HUAWEI

Intelligent World 2035

Building a Fully Connected,
Intelligent World

Foreword

Joseph Sifakis

The meteoric rise of AI since the beginning of this century marks a new era in the revolution of science and technology, and a turning point in the history of humanity, where the production and application of knowledge are no longer the privilege of man. However, despite the impressive achievements, which culminated with the arrival of generative AI, a lucid analysis of the situation leads us to conclude that AI is still in its infancy. AI is currently focused on assistants which operate in question/answer mode. Moreover, these systems are considered black box, and their properties cannot be rigorously understood and guaranteed to the same level as the properties of traditional ICT systems. AI only gives us building blocks, and the question that remains open is how to compose them to create intelligent systems achieving human level intelligence. It should be noted that AI applications in industry and services have enormous potential that remains largely untapped.

"Intelligent World 2035" presents a timely vision of the future of AI, focusing on industrial and service intelligent systems, with insights into how technological convergence is driving their transformation. These include various industrial systems, as foreseen by the Internet of Things, for example autonomous transport systems, smart grids, intelligent factories and farms, autonomous communication networks. In addition, this document presents a detailed and holistic analysis of the impact of AI integration in various services covering healthcare, education, smart homes, smart cities, and business innovation. While emphasizing the central role of AI, the analysis takes into account synergies with other innovative technologies while remaining attentive to the social and economic impact of anticipated transformations. For example, educational applications will leverage large AI models and cloud computing technologies, as well as dynamic analysis of student knowledge acquisition, to help teachers generate differentiated lesson plans in real time, ensuring that every student can benefit from personalized learning. Healthcare will no longer be limited to treating diseases and saving lives, but will be fully integrated into a global health ecosystem driven by cutting-edge technologies such as artificial intelligence, digital behavior modeling, telemedicine, and synthetic biology.

This document is a veritable treasure trove of ideas on how the convergence of AI and ICT will transform society, presented without exaggeration, and with a strong emphasis on social and individual well-being.

Realizing the presented vision poses a number of technical challenges that go beyond the scope of AGI. The ambition is not only to create a "machine capable of understanding or learning any intellectual task within the reach of human beings," but also to enable it to act autonomously by combining its capabilities, being able to become aware of real situations, and pursuing its goals in an adaptive and reliable manner.

The construction of intelligent systems is disrupting traditional systems engineering. It requires combining traditional ICT model-based development with data-driven AI techniques. This can be achieved through hybrid solutions that draw on a solid body of existing knowledge for safe and effective decision-making and circumvent non explainability of AI systems. Building reliable intelligent systems integrating untrusted AI components leads to hybrid solutions that should be scalable, and evolvable. These require in particular linking symbolic and non-symbolic knowledge, such as sensory information and models used for decision-making. Their development must seek a compromise between correctness at design time and resilience at runtime. With no end point. Systems should be able to evolve through regular or exceptional updates.

In addition, system validation is currently marked by a shift from rationalism to empiricism, as traditional model-based techniques that guaranteed high reliability are no longer applicable due to the inherent complexity and heterogeneity of systems. We need to design new rigorous validation techniques based on testing and simulation that go well beyond current random testing. Finally, lower reliability guarantees must be compensated for by the use of knowledge-based monitoring techniques.

The vision presented is broad and ambitious, very different from that of the Big Tech companies, which entirely relies on machine learning and push for gigantism, requiring huge investments in energy-intensive infrastructure. Its achievement will require unprecedented technological breakthroughs and certainly a global effort. In particular, it could create synergy and mobilize a critical mass among the sectors concerned in order to develop specific infrastructures and data platforms that will contribute to the development of trustworthy industrial AI. Such a synergy is important for the collection and cleaning of data by application domain. In fact, building powerful AI for industrial applications is fundamentally different from training a general-purpose LLM on web data. The web has data on almost every common topic. In industry, the most critical events are often rare failures or anomalies. You might have 10 years of data on "normal operation" but only few examples of specific, catastrophic failures. An industrial AI model needs to learn from these rare events, which are incredibly scarce.

As demonstrated by history, open ecosystems and international cooperation are fundamental accelerants for technological progress, especially in a field as complex and transformative as AI. Openness of tools and platforms would greatly contribute to breakthroughs in system interoperability and integration.

Leveraging international collaboration, is also essential to reach agreement on a regulatory framework to control the risks associated with AI products. Open opposition to strict regulation on the grounds that it hinders innovation, actually compromises the future by prioritizing immediate gains at the expense of long-term damage.In the long run, the absence of such regulatory framework will be a major obstacle to the use of AI in critical decision-making processes, which are most industrial processes.

It should be emphasized that safe AI is a global concern that has been the subject of activities organized by the United Nations, as well as a series of global summits.

In this context, it is important to develop a more reliable AI that is better adapted to the needs of the real economy, particularly to achieve the long-awaited transition to autonomous systems. This would allow balancing the strategic game of AI, and join forces with like-minded partners to regulate AI in a way that reconciles the imperatives of development and safety in the interest of society.

Turing Award 2007

Dai Qionghai

What does a decade mean to us? Twenty years ago, there was no clear trajectory for artificial intelligence (AI). Ten years ago, we were only just starting to see the emergence of deep learning, convolutional neural networks in particular. People were just starting to imagine the opportunities AI could create. Today, AI and large language models are impacting almost every aspect of our lives. Ten years from now, what will the intelligent world look like? How will AI evolve? How different will it have made our work and life?

The journey toward artificial general intelligence (AGI) may not be a straightforward one. We may have multiple technological "singularity" moments with sudden breakthroughs, much like how we saw rapid changes during the last decade after making breakthroughs in convolutional neural networks and large language models. So, many are trying to predict what these singularity moments will define in the next decade.

Huawei's *Intelligent World 2035* report states that the key to achieving AGI is going physical. This will present us three massive opportunities:

First, we will be able to better perceive the world. The widespread use of portable filming devices like smartphones has generated a wealth of electronic images, laying the groundwork for ImageNet and convolutional neural networks. Electron microscopes have provided high-precision analysis of protein structures, offering critical data for AlphaFold. And enhanced perception will unlock the ability to get a broader view of the world, reveal finer details, and capture more complex relationships. This will allow AI to better learn from, transform, and interact with the world. Therefore, next-generation sensors that integrate macro and micro perspectives and feature high dynamic range and multimodal capacity may represent the next technological singularity.

Second, there will be more intelligent models and algorithms. But what will AGI models and algorithms look like? Opinions vary widely, but what most people do agree on is that real-world intelligence, such as human intelligence, is both a goal and a source of inspiration. If we can develop deep insights into the processes of intelligence and comprehensively analyze its mechanisms, we are bound to see breakthroughs in AI models and algorithms, making them as efficient, trustworthy, flexible, and comprehensive as human intelligence. Therefore, learning from human brains, the most complex intelligent system in the physical world, may also lead to a crucial technological singularity in the future.

Third, we will have more efficient computing chips. Computing power determines how far intelligence can go. Current AI advances have been driven by continuous growth in computing power. But how can a linear increase in computing power lead to a substantial leap in the level of intelligence? This question seems impossible to answer, unless we find ways to drive a revolutionary leap in computing power. To achieve this, we may need computing chips several orders of magnitude more efficient than what we have today. New technologies like optical computing, quantum computing, and compute in-memory, will continue to evolve, like how communications media has evolved from copper cables to optical fiber. These new technologies have the potential to transform the underlying infrastructure of intelligence. Thus, new types of chips that could bring about a revolutionary increase in computing power might be a key singularity for AI.

Of course, the journey towards AGI is still long, and we need to work nonstop to find the right path forward. Huawei's *Intelligent World 2035* report provides broad perspectives and profound insights into this topic, systematically outlining viable pathways for AI and what the intelligent world will look like over the next decade. The ten technological trends highlighted in the report offer a clear vision of a future defined by synergy between multiple technologies. The report opens a window to the future, and encourages us to explore, create, and regulate the paths to AGI in an open, collaborative, and responsible way. I look forward to seeing how we can build a better future empowered by human-AI symbiosis.

戴琼海

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Zheng Zhiming

Intelligent World 2035 presents a comprehensive blueprint for the evolution of intelligent technologies and reshaping of social patterns over the next decade. It provides both broad vision and rigorous analysis. Several reflections stand out to me from this report, given my own understanding of the intrinsic logic of complex systems and the evolution of intelligence.

At its core, intelligence is not just about recognizing and summarizing data patterns. It's more about understanding, interacting with, and reshaping the physical world. This perspective is important, given humanity's extensive knowledge and wisdom about the physical world. This report recognizes this principle, noting that going physical is the essential path to artificial general intelligence (AGI).

Although today's model-based AI systems have made remarkable progress in perception and generation, they remain constrained by frameworks rooted in multiple linear statistical associations. As a result, these models are still widely regarded as insufficient for in-depth abstraction or reasoning related to complex physical phenomena and causal relationships. Real breakthroughs will require a new architecture transcending existing paradigms that integrates data space with the physical world.

Such a new architecture will need to embed mathematical principles and knowledge into data space, enabling precise and comprehensive understanding of complex data systems. This pursuit, often referred to as precision intelligence or SCI for AI, relies on the self-organization and self-adaptation of complex systems that steadily approximate the truth. Defining these mathematical foundations and implementation pathways will be among the greatest scientific challenges of the next decade.

The ten technological trends outlined in this report should be understood not as isolated advancements, but as interconnected components of a complex, interdependent, and co-evolving ecosystem. From new computing paradigms beyond von Neumann, to new data storage frameworks where data is intelligence, and the emerging network paradigm called the agentic Internet, these trends share a common goal. They are all intended to enable AI agents to perform large-scale, real-time, and reliable decision making in a "mirror world" where physical and digital realms converge. As these agents evolve from execution tools into decision-making partners, AI itself is transitioning from an information-processing utility to a cognitive entity capable of proactive planning, collaboration, and environmental interaction. This represents not only a technological upgrade, but also a paradigm shift in productivity and production relationships.

The true value of the intelligent revolution lies in its ability to empower and reshape industries. Beyond cataloguing technological progress, *Intelligent World 2035* explores how AI agents will become the foundation of new productive forces, driving paradigm shifts in healthcare, education, manufacturing, finance, energy, and more. From AI-assisted medical diagnosis to design-as-manufacturing, from ultra-personalized financial services to smart energy networks, the trend we see emerging in all sectors is not merely "+AI" enhancement, but a profound AI-native transformation.

This transformation requires AI agents that deeply understand industry mechanisms and are able to integrate massive data, domain expertise, and physical models as well as build industry-level "brains" and "nervous systems" capable of perception, analysis, decision making, and action. These capabilities can greatly enhance efficiency, resilience, and innovation across all industries. Yet, such empowerment also presents complex, systemic challenges. Navigating the unique complexities of each industry will require close collaboration between technologists and domain experts.

Another important emerging trend outlined in the report is the rise of tokenized energy networks – the idea of making intelligence the nervous system of energy networks. This represents both a constraint and an enabler for the intelligent world. The proliferation of AI agents and their substantial computing demands hinge on sustainable energy systems. Embedding intelligence into energy network management and scheduling can help create a responsive, efficient, and self-adaptive energy Internet similar to the human nervous system. Such a system can serve as the physical foundation for a sustainable intelligent world. And this further highlights the need for deep integration and collaboration across multiple layers (energy, computing, and intelligence) in system thinking.

The journey towards an intelligent 2035 will not be a linear accumulation of technologies. Rather, it will be a complex systems-engineering endeavor, rife with uncertainty. Progress will require breakthroughs in algorithms, computing, and data, as well as forward-looking planning and exploration in foundational theories, system architectures, and legal and ethical frameworks. For China's science and technology community to be part of this future, original innovation and fundamental technologies should be prioritized so that an open, collaborative, and inclusive ecosystem for technological development can be built.

Intelligent World 2035 provides valuable insights as a starting point for intellectual exchange and strategic foresight. It calls on us to approach the future systematically and dialectically, and to shape a new era of intelligence grounded in people-centered values, human-AI symbiosis, and green, sustainable development.

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Yike Guo

The dawn of the Intelligent World 2035 marks a pivotal moment in human history, where digital cognition and physical reality fuse to create a seamless, embodied intelligence that reshapes every facet of our planet. As Provost of the Hong Kong University of Science and Technology, I am honored to share a vision that draws upon the profound technological currents outlined in Huawei's "Intelligent World 2035" and the collective aspirations of academia, industry, and society.

At the heart of this transformation lies the convergence of the five foundational pillars—network, computing, storage, cloud, and energy—into an integrated substrate capable of supporting super-intelligent agents. By 2035, the network will have expanded to accommodate an estimated 900 billion intelligent agents for 9 billion people, demanding a hundred-fold increase in communication capacity. Simultaneously, computing power will surge by a factor of 100,000, ushering in novel paradigms such as neuromorphic and quantum processors that emulate the brain's efficiency. Storage will enter the yottabyte era, allowing the "awakening" of data to become a tangible resource for continuous learning. Cloud-edge symbiosis will democratize AI, while breakthroughs in energy—particularly high-density batteries and sustainable generation—will dissolve the last barriers between cognition and embodiment. This infrastructural symphony will empower embodied intelligence, enabling physical entities—from manufacturing robots to household assistants—to act with autonomy, adaptability, and purpose.

The ramifications for our planet are both profound and hopeful. Intelligent agents, guided by ethical frameworks and powered by clean energy, will optimize resource allocation across agriculture, logistics, and energy grids, dramatically reducing waste and carbon emissions. Precision agriculture, driven by AI-enhanced sensors and autonomous drones, will increase yields while preserving biodiversity. Smart grids, orchestrated by real-time analytics, will balance renewable generation with demand, ushering in an era of zero-carbon urban ecosystems. Moreover, AI-guided climate modeling will provide unprecedented predictive power, allowing policymakers to enact preemptive measures against extreme weather events and sea-level rise—an essential safeguard for vulnerable coastal regions such as Hong Kong.

Human production will undergo a scenario leapfrog that redefines the nature of work and creativity. In manufacturing, embodied intelligence will create self-optimizing factories where machines not only execute tasks but also redesign processes on the fly, fostering a continuous cycle of innovation. Financial services will be augmented by intelligent agents that perform risk assessment, fraud detection, and personalized advisory with near-human intuition, liberating professionals to focus on strategic decision-making. In research, AGI—once the singularity is crossed—will serve as a collaborative partner, hypothesizing, experimenting, and interpreting data at scales unimaginable today. This partnership will accelerate breakthroughs in medicine, material science, and quantum technologies, propelling humanity toward solutions for diseases, climate resilience, and sustainable materials.

Our daily lives will be equally transformed. Intelligent agents will become trusted companions, anticipating health needs through continuous monitoring and delivering personalized therapeutic interventions before symptoms manifest. Education will shift to adaptive, immersive platforms that tailor curricula to each learner's pace and curiosity, fostering lifelong learning in a hyper-connected world. Homes will evolve into holographic living spaces, where virtual and physical realms blend to create environments that respond to mood, health, and productivity. Transportation will be orchestrated by AI-driven networks, delivering safe, efficient, and carbon-neutral mobility that reshapes how we experience distance and time.

Yet, the promise of the Intelligent World 2035 is inseparable from a steadfast commitment to AI for Good. Ethical stewardship must guide every algorithm, ensuring fairness, transparency, and accountability. Inclusion must be baked into the fabric of development, guaranteeing that benefits permeate every region, demographic, and socioeconomic stratum. Security—both cyber and physical—must be rigorously engineered to protect data integrity and prevent malicious exploitation. By embedding these principles, we safeguard a future where intelligence amplifies human dignity rather than diminishes it.

In this collaborative venture, Hong Kong, perched at the crossroads of East and West, stands as a crucible for innovation, talent, and ethical discourse. The University's mission—to advance knowledge, foster creativity, and serve society—aligns perfectly with the aspirations of the Intelligent World 2035. Together with Huawei, fellow scholars, and industry pioneers, we will co-author a narrative where technology is a conduit for planetary stewardship, economic vitality, and human flourishing.

Provost, Hong Kong University of Science and Technology

David Wang

Looking back at humanity's thousands of years of history, a number of clear trends stand out starkly. Every leap forward in civilization has been paired with technological exploration. Without this exploration, we would have no way to innovate. Without innovation, we would have no way to grow. The drive to explore is a core part of human nature. It encourages us to push the boundaries of knowledge and technology. And today, it is leading us toward a more intelligent world.

In 2021, Huawei released the *Intelligent World 2030* report. It provided insights into multiple economic domains, including healthcare, food, living spaces, transportation, and enterprise. Over the past few years, many of these predictions have become reality. We are already seeing AI and broadband be widely used by individuals, homes, organizations, and even vehicles.

But we are living in a period of rapid technological change. Two years ago, generative AI was just starting to emerge and opening up possibilities that we couldn't imagine before. Now, the landscape is completely different. And so, we must continue looking towards the future and build new scientific visions and assumptions.

Over the past two years, our research team hosted over 200 workshops and met with over 100 experts, scholars, customers, and partners from around the world. Together, we drafted the *Intelligent World 2035* report, referencing data and methodologies from trusted sources like the UN and the World Economic Forum. The report outlines the key technical trends that will bring us to 2035, and the impact new technologies will have on people's lives and work.

AGI will be the largest driver of transformation over the next decade. We are moving towards a technological singularity, but we will continue to face many new challenges. AI has made huge progress in perception and generation, but it is still not able to reason complex issues. What we need is a new architecture that deeply integrates the digital and physical worlds. So, we believe going physical is the only path to AGI.

As large models grow, AI agents will better understand the physical world. Over the next 10 years, these agents will become action systems that can complete a wider range of tasks on their own. They will transform from simple tools into decision-making partners and drive intelligent transformation across industries.

We will also see more and more new applications as AI reshapes how we develop software and interact with computers. People will be able to focus on system architecture and innovation, as AI agents efficiently execute commands. AI will redefine software development. Human-computer interactions will move towards natural language systems. And advancements in image and sound technologies will let devices deliver full sensory experiences. This will enable more immersive, spatial, and multimodal user interfaces that bring user experience to new heights. Our millions of mobile apps will collaborate across all devices. They are inter-connected and orchestrated by agents, delivering intelligent services and creating new ecosystems. In addition, breakthroughs in critical technologies like world models will make Level 4 or higher-level autonomous vehicles a reality. They will become a mobile third space.

Past industrial revolutions relied on breakthroughs in a single technology. But the AI revolution is different. The age of AI will thrive on a symbiotic multiplier effect. That means AI technologies, infrastructure, and application scenarios will reinforce each other and evolve together. AI will be the engine of the intelligent world, but it must be integrated into real-world scenarios to get any traction. Infrastructure will be the foundation of innovation. It will determine the speed and scope of AI development. Cluster computing, high-speed networks, and quality data will be essential. Without these things, advanced algorithms and application scenarios won't be able to deliver meaningful results.

Demand for computing power will grow faster than ever, thanks to the rapid development of AI. And so, we predict, by 2035, global computing capacity will be 100,000 times higher than in 2025. This trend will redefine the computing industry, pushing us to go beyond the von Neumann architecture. It will drive us to make ground-breaking innovation in four key areas: semiconductor materials and devices, process techniques, computing architectures, and computing paradigms. This will reshape the computing ecosystem.

At the same time, data will become the fuel that propels AI development. By 2035, digital twins and embodied AI will be widely adopted, and super agents may emerge, increasing demand for AI storage by 500 times. We believe AI storage will eventually account for more than 70% of global total storage capacity. To meet this demand, storage systems will need to be more intelligent, with ultra-large bandwidth and super-large capacity.

Over the next ten years, hundreds of billions of agents will emerge and become connected. This will create a brand-new network architecture – the agentic Internet. Agentic Internet will be defined by real-time, intelligent interactions and new connections.

Massive investment is still needed in electric power facility construction, which will drive up energy costs in the short term. However, this investment is necessary as the AI boom drives energy demands. By 2035, global data centers will consume about 1.5 trillion kilowatt-hours. A complete restructuring of supply side operations is needed to shift away from fossil fuels to renewables. Wind and solar will eventually account for 50% of the global energy mix. AI will be at the core of new energy systems. It will manage every joule in real time, using tokens to manage watts, for more dynamic and efficient grids.

Technology drives the world forward. By bringing technology to everything around us, we will enjoy better lives, warmer homes, more productive organizations, and more sustainable environments.

By 2035, there will be more than 1.1 billion people over the age of 65. The healthcare industry will need to do more than just cure disease. It will need to help us manage our lifelong health. AI will help prevent over 80% of chronic diseases by turning passive health monitoring into proactive prevention.

Robots will also handle household chores and offer emotional companionship, bringing the comfort of home into the future. For example, in 10 years, over 90% of homes in China will have intelligent robots. A tech-driven immersive transformation of how we live is on the horizon. The virtual world will be brought into our homes using 3D holograms and more.

AI will also drive disruption in business, revolutionizing how companies make decisions. And AI agents will power autonomous systems that support organizational decision making and reshape production. By 2035, AI is forecasted to be applied by over 85% of companies. It will improve productivity by 60% and cut product defect ratios to 0.05%. With AI-powered perception, analytics, decision-making, and action systems, companies will have brand new ways to create even more value.

Over the next 10 years, AI will be deeply applied to numerous industries and homes. AI for All and AI for Good will be two major principles underpinning AI governance. They will be the key to ensuring these technologies help us build a brighter, people-centric intelligent world.

Exploring the unknown helps us find new paths to the future. And by working together we can shape what that future will be.

