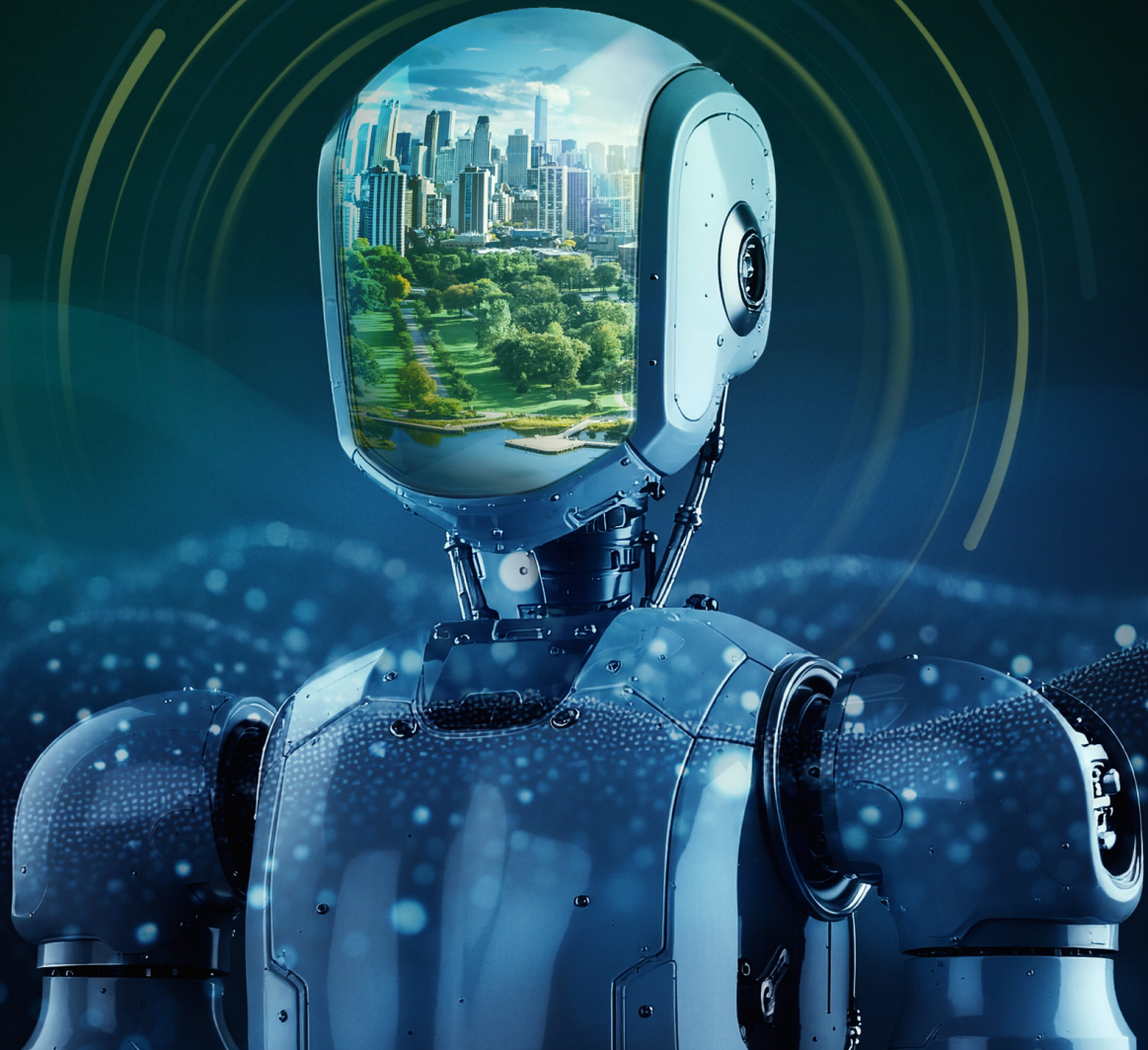


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Robotics & Physical AI

Intelligence in motion



How robotics and physical AI are reshaping industries and society

In a gleaming factory in the Pacific Northwest, something remarkable is happening. Agility Robotics' RoboFab facility—the world's first factory dedicated to mass-producing humanoid robots—is churning out up to 10,000 Digit robots annually.¹ Like oversized action figures brought to life, these bipedal machines stand nearly six feet tall and navigate warehouse floors with human-like dexterity, lifting packages and collaborating seamlessly with human workers.

