoid can yet hold a weld tolerance. At the industry's $20,000 purchase target, with a 95% success rate, the cell would cost about $80,000 installed and pay back in about four months, and every line in the plant would become a candidate. Three lessons follow. Automation's economics are the wage rate against the installed cost, and the cost has fallen faster than wages have risen almost everywhere. Integration, not the robot, is the largest cost and the largest barrier. And the jobs arithmetic is in the example: six jobs became three in Ohio, the three that remain load and inspect rather than weld, a share of a technician's time is added, and a plant that did not automate might have lost the contract and all six.

Module 5 Key Points

Factories and Warehouses

• About 5.08 million industrial robots were at work at the end of 2025, and a record 603,000 were installed that year.

• China installed 59% of the world's robots in 2025, and its own makers supply 55% of its market.

• China's robot density was recalculated in 2026 to 166 per 10,000 workers, far below Germany and Japan, on revised labor statistics.

• Amazon passed a million warehouse robots in 2025; its internal documents projected 600,000 fewer hires by 2033.

• A cell's payback is the wage against the installed cost, two years in Ohio and six in Shenzhen, and integration is the largest cost.

Module 5 Quiz

Check Your Understanding

1. What share of the world's 2025 robot installations went to China?

A) About 59%
B) About a quarter, behind Japan
C) 40%
D) About 10%, behind Japan and Korea

2. Why does the module caution against reading China's density figure as a decline?

A) The IFR recalculated it with China's revised count of manufacturing workers, so the change reflects the denominator rather than the robots.
B) China stopped reporting its installations in 2025.
C) China's factories scrapped their older robots.
D) The IFR now counts only robots made in China.

3. Which customer industry installed the most industrial robots in 2025?

A) Electronics
B) Cars, with about a third
C) Steel
D) Chemicals and plastics, which passed metals and machinery for the first time

4. What is DeepFleet?

A) Amazon's delivery-van network
B) A fleet of Agility's Digit humanoids working in Amazon's warehouses
C) A rival warehouse-robot maker that Amazon bought in 2012
D) An AI model coordinating Amazon's robots

5. In the worked example, what is the largest cost of the automated cell?

A) The two robot arms
B) The electricity to run the cell for three shifts a day, every working day of the year
C) Integration
D) The safety fencing and the conveyors

Module 6 — Autonomous Vehicles

The Largest Deployment of Robots Among the Public

Recommended Reading / Reference

Reference: Waymo's Safety Impact data hub (waymo.com/safety/impact), updated quarterly, and the National Highway Traffic Safety Administration's (NHTSA) crash reports for automated vehicles

6a. The State of the Road

Operator	Fleet	Service (October 2026)	Technology	Note
Waymo (Alphabet)	More than 4,000 vehicles	More than 500,000 paid rides a week; operating in 14 US markets, with Denver, San Diego, and Tampa added on September 1, 2026; more than 20 million rides in all	Lidar, cameras, radar, and detailed maps	Raised $16 billion at a $126 billion valuation (February 2026)
Tesla	About 200 cars without a safety monitor by the end of August, on a crowdsourced count (Tesla gives none)	Driverless rides in Austin, Dallas, Houston, Miami, Orlando, and Tampa; more than a million miles without a monitor, Tesla says (September 2026); no driverless permit in California	Cameras only	Cybercab production since April 2026; a Nevada permit (August 2026)
Baidu Apollo Go	Not disclosed	27 cities and more than 23 million rides in all; weekly rides above 350,000 early in 2026, then about a million in the whole second quarter, on figures reported from Baidu's earnings call	The purpose-built RT6	A system failure froze at least 100 of its cars in Wuhan at the end of March 2026, by the police's count; service in Abu Dhabi, Dubai, and Seoul; testing in London with Uber and Lyft
Pony.ai	1,975 robotaxis (June 30, 2026)	Driverless service in Guangzhou and Shenzhen; a public service in Singapore; the system behind Verne's paid service in Zagreb, Croatia, billed as Europe's first, with safety operators aboard and Uber as a partner (April 2026)	Lidar and cameras	2025 revenue $90.0 million, of which robotaxis $16.6 million; a contract to deploy more than 2,000 robotaxis in Europe with Uber
Zoox (Amazon)	Not disclosed	Paid rides in Las Vegas; free rides in San Francisco while state permits are pending, and free test rides in Austin and Miami	Lidar, cameras, and radar on a purpose-built vehicle	The first federal exemption for a commercial robotaxi without manual controls (July 30, 2026), for up to 2,500 vehicles a year for two years
Aurora	30 trucks (February 2026)	Ten Sun Belt routes, including a 1,000-mile Fort Worth-Phoenix run	Lidar; highway driving	Planned runs on new trucks with no observer in the cab from the second quarter of 2026 (company, February 2026)

Company statements and filings, NHTSA, police and press reports, and crowdsourced trackers, as of early October 2026. Cruise, General Motors' robotaxi company, is gone: after one of its cars dragged a pedestrian in October 2023, General Motors withdrew in December 2024.