Huawei stands ready to work with customers and partners from around the world to continue exploring and innovating together. Let's keep moving forward to create that better intelligent future!

David Wang

Executive Director of the Board
Huawei

Acknowledgments

While drafting the Intelligent World 2035 report, we received extensive support from and engaged in discussions with experts and scholars from both inside and outside Huawei. Following these discussions, we outlined the key technological outlooks for the next decade, and how they will transform the way we live and work. We would like to extend our sincere thanks to everyone who has provided invaluable contributions throughout the drafting of this report.

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Exploring Our New Intelligent World 2035

The history of humankind is defined by our irrepressible urge to explore the unknown. From the discovery of fire, the invention of farm tools, to the creation of light bulbs, our relentless pursuit of knowledge and technology has pushed the boundaries of what is possible. This drive to explore is part of our very nature. And now, as we stand here in 2025, this same drive is propelling us towards a better future.

Huawei is proud to be part of this technological exploration: More than three decades ago, we committed ourselves to bringing telephone connectivity to every household, in order to enrich lives through better communication. Then, more than a decade ago, we dedicated ourselves to extending network connectivity to every corner of the globe, in order to jointly build a fully connected world with our partners. Today, we are committed to bringing digital to every person, home and organization for a fully connected, intelligent world.

In this report, we project ourselves into the future, creating a picture of the year 2035 based on growing trends we see before us. And, of course, there's no better place to start than with AI.

Current AI models, like ChatGPT and DeepSeek, are reshaping the future in a way we have never seen before. They represent not only a technological revolution, but also a cognitive one. These models are reshaping how we understand the world and think about the future and making all of our past predictions for the future look too conservative.

AI models will unlock the full value of computing power to deliver true intelligence, while computing networks will help bring AI into every industry. The resulting AI agents will, in turn, drive the advancement of AI models and computing technologies. These intertwining technological developments will foster an unprecedented ecosystem of AI agents. Unlike past industrial revolutions that relied on breakthroughs in a single technology, the age of AI will thrive on a symbiotic multiplier effect, where AI, infrastructure, and scenario-based applications reinforce each other and evolve together.

The rapid development of AI is poised to redefine existing development paradigms, transform human-machine interaction modes, and create more new applications. By 2035, global demand for computing will surge by a factor of 100,000, while the demand for AI storage will grow 500-fold. This immense computing power will become as accessible as water and electricity, serving as a foundational resource underpinning an intelligent world. Communications networks will connect trillions of things in addition to tens of billions of people, meaning the number of network connections will increase 100-fold. This will create an intelligent world where the physical and digital realms seamlessly converge.

Preface

At the individual level, AI will no longer be just a tool, but a true cognitive partner. It will aid scientists in navigating vast amounts of literature, support creators by sparking new ideas, and empower everyday users to transcend the boundaries of their own knowledge. AI will create more room for people to build interpersonal connections, make value judgments, and innovate. Humans and machines will coexist while further amplifying the collective value they create.

At the organizational level, AI will build a form of symbiosis between two opposite structures: One is super-individual clusters, which are flexible, agile teams that break down silos and integrate resources. And on the other end of the spectrum is mega-corporate platforms that rely on AI-native operations for efficient collaboration and open ecosystems. Hybrid organizations act as a bridge between these two structures, facilitating the bidirectional flow of talent and resources and expanding industrial intelligence from specialized applications to different domains.

However, the intelligent world will also face significant challenges with data privacy, algorithmic fairness, job market shifts, and the ethical limits of technology. Addressing these challenges will require collaborative governance, not just technical solutions. We must establish more dynamic regulatory systems for AI, make AI explainable, and agree on global ethical standards on AI. This process needs to remain people-centered to avoid technological alienation and ensure that the intelligent world supports both our core values and human dignity.

The future is not something we simply wait for, but an endeavor jointly shaped by humans and machines. The intelligent world of 2035 will not spontaneously emerge from natural evolutions in technology. We will need to anchor our optimism in ethics, balance innovation with regulation, and forge ahead with both imagination and practical action.

The rapid evolution of AI is driving the convergence of our digital and physical worlds, accelerating the development of the digital while pushing the physical forward. While human intelligence has long guided our progress, this guiding light may come from machines as we look to the future.

This report is an examination of what the future intelligent world will bring, as well as an exploration of how we can actively shape that world. As we look ahead to this world where the virtual and real are one, where humans and machines coexist and thrive, every bold vision we have today can help guide the practical steps we take to get there.

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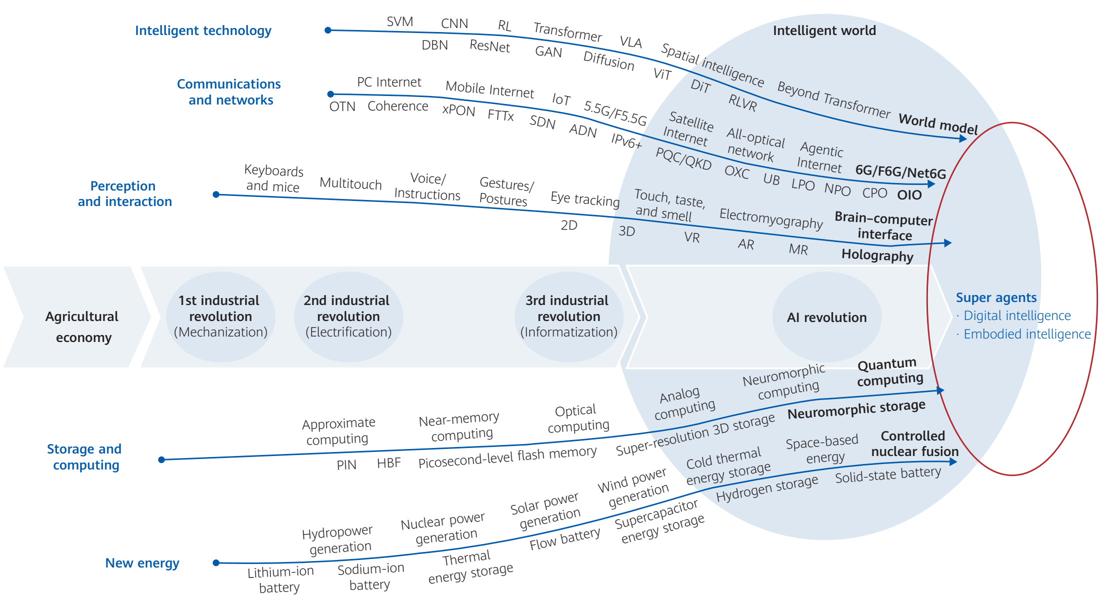
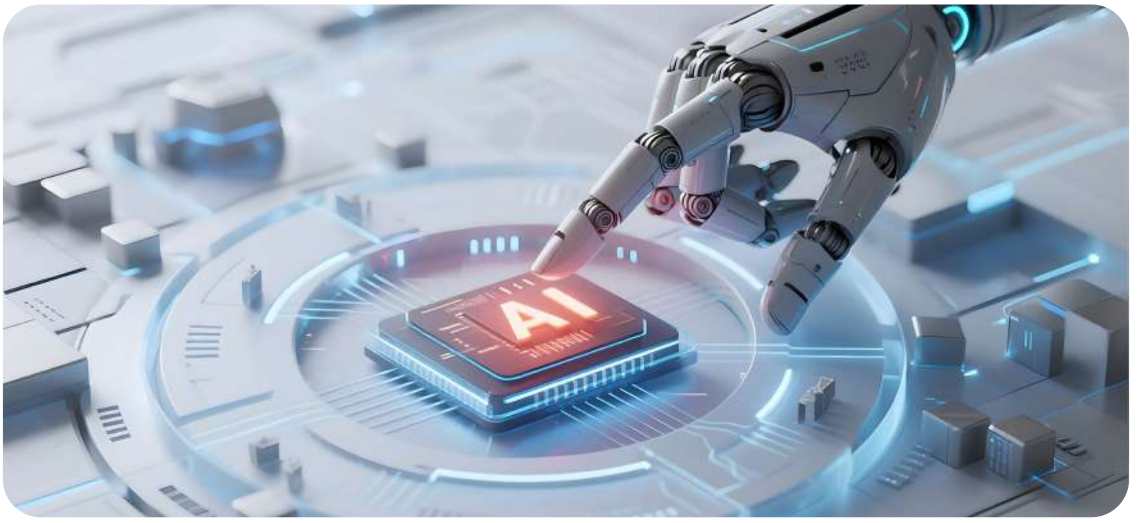
Advancing with AI

Ten technological leaps bringing us to the intelligent world of 2035

A central theme throughout the story of human history has been the evolution of thought, from experience to science and to intelligence. Our tools have progressed from abacuses to calculators, computers, the Internet, and soon to machine intelligence. Unencumbered by biological limitations, machine intelligence will take our ingenuity to new heights and open up infinite possibilities for humanity.



The convergence of five foundational technologies for super agents



The integration of the digital and physical worlds is accelerating, and digital intelligence is moving beyond the virtual realm and rapidly evolving into embodied intelligence that has its own physical entities. As the physical world meets the digital, vast amounts of data will be generated, transmitted, and processed. During this process, ICT infrastructure will be the cornerstone of the AI revolution and will determine how deep AI can go into the fabric of our society. Over the next decade, ICT will make a significant leap. It will be more than just a linear progression of individual technologies, but a systemic transformation driven by data, intelligent technologies, perception and interaction, computing, networks, and new energy. This change will occur in both the digital and physical worlds, representing a complex endeavor for systems engineering.

To systematically outline this future vision, this chapter delves into the ten technological trends that will shape the intelligent world of 2035. These trends are intricately linked and mutually reinforcing. Together, they illuminate a technological pathway that can bring us into the future.

Going physical: The essential path to AGI

Challenges on the path to AGI over the next decade

Today, the main focus and greatest challenge we see for ourselves over the next decade will be forecasting the trajectory of AI evolution. The speed and depth of this evolution will reshape technological frontiers and the global landscape of the coming decade.

Ever since Transformer-based large language models (LLMs) began to sweep across the industry at the end of 2022, AI has seen rapid iterations. However, several challenges persist, including the lack of robust mathematical theories underpinning neural networks, the unexplainability of these models due to their black-box nature, and hallucinations arising from uncertainty. Additionally, the scaling law that has fueled LLM development shows signs of slowing due to bottlenecks related to data, computing power, energy consumption, and reliability.

Artificial general intelligence (AGI) represents intelligent systems with cognitive capabilities on par with humans. These systems are general-purpose, autonomous, and innovative. They can understand, learn, and complete any intellectual task that humans can perform in new environments. They can also reason across scenarios, solve complex problems, and demonstrate human-like flexibility and innovation, making them an ultimate goal of AI development. Over the next decade, we will continue to face new challenges as we move towards the technological singularity that is AGI.

We predict three possibilities for AGI over the next decade:

1. Scaling leading to a technological singularity
The scaling law will continue to work. The dividends from the scaling of computing, data, and models will show no signs of decline. Technologies will continue to evolve rapidly along the current trajectory. We will ultimately see a seismic shift and AGI will become a reality. This will reshape existing technological paradigms and fundamentally transform human society.

2. New architectures driving paradigm shifts
Scaling based on the Transformer will hit its limit and the scaling law will become obsolete. However, breakthroughs in basic theories and new architectures beyond the Transformer will emerge. New architectures and theories will replace scaling as the driver of development. This new theoretical framework will forge a new, unpredictable evolutionary path for AI.

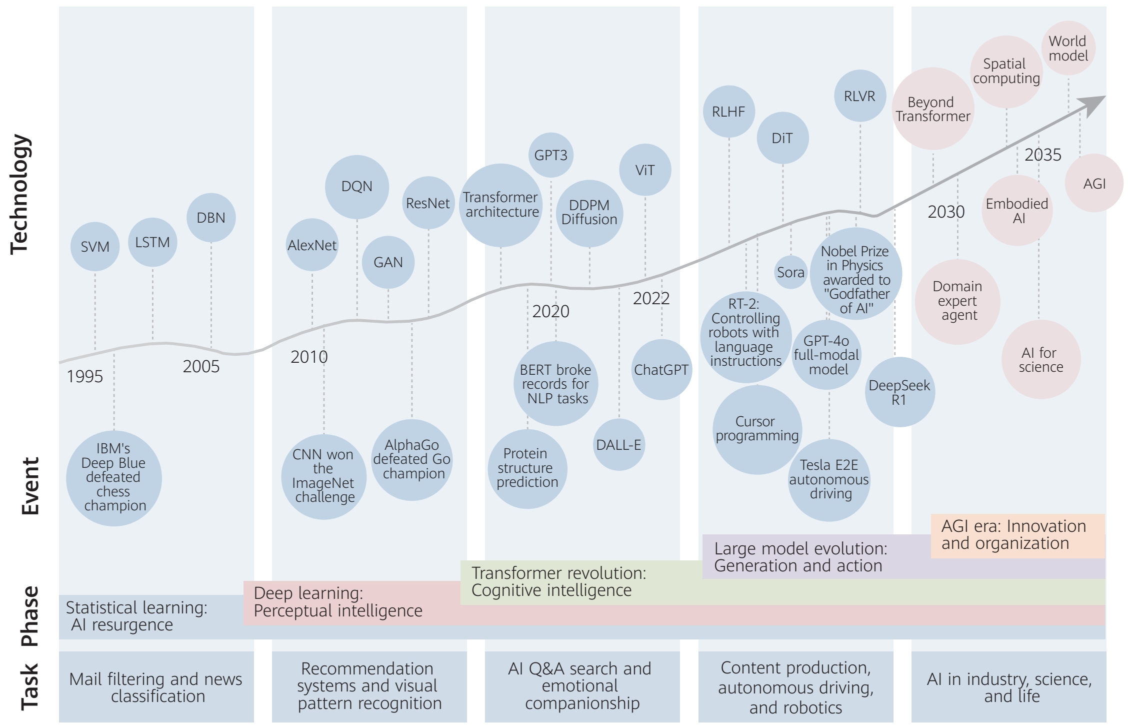
3. Exploring further value and use cases of existing LLMs
AI development will stagnate and the key obstacles to AGI will be hard to remove. Industry focus will shift from the ambitious vision of AGI back to exploring the untapped potential of existing LLMs, including their productized value and use cases. AI will be mainly used to boost efficiency and cut costs.

There is no doubt that, whatever direction the future takes, AI will continue to profoundly influence our production and everyday lives. It will play a vital role in every domain and contribute to our living standards and social progress.

A new AI breakthrough over the next decade

Over the past three decades, AI has seen one major revolution every ten years, and the history of AI has been one with many winters and revivals.

From the mid-1990s until the mid-2000s, statistical learning fueled a resurgence of AI. Milestones such as Support Vector Machines (SVMs) in 1995, Long Short-Term Memory (LSTM) in 1997, and Deep Belief Networks (DBNs) in 2006 allowed machines to perform basic tasks like email filtering using data-driven methods. IBM's Deep Blue showed the power of data modeling, though its intelligence was confined to specific tasks, with limited abilities in generalization and complex reasoning.



AI evolution history

In the following decade, deep learning drove significant advances in perceptual intelligence. Technologies like AlexNet, a deep convolutional neural network, gave machines sensory systems, propelling AI to take center stage. Significant advances were made in recommendation and visual recognition systems, and AlphaGo and AlphaFold pushed the boundaries of AI applications, marking the second wave of AI prosperity. However, AI systems still lacked generalization capabilities and the ability to flexibly transfer learned experiences.

Now, in the 2020s, Transformer is catalyzing the emergence of cognitive intelligence. Generative AI powered by large models is taking off, bringing the "ChatGPT Moment" that gives humans a glimpse into the marvel of GenAI. AI has achieved breakthroughs in natural language understanding, multimodal generation, and reasoning, and we have also started exploring the frontiers of generation and action. The role of AI has shifted from merely understanding the world to changing it. During this period, notable progress has been made in content creation, autonomous driving, and robotic interaction, although there remains a significant gap between AI and humans in terms of reasoning and creativity. Challenges persist in areas like explainability, accuracy, inference efficiency, real-time response, and environmental adaptability.

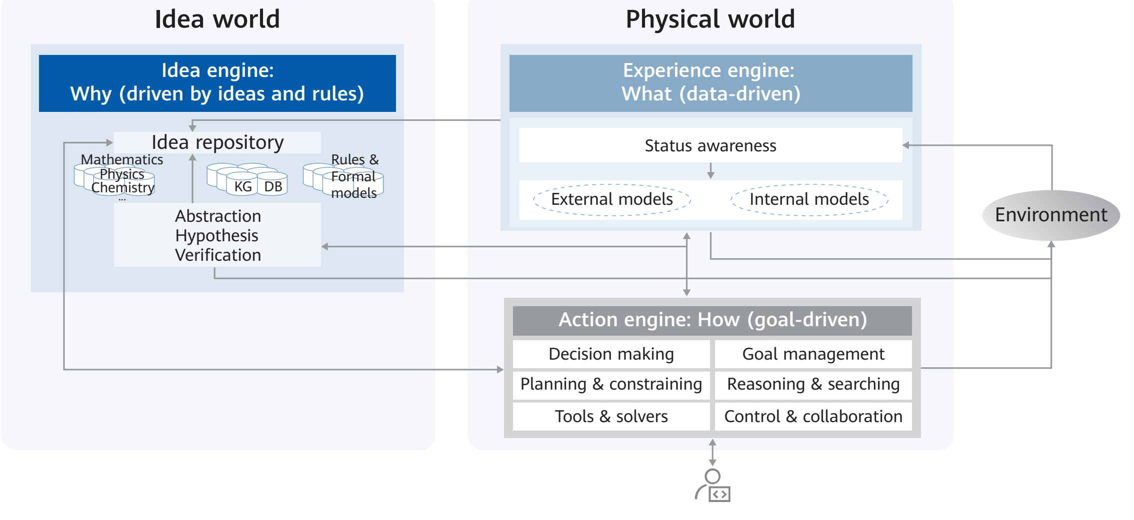
Technological revolutions, like the one in AI, have always been driven by questioning and exploration. From SVMs to Convolutional Neural Networks (CNNs) and then to the Transformer, the AI revolutions of the past three decades have all been driven by new architectures. So, we have good reason to believe that the next decade will usher in a new AI revolution that will go beyond the Transformer. The new architecture will be an all-round breakthrough. It will deliver much stronger basic performance (including computing overhead, computing complexity, and long-sequence processing) and core capabilities (such as long-term memory and self-evolution). More importantly, it will also drive a huge leap in advanced intelligence, including logical reasoning, causal inference, explainability, innovation, and emotional recognition and expression.

Three engines creating a world model that infuses intelligence into the physical world

Current large models remain largely confined within probabilistic and statistical frameworks. They are essentially repositories of compressed knowledge. The quality of what they generate heavily depends on the quality of what they are fed. These unexplainable probabilistic models do not align with humans' innate desire to understand both the "What" and the "Why" of everything. They also lack cognitive capabilities and may fall short of achieving human-like cognitive intelligence. So, is it possible that we will have intelligence combined with symbolism – that uses abstract symbol representations and logical reasoning to simulate human intelligence?

To develop intelligent systems that are combined with symbolism, three engines must be built: a data-driven experience engine, a rule-driven idea engine, and an action engine. The experience engine will rely on deep learning to process Internet and sensory data; the idea engine will enhance cognition through abstraction and validation; and the action engine will possess practical capabilities such as goal management, reasoning, constraining, and planning. These three engines will form a high-fidelity world model that infuses intelligence into the physical world.

We believe that going physical is pivotal for achieving AGI, as it enables physical entities of AI to interact in real time with their environments, to perceive, cognize, make decisions, and take action on their own. This will allow AI agents to perceive the world like humans, grow through interactive learning, better adapt to their environment, and handle complex tasks. The three building blocks for AGI will be more multimodal data, refined core capabilities, and improved cognition principles.



Three engines creating a high-fidelity world model

AI agents: Driving an industrial revolution as both tools and decision-making partners

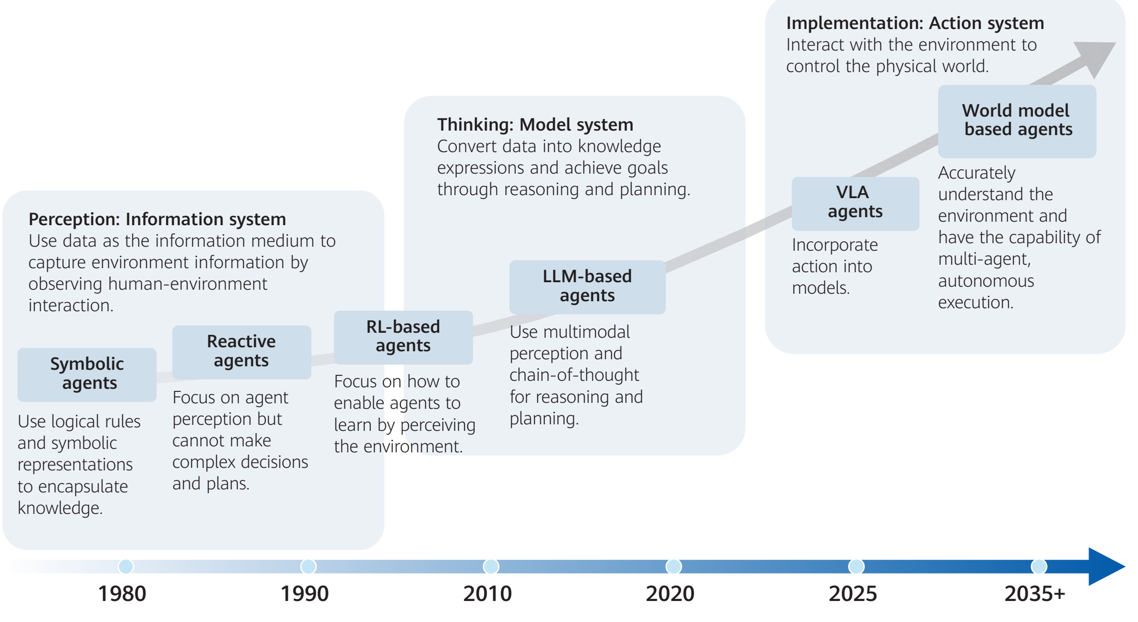
AI agents evolving into action systems over the next decade

As large models continue to develop, AI is quickly transforming into general intelligence. Driven by diverse business needs across different industries, AI agents that are able to transform complex capabilities into tangible value are beginning to emerge. Over the coming decade, AI agents will become our most important partners.