And then there are quadrupeds, the unsettling but oddly appealing robotic systems that mimic the movement of four-legged animals. Boston Dynamics' Spot quadruped has been deployed across multiple industries, from manufacturing facilities and police departments to offshore oil rigs and construction sites.²

If humanoids and quadrupeds are the brightest stars in the physical AI firmament, then autonomous mobile robots (AMRs), autonomous vehicles, and drones are the everyday workhorses, the behind-the-scenes members of industry and operations.

These systems have quietly achieved remarkable commercial scale, transforming logistics, transportation, delivery operations, and numerous other segments worldwide.

We're witnessing the emergence of what industry leaders call physical AI—intelligent machines that can perceive, reason, and act in the physical world with unprecedented sophistication. Formerly a realm of science fiction, physical AI is becoming a reality, signaling a profound shift in how the world thinks about work, productivity, and the future of human-machine collaboration. As humanity stands

at this inflection point, the question is no longer whether physical AI will transform the economy and society, but rather, how quickly and in what ways that transformation will unfold.

This report aims to explore how the rise of robotics and physical AI is reshaping industries and society, understanding the technological, economic, and labor market forces driving this sea change and the profound implications for the future of human-machine collaboration. To help business leaders fully grasp and strategically respond to this upheaval, we present our **Physical AI 6Ps Framework**, a broad lens for understanding the multifaceted impacts and opportunities across the industry from planning and preparation to post-robot deployment.



Driving forces behind the physical AI surge

The current physical AI revolution stems from a perfect storm of three factors: technological advancements, affordability, and labor market pressures. The integration of various forms of AI (e.g., computer vision, sensor fusion, motion planning, large language models (LLMs)) into robotics systems has been profound, enabling robots to understand natural language commands and adapt to new tasks without extensive reprogramming.³ Computer vision accuracy has also substantially improved,⁴ and advanced simulation environments and the high-quality synthetic data that such simulations generate can dramatically enhance robot performance and accelerate training.⁵

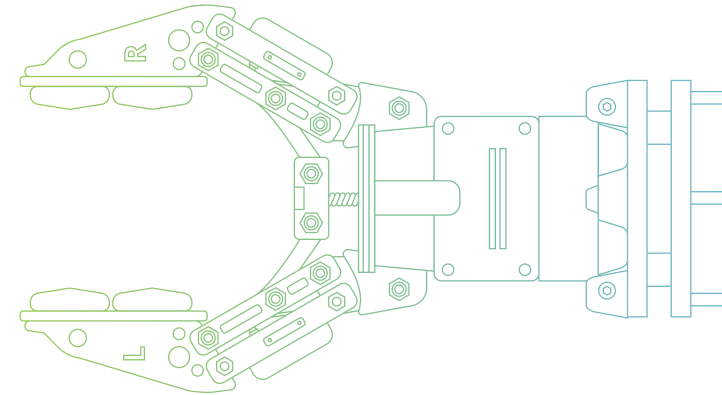
Equally important, the increased affordability of robots and their hardware components makes robotics applications more economically viable. For example, the manufacturing cost of humanoid robots dropped 40% between 2023 and 2024, primarily due to cheaper sensors, actuators, processors, and other components; more supply chain options; and improved production techniques.⁶ As a result, consumers can purchase their own Unitree R1 humanoid robot for US \$5,900, a price point that moves us closer to mass consumer

adoption and humanoids in the home. Finally, labor market pressures have created unprecedented demand for robotics and automation solutions. According to the Conference Board and other leading experts, the labor demand exceeds supply, and this gap is only growing.⁷ The US economy alone needs 4.6 million additional workers per year to maintain current supply and demand levels.