The self-driving car is the robot that works in public, and the table shows who runs it at scale. Waymo is the leader, built on the most expensive sensor suite, and its tenfold growth since May 2024, when it gave about 50,000 paid rides a week, came from adding cities and cars rather than from a change of method. Tesla is the challenger, with a different technical bet weighed below, and it moved from rides with a safety monitor aboard, begun in Austin in June 2025, to the small driverless fleet in the table. China's largest fleet has proved fragile, as the Baidu row shows. None of it is Level 5. Every driverless service in the table is Level 4: it runs inside a bounded area, in the weather it has been validated for, with remote assistance, people in an operations center who answer a stuck car's questions without driving it, and it expands city by city. The rules are being written as the fleets grow. In 2025 federal regulators streamlined crash reporting, widened their exemption programs, and began rewriting the safety standards for cars with no steering wheel, the path that led to the Zoox exemption in the table. A national self-driving bill, the SELF DRIVE Act, advanced in a House Energy and Commerce vote in February 2026, but no federal law has passed, so the states still license the services and decide where they may run.

6b. The Safety Record

Crash type	Waymo	Human benchmark	Reduction
Serious injury or worse	0.01	0.21	95%
Any injury	0.67	3.77	82%
Pedestrian injury crashes	7	93	93%
Cyclist injury crashes	9	65	86%
Injury crashes between vehicles at intersections	15	404	96%

Waymo Safety Impact hub, release of September 24, 2026: 271.3 million rider-only miles through June 2026 in Phoenix, San Francisco, Los Angeles, Austin, and Atlanta, against human drivers on the same roads. The first two rows are crashes per million miles; the others are crash counts over the same miles. The reductions are Waymo's own, computed from unrounded figures.

Waymo's record is the largest published safety record of any autonomous machine, and its reductions are largest in the crashes that kill and maim. The finding has held as the miles have grown and the cities have diversified, in peer-reviewed comparisons that adjust for the roads and the reporting. It has caveats. The miles are on urban streets in mapped, mostly mild-weather cities, and the human benchmark includes drunk, tired, and distracted drivers, so the comparison is with the average driver rather than a careful one. The rare failures are the cases regulators investigate and the public remembers. After Waymo cars passed stopped school buses, NHTSA opened an inquiry in October 2025, Waymo recalled the software of its whole fleet in December after repeated violations in Austin, and the National Transportation Safety Board (NTSB) opened its own investigation in January 2026. The NTSB's preliminary report described a car that stopped, asked a remote assistant whether the bus's signals were active, was told they were not, and drove past the bus with its stop arms out.

The technical argument is over Tesla's cameras-only design. Its advocates argue that people drive with eyes alone, that a car without lidar costs a fraction as much to build, and that millions of customer cars supply training video no rival can match. Waymo's answer is that lidar and radar see what cameras miss, in darkness, glare, and fog, and that its redundant sensors are why its record exists. The evidence in 2026 cannot settle it. Tesla's driverless miles are too few to measure a serious-crash rate as low as the human benchmark in the table, and Tesla publishes no record comparable to Waymo's. This course's reading is that where it operates, the lidar-and-map robotaxi is far safer than the average human driver, that the camera-only bet is unproven rather than disproven, and that the next test for both is whether the record holds as the services spread into snow and denser, older cities.

6c. A Robotaxi's Costs per Ride

Worked example — A robotaxi's costs per ride

Take a robotaxi in an American city and cost a ride, using Waymo's published fleet figures and round assumptions for the rest. Waymo has said its cars drive more than 4 million miles a week, so with the fleet and rides in the table, each car drives about 1,000 miles and carries about 125 rides a week, about eight miles driven for every ride, including the empty miles between rides. Suppose the car, with its sensors and computer, costs $100,000 and lasts five years, about 250,000 miles at that rate, so that its capital cost is about $0.40 a mile. Suppose operations cost about $0.45 a mile: $0.05 for charging, and about $0.10 each for cleaning and maintenance, insurance, depots and chargers, and remote assistance, with one assistant watching 10-20 cars. A mile then costs about $0.85 and a ride about $7. A human driver paid $25 an hour who completes two rides an hour costs $12.50 a ride in wages alone, before the car, the fuel, and the platform's share, so a robotaxi can undercut a human ride on cost even with today's hardware. Baidu's RT6, which Baidu says costs under CNY 200,000 (about $28,000), would cut the capital cost to about $0.11 a mile and the ride to under $5, which is why Baidu says its Wuhan fleet broke even per vehicle first, and why Tesla's Cybercab is a bet on cost rather than on sensors. The cost of a ride is not the business, however. At, say, $15 a ride, Waymo's fleet would earn about $8 a ride over its costs, or about $200 million a year at its current volume, while Alphabet's Other Bets segment, which includes Waymo, lost $3.6 billion in the fourth quarter of 2025 alone. Three lessons follow. A robotaxi is a capital business whose economics are the vehicle's cost and the hours it is busy. A human driver's wage is the price it must beat. And the research bill makes the industry a contest over who can afford to reach the scale of millions of rides a week.

Module 6 Key Points

Autonomous Vehicles

• Waymo leads with more than 4,000 cars, 500,000 paid rides a week, and 14 US markets; every driverless service is Level 4.