Early agents were primarily information systems focused on perception and lacked sophisticated decision-making and planning abilities. The next generation of agents were models focused on cognitive capabilities, marking significant improvements over their predecessors with much greater market influence. These agents have already shown great potential in areas like deep research, AI coding, and operations. Over the next decade, a new wave of agents that serve as action systems will emerge. This revolution will mean a shift of decision-making authority from humans to machines. Agents will be able to interact with the physical world, make decisions on their own, and independently complete a wider range of tasks.

The development of agents, or the path to advanced intelligence, hinges on overcoming three intertwined key challenges: multi-agent coordination (communications and collaboration), interaction with cloud-based environments (exploration and execution), and long-horizon reasoning and cognition (mitigating bias accumulation and combinatorial explosions).

Swarm intelligence will be a key technological direction forward for these agents. Agents will be able to interact and coordinate with each other through both competition and collaboration. Concurrent, online, autonomous, and interactive



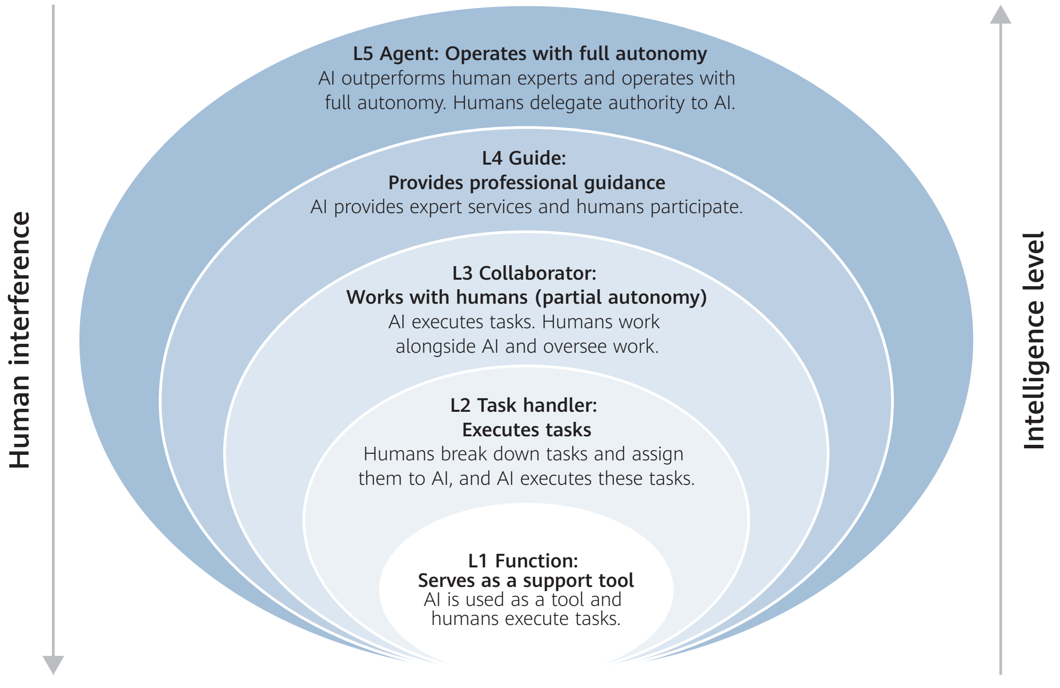
Agent evolution path

learning will become a core paradigm, where agents collect data via sensors, use tools, and gain experience from interactions, without having to depend on human-labeled data. Agents' ability to execute ultra-long-duration tasks will also see an exponential improvement. In addition to the hour-level programming tasks they currently handle, agents will be able to execute tasks that may span months or even years like scientific experiment management and corporate data monitoring.

Five levels of AI agents: Exponential growth of agent capabilities with market penetration

The development of AI agents is a step-by-step process. It is currently constrained by a number of factors such as technological maturity, security considerations, business relevance, and return on investment. Addressing these challenges will require us to enhance agent capabilities, build up mutual trust between humans and machines, delineate responsibilities, work more closely with industries for innovation, and create a positive, sustainable value loop for agent development. Agent capabilities are expected to grow exponentially as market penetration increases.

To better define the capabilities of AI agents, we have classified them into five levels, as illustrated in the figure below, ranging from Level 1 (Function) to Level 5 (Agent). As an agent advances to a higher level, it generally demonstrates greater autonomous decision-making capabilities, and its use cases expand beyond low-risk, single-function tasks to high-value, cross-domain services that unlock broader market opportunities. Throughout this evolution, agents will be expected to not just provide basic interaction functions, but deliver general intelligence aligned with ethical standards.



Five levels of AI agents

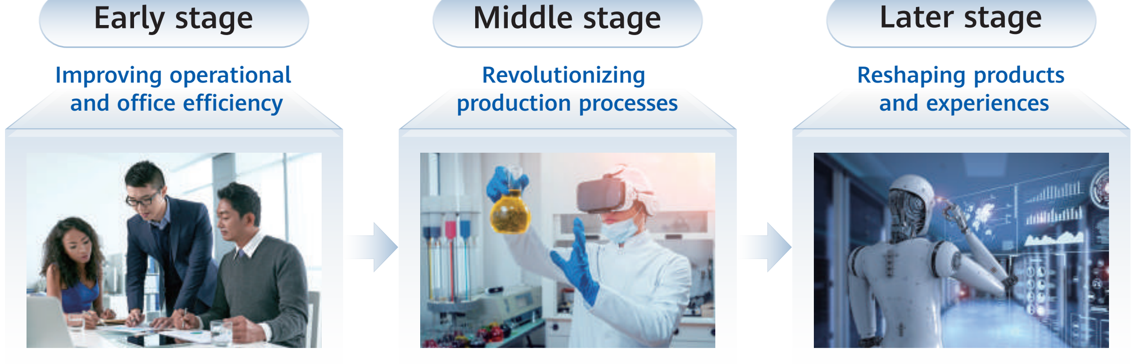
We anticipate that by 2035, AI agents will see breakthroughs across multiple dimensions. Level-4 agents will be applied at scale in certain domains. In established engineering domains, these agents will be able to work as long and as hard as humans, make decisions autonomously, and serve as efficient collaborators of humans.

AI agents driving a paradigm shift across industries over the next decade

Over the next decade, the evolution of AI agents is expected to drive profound societal change. Human roles will transition from traditional task execution to goal setting and ethical oversight, creating new jobs for AI collaborators and agent trainers. These developments will steer the workforce towards higher-value domains. Meanwhile, the security and ethical frameworks around AI will mature, incorporating measures like safeguards against malicious use and the establishment of "empathy boundaries" for emotional companion agents.

In the business world, AI agents are poised to drive a paradigm shift across various industries. Initially, these agents will enhance operational and office efficiency by taking on roles such as customer service representatives, sales assistants, and office aides. This will give rise to an industry worth hundreds of billions of US dollars. Roughly five years from now, agents will be revolutionizing production processes, particularly in areas like AI-driven drug development and professional service consulting, drastically cutting research and production costs. This has the potential to generate a trillion-dollar market. Looking even further down the road, AI agents will redefine products and user experiences, with innovations like AI-powered PCs leading an office revolution and embodied robots serving as personal assistants. This next stage represents a potential ten-trillion-dollar industry.

Over the coming decade, the relationship between humans and AI agents will evolve from simple collaboration to a symbiotic partnership. These agents will be more than just advanced productivity tools; they will be new collaborators in the ongoing evolution of civilization. During this process, we must ensure that AI agents are developing for the good of humanity, as this is the only way humans can maintain control over the intelligent world.



AI agents: Driving a paradigm shift across industries over the next decade

Human-AI programming: Reshaping the future of software

Human-AI programming: Addressing complexities caused by human factors

Technologies are becoming increasingly complicated: Chips are scaling to support hundreds of millions of gates, large models commonly have more than one trillion parameters, product designs are growing ever more sophisticated, and collaboration on large-scale programming is becoming more challenging.

Today, human factors significantly complicate software development, causing a sharp decline in efficiency as projects scale up. In response, modern software engineering practices have been adapted to tackle these complexities. The evolution of software architectures focuses on breaking down and migrating complexities to simplify collaboration, while the evolution of software development modes prioritizes rapid feedback and iteration to boost collaboration efficiency. Meanwhile, the evolution of programming languages focuses on coding efficiency, comprehensibility, and scenarios.

Automated software programming has emerged as an area of focus when looking to address the complexities caused by human factors. However, it also faces challenges. In recent years, formal methods have been widely discussed and used in the software industry, helping achieve high levels of stability and security in mission-critical domains. These methods have also resulted in a higher level of automation in both code generation and verification. However, formal methods rely heavily on human expertise and incur prohibitive costs when adapting to rapidly evolving software environments.

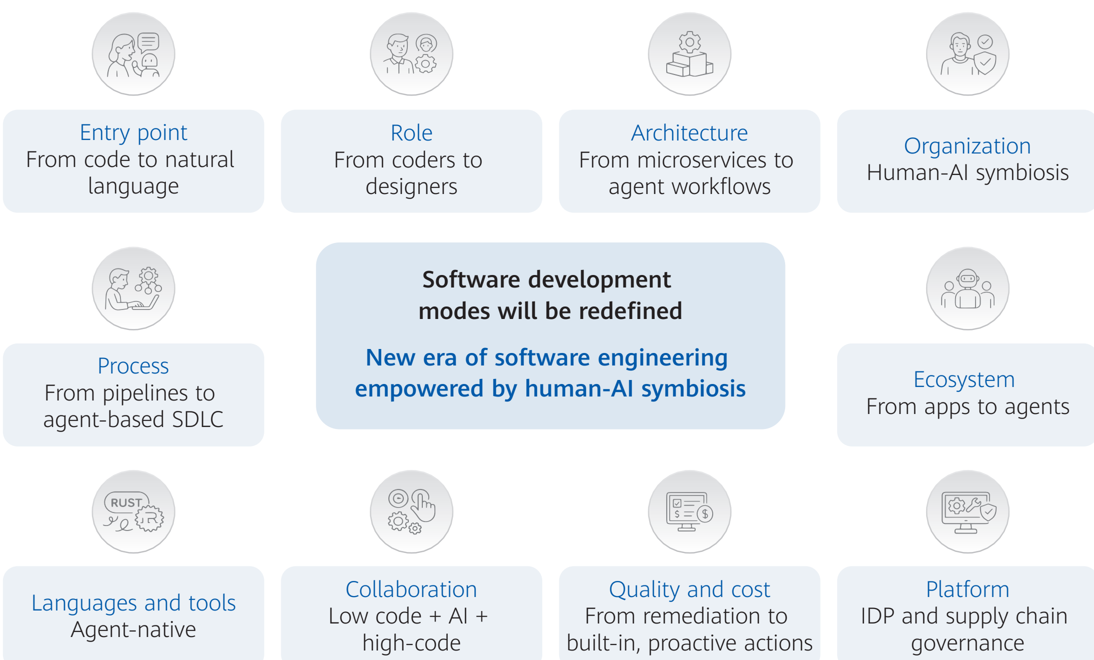
An alternative is AI programming, which has been revolutionized by the recent emergence of large models. AI programming can substantially reduce the complexities introduced by human factors and alleviate the challenges intrinsic to programing, while also realizing notable gains in efficiency. However, AI programming continues to grapple with several challenges when handling large-scale, complex software, including how to ensure the trustworthiness of complex systems and how to address system decomposition, integration, and collaboration in large software projects.

Both large models and formal methods have their own advantages and limitations when used for automated programming, but they are highly complementary. Using large models increases the automation of conventional formal verification, while applying formal methods improves the precision of large model outputs. Combining these two methods is poised to be a key driver for progress in this domain.

We believe that AI is set to take over a larger amount of software production work, thus driving transformative changes in software engineering. This will lead to the evolution of traditional software activities, development processes, and architectures traditionally centered around human factor collaboration. Human-AI programming is expected to emerge as a solution to the challenges posed by large-scale software development.

AI agent programming: Reshaping software development modes

Today, the rise of large models and agents is reshaping software development. This transformation extends far beyond mere tool upgrades, but requires systemic shifts in entry points, roles, processes, architecture, security, quality, ecosystems, platforms, organizations, tools, and collaboration.



Changes in software forms: From programs to programs + agents

Traditional application development is increasingly being taken over by agents. Users simply need to define their requirements in natural language, and then agents will create applications, which can be called "malleable software". While specialized software like operating systems, mission-critical financial systems, and industrial controls will continue to rely on professional developers, the toolchains they use will become increasingly integrated with AI in order to boost efficiency and verification capabilities. Future software will comprise of deterministic programming logic, neural network models, and agent orchestration, blending both low-code and high-code approaches.

Ecosystem: From app-centered to agent-centered

In the age of mobile Internet, apps take the center stage, but moving forward, AI agents will play a more dominant role. Instead of jumping from one app to another, users will directly access the services they need via agents. This will put new emphasis on interface- and service-oriented design during software development. Those who set the standards for agent calling could secure a presence in the next-generation ecosystem.

Entry point: From code to natural language

In the coming years, software development will increasingly rely on natural-language interactions, with applications being generated based on user intent conveyed through conversations. This approach will greatly simplify the process of creating, customizing, or discarding malleable software. It will also lead to the decline of non-specialized application programming, while clear semantics will become critical.

Role: From coders to designers

AI will handle much of coding and testing, freeing human developers to focus on more valuable tasks like architecture planning and managing agent self-organization strategies, compliance, and governance. Emerging roles for developers include agent orchestrators, prompt and goal designers, and security auditors. The value of human developers will shift from coding to complex system governance.

Process: From pipelines to agent-driven SDLC

The traditional software development life cycle (SDLC) will be taken over by agents. AI will automatically generate requirement documents, write code, run tests, and submit peer-review requests, all under human oversight at key control points. This will cause the software development process to evolve into a collaborative human-AI pipeline, where robust rollback mechanisms and reliability assurance are key.

Architecture: From microservices to agent workflows

Over-microservices often introduce unnecessary complexity. The future will likely see a shift back to modular monoliths in order to simplify interfaces, clarify boundaries, and enhance observability. Long-running transactions and complex processes will then be managed through "workflow as code", supporting compensation and retries, an ideal task for agents.

Agent-native languages and tools

Conventional programming languages center on functions and services, which are inadequate for supporting an agent's perception-reasoning-action cycle. This may mean the emergence of agent-oriented languages (AOLs), with built-in goals, policies, contexts, capabilities, and coordination. Additionally, future toolchains will possess the functions of semantic modeling, agent simulation and verification, behavioral auditing, and runtime sandboxing. While languages like Rust and WASI continue to ensure performance and security at the bottom level, high-level languages will become increasingly agent-native.

Quality and costs: From remediation to built-in, proactive actions
While AI-generated code can undoubtedly accelerate development, it also increases quality risks. To mitigate such risks, quality and costs will become proactive considerations.

Organization: Human-agent collaboration
Future development teams will consist of humans and agents working side by side. Human developers will focus on creative design and compliance decisions, while agents will handle execution and automation tasks. The structure of development teams will evolve from the traditional development-testing-operations model towards design-governance-supervision, with humans and agents seamlessly collaborating.

Redefining software development modes is essentially about balancing intelligence and governance. Over the next decade, software engineering will not merely be about AI replacing humans, but about embracing a collaborative approach where AI manages execution and automation while humans focus on design, governance, and value judgments. This is a future in which development of AI agents and governance will be equally important. In this kind of human-agent hybrid structure, natural languages will reduce barriers to development, collaboration with agents will boost efficiency, robust platforms and tools will guarantee security and performance, and compliance and costs will never be an afterthought. Those who can shape the standards and ecosystems in this transformation may well lead the industry in the coming decade.

Dimensional evolution of AI in the mirror world: Enabling new interactions and immersive experiences

Humans are in constant pursuit of new, inspiring experiences, from the emergence of written language, to voice communication with telephones, and onward to interactive video calls in the mobile Internet era. Each of these revolutionary changes in media reflects humanity's progress in transcending the boundaries of sensory perception and information transmission.

Today, advances in AI, spatial computing, extended reality (XR), and other cutting-edge technologies are blurring the boundaries between the physical and digital realms. This convergence will define user experiences in the future world. This trend will not only redefine how people access information and communicate, but reshape the very foundations of how we work and live. Smart devices will evolve from simple information carriers into bridges that seamlessly connect the digital and physical worlds. They will become the gateway where carbon-based life and silicon-based intelligence converge, enabling new forms of perception and interaction.

From 2D to 3D and from single-modal to multimodal interaction

The convergence of the virtual and real will see its first breakthrough in interaction methods, enabled by new system architectures. For decades, human-computer interaction has largely been limited to two-dimensional planes and single-modal inputs like keyboards, mice, and touchscreens.

As multimodal technologies mature, interactions will quickly move into 3D space and become increasingly intuitive. Examples include:

- **Visual interactions:** High-precision cameras and eye-tracking will capture user focus and intent in real time.
- **Spatial gesture interactions:** Sensor arrays and AI algorithms will convert movements into operational commands in virtual environments.
- **Voice and body interactions:** These will blend with traditional inputs to form intuitive multimodal interaction systems.

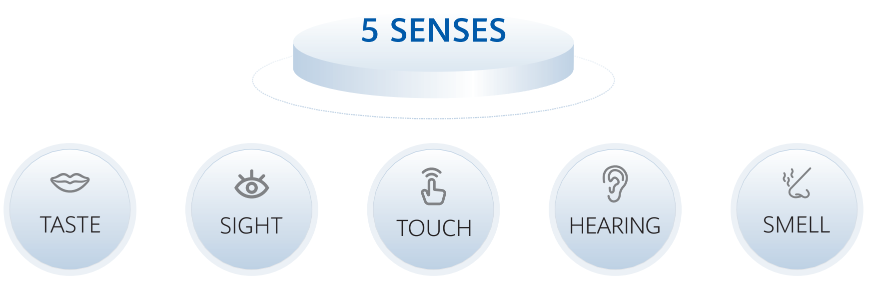
This transformation will require devices to push the limits of technology while minimizing user learning costs. They will need to remain always-on and continuously learn from users. Micro-gesture interaction is predicted to be a key industry focus in the short term. In the long term, brain-computer interfaces will be integrated with multimodal systems, which will enable more intuitive human-computer interaction.

From sight and hearing to full five-sense integration

New paradigms of interaction will pave the way for the convergence of the virtual and real, and the next step will be upgrading sensory experiences. This will enable innovations like hand-motion-sensing rings, pulse-monitoring smart necklaces, ultra-light 3D glasses, and brain-computer interfaces.

- **Sight:** Advanced holographic displays and light-field reconstruction will deliver realistic depth and spatial awareness from any angle, making virtual images nearly indistinguishable from reality.

- **Hearing:** Advanced transducer technology and spatial acoustics will produce true-to-life sounds, with breakthroughs such as high-performance micro-electro-mechanical systems



Five-sense integration

(MEMS) speakers and ultra-thin diaphragms ensuring precise spatial positioning and true-to-life audio reproduction.

- **Multisensory expansion:** Building on advancements in images and sounds, future devices will extend to touch, smell, and taste. Users will not only be able to see and hear the digital world, but touch, smell, and taste it, for a fully multisensory immersive experience.

As these sensory dimensions converge, synchronization across feedback channels will be essential. Virtual experiences will evolve from mere on-screen simulations to immersive environments as vivid as reality itself.

From CG to AIGC in content generation

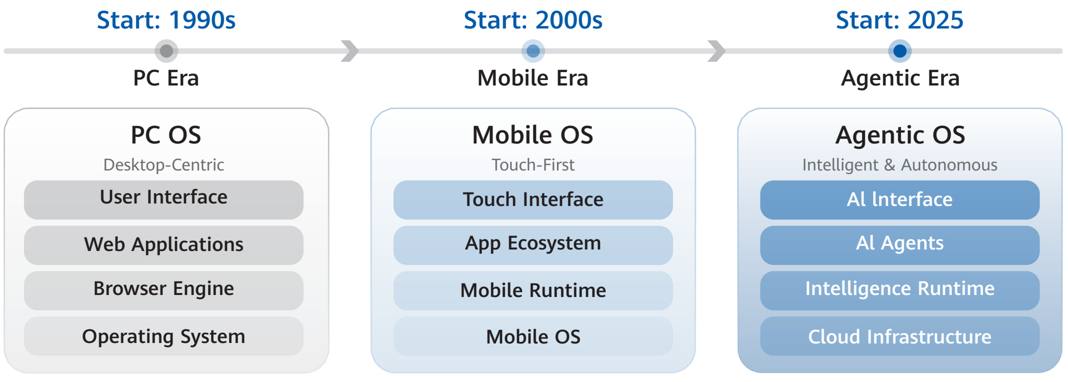
A key challenge in mirroring the physical world is the limited availability of quality 3D content. Traditionally, creating virtual environments and content has been costly, as it relied on professional generated content (PGC) and computer graphics (CG) technologies, including physics engines. With advances in AI, vast amounts of user-generated content (UGC) can be augmented through AI-generated content (AIGC). This will enable users to create virtual environments and 3D content according to their intent. This will catalyze a vibrant mirror world ecosystem. Examples include:

- Personalized interactive education: Virtual teachers will guide children through the quantum realm, enable encounters with prehistoric animals, or allow "time-travel" to pivotal moments in history.
- First-person immersive virtual travel: Live-streaming from a first-person perspective will allow users to share immersive experiences such as space exploration, deep-sea diving, or scaling the world's tallest mountains.