The manufacturing sector faces a particular set of challenges, including difficulties in worker attraction and retention, especially in advanced roles; technology advancements that have led to a gap between needed and existing workforce skills; an aging population and immigration shifts, which have impacted the traditional manufacturing labor pool.⁸

The numbers also tell a compelling story of market readiness. The global robotics industry has experienced significant growth, with the market for both traditional and AI-enabled robots in both industrial and service applications projected to top US \$392 billion by 2033.⁹ Globally, the total addressable market for humanoids is expected to reach US \$38 billion by 2035.¹⁰

Investment patterns reflect growing confidence in the sector's commercial potential. In 2024, robotics startups raised over US \$7 billion in seed-stage through growth-stage investments.¹¹ The investment focus has shifted dramatically toward AI-powered robotics,¹² reflecting a broader transformation toward physical AI systems that can adapt and learn.



A primer on robotics and physical AI

Robots have existed for years, unlocking capabilities for enterprises in industries like manufacturing and warehousing. These robots work alongside humans to accomplish tasks more effectively and open up new possibilities. However, this early generation of robots have fixed, pre-planned routes, and are unable to adapt when their environment changes or unexpected events occur. Enter physical AI.

Comprising several technologies, physical AI enables machines to perceive their surroundings, process information in real time, make intelligent decisions beyond pre-planned routes, and act to achieve goals rather than merely complete tasks.

A counterpart to generative AI, physical AI refers to intelligent systems that enable machines to autonomously interact with, interpret, and make decisions within physical environments, often in real time and with real-world feedback loops. When physical AI is combined with the mechanical capabilities used to manipulate physical environments—robotics—the result is intelligent machines, capable of physical automation and autonomy guided by human supervision.

The core distinction between physical AI systems and conventional robots lies in the intelligence architecture. Traditional machines—such as pick-and-place robots, automated guided vehicles (AGVs), and SCADA systems—execute rule-based automation via pre-programmed, human-written instructions. On the other hand, many physical AI systems are trained on neural networks known as vision-language-action (VLA) models that process visual input, understand language commands, and output physical actions.¹³

Through reinforcement learning in simulated environments, robots, drones, self-driving cars, and other machines can comprehend spatial relationships, physical dynamics like gravity and friction, and geometric principles. They can develop sophisticated motor skills and adapt to new situations. They can perceive, reason, and act; in other words, they can interact meaningfully with the world around them.¹⁴

DEFINING ROBOTICS AND PHYSICAL AI

ROBOTICS

Mechanical capabilities used to manipulate physical environments



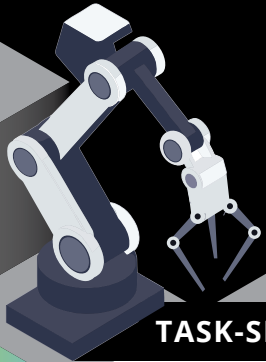
PHYSICAL AI

Intelligent systems that enable machines to autonomously interact with, interpret, and make decisions within physical environments, often in real time and with real-world feedback loops



Intelligent machines capable of physical automation and full autonomy

6 KEY FORM FACTORS OF ROBOTICS AND PHYSICAL AI

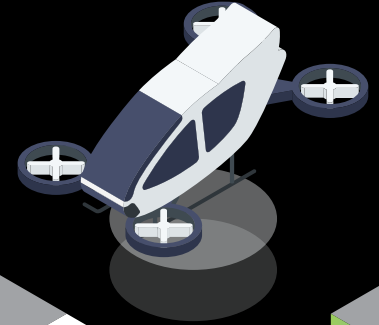


TASK-SPECIFIC

Robots designed for a specific purpose that accomplish a given task more effectively or efficiently than a human would

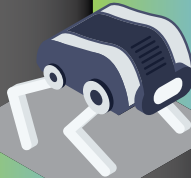
HUMANOIDS

Robots designed to look and function like humans, able to complement or supplement human tasks



DRONES

Aerial robots able to observe, decide, and act autonomously for delivery, observation, and security