• Tesla runs a small camera-only driverless fleet in six cities; Baidu's reported rides fell sharply in the second quarter of 2026.

• Over 271 million miles, Waymo had 95% fewer serious-injury crashes than human drivers on the same roads.

• Rare failures, such as passing stopped school buses, drew a fleet recall, an NHTSA inquiry, and an NTSB investigation.

• Zoox won the first federal exemption for a commercial robotaxi without manual controls; no federal self-driving law has passed.

• A robotaxi's economics are the vehicle's cost and its hours of use; the research bill decides who reaches scale.

Module 6 Quiz

Check Your Understanding

1. At what level of autonomy does every driverless robotaxi service operate in 2026?

A) Level 5 in Waymo's cities, Level 4 elsewhere
B) Level 4
C) Level 3, with a remote driver
D) Level 2, with a monitor aboard

2. What did the NTSB's preliminary report say happened before a Waymo car passed a stopped school bus?

A) Its software had no rule for school buses
B) Its cameras were blinded by the sun
C) A remote assistant told it the signals were off
D) A remote assistant took control and drove it past the bus

3. In Waymo's September 2026 safety release, how did its rate of crashes causing serious injury or worse compare with human drivers'?

A) 95% lower, 0.01 against 0.21 per million miles
B) About the same
C) 82% lower
D) Twice as high in the first year, then lower once the software was updated across the fleet

4. Why can Tesla's 2026 driverless record not settle the argument over cameras and lidar?

A) Tesla runs no cars without a safety monitor
B) Its driverless miles are too few to measure a serious-crash rate as low as human drivers'
C) Its cars drive only on highways
D) Its fleet runs only in California

5. In the worked example, about what does a robotaxi ride cost on its round assumptions?

A) About $7
B) About $12.50
C) About $15
D) $0.85

Module 7 — Humanoids

The Bet on the General Form

Recommended Reading / Reference

Reference: Counterpoint Research's and IDC's humanoid shipment trackers, and Unitree's listing prospectus (March 2026), the fullest public account of a humanoid maker's business

Essay: Rodney Brooks, 'Why Today's Humanoids Won't Learn Dexterity' (September 2025), the case against the industry's method by a cofounder of iRobot

7a. The Count

Count	Units	Leaders	Note
2025, Omdia	About 13,000, more than five times 2024	AgiBot 5,168; Unitree 4,200; UBTech about 1,000	Unitree says it shipped more than 5,500, and each of the top two claims first place
First half of 2026, Counterpoint	More than 22,000, nearly four times a year earlier	AgiBot about 9,700 (43%); Unitree more than 7,000 (31%); Galbot more than 1,100; UBTech about 1,000; Leju 650	Entertainment, research, education, and data collection more than 60%; guiding shoppers in stores about 19%; manufacturing 13%; warehousing 5%
First half of 2026, IDC	About 25,000, worth more than $740 million	AgiBot more than 8,600, a figure AgiBot supplied	Chinese makers above 95% of units; buyers in China about 78%
First half of 2026, Smart Analytics Global	About 19,100	AgiBot about 8,400; Unitree about 5,900	Chinese makers above 97%

Trackers' figures as reported in the press; their counts by maker often come from the makers.

The humanoid is a wager that the general form beats the special one. The count shows whose wager it is: China's, with the plan of Module 5 and the parts supply of Module 3 behind it. It also shows what the machines do: by Counterpoint's shares, about 4,000 of the first half's humanoids went to factories and warehouses.

7b. The Makers

Maker	Robot	Where it works (October 2026)	Money and claims
Tesla	Optimus	A first-generation line in Fremont, converted from the Model S and X and designed, Tesla says, for a million robots a year, was due to begin slow production in late July or August 2026, with no start confirmed by early October; no volume target for 2026	Elon Musk puts the eventual price at $20,000-30,000
Figure AI	Figure 03	Parts sequencing at BMW since June 2026, in undisclosed numbers	Valued at $39 billion (September 2025); its BotQ plant can build 12,000 robots a year, it says

Maker	Robot	Where it works (October 2026)	Money and claims
Agility Robotics	Digit	Moving totes for GXO, Schaeffler, Toyota Canada, and Mercado Libre; pilots at Amazon; nine customer sites, more than 65,000 hours of work, and more than $300 million of contracted orders, the company says	Going public through a merger with Churchill Capital Corp XI at about $2.5 billion (announced June 2026); its RoboFab plant in Salem, Oregon, is rated for 10,000 a year
Boston Dynamics (Hyundai)	Atlas, with 56 degrees of freedom	Every 2026 unit committed to Hyundai's new robotics application center and to Google DeepMind	Hyundai plans an American plant for up to 30,000 robots a year
Apptronik	Apollo	Mercedes-Benz, GXO, and Jabil	Raised $520 million in February 2026, at a reported $5-5.5 billion
1X	NEO, for the home	Built in Hayward, California, at a factory opened on April 30, 2026; no customer delivery independently confirmed by mid-2026	$20,000, or $499 a month
Unitree	G1, R1, and H2	Mostly research, education, and entertainment; in China the G1 starts at CNY 85,000 (about $12,000) and the R1 Air at CNY 29,900 (about $4,300)	2025 revenue CNY 1.70 billion, more than four times 2024's
AgiBot	Yuanzheng A2, Lingxi X2, and Genie G2	Says it had built 20,000 robots by September 2026	Began a Hong Kong listing process in July 2026; valued above CNY 20 billion (about $3 billion) after its 2025 rounds
UBTech	Walker S2	Car and electronics plants; customers include BYD, Geely, and Foxconn, and Airbus is testing it	CNY 1.4 billion of humanoid orders in 2025, the company says
Others in China	Xpeng's IRON; Galbot; Engine AI; Leju	Xpeng's production line opened in September 2026	Galbot raised CNY 2.5 billion in March 2026; Engine AI and Leju are preparing to list