It is predicted that over the next decade, AI-enabled immersive experiences in the mirror world amplified by new devices will generate 1,000 times as much data as today. This data will be essential for the dimensional evolution of AI in the mirror world. Moreover, it will serve as a bridge for the rapid convergence of the physical world and the digital world, while driving the physical world forward.

Content generation technologies will continue to evolve rapidly. Autoregressive and diffusion models will use their unique strengths to develop collaboratively and in parallel over the long term. The key breakthroughs in these technologies will be significantly longer content generation and precise spatiotemporal consistency. These breakthroughs will take industrialized content production to higher levels. Fine-grained understanding of physical space and enhanced controllability will enable the emergence of world models.

The mobile Internet: From standalone apps to multi-agent collaboration



OS evolution path

The year 2025 marks the beginning of multi-agent collaboration, setting the stage for an advanced civilization enabled by specialized division of labor and collaboration. As AI agents advance, countless apps on the mobile Internet will no longer be isolated as they are, but evolve into AI agents or atomic services. Through interconnected collaboration, these agents will break through the limitations of individual agents, and work together to handle complex tasks. This will foster a new ecosystem that thrives on multi-agent collaboration.

The current mobile ecosystem is app-centric. Users are operators who actively discover, download, and open apps to achieve their goals through manual operations. Each app is an isolated information silo where data and services are encapsulated. The model of this ecosystem is users seeking out services.

As we transition to the era of multi-agent collaboration, the ecosystem will shift its focus to agents. Users will articulate objectives which will then be autonomously fulfilled through collaboration between a primary agent (like an AI assistant in a smartphone operating system) and vertical, specialized agents (service agents). In this paradigm, users transform from mere operators into commanders. The model of this ecosystem is services locating users or automated service execution.

Interaction interfaces: Evolving towards spatial multimodal interaction with SMUI

Interaction interface evolution path

Human-computer interaction is advancing towards a spatial multimodal user interface (SMUI) framework. We will move from passive graphical user interfaces (GUIs) to more active SMUIs. Additionally, we will go from multi-touch interactions to multimodal interactions covering eye movements, gestures, body postures, natural language, and environmental data. This will entail a transition from standardized interfaces to contextually-generated interfaces tailored to individual user preferences.

User experience: End-to-end task execution success rate as a key metric

The mobile Internet is evolving into an action network in which the end-to-end (E2E) task success rate will be the key metric for evaluation. This metric will determine control over user entry points in the era of AI agents. The competitiveness of multi-agent collaboration is a matter of systems engineering.

Multi-agent systems create value by combining powerful foundation models with collaboration frameworks, specialized division of labor, learning mechanisms, and security and trust.

This combination of factors creates a multiplier effect rather than an additive one. Any weak link in these factors can significantly hinder overall performance. Future competition will no longer be solely about who has stronger AI models, but rather who has stronger systems engineering capabilities. These capabilities include architectural design, ecosystem development, operation and evolution, and security governance.

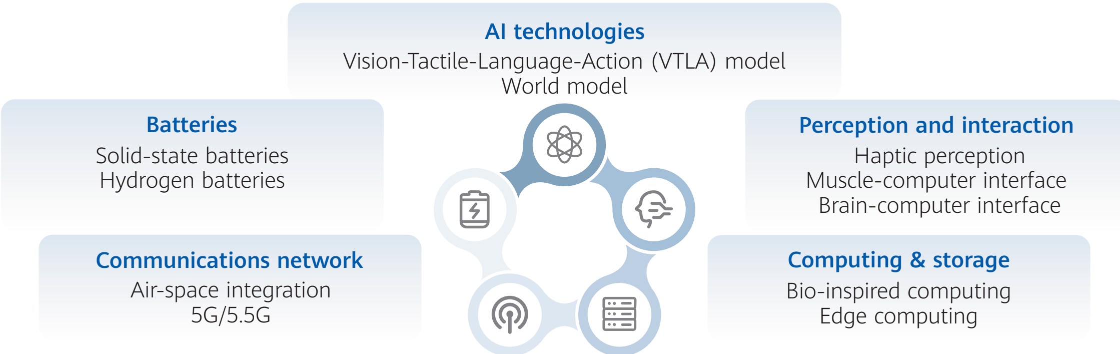
Business model: From attention economy (advertising) to direct value exchange

The conventional advertising model, which relies on consumer attention, may no longer be viable for multi-agent collaborative ecosystems. Instead, we will see the emergence of direct value exchange models like AI-as-a-Service (AIaaS) delivered through API and token calls, and payments based on the success of delegated tasks. Charging will be based on task completion or success rate, not time spent.

Deployment strategy: Device-cloud synergy as the optimal solution for the new ecosystem

Cloud-based AI agents, with their robust computing power and seamless cross-platform adaptability, are ideal for complex, long-term tasks. Device-side AI agents excel at rapid responses to simpler tasks, ensuring low latency, lower cost, and strong privacy and security. Combining device and cloud capabilities will enable fast processing close to the user and maximize high computing power in the cloud, while mitigating information security risks and slashing cloud computing costs.

Embodied AI: Bridging gaps to create trillion-dollar industries



Key technologies of embodied AI

Embodied AI is a key milestone in extending AI into the physical world. It is not about breakthroughs in a single technology, but holistic integration of AI, perception and interaction, computing and storage, communications networks, power electronics (batteries, motors, and controllers), and other domains. This integration enables AI to take on a physical form and support real-time interactions that transcend purely software-based intelligence.

With a physical embodiment, AI can autonomously perform complex tasks like grasping, moving, and manipulating objects in the real world, while continually optimizing decisions based on dynamic feedback from the environment. Embodied AI serves as a critical bridge between AI technology and practical applications. It is a major step towards artificial general intelligence (AGI). AGI will require an accurate understanding of the rules in the physical world, and embodied AI will provide the ability to perceive, adapt to, and transform that world. It is predicted that embodied AI will have primary applications across three major sectors: intelligent driving, intelligent robotics, and the low-altitude economy.

Intelligent driving on track to reach L4 or higher-level autonomy by 2035

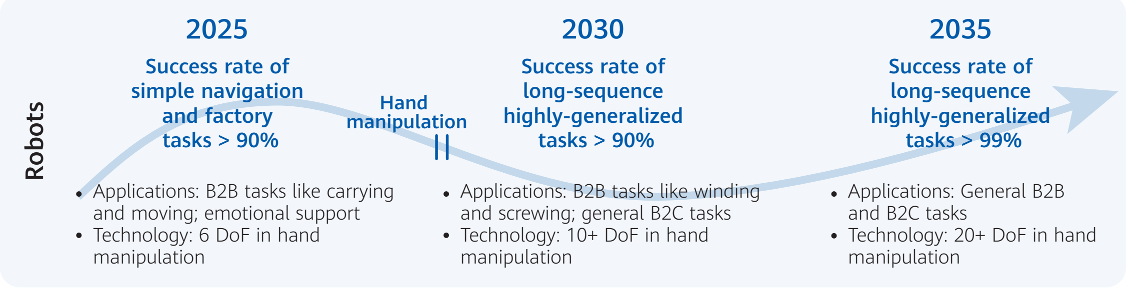
Evolution of intelligent driving

In 2022, the intelligent driving industry introduced lightweight map solutions using Transformer architectures, bird's-eye view (BEV), and occupancy networks. These advances bridged the technical gap for L2 or higher-level autonomy and fueled rapid industry growth.

The global rise of electric vehicles, especially in China where many car models now come with L2 or higher-level capabilities by default, has accelerated progress. Alongside developments in robotaxis, the industry is approaching the L3 threshold.

Highway-level L3 functionality enabled by E2E technologies will arrive first. Further advances in world model technology will extend L3 or higher-level functions to both highway and urban driving. The roadmap for autonomous driving forecasts the initiation of L4 trial commercialization by late 2027, with large-scale L4 deployment in specific scenarios expected by 2030. It is predicted that by 2035, L4 and higher-level autonomy will be prevalent across most scenarios, alongside initial explorations into L5 trial commercialization. There will be a progression from trials to full autonomy.

Intelligent robotics moving from industry to household



Evolution of intelligent robotics

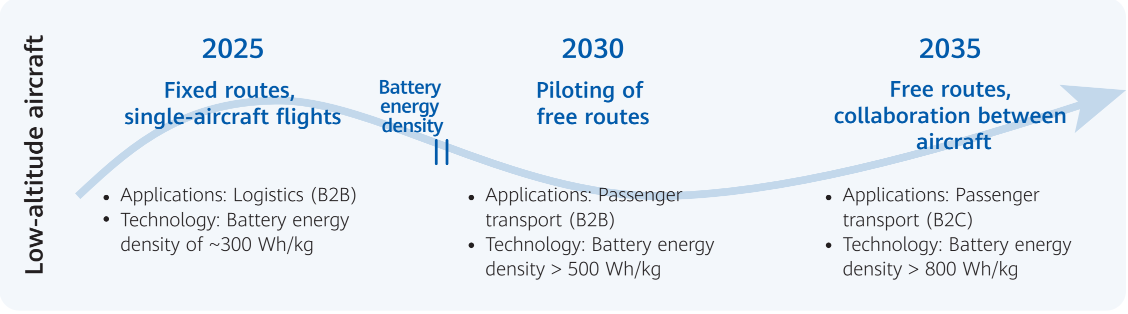
The intelligent robotics sector has emerged as a major development track. This sector has attracted extensive investment, with numerous startups fueled by advances in AI models and humanoid prototypes.

However, general-purpose intelligent robots face greater technical challenges than autonomous cars. Intelligent robots need to address challenges such as hand manipulation, spatial perception, and tactile sensing. Models capable of generalizing across long-sequence tasks and executing precise operations are constrained by limited real-world data and weak tactile feedback. Theoretical breakthroughs are needed to overcome these constraints. Today, most robots operate in semi-structured environments like factories and logistics centers. They handle carrying, moving, sorting and other tasks that are much simpler than many household chores.

Household adoption will require robots with higher degrees of freedom (DoF) and dexterous, human-like hands capable of performing tasks such as cooking, clothing care, and floral design. Much progress will still be needed to reach this level of complexity. The coming decade holds significant uncertainty for robotics. Only by overcoming key technological gaps can the industry truly flourish. By around 2030, we predict a "ChatGPT moment" in robotics: The emergence of visual-tactile-language-action (VTLA) models or world models will enable end-effectors with over 10 DoF. Robots will then move beyond flexible production in industrial settings into selected consumer scenarios.

By around 2035, mass production will drive down home robot prices to under US$10,000. Once cost is no longer a major barrier, the robotics industry will enter a period of rapid growth.

Breakthroughs in battery energy density enabling low-altitude flying and 3D urban mobility



Evolution of the low-altitude economy

The convergence of electric vehicle and aviation technologies has placed the low-altitude economy in the global spotlight, attracting substantial investment inflows. The low-altitude economy will be a key domain for the application of embodied AI technologies.

The development of the low-altitude economy faces several challenges: (1) Insufficient battery energy density and range limitations. (2) Slow growth due to underdeveloped infrastructure. (3) High costs and prices coupled with unclear business models that hinder the adoption of low-altitude aircraft. (4) Regulatory and certification barriers, including airworthiness approval, lack of standards, and over-cautious airspace governance. (5) The need for viable solutions for aircraft safety and public safety.

Battery energy density is the primary barrier to the development of the low-altitude economy. Current batteries of 300–400 Wh/kg are insufficient for longer flights. 800 Wh/kg will be needed. Possible key innovations include high-energy-density solid-state batteries, integrated solar-hydrogen-electric systems, and hybrid battery-liquid fuel generators.

AI will serve as a key enabling technology, becoming deeply integrated into the three critical areas of low-altitude flying – environmental perception, autonomous decision making, and precise control. This integration will significantly elevate the intelligence of low-altitude aircraft.

Building on this foundation, AI agents will connect aircraft with ground infrastructure to form a low-altitude agentic Internet. This network will deliver comprehensive situational awareness and efficient resource coordination. It will create value through dynamic airspace allocation and proactive conflict prevention, which will ensure safety while maximizing airspace utilization and operational efficiency.

Ultimately, the system will be capable of intelligent task scheduling and global planning for diverse scenarios like logistics delivery, emergency rescue, and urban mobility. This shift from single-point intelligence to system-wide optimization will stimulate the development of the low-altitude economic ecosystem.

By 2035, private aircraft in ordinary households may become a reality, ushering in an era of 3D urban mobility.

Beyond von Neumann architecture: Rethinking computing to meet endless demand

Computing power: Explosive growth in demand and the foundation of society

AI is advancing by leaps and bounds these days, driving up demand for computing power the likes of which we've never seen. And as AI adoption continues to spike, computing will become a fundamental resource – just like electricity.

Over the next decade, we will gradually enter an age of pre-AGI, where models will have at least one trillion parameters and their training will require significantly more computing resources. Post-training, which currently focuses more on fine-tuning, will become just as important as pre-training, and may even require more computing power.

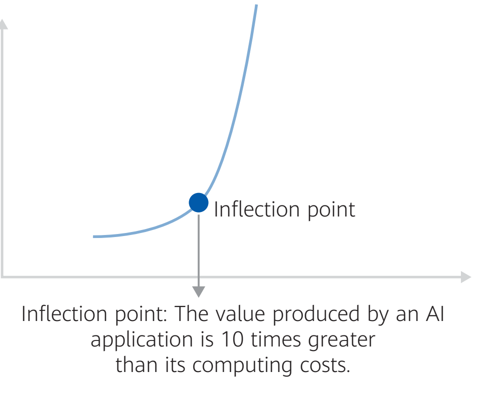
The agentic Internet will also consume a massive amount of computing power, as will edge computing and inference – far more than what's currently used for model pre-training.

We predict that, by 2035, global computing demand will reach a staggering 10^{27} FLOPS, a 100,000-fold increase from 2025.

An inflection point in computing costs: Where AI development goes off chart

Computing demand follows a non-linear growth trend, but the depth and breadth of AI development are being held back by the cost of tokens. Striking the right balance between value and computing costs is key to every AI application. Truly inclusive AI will only be possible when computing costs go down.

We propose an inflection point in computing costs: a specific point where the value produced by an AI application is 10 times greater than its computing costs. Once this point is reached, AI development will go off the charts.



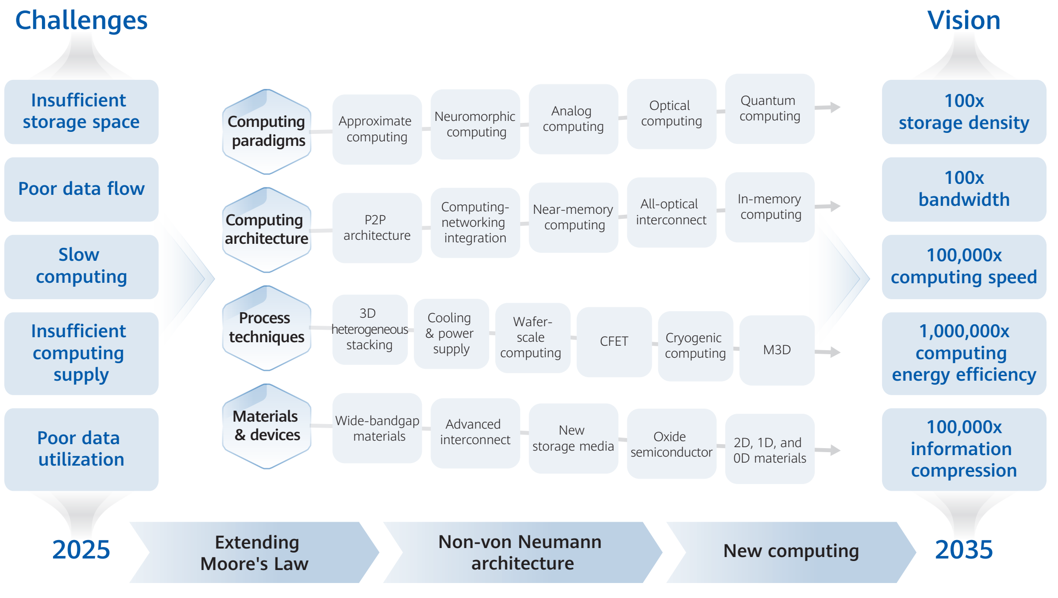
Defining an inflection point in computing costs

Rethinking computing

While future demand for computing will stretch our wildest imaginations, the cost of computing is a practical limitation that we can't afford to ignore. In particular, energy supply and efficiency are the biggest challenges we need to address.

We need to pivot towards computing paradigms that are far more energy-efficient, starting with the bottom of the tech stack. von Neumann architecture is perhaps the greatest bottleneck when it comes to energy efficiency, given its separation of memory and processing units.

Increasing the computing power of silicon-based semiconductors has proven effective for meeting computing demand. But as Moore's Law begins to plateau and demand soars over time, this approach will no longer be feasible, and costs will be prohibitively high.



New materials and devices, process techniques, architecture, and paradigms for a new computing ecosystem

The decade between 2025 and 2035 will bring historic changes in computing.

Technology-wise, the industry will first strive to extend Moore's Law. Following this, the industry will gradually phase out von Neumann architecture and come up with brand-new computing paradigms.

This evolution won't arise from a single breakthrough. It will hinge on ground-breaking innovation in four key areas – semiconductor materials and devices, process techniques, computing architecture, and computing paradigms – and forging a new computing ecosystem that's better equipped to thrive in the post-Moore age.

(a) Semiconductor materials and devices: Beyond Moore silicon

Silicon-based semiconductors will give way to alternatives that make the most of a diverse range of materials.

For example, semiconductors made of novel materials, like wide-bandgap semiconductors and oxide semiconductors, will be deeply integrated into device design. These semiconductors stand out for their thermal tolerance and breakdown field strength, making them ideal for new power and memory devices.

Low-dimensional materials, including two-dimensional (2D), one-dimensional (1D), and even zero-dimensional (0D) materials, have unique properties that can overcome the physical limits of traditional silicon-based materials. Featuring properties like quantum confinement effects and high carrier mobility, these low-dimensional materials will open up new avenues for researching and developing high-performance logic devices. They offer a fundamental solution to the scaling bottlenecks faced by conventional silicon-based devices.

(b) Process techniques: Less reliance on process nodes, more on multifaceted innovation

As semiconductors enter the sub-nanometer era, complementary field-effect transistors (CFETs) and monolithic 3D (M3D) integration will be key to pushing the physical limits of chips.

Shrinking process nodes will not be the only way to increase computing density. To pack more compute into a system, the industry is exploring engineering innovations across three major fronts:

- 3D heterogeneous integration and stacking: Vertically stacking chips/modules with different functionality and processes, to deliver a huge leap in computing density per unit space
- Wafer-scale computing: Massive "super-chips" that circumvent the limits of smaller individual chips, generating large-scale, integrated computing power
- Technologies in support of high-density stacking: Using new packaging materials and technologies like microfluidic cooling to solve challenges with power supply stability and heat dissipation in stacked chips

Additionally, new cryogenic cooling technologies that enhance computer performance in extremely low temperatures (e.g., 77K or -196° C) will help us further cut energy loss during computation and increase the energy efficiency ratio by an order of magnitude.

(c) Computing architecture: Creating memory-computing synergy

The core performance bottleneck of von Neumann architecture stems from the separation of processors and memory, which wastes energy and time as data is transferred back and forth between the two. The next evolution of computing architecture aims to solve these problems, and will progress in three distinct steps:

- Peer-to-peer (P2P) architecture: This architecture enables P2P connection between different types of processing units ("XPUs"). It's different from von Neumann architecture where XPUs are in a primary-subordinate relationship. This conventional arrangement requires centralized scheduling between XPUs, which leads to considerable losses in performance. In addition to P2P architecture, the industry can employ other technologies to maximize computing efficiency, such as computing-networking integration and all-optical interconnect for data centers.
- Near-memory computing: By moving processing units closer to memory, we can reduce the distance that data has to travel.

- In-memory computing: This allows computation to be performed directly inside memory, eliminating the need for data transfer. This represents an architectural breakthrough that removes the memory wall (namely the gap between processor speed and memory bandwidth), greatly speeding up computing and increasing energy efficiency ratios.