QUADRUPEDS

Four-legged robots designed to complete tasks that do not require or cannot be completed with the humanoid form factor

AUTONOMOUS VEHICLES

Self-driving vehicles able to transport people and goods on the road



Autonomous mobile robots designed for general-purpose navigation, observation, handling, and delivery

AMRS



*Other form factors include soft robots, exoskeletons, nanobots, underwater robots, swarm robots, and more

The Physical AI 6Ps Framework: A broad approach to a complex market

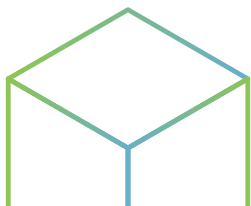
The convergence of robotics and physical AI creates unprecedented opportunities and risks, enabling novel use cases and business models along the way. A multifaceted market comprising multiple technologies, form factors, and services is on the verge of tremendous global expansion. Yet this rapid growth masks underlying complexity, and organizations that treat robotics deployment as merely another technology implementation risk significant operational disruption.

We recommend that organizations navigating this landscape adopt a broad view of the industry instead of focusing narrowly on individual technologies, form factors, or other singular components in isolation. Without adequately addressing these considerations in a broad, cohesive manner, organizations could fail to capture the transformational value that physical AI promises to deliver. The 6Ps Framework was designed to

provide business and technology leaders with a systematic approach to understand and harness the market-shifting potential of robotics and physical AI, while managing the inherent complexity and uncertainty that defines this rapidly evolving market.

The Physical AI 6Ps Framework (see next page) for understanding the robotics and physical AI market revolves around six key market capabilities, some led by people, others by machines, and still others co-led by both people and machines.

As you read and digest the rest of this report, the Physical AI 6Ps Framework can serve as a touchstone. Refer back to it to understand how the robotics and physical AI puzzle pieces fit together to form an integrated whole.



PREPARE

Prior to any significant robotics and physical AI deployment, organizations must address the business and human capital implications of robots in the workplace, make decisions on material selection, data architecture, spatial computing, and cybersecurity. For some organizations, establishing a dedicated physical plant to manufacture, assemble, and test these robots is also a necessary step.

PERCEIVE

A series of technologies working together to allow robotic systems to ingest environmental data, including visual, auditory, and tactile.

PROCESS

The ability of machines to make sense of the perceived data, turning data into decisions in real time.

PERFORM

The technologies, form factors, and components in this category comprise the physical configurations that interact with their environments.