Company statements and filings, reported press, and trackers, as of early October 2026. Deployment figures are the companies' own.

7c. The Bet

The case for the humanoid, as its builders make it, starts with the world as built. Every special-purpose robot pays for the human-shaped workplace in fixtures and integration (Module 5), and a machine that walks to a station and learns the task removes that cost, turning automation from a project into a purchase. The hardware is on a cost curve like the ones solar panels and batteries have run (Module 3). The models of Module 4 supply the generality, labor is scarcest where the work is dull and dangerous, and China will build the form at scale whether or not anyone else does. The first deployments follow the Roomba's lesson of Module 2: one task done reliably, and then the next.

The case against is made most sharply by Rodney Brooks. He argues that the industry is collecting the wrong data: video and teleoperation record what a hand did but not what it felt, and he cites a study in which people with numbed fingertips took about four times as long to light a match. He warns that a full-size walking robot stores enough energy in its limbs to injure anyone it falls on, and advises people to stay at least three meters away. His forecast is that the humanoids that eventually make money, more than ten years from now, will have wheels, extra arms, and hands unlike ours. Today's designs, he predicts, will be 'mostly conveniently forgotten'. Other skeptics add that many demonstrations are teleoperated and that for most tasks an arm on a wheeled base does the same work for less.

The evidence through October 2026 supports parts of both. Tesla missed the two goals Elon Musk set for 2025, about 10,000 robots built that year and thousands at work in its factories by its end, and in January 2026 he said no Optimus was yet doing useful work there. Figure's account of its pilot at BMW's plant in Spartanburg, South Carolina, is the most detailed public record of humanoid work: it says its Figure 02 robots worked 10-hour shifts for 11 months, loading more than 90,000 sheet-metal parts for more than 30,000 cars before they were retired in November 2025, figures no one outside the company has checked. 1X's NEO relies on a remote operator in a virtual-reality headset for the chores it cannot yet do, a mode 1X calls Expert Mode, and a Wall Street Journal test found that essentially every complex chore ran that way. The money says investors believe the case for. Unitree earned CNY 590 million in 2025 before one-off items and took about half its revenue from humanoids in the first nine months of the year. It sold its shares at CNY 150.80 in its Shanghai listing on August 19, 2026, closed its first day 460% higher and worth about $50.7 billion, and by early September traded at about half its opening high.

This course's reading is that the humanoid is a real industry and an unproven worker. The cost curve is credible, China is building at scale, and selling to laboratories and stages is already a profitable business. But productive work is still a small share of what the machines do, and the decisive figure, the success rate on unscripted tasks, is one no maker publishes. That figure, not the shipment count or the valuations, will settle the bet.

Module 7 Key Points

Humanoids

• About 13,000 humanoids shipped in 2025 and more than 22,000 in the first half of 2026, nearly all from Chinese makers.

• Factories took 13% and warehouses 5% of first-half shipments; laboratories, stages, shops, and data collection took most of the rest.

• Figure says its robots loaded 90,000 parts at BMW in 11 months; deployment figures across the industry are the companies' own.

• The case for: the general form removes integration, automation's largest cost, on a falling cost curve.

• The case against, made by Rodney Brooks: the industry records video, not touch, and walking humanoids are dangerous to stand near.

• The decisive figure is the success rate on unscripted tasks, which no maker publishes.

Module 7 Quiz

Check Your Understanding

1. About how many humanoids did Omdia count as shipped worldwide in 2025?

A) About 130,000, mostly to Chinese car plants
B) About 13,000
C) About 1,300, nearly all to laboratories
D) About 50,000, the figure most trackers reported

2. By Counterpoint's count, what share of the first half of 2026's humanoid shipments went to factories?

A) About half, led by car plants
B) About a third
C) 60%, the largest single use
D) 13%

3. What does Rodney Brooks argue the humanoid industry's training data lacks?

A) Enough hours of video
B) Touch: video and teleoperation record what a hand did but not what it felt, the sense people rely on to handle objects
C) Examples of walking
D) Language labels for each task, so the models cannot follow spoken instructions

4. What did a Wall Street Journal test find about 1X's NEO home robot?

A) It finished every chore on its own, faster than the owner could.
B) Essentially every complex chore ran by remote operator.
C) It could not climb the stairs of an ordinary house, so 1X withdrew it.
D) It folded laundry but broke dishes.