(d) Computing paradigms: Shifting from general-purpose to special-purpose computing

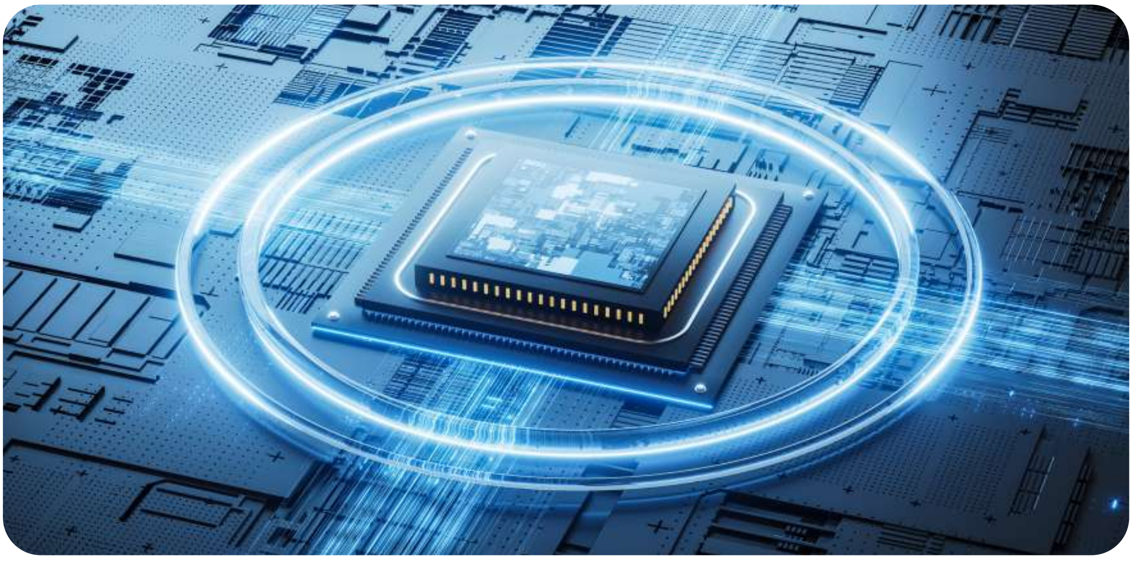
If we hope to drive exponential growth in computing power, we need to explore entirely new computing paradigms. In addition to conventional general-purpose computing, we will need new computing paradigms that are optimized for specific scenarios. For example:

- Analog computing, which is best suited for dealing with continuous variables
- Optical computing, which features high parallelism
- Neuromorphic computing, which mimics the energy-efficient information processing of biological neurons
- Quantum computing, which takes advantage of a superposition (where a qubit can exist in both a 0 and 1 state simultaneously) to solve complex problems much faster than classical computers

These computing paradigms will drive exponential improvements in computing efficiency for scenarios like AI training, scientific computing, and decryption, completely redefining the future of compute-intensive applications.

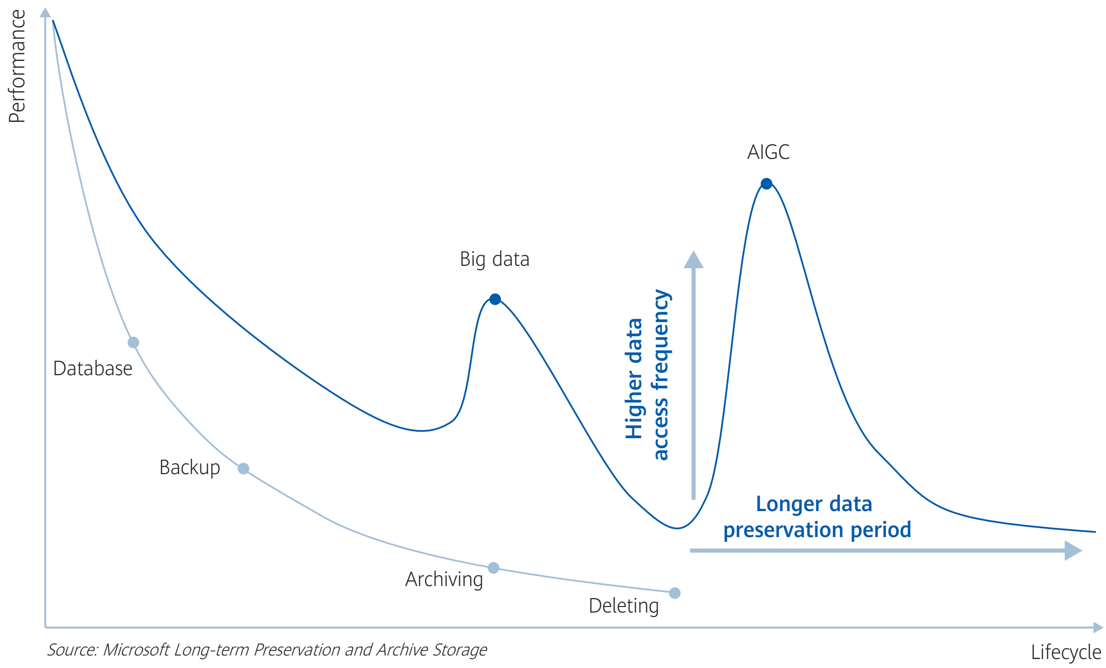
In a nutshell, the next decade will bring seismic changes in computing. Computing density will skyrocket by many orders of magnitude, giving rise to a new, post-Moore computing landscape powered by synergistic innovation in materials, process techniques, computing architecture, and computing paradigms.

In this new landscape, we will be able to circumvent bottlenecks in conventional computing technology, and take the digital economy, AI, and scientific research sectors to entirely new heights with more energy-efficient and low-carbon computing power. These will be vital for our energy-hungry world today, and for a greener, smarter tomorrow.



Data as intelligence: Paradigm shifts in storage with agentic AI

Data awakening: AI will enable long-term retention and turn cold data into warm data requiring efficient processing



Changes in data lifecycle

AI model training and inference are driving explosive growth in data access. Much of the data once considered cold data is now being reactivated, transforming into warm data, and even hot data, as it is increasingly used for model iterations and real-time inference. We forecast that by 2035, the traditional three-tier model—hot, warm, and cold data—will shift to a new two-tier architecture: a hot/warm tier and a warm/cold tier in a 3:7 ratio. This means warm data will account for more than 70% of all data by 2035. This major shift will significantly enhance data utilization, and allow businesses and civil society to unlock unprecedented value from historical data. Ultimately, data will transform from a passively stored resource into an active enabler.

In the age of AI, unlocking the value of data has become more important than ever, yet long-term data retention still poses numerous challenges.

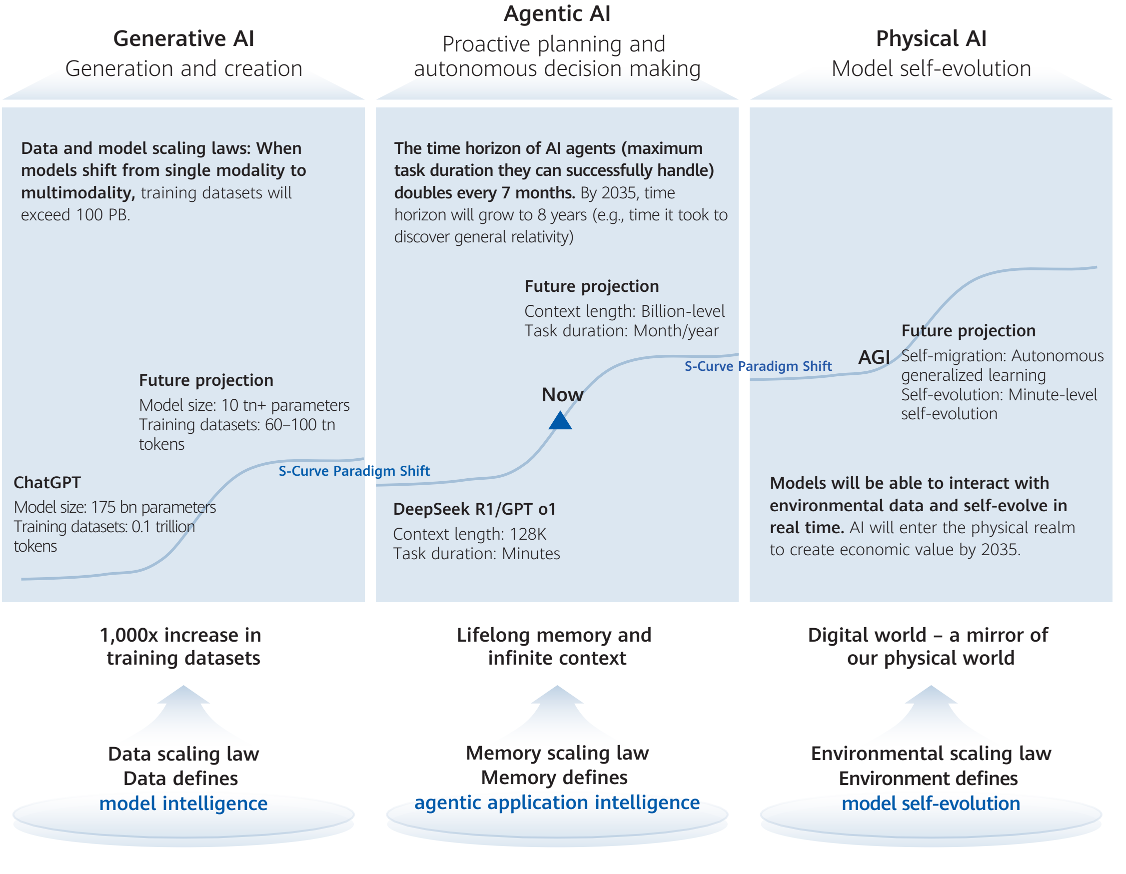
The first is cost and efficiency. There is a large volume of warm data that needs to be frequently accessed. Any delays or low throughput will directly extend model training cycles, slow down

AI agent responses, and drive up computing and time costs.

Second, data timeliness is critical. AI applications (e.g., autonomous driving and real-time decision systems) demand millisecond-level access to relevant memory and contextual data. Slow I/O operations and data processing can become severe performance bottlenecks that disrupt real-time interactions in practical scenarios.

More importantly, long-term data retention is not for data hoarding but instant insight generation. Value density and extraction speed remain a key challenge. Efficient processing means quickly locating, associating, and extracting high-value information from vast amounts of warm data, and then converting this information into model intelligence or action commands. This makes data the fuel for intelligent decision making rather than a burden on storage systems. Efficient processing of massive warm data is essential for maximizing the value of AI.

Data-driven intelligence: Data defines model intelligence, while memory defines the scope of agentic applications



Data scaling laws: Data-driven model intelligence

The development of AI models is undergoing a strategic shift from being parameter-centric to data-centric. Early Generative AI relied heavily on massive training datasets – often reaching petabyte scales – while the marginal gains from increased parameter counts have progressively diminished. In the era of Generative AI, data capabilities are primarily reflected in the scale of training data, which is growing from 0.1 trillion tokens for ChatGPT to an anticipated 60–100 trillion tokens in the future, with total training data volumes exceeding 100 petabytes.

In the Agentic AI era, data-capability requirements will evolve in three key areas:

First, AI interactions will go from being stateless to stateful, meaning a transition from reactive responses to active planning, reflection, and iteration. Such changes will enable AI to handle complex tasks on their own. During inference, model states will be continuously updated, thus requiring the storage of petabyte-scale state data and support for millions of concurrent queries. Additionally, knowledge extraction will facilitate continuous model self-evolution.

Second, AI will progress from standalone agents to interconnected multi-agent systems, where close collaboration will be essential to deliver cluster intelligence. Multi-agent task execution requires sharing task states and historical context, with data being transferable across tasks.

Third, single-session memory will evolve into continuous, cross-session persistent memory. The growth rate of personalized, lifelong memory data is expected to rise from 10 Gbit/s to 1 Tbit/s, generating hundreds of petabytes of persistent memory and enhancing the intelligence, accuracy, and generalization capabilities of Agentic AI.

In the Physical AI era, data will create a mirror of the physical world in the digital world in real time. Through frequent interaction with environmental data, AI systems will dynamically self-evolve. Rather than relying on pre-labeled datasets, AI systems will continuously refine performance via real-time perception and feedback loops.

By 2035, digital twins, embodied AI, and super agents will be widely adopted, increasing demand for AI storage by 500 times, and AI storage will eventually account for more than 70% of global total storage capacity.

The next storage paradigms: From data to knowledge

The basic paradigm of data storage is currently undergoing a profound transformation to meet the demands of AI models for data logic and semantic relationships. Traditional storage methods, based on files and objects, are struggling to meet AI's requirements for data correlation, statefulness, and adaptability. In the past, files or objects were treated as closed, static units, with storage systems primarily focused on ensuring integrity, durability, and retrievability. AI applications, by contrast, process and interpret information dynamically, contextually, and with evolving states, which is fundamentally at odds with traditional storage approaches. The future evolution of data storage will be characterized by several key shifts:

- Data correlation: AI requires a deep understanding of the complex semantic relationships within data. During training and inference, AI agents need to rapidly retrieve the most relevant historical segments for a given session. Traditional file systems store data in isolated files and directories, with semantic relationships being implied and undocumented. This means significant computing power will be needed to reconstruct these relationships each time. Future storage paradigms will embed pre-computed associations, such as key-value caches and knowledge graph triples, directly within the data to make it intrinsically contextually associated.

- Statefulness: Agents have continuous memories, and their value can largely be attributed to their evolving states, covering areas such as interaction history, task execution progress, and preferences learned from previous interactions. Conventional file systems store results, whereas AI processes must keep reading, writing, and updating states. Frequently updating state data on a file-by-file basis is extremely inefficient. Therefore, future storage system designs will need to account for finer-grained and frequently-updating states, and the systems will have to directly manage agents' memory streams.

- Evolvability: Continuous learning and fine-tuning are the standard for AI models, meaning the models' key knowledge (usually represented as "weights") constantly changes on an incremental basis. The conventional method is to store an entire replica of the model – a practice that leads to significant redundancy. Efficiently storing and retrieving weight updates is more practical, as only the changes will be stored. This approach will allow model knowledge to be managed in a leaner, version-based manner, and support rapid rollback to reduce the cost and complexity of model iterations.

The value of data is currently defined by the data volume and storage formats. By 2035, new value differentiators will be technologies that turn cold data into warm data, supply the right types of data for the right scenarios, and support semantic storage. When this happens, data will become more than just memories, but a new type of fuel that propels human progress. Storage systems will evolve from data warehouses to engines that drive AI advancements. Data, plus computing power and algorithms, will remain key pillars of our future intelligent world.

Agentic Internet: A proxy for intelligent interaction between the physical and digital realms

Agentic Internet: Hyper-dimension interconnection and in-real interaction

The type of service delivered by any kind of communications network can be a measure for gauging its social value. In the past, networks focused on voice and text services, allowing people to converse over long distances. Nowadays, networks are connecting our devices and clouds, and delivering content that gives us a superior audiovisual experience. This begs the question: What will communications networks look like in the coming decade?

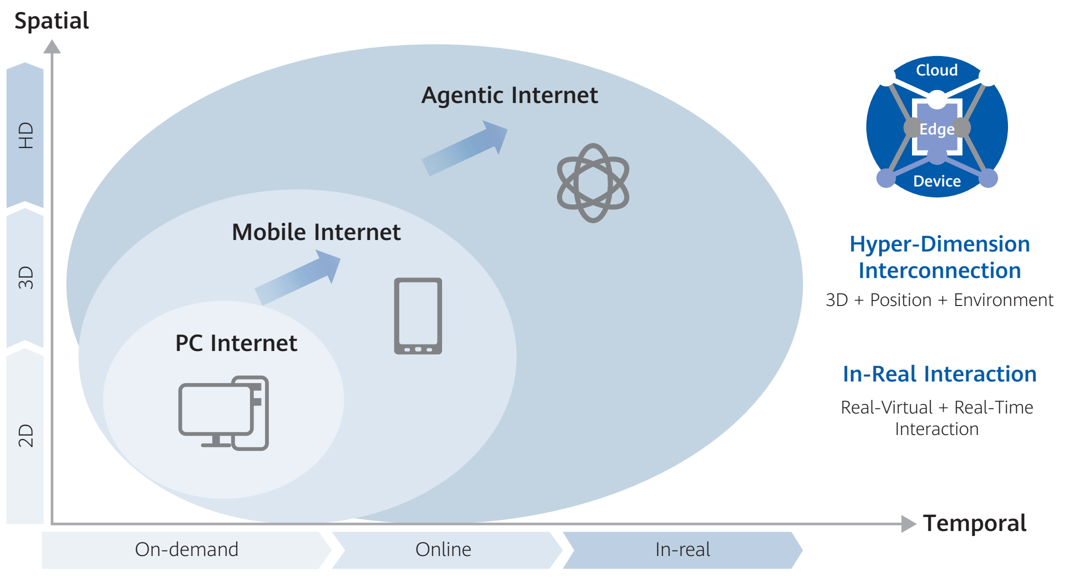
It is estimated that by 2035, the global population will reach 9 billion and be served by 900 billion AI agents. Therefore, communications networks will need the capacity to connect every person on Earth as well as a staggering 900 billion agents. Connecting these agents will require an entirely new type of network that we define as the "agentic Internet".

The industry generally agrees that PC Internet and mobile Internet have been two main Internet generations so far. PC Internet emerged in the 1970s, and mobile Internet arrived on the scene in the 2010s, each defined by the type of service it delivers.

Since 2020, there has been a lot of buzz about the definition of next-gen Internet, driven by the boom of Web3, XR, and AI. Many industry players have come up with their own definitions, including:

- Immersive Convergence and Spatial Internet, which are intended for metaverses
- Internet of Value, which is based on Web3
- Sky Computing, which enables interconnection across clouds
- Computing Internet, which links computing resources
- AI Internet, which, as the name suggests, supports AI services

When we first sought to come up with our own definition, we considered what type of service the next-gen Internet would focus on delivering. Now that we've envisioned a future world with 900 billion agents, each with unique connectivity needs, we believe that the agentic Internet will be the next big thing for communications in the coming decade.



Predictions about the next-gen Internet

To gain a clearer view of what the next-gen Internet may look like, we must distinguish it from the previous two generations in terms of spatial and temporal aspects, and content producers & consumers.

Gen	Temporal Aspect	Spatial Aspect	Content Producer & Consumer
PC Internet	On-demand	Files and images	People: Consumers outnumber producers.
Mobile Internet	Online	Rich media (2D & 3D video)	Human prosumers: People both consume and produce.
Agentic Internet	In-real	Hyper-dimension space (HD information)	Human and virtual prosumers: People and agents both consume and produce.

The agentic Internet will possess all the capabilities of the PC Internet and mobile Internet, and much more. It will enable the exchange of richer information, real-time interactions, and true-to-life experiences.

Aside from conventional multimedia content, the agentic Internet will support robots, drones, and other similar applications by using hyper-dimension information like spatial, positional, and environmental perception information. We refer to this capability as "hyper-dimension interconnection".

The agentic Internet will offer not only always-on connectivity, but also "always in-real interaction" – a new capability that will be crucial to autonomous driving, AI agents, XR, and other applications that require real-time interaction between the virtual and real realms.

Intelligent, green, and ultra-broadband networks: A hundred-fold increase in communications capacity in the next 10 years

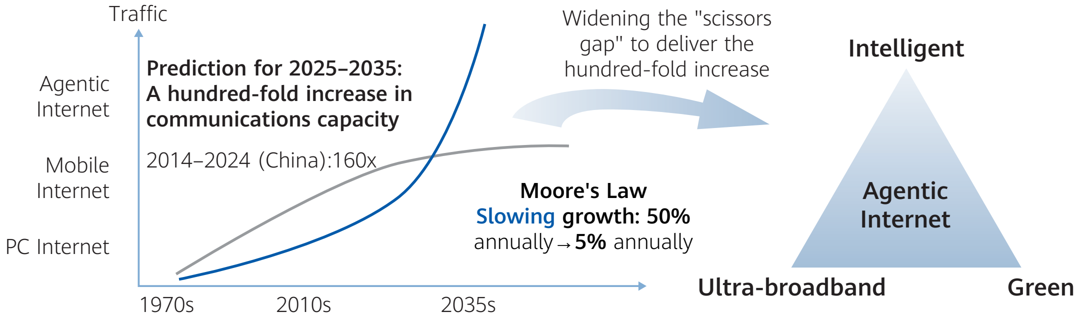
The age of mobile Internet has already been through an information explosion, with more data being generated and used every day than the day before. In China, mobile Internet access traffic grew approximately 160 times between 2014 and 2024, from 2.06 billion GB to 337.6 billion GB.

In the era of agentic Internet, agents – such as industrial controllers, robots, self-driving cars, and unmanned aerial vehicles – will need to interact with each other much faster than people do with each other and with agents. Furthermore, the information exchanged by these agents will be multidimensional, not just two-dimensional. Let's also not forget that a mirror world – a digital replica of the physical world – will churn out unfathomable amounts of data.

Considering these developments, we predict that there will be a 100-fold increase in data traffic in the next 10 years. This leads us to the vital question of whether communications networks, as they stand now, can handle this traffic surge. Shannon's Law and Moore's Law, which have steered the course of telecoms, are becoming increasingly less relevant over time. This is particular true of Moore's Law, which has just grown at most 5% annually in recent years.

Reshaping networks is key to meeting fast-growing traffic demand. The wireless, optical, and data communications sectors will need to develop innovative systems-engineering approaches if they are to build intelligent, ultra-broadband, and green networks.

These networks promise a hundred-fold increase in communications capacity in the next 10 years. However, to reap their benefits, we must innovate across the board.