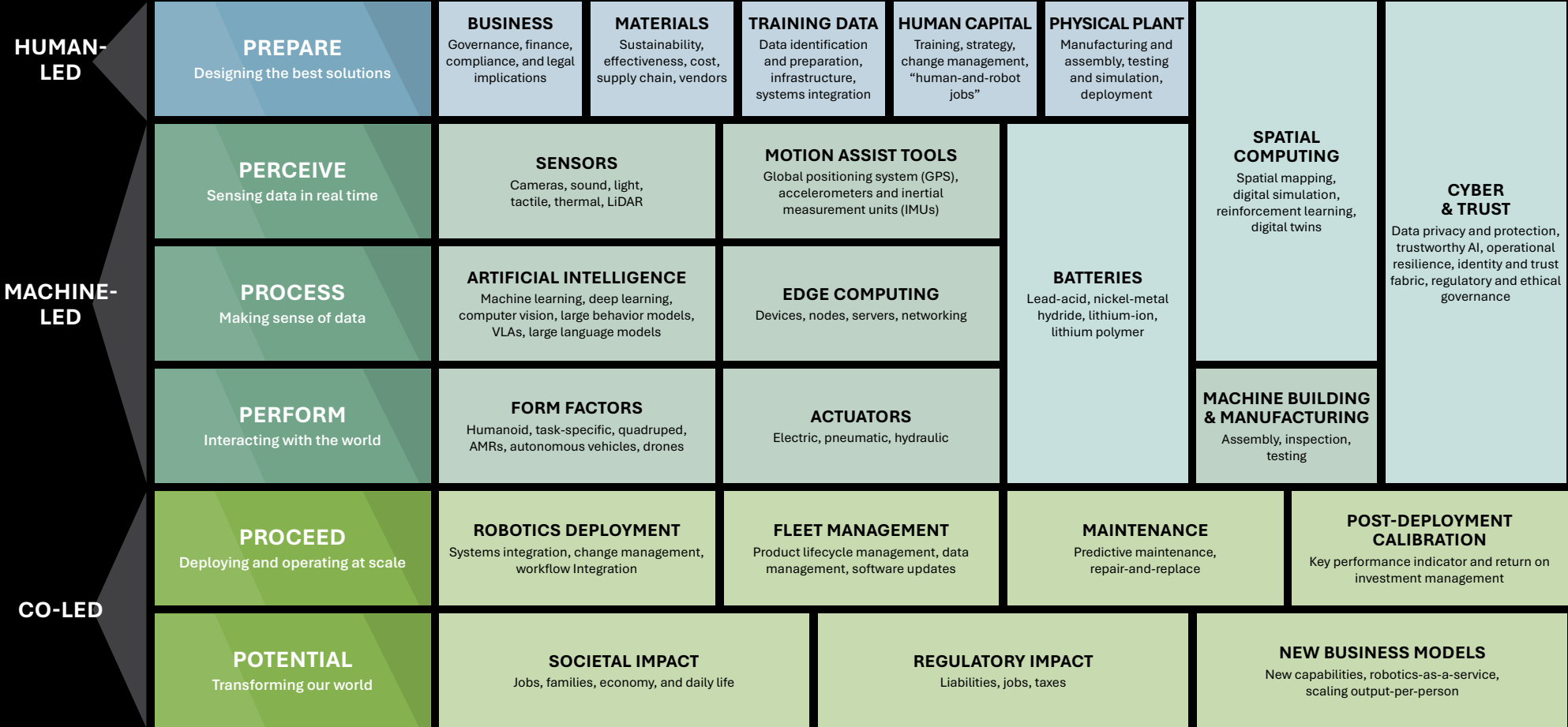
PROCEED

Services related to deployment, management, maintenance, and success measurement of robotic systems will enable them to operate effectively at scale.

POTENTIAL

Intelligent, autonomous physical systems have the potential to reshape various parts of society, including the workplace, the home, the normal operations of entire cities, and even the global economy. New regulations and business models will need to accompany this new technology.

PHYSICAL AI 6Ps FRAMEWORK



An introduction to the 6 functions of robotics and physical AI

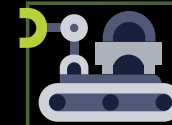
Several functions and use cases have emerged as industries experiment with integrating robotics and physical AI. Let's explore them in more detail.

CREATE

Here, robotics and physical AI are used to manufacture, build, and construct physical goods across diverse industries. The manufacturing and construction sectors represent a significant opportunity, as collaborative robots automate repetitive tasks to produce goods more efficiently, quickly, and cost-effectively, and to help address labor shortages. One example of labor augmentation in the construction industry is a company called Built Robotics, which boasts an autonomous bulldozer as its featured product. Without the need for a bulldozer operator, construction sites can automate the process of moving dirt and rubble while humans are brought into more strategic or challenging tasks on the project site. This is just one example of how physical AI can enable better outcomes in construction.¹⁵

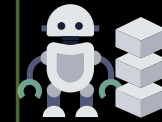
In the construction industry, machines automate building tasks to enhance safety, reduce timelines and costs, and improve precision. Construction is a dangerous job, and taking humans out of harm's way in favor of risking robot health is a significant and positive tradeoff. Construction startup Automated Architecture offers a "robotic micro-factory" that is delivered to building sites, complete with wood-frame panels for floors, walls, and roofs, which are assembled onsite by an included robot that has vision capabilities and can handle nailing, lifting, and customizing the wood panels. The company says its robots are five times faster than humans and trim labor costs by 30% and supply chain, logistics, and transport costs by 80%.¹⁶