5. Which company says its robots loaded more than 90,000 parts at BMW's Spartanburg plant?

A) Tesla
B) Agility Robotics
C) Figure AI
D) Boston Dynamics

Module 8 — Drones and the Military

The Cheap Drone's War, and the Autonomy Line

Recommended Reading / Reference

Book: Paul Scharre, *Army of None: Autonomous Weapons and the Future of War*

Reference: The Institute for Science and International Security's review of Russia's 2025 Shahed campaign (January 2026), built on Ukrainian Air Force data

8a. The Cost Exchange

System	Cost	Role	Scale, 2025-26
First-person-view (FPV) quadcopter	$300-1,000	Strikes vehicles and soldiers, flown by a pilot wearing video goggles; fiber-optic versions trail a thin cable, so jamming cannot break the link	Ukraine's government says its industry can build more than 8 million a year (January 2026); Ukraine says it produced 2.2 million drones of all kinds in 2024
Shahed-type drone	$20,000-50,000	One-way attack on cities and the power grid along a programmed route	54,538 launched at Ukraine in 2025, about 32,200 of them armed and the rest decoys; 8,150 drones of all types in May 2026
Interceptor drone	About $2,500 for the Sting; about $1,000 for the P1-SUN	Hunts the Shahed and destroys it in the air	100,000 built in 2025 and about 950 a day delivered from December 2025; about 30% of all air targets destroyed by early 2026, and more than 70% of the Shaheds downed over Kyiv
Patriot PAC-3 MSE missile	About $4 million	The high-end interceptor	Lockheed delivered 620 in 2025; a framework to reach about 2,000 a year, and a contract worth up to $58.6 billion through 2033 (July 2026)
SM-6 missile	About $4-6 million	The Navy's interceptor	Fired at Iranian Shaheds in 2026
Sea drone (Magura V5)	About $250,000	Strikes ships at sea and in harbor	Hit 18 Russian vessels in 18 months, Ukraine's military intelligence says
Loitering munition (Switchblade, Lancet)	Tens of thousands of dollars; about $80,000 for a Switchblade 300	Circles over an area until it finds a target, then dives onto it	The middle tier between the FPV and the missile

Costs are outside estimates; Lockheed's figures are its own production counts. Wartime figures are claims of the side that reports them.

The drone remade war between 2022 and 2026 by an arithmetic armor could not answer. A quadcopter built from commercial parts can destroy a vehicle worth thousands of times its price, and Ukraine says FPVs now cause about 60% of Russia's losses. The second arithmetic ran the other way. A Shahed costs about a hundredth of the missile sent to stop it, so every one shot down is a gain for the side that launched it, and Russia's decoys exist to draw that fire. Ukraine's answer reversed the exchange with interceptor drones that cost about a sixteen-hundredth of a Patriot. At sea, its drone boats, together with missile strikes, pushed most of Russia's major warships from Sevastopol to Novorossiysk, and a navy's defenses were outpriced in turn.

8b. The Iran War

The war that began with American and Israeli strikes on Iran on February 28, 2026 taught the same lesson at American expense. Iran answered with missiles and drones against Israel, American bases, and the Gulf states, and the United Arab Emirates says that by early April 2,141 drones had been fired at it alone, along with 498 ballistic and 23 cruise missiles. The New York Times reported that Middle Eastern states fired more than 800 Patriot interceptors in the first three days, more than Lockheed built in all of 2025. The Center for Strategic and International Studies (CSIS) estimated in July that the United States had about a third of its prewar Patriot stock left, 759-827 missiles. On March 5, by Volodymyr Zelensky's account, the United States asked Ukraine for help, and the next day Ukraine sent interceptor drones and a team to protect American bases in Jordan. A ceasefire brokered by Pakistan in April broke down in July, and as of early October 2026 there is no settled peace: the Strait of Hormuz was effectively closed as of September, with no reopening reported, and an American blockade of Iran's ports continues.

8c. The American Response

The Pentagon's first answer missed its mark. Replicator, launched in August 2023 to field 'multiple thousands' of cheap autonomous systems within two years, fell short of that goal, by the Congressional Research Service's account. In 2025 it was absorbed by the Defense Autonomous Warfare Group of Special Operations Command, for which the department requested $54.6 billion for fiscal 2027, nearly all of it from a budget-reconciliation bill. The newer programs buy drones as ammunition rather than as aircraft. A July 2025 memo from Defense Secretary Pete Hegseth reclassified small drones as consumables, the Drone Dominance program is spending $1.1 billion on more than 300,000 small attack drones in a series of six-month competitions, and the Army expects to buy at least a million drones within two to three years, against about 50,000 a year before. Joint Interagency Task Force 401, set up in August 2025, leads the defense against small drones at American bases at home and abroad.

8d. The Autonomy Line

Most of the drones in the table are flown by a person or along a programmed route, and the next turn is the one the models of Module 4 make possible: a drone that finds its target and decides to strike with no one in the loop, which jamming cannot stop. The argument is over whether a machine may select and engage a human target on its own. The case against such weapons, as the campaign for a treaty makes it, is that a machine that decides to kill removes the human judgment the laws of war depend on, telling a soldier from a civilian and weighing an attack's harm, and the accountability that follows a decision, since no one answers for what a policy did. Cheap autonomous weapons would spread to every army and militia, lower the threshold for war by removing the soldier's risk, and fail at machine speed. The Secretary-General of the United Nations and the president of the International Committee of the Red Cross have called for a binding treaty by 2026.