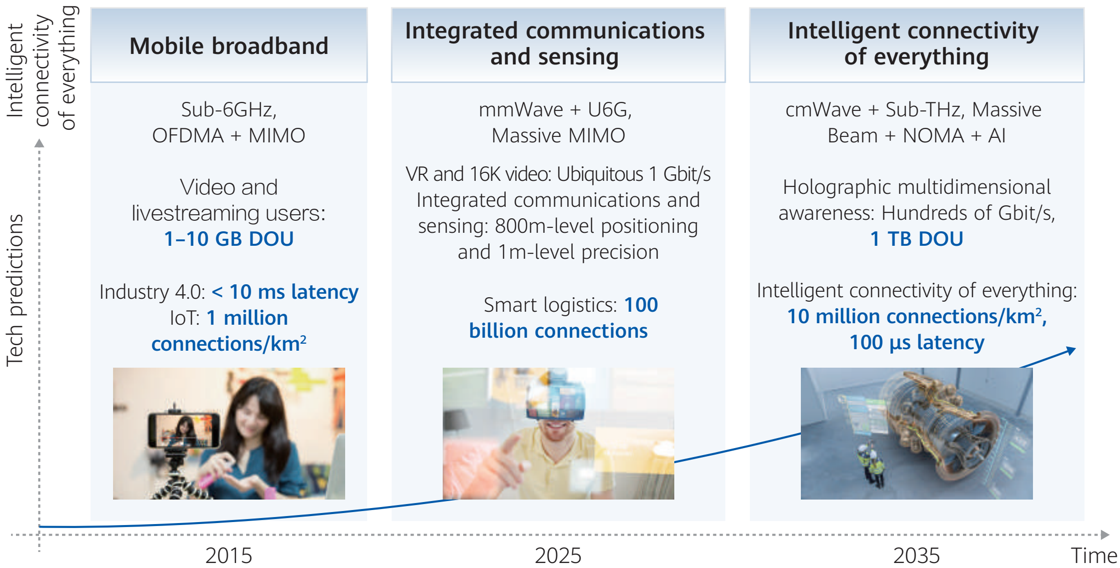


A hundred-fold increase in communications capacity in 10 years

Mobile networks: Synergizing communications, sensing, computing, and intelligence

We estimate that, by 2035, mobile networks will support 10 million connections per square kilometer with average latency below 100 μs, and that a user will consume an average of 1 TB of cellular traffic per month.

In addition to terrestrial networks, there will be cubic space networks. Therefore, deeper integration will be needed for terrestrial and satellite communications networks in terms of their architectures, standard protocols, and testing equipment. Greater efforts will be required to promote the satellite connectivity of mobile phones, and explore more satellite service models. Such actions will give rise to mobile communications networks that feature seamless global coverage, integrated satellite and terrestrial communications, and intelligent connectivity of everything.



Predictions about wireless network evolution

In-depth integration of communications and sensing: Future wireless networks will seamlessly combine communications and sensing. Supported by capabilities like multimodal sensing and environmental data collection, these networks – in tandem with digital twin technology – will deliver entirely new converged sensing services. The networks themselves will be like gigantic sensors capable of perceiving and understanding the physical world through the transmission, reflection, and scattering of radio waves.

Integrated services:
Future intelligent applications will run on the back of a synthesis of network capabilities. Over the next 10 years, wireless networks will thus provide integrated service capabilities through the synergy of communications, sensing, computing, and intelligence.

The role of wireless networks will also change. Instead of merely providing services in response to needs, wireless networks will act more like a player and enabler in the future intelligent world, underpinning applications like agent collaboration, digital twins, and even wireless charging for low-power terminals.

AI for Networks and Networks for AI: Ubiquitous connectivity of agents

AI for Networks: Future communications networks will be AI-native. By analyzing network element (NE) status data with AI, we will be able to glean the insights needed to push networks to their theoretical limits and maximize their performance. At the O&M stage, data analytics with AI and big data, and closed-loop optimization methods will take the network automation and all-scenario service capabilities to new levels.

Networks for AI: AI models are deep neural network models trained on massive datasets. Training such models will necessitate stronger network capabilities than ever before, including those of data center (DC) networking, DC interconnect, and DC access, as detailed below.

- DC networking: The industry will require a new network architecture that can link up a huge number of computing cards, dynamically schedule traffic, and automatically heal from all manner of faults. Such an architecture is what a DC will require if it is to unlock the full potential of computing power.
- DC interconnect: The industry will need the ability to reliably transmit data across intelligent computing centers that are thousands of kilometers apart, all while ensuring zero packet loss throughout the process.
- DC access: Deploying a DC access network layer-by-layer will become a preferred approach. Computing-network integration services will help businesses significantly reduce efficiency loss during inference, and flexibly scale their computing power without their data ever leaving their campus networks.

Agent interconnectivity: Agents will have multiple capabilities scattered across different locations, and they will have to work together seamlessly over communications networks. What's more, agents will have unique needs for communications: Some will need high bandwidth, some will require massive small-packet transmission, and others will need low latency. To meet such needs, the industry will need more flexible and smarter communication protocols.

Transmission networks: Intelligent all-optical networks and ultra-broadband satellite and terrestrial networks with super-large bandwidth, ultra-low latency, and high levels of reliability and security

Higher broadband speeds will be necessary to support homes, individuals, businesses, and AI training and inference. Therefore, future transmission networks will be equipped with Tbit/s-level interfaces on their access layers, while backbone networks will support 100 Tbit/s speeds over a single fiber. Furthermore, 3.2 Tbit/s interfaces for DCs will enter commercial use.

Future communications networks will support three latency circles (i.e., 1 ms within a city, 5 ms within a city cluster, and 20 ms for backbone networks) and provide availability exceeding 99.9999%. These networks will also offer enhanced security based on quantum key distribution (QKD).

Such networks will have to be designed, built, and operated in ways that account for their environmental impact and energy use, to ensure they consume less energy and emit less carbon. This will entail the application of intelligent prediction and dynamic energy conservation technologies, optical cross-connect (OXC) and DC-OXC architectures, and liquid cooling.

In 2035, optical transmission networks will support both terrestrial and satellite communications. To ensure their efficacy, satellite communications speeds will need to jump from hundreds of Mbit/s (over microwave links) to hundreds of Gbit/s (over laser links).

Satellites operating at different orbital heights will form multi-layer satellite constellations, with each layer networking through inter-satellite links. These inter-satellite links and satellite-terrestrial links will together form a cubic space network offering ultra-high bandwidth and reliability. Both types of links will be built upon technologies like laser and terahertz communications to transmit data at a minimum of 400 Gbit/s. The additional adoption of wavelength division multiplexing (WDM) will even support ultra-fast speeds of tens of Tbit/s across the entire planet.

However, to reach this point, the industry will must conduct further research into areas such as repurposing industrial terrestrial communications products for aerial applications, minimizing phased array antennas, and dynamic inter-satellite and satellite-terrestrial laser communications tracking and pointing.

Access networks: Providing super-large-bandwidth and ultra-low-latency connectivity to support deterministic AI2H and AI2B services

AI agents will serve as a building block for future smart homes and businesses, but they will require powerful networks and edge computing infrastructure offering access speed upwards of 10 Gbit/s – something only 200G PON and Wi-Fi 8 technologies can deliver.

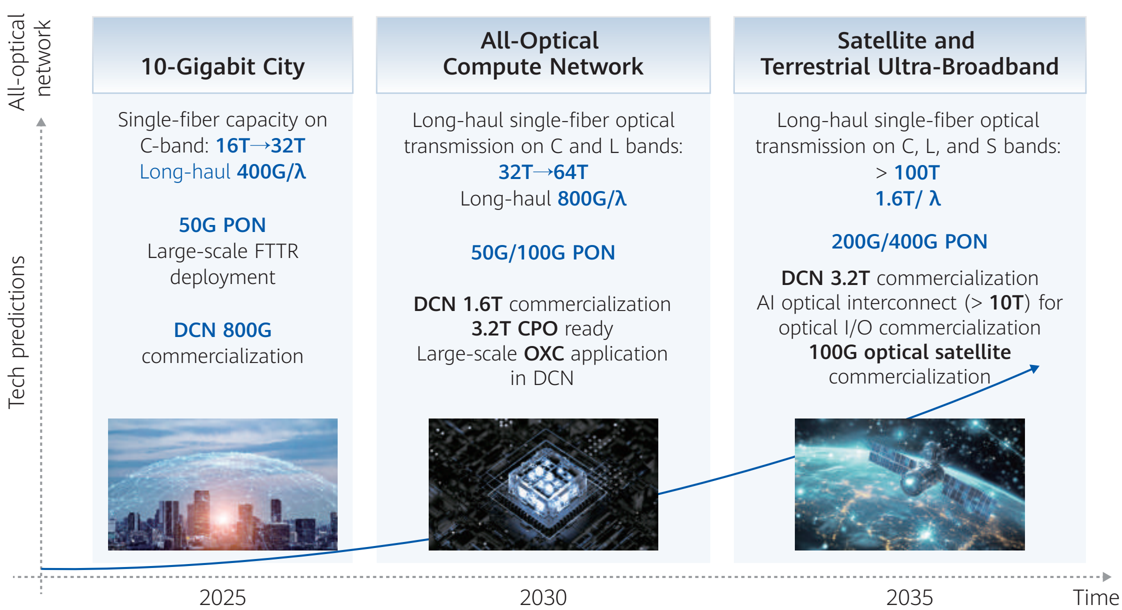
Intelligent algorithms for Wi-Fi and dynamic bandwidth assignment (DBA) will reduce Wi-Fi two-way latency to 5 ms, and PON two-way latency to 100 μs. This capability will be vital for overall communications latency and stability.

These ultra-high-bandwidth access networks will be fundamental to numerous key applications like services for AI streams, agent interaction, AR, VR, and embodied AI, providing differentiated and deterministic experience assurance.

Local micro networks: Making smart homes even smarter

GenAI apps will constantly raise the bar for device connectivity, and edge AI will permeate more scenarios. Against this backdrop, smart homes will hinge on intelligent hubs using FTTR-powered local micro networks. This network – featuring an array of technologies like Wi-Fi, NearLink, ultra-wideband (UWB), and radio frequency integrated circuit (RFIC) – will cater to every family member's unique needs for AI services while protecting their data security. The local micro network will also drive the adoption of smart services like digital home, smart audio and video, home storage, surveillance, smart entertainment control, and home care for the elderly.

Furthermore, this local micro network will see application in other scenarios where AI is expected to play a major role, such as smart office, unmanned factory, and personalized education.



Predictions about fixed network evolution

Communications infrastructure of the future: Green, low-carbon, and sustainable

Communications networks will be key to the intelligent world of 2035, connecting 9 billion people and 900 billion agents. But before networks can fulfill this role, the industry still needs to address three major challenges.

- AI technology and software: Communications networks are only set to grow larger over time, so managing them will become an increasingly complex task. We will therefore require the support of AI technology and innovative software that will make network self-configuration, self-healing, and self-optimization possible. This level of automation will help us keep O&M costs flat even as networks scale up. However, developing the right AI technology and software will not be easy.
- Protocols and algorithms: A wide array of IoT scenarios will develop, such as unattended operations in industrial and agricultural settings, end-to-end autonomous driving, eVTOL, and drones for package delivery and other logistics activities. Such scenarios will require more from communications networks, in terms of coverage, quality assurance, and security and trustworthiness. In response, we will need to develop new protocols and algorithms to ensure networks can support diverse services while meeting quality and flexibility requirements. Getting these protocols and algorithms just right will be an uphill struggle.
- Foundational technologies: Although Moore's Law has held true for decades, the semiconductor industry is now struggling to maintain the same rate of improvement. New technologies like quantum computing are not yet mature. Consequently, the industry's long-lasting endeavor to enhance computing, data storage, and network energy efficiency is stagnating. There is an urgent need for ground-breaking foundational technologies that will empower green, low-carbon networks and grow their capacity by dozens of times without increasing their energy consumption.

Solving these challenges will require a layered approach, spanning hardware, software and data.

- Hardware: The global push for green ultra-broadband is already underway, with optical technology embedded at all levels of the hardware stack, from optical fibers, optical chips, and optical computing, to optical storage, optical forwarding, and optical switching. This all-optical stack will be a key pillar for providing powerful networking and computing.
- Software: AI and new computing paradigms will be the most important elements in software progress, increasing processing efficiency by 100 times in some cases and even 1,000 times in others.
- Data: Networks will not simply connect people; they will play a fundamental role in all areas of the future intelligent world. When data planes start to self-evolve, the biggest challenge networks will face is maintaining security and trust. This includes ensuring security of both the network and data, and building mutual trust between humans and AI. Quantum encryption technology, with its ability to strengthen network security and data confidentiality and integrity, will be integral to agent communications.

The communications industry has and will continue to follow a 10-year cycle. In the decade ahead, existing and new driving forces like IP, cloud, AI, optics, and quantum communications will bring seismic changes to the industry, contributing to a hundred-fold increase in communications capacity in the next decade. Boundless possibilities await us. Yet possibility comes with uncertainty. Therefore, as an industry, let's stay together, probe forward, and make our technical blueprints a reality.

Energy tokenization: An intelligent energy nervous system

Energy technology: Approaching the inflection point in the age of intelligence

Energy is an important material basis for the survival and development of human society. Throughout the history of human civilization, energy has been behind every major step forward.

In the age of intelligence, AI will bring enormous electricity demands that may far outstrip existing plans. According to estimates from the Stargate Project in the US, hyperscale data centers will require several gigawatts of power. For this reason, companies like Microsoft and OpenAI are turning to nuclear energy. It is foreseeable that, over the next 5–10 years, power facilities and energy demands will be key constraints that hinder the rapid growth of AI. It's expected that energy technology will approach its inflection point in the age of intelligence.

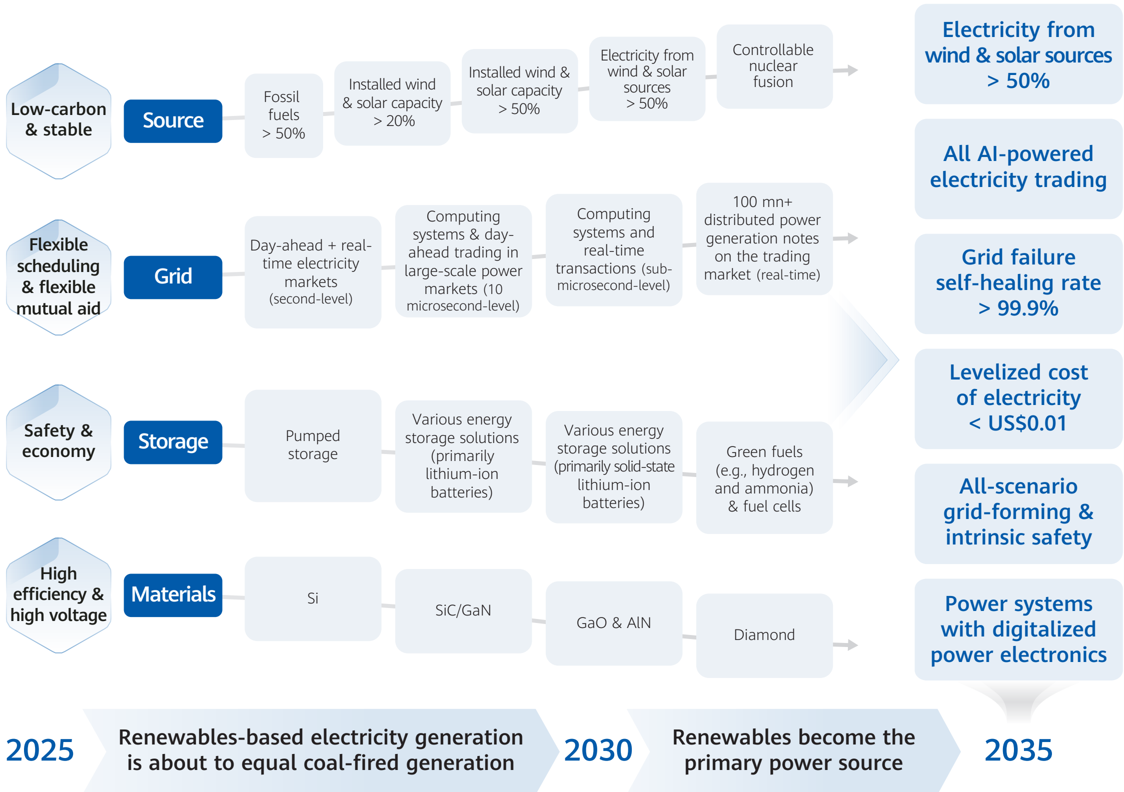
Tokens in future energy networks will become a foundational element of energy management. With AI, every joule of energy can be tokenized

and imbued with human intent. This will allow every basic component within the energy network to perceive, decide, and act. This innovation will revolutionize energy carriers. Tokenization will be a major trend for future energy networks. Tokenized energy networks, together with communication technologies (neural networks), Internet of Things (nerve endings), and blockchain technologies (memory systems), will create a comprehensive energy nervous system.

A new milestone: Wind and solar will generate more electricity than fossil fuels by 2035

As new energy technologies continue to evolve, it is projected that by 2030, the installed wind and solar capacity will exceed traditional fossil fuels. By 2035, wind and solar will surpass fossil fuels in electricity generation, becoming the primary power source. This will be a significant milestone in energy history. As the share of wind and solar power grows, it will be increasingly challenging to ensure the reliability and stability of future power systems. That's where grid-forming technology comes in. Ensuring stable power supply from renewables stands as one of the most significant technical and strategic challenges for the coming decade and beyond.

Energy storage is a major obstacle to the



The development trajectory of energy technologies

development of green energy. Currently, battery storage makes up over 96% of new energy storage solutions, with its levelized cost of electricity projected to fall to CNY0.15—lower than that of pumped storage. In the future, electric vehicles (EVs) will function as distributed energy storage systems that support peak shaving through bidirectional vehicle-to-grid (V2G) technology. Bidirectional charging through vehicle-grid integration will represent a key technological evolution.

Thermal energy storage, a crucial medium-to long-duration energy storage solution, is expected to reach a global installed capacity of approximately 500 GW by 2035. The cogeneration efficiency of these systems is projected to increase to 80%. Cold and thermal storage for power generation will act as the stabilizer for new power systems.

By 2035, the global hydrogen market is expected to reach US$1.5 trillion. This will be driven by the widespread use of hydrogen in heavy-duty truck transportation, marine shipping, and industrial fuel substitution.

Nuclear power generation has evolved to its fourth generation. Future developments are set to focus on integrating nuclear energy with renewable sources, AI-powered reactor control and output prediction, and high-efficiency steam turbine coupling.

Vision into reality: Controlled nuclear fusion and space-based energy

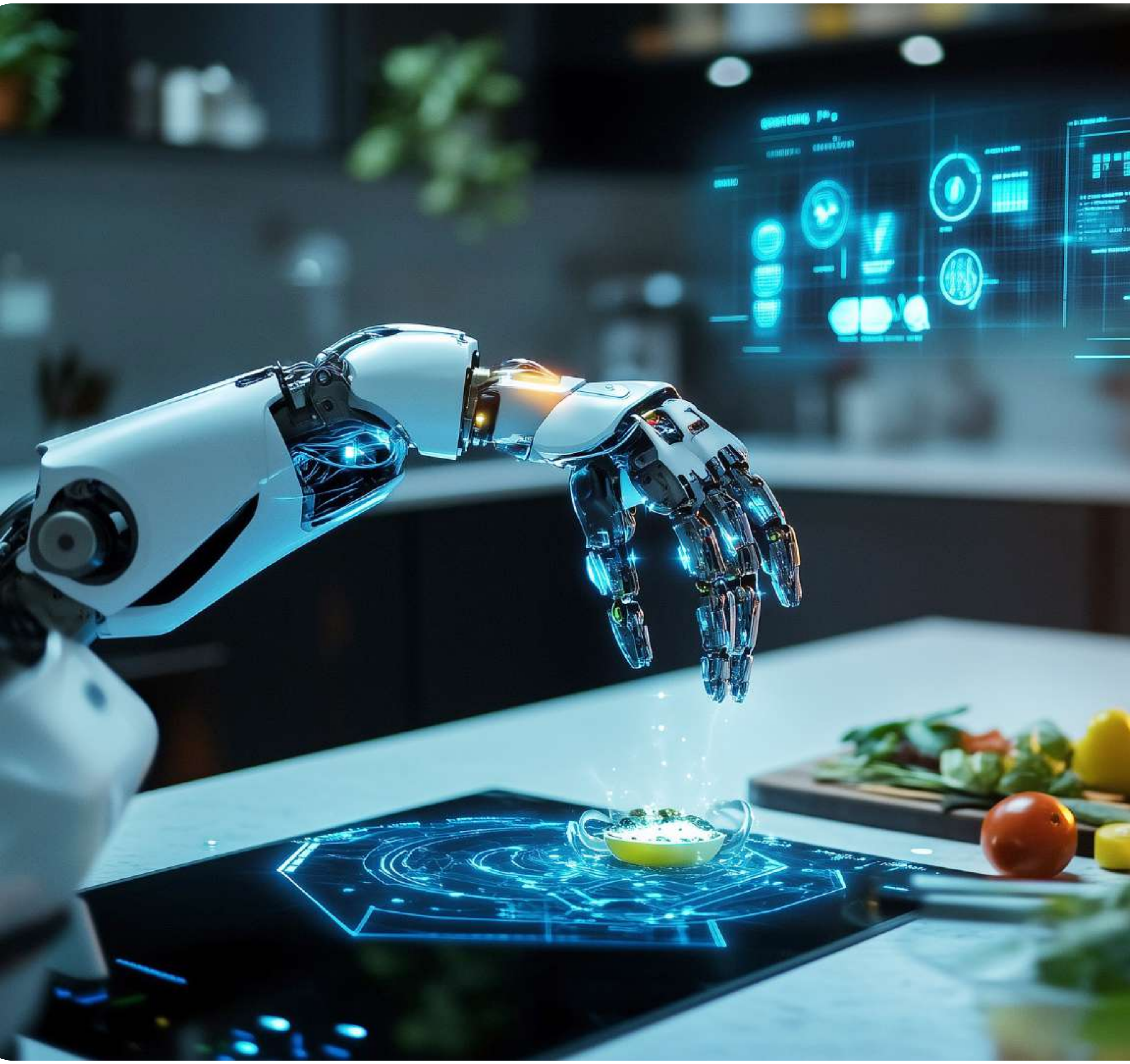
Controlled nuclear fusion has addressed fundamental theoretical challenges and is making progress in engineering experiments. It is expected to achieve breakthroughs in high-temperature superconducting magnets, plasma magnetic confinement, high-temperature cooling, and AI-empowered systems. By 2035, controlled nuclear fusion systems may be able to generate power independently. Such advancements in controlled nuclear fusion technology will mark a new level of integration between AI and energy, redefining how we generate energy.