6 FUNCTIONS OF ROBOTICS AND PHYSICAL AI



CREATE

The use of robotics in the manufacturing, building, or constructing of physical goods



HANDLE

The use of robotics to interact with the world through manipulating objects, sorting, gathering, cleaning, or using tools



TRANSPORT

The use of robotics to move and deliver people or goods



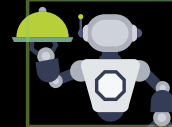
OBSERVE

The use of robotics to observe, survey, or view an area



PROTECT

The use of robotics for physical protection or prevention of dangerous situations



INTERACT

The use of robotics to supplement human interaction

HANDLE

AI-enabled robots can interact with the physical world by manipulating objects, sorting, gathering, cleaning, and performing precise manual tasks that traditionally require human dexterity.

In the healthcare sector, robotic tools have been a mainstay in operating rooms for over two decades, but they're typically controlled by a surgeon sitting behind a console. Integrating physical AI into these tools is set to transform the field. In 2024, researchers used surgical videos combined with machine learning and imitation learning to train a surgical robot to perform three basic procedures as skillfully as human surgeons.¹⁷ Even more recently, they trained another surgical robot to remove a gallbladder, and these tools are actively being used in surgeries around the world today.¹⁸ As a result, robotic surgeries enabled by proper human-machine collaboration are leading to better patient outcomes and increased trust in medical organizations.

In smart warehousing operations, automated systems and pick-and-place robots can streamline inventory management by cutting costs, boosting accuracy, and accelerating fulfillment processes. Humanoid robots can move totes between

warehouse shelves, and cleaning robots can help maintain facilities. For example, Manhattan Associates, a supply chain solutions provider, has partnered with numerous vendors to integrate autonomous storage and retrieval systems (ASRS), AMRs, and even humanoid robot fleets with its warehouse management solution (WMS).¹⁹

TRANSPORT

Robotics systems excel at moving and delivering people or goods efficiently across various environments, from autonomous vehicles providing rides to airports, to drones delivering food from restaurants to suburban homes.

Transportation is one of the most visible and rapidly developing use cases of robotics deployment. As just one highlighted example, Waymo recorded its 10 millionth paid ride in May 2025.²⁰ In an adjacent industry, Aurora Innovation recently became the first company to operate a commercial self-driving service with heavy-duty trucks on public roads, making regular deliveries between Dallas and Houston. Meanwhile, Amazon Prime Air is taking to the skies, bringing little brown boxes to a front stoop near you via the air in short order. Walmart is also gearing up to provide drone delivery service at scale,²¹ and several companies are ramping up food delivery services using robots and drones on

city streets and airspaces.²² These autonomous transportation solutions, whether transporting people or goods, are becoming normal at an incredible rate. The first time you see a driverless car can be jarring, but before long, the novelty wears off, and life moves forward.

OBSERVE

When combined with sensor networks, drones and other robotic platforms can analyze data, enable decisions, and detect anomalies in challenging environments, transforming how organizations monitor operations, conduct surveillance, and gather real-time intelligence.

AI-enabled drones outfitted with advanced cameras and sensor systems can be deployed to inspect bridge structures and road surfaces, saving time and money and minimizing the use of human inspectors in dangerous situations.²³ Unlike prior generations of camera-loaded drones, these physical AI-enabled drones can process visual input, determine their next flight path, and act in real time in response to dynamic environments and unpredictable conditions. Add barcode and QR code scanners, and they can be used to conduct inventory management in warehouses.²⁴ In data centers, autonomous robots can augment human employees by handling repetitive observational

tasks, such as tracking temperature, monitoring equipment, and inspecting facilities.²⁵ As another example, the US Department of the Interior has long used drones to monitor wildfire spreads, and with advances in physical AI, these drones may become stocked with fire retardant and be given permissions to deploy the retardant at will based on real-time processing of fire spreads.

PROTECT

Protection-focused robotics applications involve securing public areas from potential threats while providing physical protection and security services. These applications can help address growing security concerns and the need for consistent, reliable protection services that can operate continuously without human limitations.