The case against a ban, as its opponents make it, is that every major military is already crossing the line, so a treaty that binds the democracies and not their adversaries disarms only the democracies. The alternative to an autonomous interceptor is a city hit by drones, a machine does not panic or hate, and its errors can be audited. 'Meaningful human control', the campaign's standard, has no agreed definition, and almost any definition either bans the interceptor or permits the autonomous strike.

The diplomacy has produced majorities but no rule. The General Assembly backed action on autonomous weapons by 152 votes in 2023 and 166 in 2024, and by 164 to 6 in December 2025, when the United States

voted against, reversing its earlier support. The chair's rolling text in the expert group under the Convention on Certain Conventional Weapons (CCW) would ban systems whose effects cannot be anticipated and limited and require 'context-appropriate human judgement and control', a phrase critics call weaker than the campaign's. In September 2025, 42 states said they were ready to negotiate, but no negotiation has opened, and American policy, Defense Department Directive 3000.09, requires only 'appropriate levels of human judgment over the use of force'. This course's reading is that the line will be drawn by practice before it is drawn by law. Defensive autonomy against drones and missiles is already accepted, and the weapons that select people are the real question. With the United States opposed and the CCW deciding by consensus, its review conference is more likely to produce principles than a ban.

8e. Civil Drones

Civil drones are a smaller market with a sharper politics. The Federal Aviation Administration (FAA) counted 837,513 registered drones in November 2025, an undercount, since one recreational registration covers all of a flyer's drones. In one construction-industry survey (August 2026), China's DJI was the main drone of 97% of the firms that fly one. In December 2025 the Federal Communications Commission (FCC) added all foreign-made drones and their critical parts to its Covered List, so new foreign models cannot be authorized for sale, while models already approved can still be sold and flown. The exceptions are conditional approvals for 11 non-Chinese makers, through December 31, 2026, and a few single-product exemptions. DJI says 25 planned launches are blocked and has challenged the decision in a federal appeals court. Tariffs under Section 232, a national-security trade law, took effect on September 3, 2026: 100% on drones over 25 kilograms, thermal-camera drones, and docks, and 25% on most others. Part 108, the rule that would let drones fly beyond their pilots' sight without case-by-case waivers, was proposed in August 2025, missed the February 2026 deadline an executive order had set, and went to White House review on July 10, 2026, where it remained in September. Delivery is growing anyway. Walmart says it passed a million drone deliveries in May 2026, from 66 stores, and Zipline says it had made 2 million deliveries worldwide by January.

Module 8 Key Points

Drones and the Military

• A cheap FPV drone can destroy a vehicle worth thousands of times its price, and Ukraine says it can build 8 million a year.

• Russia launched 54,538 Shahed-type drones at Ukraine in 2025; interceptor drones at about $2,500 reversed the cost of shooting them down.

• In the 2026 Iran war, Middle Eastern states fired more than 800 Patriots in three days, more than Lockheed built in 2025.

• The Pentagon now buys small drones as ammunition: 300,000 for $1.1 billion, and the Army expects to buy at least a million.

• The UN majority backs limits on autonomous weapons, the United States voted no in 2025, and no treaty negotiation has opened.

• New foreign-made drones are barred from FCC authorization, with limited exceptions, and Walmart says it passed a million drone deliveries.

Module 8 Quiz

Check Your Understanding

1. Whom did the United States ask for help against Iranian drones in March 2026, by Volodymyr Zelensky's account?

A) Israel's drone makers
B) Taiwan
C) Ukraine, which sent interceptors to Jordan
D) South Korea, which sent missiles and crews to Qatar

2. What did the Drone Dominance program set out to buy?

A) More than 300,000 small attack drones for $1.1 billion
B) Ten new Patriot batteries
C) A fleet of large drones
D) Ukrainian interceptors

3. About how many Shahed-type drones did Russia launch at Ukraine in 2025, by Ukraine's count?

A) About 5,400
B) About 540,000
C) About 13,000
D) 54,538, of which about 32,200 were armed and the rest decoys

4. How did the Patriot interceptors fired in the Iran war's first three days compare with Lockheed's 2025 production?

A) More than 800 fired, against 620 built in all of 2025
B) About 80 fired, a tenth of a year's output
C) About 300 fired, half a year's output
D) About 2,000 fired

5. How many registered drones did the FAA count in November 2025?

A) About 2 million, the figure often quoted
B) 84,000
C) About 8.4 million, mostly recreational
D) 837,513

Module 9 — The Arguments, and What to Watch

The Cases as Their Advocates Make Them, and the Dates

Recommended Reading / Reference

Paper: Daron Acemoglu and Pascual Restrepo, 'Robots and Jobs: Evidence from US Labor Markets', *Journal of Political Economy* (2020), the standard estimate of what robots did to American jobs

Paper: Wolfgang Dauth, Sebastian Findeisen, Jens Suedekum, and Nicole Woessner, 'The Adjustment of Labor Markets to Robots', *Journal of the European Economic Association* (2021), the German counterpoint

9a. The Physical AI Thesis

The case that the turn is real, as its advocates make it, is the 'physical AI' thesis: that the body is the next frontier for the models that mastered language, and that the scaling which produced them will produce the general robot. Nvidia's chief executive, Jensen Huang, said at CES in January 2025 that 'the ChatGPT moment for general robotics is just around the corner'. The advocates read the deployments of 2025-26 as the signs: robotaxis carrying paying passengers in dozens of cities (Module 6), the warehouse fleets (Module 5), the drone war (Module 8), and the humanoid shipments (Module 7). They add the demand, from aging countries with shrinking workforces and from the shifts no one wants, and the cost curve of Module 3.