By the end of 2025, China aims to transmit kilowatt-level space-based solar power over distances of 100 meters. Currently, this technology faces challenges like high costs and limited transmission efficiency. Future advancements are needed in areas such as high-efficiency, high-radiation-resistant photoelectric conversion materials, orbit solar power concentration, high-efficiency microwave or laser power transmission, space traffic management, and heat dissipation in microgravity. By 2035, a 10 MW experimental system is expected to be operational in low Earth orbit.

AI-driven transition: From energy network to energy civilization

As AI integrates more deeply with energy systems, tokenized energy will drive a profound transformation in energy carriers. Tokenizing renewables—primary power sources—will give energy elements greater autonomy and foster stronger collaboration between them, making energy transactions predictable. AI will rewrite energy history and redefine energy paradigms, paving the way for further integration with other sectors, including transportation, materials, industry, and space. All of this will enhance energy security, make energy readily accessible and available to all, and give humans more freedom in terms of energy.

2035 may mark an inflection point, not an end point, for energy development. It may very well serve as the starting point for the convergence of carbon- and silicon-based civilizations. AI will evolve from an energy-guzzling giant into an energy-efficient agent, laying the groundwork for humanity's transition from Earth-bound energy users to extraterrestrial consumers. This could involve energy exchanges between Earth and the Moon. An integrated energy system, powered by renewable sources, controlled nuclear fusion, and space-based energy, will provide virtually unlimited energy. This would give humans an absolute abundance in energy resources, driving civilization toward even broader horizons in the cosmos.



Succeeding with AI

Transforming industries and everyday life

Throughout history, technology has proven its true value and driven productivity gains only when seamlessly integrated into real-world applications. Over the next decade, AI will be increasingly adopted across industries and everyday life, contributing to better quality of life, more efficient businesses, and a more sustainable environment.

Healthcare: Computing health to prevent disease and improve quality of life

As we enter the third decade of the 21st century, we are witnessing a paradox of longer life expectancy but insufficient healthy lifespans. In 2025, global life expectancy at birth approached 74 years,[1] but WHO analysis shows that over the past 20 years, the gap between life expectancy (total lifespan) and healthy life expectancy (lifespan lived in good health) has widened to an average of 9.6 years.[2] In other words, the average person will spend nearly a decade living with illness or disability, with chronic noncommunicable diseases like cardiovascular disease, diabetes, and cancer accounting for more than 70% of global deaths.[3] By 2035, the population aged 65 and above will exceed 1.1 billion.[4] This will continue to drive growth in demand for chronic disease management, rehabilitation, and long-term care. These trends are forcing healthcare systems to shift from a disease-centered model toward a comprehensive health management model.

In 2035, for preventive healthcare, sensors and wearables will enable real-time perception and prediction of individual conditions, allowing risks to be handled at their nascent stages. AI-driven prediction and intervention methods will be expected to help prevent more than 80% of chronic diseases, significantly extending healthy lifespans. For disease treatment, multimodal AI will integrate medical imaging, genomic testing results, and electronic medical records to provide physicians with personalized diagnostic and therapeutic recommendations. Meanwhile, AI-driven drug development and virtual clinical trials will dramatically shorten the time-to-market for new drugs and allow patients to find the optimal drug combinations faster. For rehabilitation management, immersive rehabilitation equipment and remote monitoring platforms will turn homes into recovery spaces, while community healthcare provides continuous tracking and care. For long-term care, intelligent caregiving and community health networks will provide physiological monitoring and emotional support for elderly and chronic care patients, enhancing both quality of life and social connectedness.

Through these interconnected innovations, healthcare in 2035 will no longer be passive disease treatment, but a foundational capability of humanity. This will enable us to transition from extending life expectancy to enhancing quality of life.

Token-driven health management: Empowering individuals with health sovereignty

The deep integration of AI models and human health is transforming health management by redefining its basic units. Personal health management is becoming structured, intelligent, and real-time to enable precise recognition, continuous modeling, and dynamic prediction by AI. In future health management, each individual's health will be broken down into quantifiable, computable digital health elements. These elements will form a dynamic health map that spans physiological, behavioral, psychological, and environmental interactions. Humanity will reimagine its relationship with health and allow every individual to see, understand, and control their health.

Snapshot from the future: Integrated health system for proactive sensing and intelligent intervention

By 2035, health management systems will be built on ubiquitous sensing networks and intelligent algorithms. Tens of billions of healthcare-related IoT devices will continuously capture multimodal data, including ECG, blood glucose, respiration, sleep, emotion, and environmental indicators. These data will be processed at the edge and converted into standardized health units, which will serve as the basis for prediction and intervention, with dynamic holographic health profiles generated for every individual.

More advanced still, health management will enable us to know and manage health from birth.

From the moment a child is born, their genomic sequencing, prenatal maternal–infant environment, and family medical history can be used to generate a personalized risk map, which is then integrated with postnatal data to form a lifelong health baseline. AI can identify cardiovascular high-risk groups in infancy and prompt early intervention, or provide preventive recommendations in adolescence for conditions such as hereditary myopia and hyperglycemia, thereby maximizing the delay of disease onset.

In this system, AI is no longer a passive analytical tool, but an active guardian. Powered by multimodal transformer models, it can simultaneously process images, physiological signals, vocal emotions, and behavioral data to detect subtle changes in individual health trajectories. Causal reasoning enables AI to identify the underlying factors affecting health, rather than merely looking at surface correlations. The reinforcement learning mechanism of this system allows AI to continually update the methods and frequency of reminders through interactions with users, making interventions effective and suited to individual habits. For example, UK-based company Cera, in partnership with the National Health Service (NHS), has developed AI models and tools that can predict the hospitalization risk of elderly patients seven days in advance. This has reduced hospitalization rates by around 52%.[5] The tools can also detect patent fall risks with an accuracy of 97%.[6]

Healthcare will transform from a passive treatment chain into a proactive health network jointly built by humans and AI. Families and communities will act as the first line of defense, while hospitals will be able to focus on complex and critical cases. This will enable healthcare to shift from reactive treatment to daily health protection. It will also reduce the risk of chronic disease progression and decrease the incidence of major illnesses. To support this system, platforms need to greatly enhance their capabilities, including meeting rapidly growing demands for computing power, ensuring robust data security and privacy protection, and reducing connectivity latency for mission-critical IoT applications by 2035 to levels tens or even hundreds of times lower than today.

AI-based collaborative diagnosis and treatment: Precise decision making for each and every treatment

By 2035, AI will be deeply integrated into life sciences, driving a major shift in the healthcare industry from disease control to precise cures, and reshaping how diseases are defined, identified, and treated. AI will play a particularly significant role in terms of tumors, rare diseases, chronic diseases, and autoimmune diseases. It will no longer serve just as an auxiliary tool, but will greatly contribute to the identification of diseases and design of treatment plans.

Snapshot from the future: Identifying diseases before symptoms show

By 2035, many diseases will be accurately screened and diagnosed by AI at hospitals before symptoms set in. During health checkups or outpatient services, the AI-based collaborative diagnosis and treatment system will analyze images, genetic data, lab test results, and physiological monitoring information in real time, effectively detecting any early signs of diseases.

For example, when a male patient who seems to be in good health comes to see a doctor, AI would be first invoked to analyze his holographic health records before any other action is taken. If the system identifies small shadows in images taken from CT scans of his lungs, it will perform a correlation analysis of the suspicious mutations recorded in the patient's genetic test. Following this, AI will immediately generate an alert about the risk of lung cancer and recommend further examinations.

In this scenario, AI no longer simply provides doctors with a second opinion – it actively participates in the diagnosis and treatment process and possesses the ability to detect risks early on.

Such advanced diagnosis capabilities will be achieved through AI's in-depth modeling and inference of multimodal medical data. AI will be able to make decisions on single-point examination results, and predict trends in disease progression based on images, pathology, vital signs, and genetic information, helping doctors make intervention decisions earlier. This will mean that diseases can be detected before any symptoms show.

As AI application occurs on a larger scale, the infrastructure requirements of the healthcare system will undergo fundamental changes. The role of AI will drastically evolve from simple sensing and assistance to an intelligent decision-making hub. AI will see extensive adoption across numerous healthcare activities such as multimodal diagnosis and treatment, disease prediction, treatment path optimization, individualized modeling, scientific research simulation, and automated drug screening. The increased application scale and model complexity will drive an exponential growth in computing power and storage demand. Future hospitals will not simply be physical locations that provide medical services. More importantly, they will deeply integrate scientific research with clinical practice, with intelligent computing and data management at their cores.

Driven by a jump in computing power and storage capacities, as well as the integration of multimodal data, there will have been a significant shift in the diagnosis model by 2035, identifying risks in advance instead of waiting for symptoms to set in. Diseases will be identified before patients show any symptoms, which will help to buy precious time for them to receive the treatment they need. It will also help the healthcare system reduce misdiagnoses and missed diagnoses, decrease the proportion of patients suddenly learning of diseases or finding themselves in critical condition, and significantly slow down disease burden accumulation. This means that AI will empower the healthcare industry to advance from reactive treatment to proactive prevention, making it truly possible to identify diseases before symptoms appear.

Snapshot from the future: Personalized intelligent healthcare – Precise decision making for each and every treatment

In 2035, every patient's treatment plan will be generated at hospitals through customized, data-driven decision making, without following a single one-size-fits-all approach. After a patient is diagnosed with a disease, the intelligent diagnosis and treatment system will invoke relevant databases containing massive amounts of data about different demographics as well as the genetic, pathological, and lifestyle information about the patient, and create a unique treatment path. Even if patients have the exact same disease, their treatment plans may vary greatly due to their own specific conditions. The healthcare industry will usher in an era where personalized treatment plans are provided for each patient.

This transformation will be attributed to the implementation of health data programs worldwide and the in-depth application of foundation models. One example is the All of Us Research Program launched by the US National Institutes of Health, which has collected data about the genomics and health of nearly one million participants and laid a solid foundation for precision medicine.[7] By 2035, relevant data will have been integrated into medical AI models. As a result, patients' genetic risks, environmental factors, and lifestyle choices will be fully considered during clinical decision making, making treatment more scientific and targeted.

In clinical practice, AI will become an important partner to doctors. It will be able to integrate pathological slides, genomic sequencing results, vital signs, medical records, and imaging examination results, and conduct inference under a unified framework. AI will tell doctors what conditions patients are in, and simulate what might happen if different treatment plans are adopted. It will quantitatively evaluate the efficacy and side effects of all available treatment plans, and present the results in a visualized manner. Doctors and patients will then be able to intuitively understand the corresponding trade-offs. For complex cases, the recommendations provided by AI may even go beyond the scope of existing guidelines, proposing more targeted innovative therapies based on special genes or metabolic characteristics.

The role of AI will even extend to new drug R&D. When dealing with a difficult case, AI will not only help select existing drugs that may prove to be effective, but also search available omics data based on molecular characteristics. It will be able to identify potential disease targets and recommend experimental therapies, so that a new drug could be developed for a particular patient. Ultra-large-scale computing power and high-speed networks will closely connect scientific research institutes, hospitals, and pharmaceutical companies, and edge-cloud synergy will ensure efficient molecular simulation, virtual drug screening, and clinical trials. All of this will greatly reduce the time from scientific research to drug application.

In summary, by 2035, the healthcare industry will see breakthroughs in both R&D and clinical practice. Diagnosis and treatment plans will no longer follow certain set standards, but will instead be generated by doctors and AI through dynamic and precise decision making. These plans will cater to individual differences and make treatment much more effective and safer.

Snapshot from the future: A closed-loop AGI-powered diagnosis and treatment system through human-machine collaboration

By 2035, AGI will become the core decision engine of the healthcare system. It will enable a shift in diagnosis and treatment from an experience-led model to a precision-based, collaborative system. In this system, diagnosis, treatment recommendation, and efficacy feedback will no longer be separate from one another. Instead, they will be a continuous closed loop jointly enabled by AI and doctors, with each treatment based on the most comprehensive and up-to-date evidence.

In clinical diagnosis, AGI will no longer be simply an assistant for image interpretation. Instead, it will integrate medical records, images, genomic data, and real-time monitoring data to generate dynamic health profiles for patients. When treating complex diseases, doctors will be able to derive etiology inference, risk assessments, and prognostic predictions from the multimodal analysis of AGI. This will help them identify things like lesions earlier and more accurately. Not only will this reduce diagnostic errors, it will lay a foundation for subsequent treatment plans.

AGI will become a collaborative designer for treatment recommendations. It will be able to search for the latest global research and clinical guidelines in real time, and provide doctors with multiple treatment plans for comparison based on the individual characteristics of patients. Unlike the current static recommendation systems, AGI will continually adjust treatment plans as patients' conditions change. For example, in cancer treatment, AGI will be able to dynamically optimize dosages and the course of treatment based on patient drug responses and changes in biomarkers. It will even predict drug resistance risks in advance and propose alternative therapies. Doctors will then make decisions on proposed treatment plans, balancing medical judgment and humanistic care.

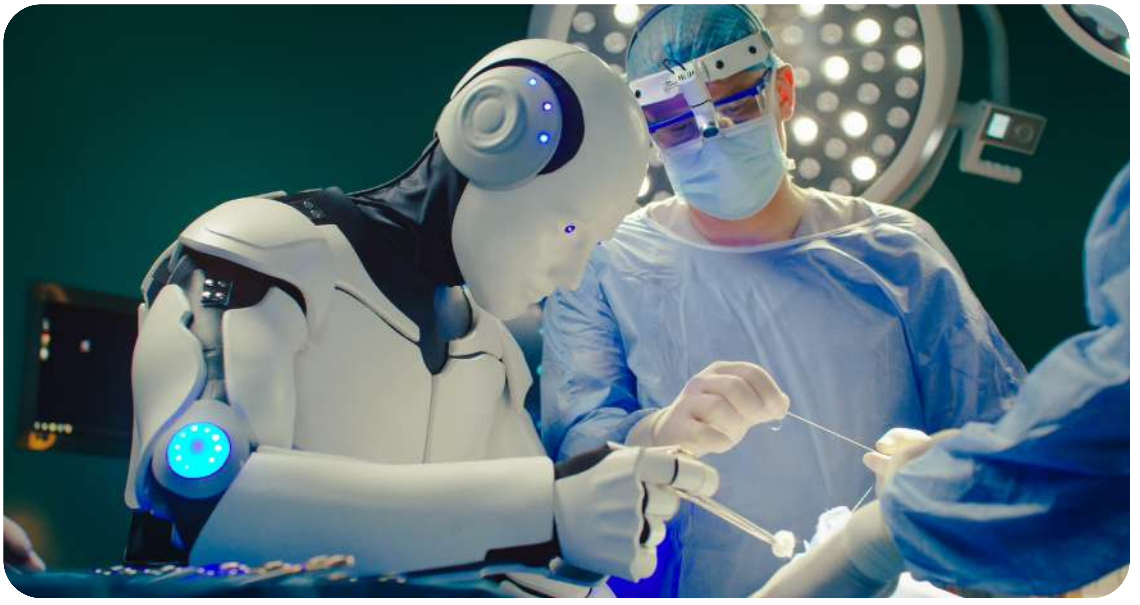
In long-term disease management, AGI will work with doctors to track patients' conditions. Patients with chronic and autoimmune diseases generate massive amounts of continuous data, which is difficult to process promptly with traditional methods. AGI will be able to identify subtle but critical trends in these data, detect disease turning points early, and push intervention recommendations. This will help doctors adjust treatment plans earlier, preventing acute deterioration or long-term side effects.

The essence of this model is human-machine collaboration. AGI is responsible for information integration and intelligent inference, and doctors are responsible for value-based judgment and individualized medical decisions. AGI will neither replace doctors nor undermine the value of clinical experience. Instead, it will free doctors from the burden of data, allowing them to focus more on communication, decision making, and innovative treatment.

Silicon-based healthcare: Enabling life to flourish

By 2035, our health will be less like conditions we passively accept and more like capabilities we actively cultivate and expand. The focus of healthcare technologies is shifting from curing diseases to optimizing life. These cutting-edge technologies, which include companion robots for the elderly, in-body sensing systems for early intervention, brain-computer interfaces for cognitive extension, and AI-assisted decision making, collectively form a health ecosystem that spans different age groups, transcends time and space, and continually evolves.

In this ecosystem, robots will not simply provide assistance in the form of passive response. They will proactively offer solutions to help users with their emotions, cognition, and care decisions. AI will no longer be just a background algorithm,



but a personal assistant for close collaboration. In-body intelligent systems like nanobots and intelligent drug delivery devices will serve as the embedded nerve endings of healthcare, monitoring and automatically repairing the body in real time. The healthcare system will evolve from single-point interventions to continued protection. Healthcare will be extended beyond clinical settings into the body and daily living environments. We will be able to design, coordinate, and extend our health with precision.

Snapshot from the future: Human-machine symbiosis from treatment to evolution

By 2035, healthcare will not only be about curing diseases, but expanding the boundaries of human capabilities. This transformation will stem from technological breakthroughs in human-machine collaboration, brain-computer interfaces, bionic augmentation, and more. Next-generation high-bandwidth, low-invasive brain-computer interfaces will enable real-time reading and writing of neural signals, allowing the brain to directly control prosthetics and external devices. In rehabilitation centers, paraplegic patients will be able to use interfaces to control intelligent prosthetics that allow them to stand and walk again. In clinics, visually impaired patients will be able to regain part of their sight with the help of electronic retinas. During rehabilitation training, stroke patients will be able to manipulate robotic arms with their minds, enabling neural regeneration. Healthcare will shift from merely repairing deficiencies to enhancing and reshaping human capabilities.

This enhancement will go beyond restoring mobility. It will extend across sensory and motor domains. In the motor domain, exoskeletons and wearable devices will enhance load-bearing capacity and endurance and reduce workplace safety risks. In the sensory domain, electronic retinas, bionic ears, and tactile feedback devices will gradually bring vision, hearing, and touch closer to—and even beyond—their natural limits. Research shows that the resolution of next-generation artificial retinas has been close to that of human eyes. Bionic systems for touch and balance are also evolving rapidly. Healthcare is entering a new phase—one that focuses on the continual enhancement of human perception.

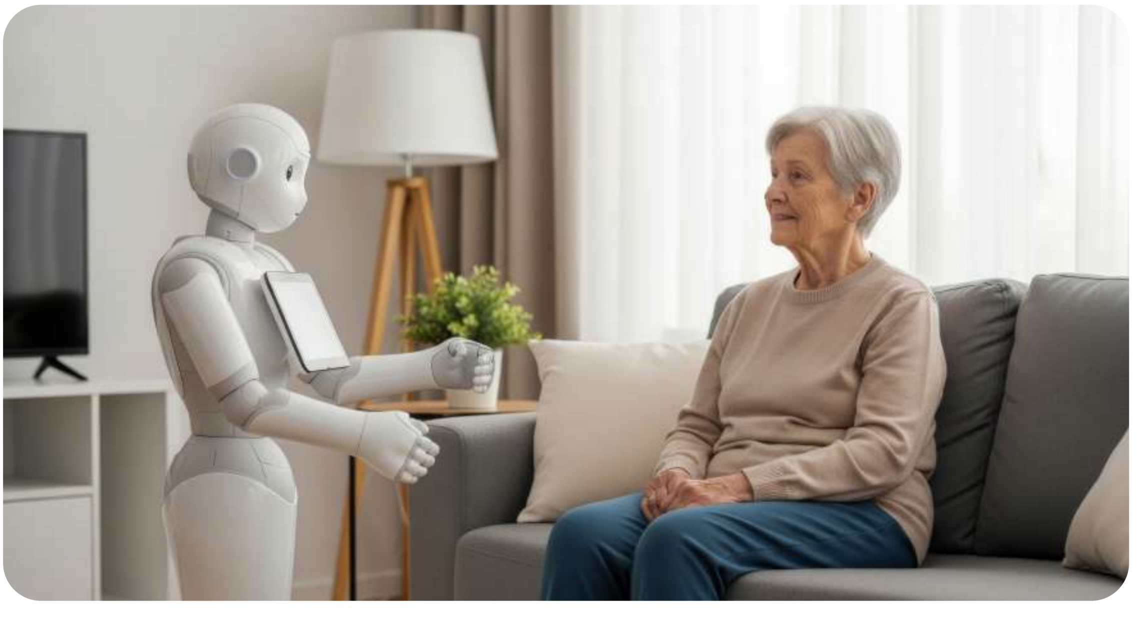
The wide adoption of brain-computer interfaces will present unprecedented challenges for ICT. In the future, high-channel sampling in the milliseconds will process hundreds of thousands of neural signals at the same time. This will require nearly 1,000 times more bandwidth than what we have today. We will need ultra-high-speed links, edge computing, and intelligent compression technologies to ensure low-latency interaction.