Knightscope's K5 robot is an AMR that roams business grounds, campuses, and public spaces to observe and report dangerous activity and take action to thwart it.²⁶ This fully autonomous patrol robot with remote monitoring and control potential gives a physical presence beyond a security camera to dissuade bad actors.

The market opportunity spans both public safety and private security sectors, where robots can

provide emergency response and monitor critical infrastructure. This encompasses everything from drones patrolling perimeters to AMRs or humanoid robots serving as building security and emergency response systems.

INTERACT

Robots can supplement the soft skills of human interaction in customer service, elder care support, and educational assistance applications.

For example, Florida's Putnam County School District is introducing to its students an interactive, child-sized humanoid robot with a friendly and engaging face and eyes. It's equipped with cameras, a touchscreen, and advanced AI capabilities, and can interact naturally with students via conversation and emotional recognition.²⁷

Robots may become mainstays in elder care facilities. By providing mobility support, personal care, medication management, and companionship, robots can complement human caregivers, increasing efficacy and delivering greater engagement and time under care for residents.



Factors affecting adoption and integration

Despite the unprecedented opportunities it presents, widespread adoption of robotics and physical AI—and integration into current enterprise workflows—is not a foregone conclusion. Commercial viability will depend on the impact of various critical factors: workforce readiness and development, technology readiness and maturity, workplace and public safety, regulatory gaps, cybersecurity vulnerabilities, and more.

WORKFORCE READINESS AND DEVELOPMENT

Without a clear labor plan, the advances of robotics and physical AI will likely stimulate questions about work and labor unions. Unlike generative AI, which augments cognitive tasks, physical AI stands to replace certain elements of manual labor. While the [Deloitte Workforce Analyzer tool](#) shows there is no role that is set to be fully replaced by a robot, organizations would need to consider redesigning roles that take into account the future of human-robot collaboration.

The impact will be most pronounced in roles with repetitive physical tasks, and having a plan in place

ahead of time may lighten the challenging questions and conversations post-deployment. Some sources estimate that tens of millions of jobs in the US could be augmented by AI-enabled robots over the next decade, but new jobs will also be created, often requiring higher-level skills. Net job creation projections are optimistic, but the transition may be challenging for workers.²⁸ Physical AI will drive changes that would rapidly affect workforce planning decisions, increasing the need for workforce development, upskilling, and adaptability to manage this transition, ease worker concerns, and maintain economic resilience.

However, the mass deployment of robots is unlikely to displace huge swaths of the workforce. Rather, an incremental percentage of tasks delegated to robots will likely be overseen by humans. Similar to how many of today's jobs are only possible with “human-and-computer” collaboration, tomorrow's jobs may be “human-and-robot,” rather than “human-only.”

TECHNOLOGY READINESS AND MATURITY

In a recent Deloitte survey of executives from large manufacturing companies, respondents' average (self-assessed) technology maturity reflects that they are meeting industry standards for technology,

data, and automation, but not exceeding them—and thus not achieving their aspirations for technology readiness.²⁹

Companies with a bias toward innovation are typically more likely to prioritize immediate technology investments and technology transformation to attract top talent now and in the future. Organizations that wait to invest in tech innovation may find themselves lagging in accessing top talent pools and achieving their desired tech readiness.

WORKPLACE AND PUBLIC SAFETY

Unlike software-based AI systems that operate within digital environments, physical safety remains a critical concern in human-robot collaboration.

When robots interact with the real world, they create liability questions if they cause harm, property damage, or workplace injuries. A successful safety strategy might combine multiple approaches, including regulatory and standards body compliance, mandatory risk assessments, continuous monitoring, training, organizational policies, physical safeguards, advanced technology, comprehensive training, and a strong safety culture.³⁰

Unlike workplace environments where safety protocols can be enforced through training and controlled access, public spaces necessitate autonomous systems to navigate unpredictable human behavior, infrastructure variations, and emergency scenarios without putting untrained civilians at risk. The success of drones, autonomous vehicles, and other AI-enabled machines operating in public spaces will depend on fail-safe designs that prioritize human safety over operational efficiency and new frameworks for protecting civilian populations.