The case that it is early answers that most of the deployed robots work in factories and warehouses, deployments decades old, and that the robotaxi took more than fifteen years from Google's first self-driving project (Module 2). The humanoids at productive work are a small share of those shipped (Module 7), the independent benchmark of Module 4 puts the best general models far from a product, the data problem has no internet to solve it, and the general-purpose robot has been promised since Unimate's era (Module 2). The evidence divides along one line. Where the sensing is rich and the action simple, as in driving a mapped street, flying to a target, or carrying a shelf, the learned machine is deployed at scale and improving; where the task needs a hand, which is most of the work people do, it is not yet. This course's reading is that the thesis is right about direction and wrong about timing.

9b. The Jobs

The jobs argument also has two cases. The first, as automation's critics make it, is that robots take jobs and wages from the workers and places they reach, that the gains go to owners and to the technicians who remain, and that a general robot would carry the same losses from the factory into the services, where most people work. The second, as the industry and many economists make it, is that automation raises productivity, that jobs move rather than disappear, and that displaced workers find the work the machines create, as they have since the mechanized loom.

The American evidence supports the first case, and the German evidence the second. Daron Acemoglu and Pascual Restrepo found that between 1990 and 2007, one more robot per thousand workers reduced the employment-to-population ratio by 0.2 percentage points and wages by 0.42% in the American commuting zones that adopted them, or about six jobs per robot locally and 3.3 nationally, once the effects across regions are counted. In Germany, Wolfgang Dauth and his coauthors found that robots displaced manufacturing jobs but that new service jobs fully offset the loss, and that the cost fell mostly on young workers who were never hired rather than on the workers already in the plants. Amazon's projections of

hires avoided (Module 5) are the newest test, because a company that stops hiring is the German pattern at the scale of the American warehouse. This course's reading is that robots have cost American jobs on net and moved German ones into services, and that in both countries the costs were concentrated while the gains spread thin. A general robot would extend that pattern into the services only by solving the hand problem of Modules 3 and 4, which makes the jobs question and the technical question the same question.

9c. The China Question

The China question has two cases as well. The first, made in Beijing and by many Western investors, is that China will lead robotics as it leads batteries and solar panels, since it leads the installations and the makers' shares of Module 5, the humanoid shipments of Module 7, and the parts supply of Module 3. The second, made in Washington and Silicon Valley, is that the value lies in the intelligence, where the leading robot models and the computers that run them are American (Modules 3 and 4), and in the most demanding deployments, such as the driverless car (Module 6), so that China's volume runs on Western brains. The evidence of 2025-26 shows the dependence running both ways. China's licensing of rare-earth magnet exports held up Optimus production in April 2025, by Elon Musk's account, because Beijing wanted assurance the magnets were not for military use. A Wall Street Journal analysis in 2026 found that about 61% of the core components of ten American humanoid makers came from China. In the other direction, the American limits on chip exports, the investigation of robot imports (Module 5), and the bar on new foreign drones (Module 8) are bets that the dependence can be cut before it matters. This course's reading is that China leads in the hardware and the count of machines, and the United States in the models and the most demanding deployments. Robotics reverses the chip industry's pattern: in chips the chokepoints are Western, while in robots the magnets and most of the core components are Chinese.

9d. The Contradictions

Four contradictions run across the modules, and no single module states them.

The cheapest robot changed the most. The drones of Module 8 are the cheapest machines in this course and the ones that changed the most, while the general-purpose machine of Modules 3 and 7 is still in pilots. So far, a robot's impact has run opposite to its generality.

The boom measures the problem. Much of the demand for humanoids is for machines that perform, teach, and record training data (Module 7), so the industry is partly buying robots to make the data that would make robots useful (Module 4). The shipment count is in part a measure of how far the models still have to go.

The leader in units is not yet the leader in work. China leads the counts (9c), but most of its humanoids are not yet at productive work (Module 7) and its largest robotaxi fleet has proved fragile (Module 6), so the country with the most machines is not yet the one getting the most work from them.

The machines arrived before the law. In robotaxis (Module 6), delivery drones, and autonomous weapons (Module 8), the machines are in service while the rules are still being written, so the law is forming around them rather than ahead of them.

9e. What to Watch

When	What	Why it matters
By the end of 2026	Waymo's goals of a million paid rides a week and a London launch; Pony.ai's target of more than 3,500 robotaxis; Aurora's of more than 200 driverless trucks	The first year in which scale, rather than the technology, sets the pace of the business
November 2026	The Seventh Review Conference of the Convention on Certain Conventional Weapons	Whether the expert group's text becomes a mandate to negotiate a treaty
Early 2027	Full-year 2026 humanoid counts from the trackers, against their forecasts of 50,000-60,000	The share going to factories and warehouses matters more than the total: a rising share means work, and a flat one means data collection
Pending	Part 108 (Module 8)	Its right-of-way terms decide how close delivery drones may fly to crewed aircraft
Pending	The Commerce Department's investigation of imported robots and machinery (Module 5)	Tariffs would raise the installed cost in every American line's payback
2026-27	Tesla's Optimus: the V3 unveiling, whether the Fremont line has started and what it makes, and any independent count of robots at work	The largest claims in the field, so far with the least outside evidence
2026-27	Deliveries of 1X's NEO, and how many of its chores still need a remote operator	The first test of a humanoid in a home
2026-27	Xpeng's first IRON deliveries; AgiBot's Hong Kong listing; the close of Agility's merger	Whether public markets keep paying for humanoid makers before their machines do productive work
September 2027	The IFR's World Robotics 2027, with the 2026 installations	Whether China's own makers keep taking their home market, the sign that the robot arm is following the solar panel
2028	Hyundai's plan to use Atlas for parts sequencing at scale, with assembly work by 2030; the end of Zoox's two-year exemption	The first scheduled test of humanoids in a car plant at scale, and of whether a car without controls earns a permanent rule
Ongoing	DJI's court challenge to the Covered List, and the FCC's proposal to withdraw some existing authorizations	Whether the bar extends from new foreign drones to existing ones
Ongoing	Employment in warehouses and factories against the robot counts, and Amazon's hiring	The jobs evidence's next chapter, in the industries automating fastest

9f. The Last Word

Every robot in this course has succeeded in proportion to how much of the world was arranged for it. The industrial arm works in a cage built around its path, the warehouse robot on a grid laid for its wheels, and the robotaxi inside a mapped area. The drone works in the emptiest place there is, the open air, which is one reason it spread fastest. The humanoid is the attempt to stop rearranging the world and to build a machine for the world as it is, and the home, which no one will rearrange for a robot, is the hardest test of all. That adds one question to the buyer's test of Module 1. Of any new robot, ask how much of the world had to change to make it work, because the answer says how far the machine has come and how far the claims made for it can travel.

Module 9 Key Points

The Arguments, and What to Watch

• Physical AI is real in the car, the warehouse, and the drone, and early wherever a hand is needed.

• Between 1990 and 2007, each American robot cost about six jobs locally and 3.3 nationally, by Acemoglu and Restrepo's estimate.

• In Germany, new service jobs fully offset robots' manufacturing losses, and the cost fell mostly on young workers never hired.

• China leads robotics in hardware and units, the United States in models; China's magnet licensing held up Optimus in 2025.

• The deployments ran ahead of the rules in robotaxis, delivery drones, and autonomous weapons alike.

• Of any robot, ask how much of the world had to change to make it work.

Module 9 Quiz

Check Your Understanding

1. What did the German study by Dauth and his coauthors find about robots and jobs?

A) Robots raised manufacturing employment in every region they entered.

B) Robots had no measurable effect on any jobs.

C) New service jobs offset the manufacturing jobs robots displaced, and the cost fell mostly on young workers.

D) Robots cut total employment by about 3% over the period, mostly through layoffs of older workers in car plants and their suppliers.

2. By Acemoglu and Restrepo's estimate, about how many jobs did one more robot cost in the American commuting zone that adopted it, 1990-2007?

A) About 60, counting suppliers

B) About one, a worker for a worker

C) About six

D) About 20 in car plants

3. By a Wall Street Journal analysis in 2026, what share of the core components of ten American humanoid makers came from China?

A) About 61%, by the Journal's count of their core parts

B) About 10%

C) Nearly all, 99%

D) About a third

4. How did China's export controls affect Tesla's Optimus in April 2025, by Elon Musk's account?

A) They raised its motors' cost by half

B) They banned the robot's sale in China, Tesla's second-largest market for its other products

C) Licensing of rare-earth magnets held up production

D) They cut off its chips

5. What question does the module's last word add to the buyer's test of Module 1?

A) Ask whether the robot is shaped like a person.

B) Ask who funded the company.

C) Ask how much of the world had to change to make it work.

D) Ask whether the robot could do the same task in a different country, under different labor laws and wages.

Answer Sheet

Answers to every module's Check Your Understanding quiz.

Module	Answers
Module 1 Quiz	1. C 2. C 3. D 4. B 5. A
Module 2 Quiz	1. D 2. D 3. A 4. A 5. D
Module 3 Quiz	1. D 2. B 3. B 4. D 5. B
Module 4 Quiz	1. C 2. B 3. B 4. D 5. A
Module 5 Quiz	1. A 2. A 3. A 4. D 5. C
Module 6 Quiz	1. B 2. C 3. A 4. B 5. A
Module 7 Quiz	1. B 2. D 3. B 4. B 5. C
Module 8 Quiz	1. C 2. A 3. D 4. A 5. D
Module 9 Quiz	1. C 2. C 3. A 4. C 5. C