REGULATORY GAPS

Historically, the pace of technological advancement and the pace of regulatory changes are not always perfectly in sync. Furthermore, not every jurisdiction regulates technologies the same way. Autonomous robots, drones, vehicles, and other AI-enabled robotic systems currently operate in a fragmented regulated landscape, where traditional regulations and laws designed for predictable machines partially apply to these autonomous machines, and partially they can

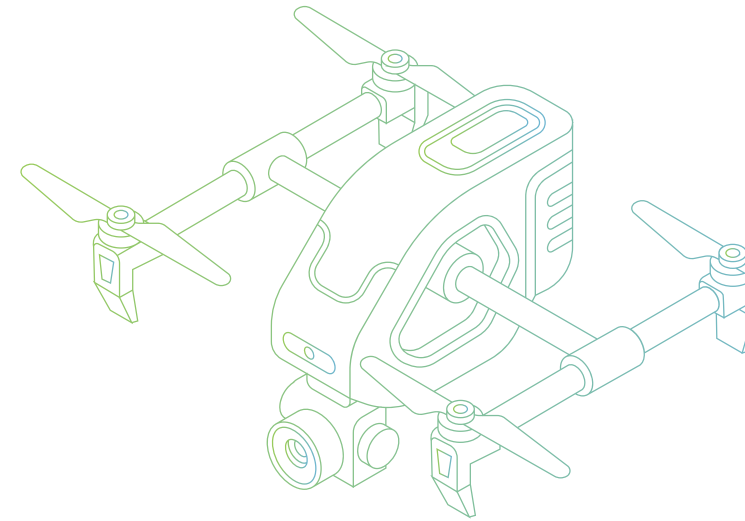
fall into a regulatory gray area. Additionally, since these autonomous machines can move from one jurisdiction to another, any regulatory inconsistency from region to region can cause conflicting standards of operation.

As a result, companies may need to navigate an evolving compliance environment while innovative technologies deploy faster than frameworks can be developed. Such regulatory uncertainty can impact innovation and introduce potential safety considerations.

CYBERSECURITY VULNERABILITIES

As robotics systems become increasingly connected, the manufacturing and industrial sectors face escalating cybersecurity threats. Because these new systems generate and consume data, organizations need to be vigilant in their cybersecurity assessments and preparation. The stakes are particularly high: One study found that 80% of manufacturing firms experienced security incidents in 2024, and only 45% are adequately prepared in their cybersecurity measures.³¹

Traditional IT security frameworks are insufficient for robots that bridge digital and physical domains. Organizations in this space will likely need real-time, contextual visibility into emerging threats and tools and techniques specifically designed for cyber-physical systems.³²



Conclusion

As we have seen, robotics and physical AI present both unprecedented opportunities and unique challenges. While enabling innovative use cases and business models, rapid growth has the potential for social, economic, and cultural upheaval and is subject to a number of technical, government, legal, and safety concerns, the outcomes of which are unknown.

Technology can be defined as new tools to augment human work and make humans more effective while unlocking new possibilities. While robotics and physical AI have had more aid from science fiction than most, the premise is unchanged: technology offers humans tools to be more effective, and this time is no different.

Navigating this uncertain future will demand more than technological prowess—it will require a nuanced understanding of the converging social, regulatory, political, and cybersecurity

dynamics at play. Without addressing technical and organizational readiness, workforce implications, regulatory frameworks, economic viability, and ethical considerations—among many others—organizations could fail to capture the transformational value that physical AI promises to deliver.

The road ahead will not be defined solely by innovations in hardware and software but by organizations' willingness to anticipate and adapt to the complex interplay of risks and opportunities. Cultivating robust governance structures, fostering cross-disciplinary collaboration, and investing in broad education and training will be essential for building resilient and trustworthy systems. A proactive approach, grounded by the **Physical AI 6Ps Framework**, can help organizations capture the vast promise of robotics and physical AI, shaping a future where technology and humanity move forward together.



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