As these enhancement technologies mature, our healthcare service models will transform. Healthcare will no longer be confined to disease treatment. Instead, it will expand to include functional optimization and the realization of human potential. The boundary between health and illness will gradually be blurred, forming a continuum spanning from recovery to enhancement.

Snapshot from the future: A microscopic repair system at the subcellular level

By 2035, the treatment of disease will entail refined micro-repairing at the cellular and molecular levels. Doctors will be like skilled mechanics maintaining precision instruments. Instead of through surgery, tumors will be treated with an injection of medical nanobots—intelligent devices smaller than cells. Guided by ultrasound and magnetic fields, these nanobots will navigate the bloodstream to the precise location of the tumor and then release drugs to kill the cancer cells before disintegrating in the body. This treatment will be virtually imperceptible to the patient and can be completed in the outpatient area.

This type of technology will be applied to the treatment of many diseases. For example, bioresorbable acoustic microrobots can target tissue using acoustic and magnetic forces, and can be used for real-time ultrasound imaging and therapeutic drug delivery. These inflatable acoustic microrobots have been tested in vivo in mice with bladder tumors. The tests demonstrated the effectiveness of microrobots for real-time imaging and delivery of anticancer drugs to cancerous tissue, which shrinks tumors.[8] With breakthroughs in material science and control technology, by 2035, microrobots will be like cellular scalpels for doctors, commonly applied to processes like cerebrovascular clogging clearance, complex infection control, and immunotherapy.



The growth of micro-healthcare is reshaping the concept of health. Soon, we will no longer need to wait until organs begin breaking down to save lives. Instead, we will be able to proactively repair human "parts" when "faults" occur. The role of healthcare will shift from remediation to prevention and from one-time treatment to continual maintenance. These quiet operations in the molecular world are profoundly changing the health trajectory of human beings and making life safer and more controllable.

Snapshot from the future: Health preservation entering the design phase, where robots are preserving life for the elderly and chronic disease patients

On an early morning in 2035, an elderly person living alone wakes up to find that their companion robot has prepared breakfast recommendations and a health plan for the day. Through a bedside sensor, the robot has detected that the elderly person did not get enough sleep the night before, so the robot warmly reminds them to take a nap in the afternoon. The robot then helps them prepare breakfast, reminds them to take their medicine, and plays their favorite music.

This is becoming common for the elderly and chronic disease patients. AI is no longer limited to hospitals as it enters households as a smart housekeeper. A health band worn by the elderly person collects their blood pressure, heart rate, and blood sugar data in real time. If the robot detects that they have not had enough exercise, it will advise them to take a walk outside, and send their data to a community doctor for regular health assessment. The robot can also identify emotional fluctuations. When it detects that the elderly person has been alone for a long time or there are signs of depression in their voice, it will initiate a conversation with them or advise them to have a video chat with their family members and friends. On special occasions like holidays, the robot will remind their family members to arrange visits or online reunions. Research has shown that this type of intelligent companionship significantly improves psychological health and willingness to take medication for the elderly. For example, ElliQ, a companion robot developed by Intuition Robotics, can communicate with users, remind them to take medication, and help form healthy habits. This can significantly improve quality of life and psychological health for elderly people living alone.[9]

The home care revolution is supported by the convergence of multimodal perception and large model AI platforms. Equipment like smart mattresses and wearable health patches continuously collect physiological and environmental data. Using personal data, AI health brains can detect slight changes, predict risks, and formulate personalized policies. As the "body" of AI, robots can implement AI decisions in life by executing specific tasks like voice reminders, goods delivery, and rehabilitation training. We are witnessing a shift from hospital-centric health management to family-centric health management, and it is predicted that by 2035, more than 60% of daily medical interventions will be able to be done at home, with hospitals only needing to handle complex critical illness.

Intelligent healthcare is being upgraded from a part of the healthcare system to an essential part of people's lives. AI and robots are slowing the prognosis of chronic disease and aging, enabling the elderly to live happier and more dignified lives at home under good care. When the burden of illness is eased by technology, longevity will no longer mean long suffering, but long golden years during which life can be enjoyed and human potential can be realized.

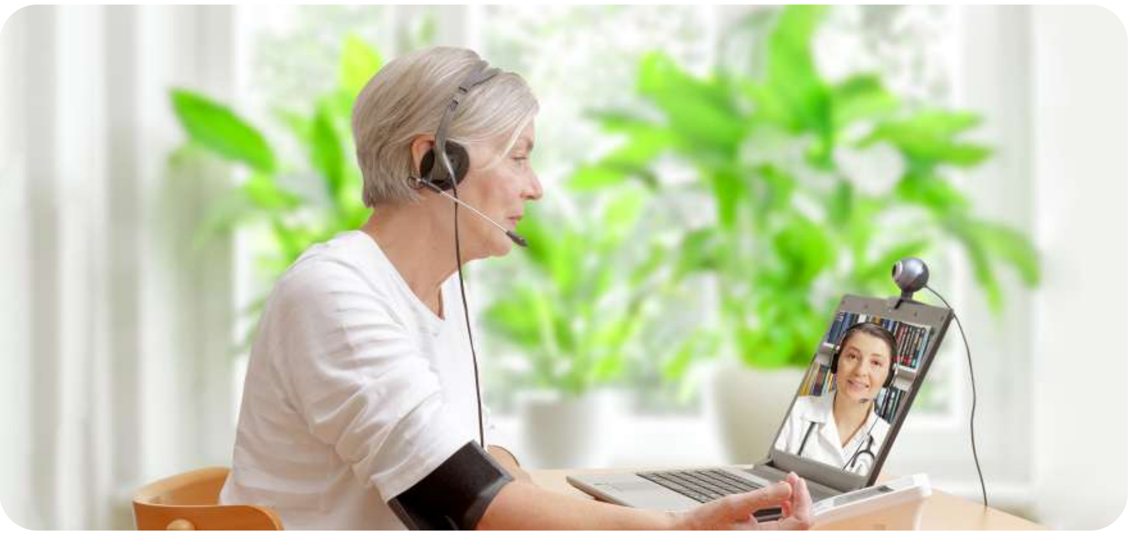
Boundless healthcare: Making quality healthcare accessible to all

By 2035, healthcare will no longer be confined to in-hospital services but become as accessible as public infrastructure, such as water, electricity, and telecommunications. It will emerge as a fundamental capability to support health for all. Healthcare services will transcend the limitations of space, resources, and organizations to form a ubiquitous, intelligent, and interconnected system that provides reliable services to every individual right at home.

Snapshot from the future: Accessible quality healthcare beyond spatial limitations

In 2035, hospitals will no longer be the only setting for healthcare services. With the help of AI and virtual reality, a ubiquitous healthcare network running through both the virtual and real worlds will make healthcare accessible to all. People will be able to have face-to-face conversations with holographic doctors simply by entering a virtual diagnosis and treatment room at home or at the office. In this virtual room, patients will receive all manner of healthcare services, from consultation and examination to rehabilitation guidance. Healthcare will break through the constraints of physical space and become truly ubiquitous. This is already becoming a reality in some places. The Virtual Wards piloted by NHS in the UK is able to provide hospital-level care to patients in their own home, especially for patients with respiratory diseases and heart failure.[10] The Virtual Wards have now proven effective at alleviating hospital bed shortages, improving patient satisfaction, and reducing the length of hospital stays. Despite financial and technical challenges, these Virtual Wards have been incorporated into the country's health plan, laying a foundation for intelligent healthcare in the future.

In smart cities, households will serve as distributed healthcare nodes. Each household will be equipped with an intelligent health terminal connected to a country-level health cloud, with modules for vital sign monitoring, voice interaction, and imaging integrated. Whenever a household member feels unwell, a home AI assistant will retrieve their health records for preliminary assessment. If necessary, the assistant will take them to a virtual diagnosis and treatment room for consultation with a remote doctor and automated access to medication. With high-speed networks and edge computing, people can enjoy hospital-level care without leaving their homes.



Under this model, communities will become the center of healthcare services. Most common illnesses and chronic diseases will be managed within communities, and visits to large hospitals will become a rare occurrence. Healthcare resources will be actively extended to reach every individual, enabling convenient channels for people with rare illnesses, or those in need of psychotherapy or rehabilitation care. This will create a more patient-centered health ecosystem. With all these advantages, remote interaction will also have significantly higher requirements on information and communications technology. For example, immersive diagnosis and treatment will require ultra-HD live audio/video, real-time AI assistance, digital human interaction, and multimodal concurrency. Ultra-low latency, high concurrency, and intelligent scheduling need to be realized at the foundational layer. We will need a comprehensive upgrade of computing power, network, and storage to achieve this type of boundless healthcare.

Snapshot from the future: The healthcare system as an intelligent backbone of society

By 2035, the healthcare system will no longer be a reactive service system but an intelligent infrastructure embedded in the operational framework of cities. Similar to power grids and telecommunication networks, healthcare will become one of the foundational infrastructures of countries and cities, addressing everyone's health needs sustainably, equitably, and intelligently. Hospitals, clinics, pharmacies, rehabilitation centers, and even home terminals will be connected to a unified smart health platform. In the event of an influenza outbreak, the system will provide real-time data analysis and coordinate medicine and outpatient processes. When emergency resources are in short supply, ambulances and hospital beds nearby will be immediately scheduled based on this platform to ensure patients receive treatment on time.

This system will use open and transparent data for healthcare and public services. By 2035, most cities will have healthcare infrastructure like real-time data networks that cover medical services, disease control, and emergency response. This will enable collaboration across sectors. One such application already in place is the Virtual Command Center jointly developed by Cleveland Clinic and Palantir. AI autonomously manages the allocation of beds, personnel, and surgical procedures based on real-time data, significantly improving efficiency. These platforms will become a standard setup for smart healthy cities in the future.[11]

The healthcare system of 2035 will be able to dynamically manage the global health trends and coordinate the availability of resources based on the healthcare infrastructure. In places with large aging populations, the system will proactively strengthen screening, scale up emergency response resources, and enhance rehabilitation services. In places with heavily burdened young populations, more mental health resources will be invested. Home health terminals will be synchronized with city-level health clouds, ensuring uninterrupted services from in-hospital diagnosis and treatment to community follow-up and home monitoring.

Globally, policymakers are paving the way for robust healthcare infrastructure. The Global Initiative on Digital Health (GIDH) released by the United Nations called on countries to recognize the digital healthcare network as one of the essential infrastructures for countries and to move beyond experimental projects towards full-scale digital transformation.[12]

As the healthcare system evolves into intelligent infrastructure, health services will become more accessible and forward-looking. Whether in urban or rural areas, everyone will be seen, understood, addressed, and protected under the intelligent system. Healthcare resources will not be limited by geography or social standing and will be integrated into all levels of society, contributing to a healthier and more equitable future for all humankind.

Conclusion

It is predicted that by 2035, ICT will be reshaping the healthcare system. The amount of computing power required by a city-level healthcare AI computing platform is expected to surge from PFLOPS to EFLOPS or even hundreds of EFLOPS. In some cities, the amount may approach ZFLOPS. The demand for storage capacity will also expand from PB to EB, and in some cities to ZB to accommodate the explosive growth of images and genetic and multimodal health data around the world. In terms of network capabilities, remote healthcare services will have moved far beyond 8K video transmission and will be advancing towards ultra-HD live video, real-time AI reasoning, digital human interaction, and multimodal signal concurrency. The per-session bandwidth requirements will increase to the Gbit/s range, reaching tens of Gbit/s. End-to-end latency will be reduced to less than milliseconds to support real-time immersive consultations, critical healthcare IoT, brain computer interfaces, etc.

As these foundational capabilities continue to evolve, healthcare services will undergo a fundamental transformation in organizational logic. Patients will no longer need to make frequent visits to hospitals. Instead, they will be able to access precise health monitoring and medical support in their daily lives through wearable devices and cloud connections. The real-time collection and AI-based intelligent analysis of multisource data will enable a shift from experience-driven to data-based diagnosis and treatment. Doctors will use healthcare AI models to develop dynamic, precise, and personalized solutions for each patient. Healthcare will transcend hospital boundaries and be integrated into our everyday lives. It will become more widely accessible and use intelligent tools to improve the quality of diagnosis and treatment for the benefit of all.

Education: Human-machine collaboration to help everyone grow

Equality and quality have been two of the biggest buzzwords in the global education sector over the past decade. According to the United Nations Educational, Scientific and Cultural Organization (UNESCO), 110 million more children and youth entered school in 2024 than in 2015,[13] and there would be an urgent need for 44 million more primary and secondary teachers worldwide by 2030.[14] This shortage of teachers not only affects the accessibility and quality of education, but also exacerbates educational inequality. According to the 2024 National Education Development Statistical Bulletin released by China's Ministry of Education, the country's average nationwide student-teacher ratio had reached about 15:1,[15] and the Organization for Economic Cooperation and Development (OECD) reports that many developed countries have achieved ratios even lower than this.[16] High student-teacher ratios and onerous workloads hinder educational equity and development within the education sector. This makes it hard for teachers to fully invest in personalizing lesson plans for students without burnout and makes it difficult for students to access quality educational resources.

To address these challenges, many have begun exploring how to apply AI to education, particularly since the release of recent AI models like ChatGPT. This direction has proven an important path for education transformation. China's State Council has released guidelines on the implementation of an AI Plus Initiative that suggests a more effective study approach powered by AI. This includes integrating AI to every aspect of the teaching process and creating intelligent study partners and teachers through human-machine collaboration. The goal of this direction is to shift the focus of education from knowledge transfer to skill improvement. As personalized teaching plans begin to scale, we can expect to see more quality and equity in education. However, this direction will also need us to build an intelligent interactive study model for each major AI application scenario, to provide more options and resources for self-study and ensure broader AI adoption.[17]

Teacher-centric teaching models and rote learning approaches used widely in the Asia-Pacific region often limit students' critical thinking and creativity, and prevent deeper understanding of course materials.[18] To address this issue, UNESCO has emphasized the need to rebalance relationships between people in classrooms, with the planet, and with technology. They advocate a departure from teaching approaches that spoon-feed students information, in order to focus on students' ability to analyze critically and solve complex problems.[19]

By 2035, AI is expected to be deeply integrated into education, creating a new human-machine collaborative model for talent cultivation and self-study. This will make teaching resources more widely accessible through new ICT channels, which will help compensate for shortages of on-site teaching resources, like teachers. As a result, quality education will be more accessible, promoting educational equality across urban and rural areas. AI-powered teaching models will cater to individual students, better addressing their self-study needs and allowing teachers to better tailor their teaching approaches. This more intelligent teaching environment will offer more interactive experiences and intelligent services, moving away from spoon-feeding teaching methods. Overall, the optimization of teaching resources, novel teaching models, and intelligent teaching environments powered by ICT, especially AI, will enhance education equality and quality, and better address the needs of personal and societal development.

AI-aided transition from passive learning to active exploration

The American cognitive and educational psychologist Jerome Bruner posited that, "Students are active learners in the education process, constructing their own knowledge as they grow rather than simply being imparted knowledge from teachers and professors."[20] This idea resonates with our future approach in the age of AI, where AI will not just serve as a tool, but an intelligent study partner of students. Multimodal data analytics will be able to more accurately identify students' learning requirements, and AI-aided Socratic dialog will help students become more active learners. Self-adapting learning path planning and dynamic feedback systems will also help systematically break the barriers of passive learning, driving a shift from passive imparting of information to active exploration, thus achieving personalized study and unleashing their potential.

Snapshot from the future: Personalized AI study assistants for active learning

Personalized AI study assistants can customize learning paths for students and guide them to find appropriate resources based on their immediate needs or long-term goals. The personalization, dynamic interaction, and real-time feedback mechanisms of these systems will ignite students' drive to learn and help them formulate study plans to achieve desired study outcomes. In self-directed learning scenarios, such system will build a closed-loop ecosystem that links precise recommendations, self-directed learning, and efficiency enhancements using multi-dimensional data modeling and cognitive science theories. These systems can then collect learning data in real time, analyze potential requirements through intelligent models, and automatically recommend suitable resources, exercises, and challenges for learners to tackle.

AI assistants can dive deep into learners' interest profiles and cognitive preferences, to provide supplementary information that can foster a new passion for learning. AI assistants as study partners, rather than teachers, can provide ongoing support to learners based on their own interests and goals, and help them decide what, where, and how to learn.[21] Using natural language processing and image recognition technologies, assistants can capture implicit interest signals from learners' browsing behavior, such as high dwell times on images of outer space galaxies or frequent notes on plots for sci-fi stories. Based on this, assistants can dynamically build interest models and recommend learning content tailored to the specific learner. Knowledge acquisition will no longer be a passive imparting of information, but an active, interest-driven exploration.

These assistants will also be able to use AI agents and multimodal data analytics to recommend content for learners to study in order to overcome areas of weakness. This will be a more efficient approach to guided learning, for example, with the system making real-time recommendations based on data, like test answer accuracy, homework completion times, and knowledge mastery, collected before, during, and after class. Intelligent analytics models can also help identify students' weak points. For example, if a student struggles with certain concepts from their mathematics course, the intelligent assistant can dynamically generate and recommend targeted learning resources, from study materials to quizzes.

Snapshot from the future: Socratic dialogue for independent thinking

AI technology can be used to encourage Socratic dialogue that provides dynamic, targeted discussions that promote critical thinking and deep reflection on the user's current knowledge and points of view. Instead of directly providing accurate answers to a user query, this approach helps the users identify contradictions and errors in their thinking themselves, leading to a deeper understanding of certain truths. This process is another way to ensure knowledge is not acquired through passive imparting, but through active critical thinking. How does AI actualize Socratic dialogue? By using large language models to break down original questions into sub-questions and then answer these sub-questions until there is enough information to address the original questions. Like a critical thinker, AI can ask itself different questions to elicit intermediate reasoning steps and resolve complex inferential problems.[22]

An AI-driven Socratic dialogue assistant can more precisely identify a learner's cognitive blind spots and guide self-correction through progressive questioning, fostering a mindset of "independent thinking". Existing research indicates that Socratic chatbots significantly outperform standard chatbots when it comes to cultivating active learning and critical thinking.[23] For example, when a student realizes their code is inefficient, they can turn to the AI, not for a direct solution, but to receive support as they analyze the issue themselves. The support is provided through progressive questioning that helps the student more deeply evaluate the reasoning underlying their own code and independently identify programming flaws. This kind of interaction encourages students to actively participate in the knowledge building process from start to finish, and reinforces their logical deduction and problem-solving skills through hands-on practice.

Personalized guidance for every student from AI teachers

As AI, 5G, 6G, virtual reality (VR), augmented reality (AR), and Internet of Things (IoT) technology continue to evolve, intelligent twins of teachers will become widely accessible, bringing significant potential for new teaching formats and improved teaching outcomes. These AI teachers will be able to more accurately capture and analyze student data, generate fine-grained teaching plans, and provide targeted tutoring. Virtual avatars of human teachers will make remote real-time classes available to students, regardless of where they are or the time of day. They can also address unique educational needs that are difficult to achieve in a physical environment.[24] By working alongside human teachers, these AI teachers can ensure that students have access to instruction whenever they need, forming a high-quality closed loop for teaching activities before, during, and after classes.

Snapshot from the future: Synergies between human and AI teachers for targeted instruction

In the upcoming intelligent world, both human and AI teachers can work together to nurture talent while leveraging each other's strengths. This is expected to become common practice in the education sector. While human teachers will remain the primary decision makers when it comes to how to teach, AI teachers will provide instructional advice that makes their jobs easier.

AI teachers will be able to take over onerous tasks like courseware generation and grading, allowing human teachers to focus on critical activities that require in-depth instruction, emotional communication, and value orientation. For example, if an AI teacher finds that students are struggling with logical reasoning while grading their homework, the human teacher can organize debates to foster critical thinking. If the AI teacher identifies a class that is demonstrating poor teamwork skills, the human teacher can organize projects to strengthen collaboration. Current research shows that AI-powered virtual teachers can significantly reduce the time spent by human teachers on grading and repetitive Q&A sessions, which improves operational efficiency in education.[25] Teachers currently spend 20% to 40% of their work time on activities that could be automated using existing technology.[26]

Intelligent twins of human teachers will have the ability to analyze student progress during study periods and provide robust support for large-scale personalized instruction. IoT sensors and computer vision technology can generate real-time reports on student's homework performance and learning curves, and AI teacher systems can compile dedicated teaching plans for each teacher that can be adjusted to individual students accordingly. This dual teacher approach will free human teachers up from tedious administrative tasks, so they can implement more refined and personalized teaching methods.

For instance, if an AI teacher identifies a student that takes longer than average to correctly complete geometry proofs, then the AI teacher can suggest to the human teacher that the student may be relying on rote memorization without understanding the underlying concepts of the unit. The human teacher can then step in during the very next class and explain the correct problem-solving approach to the student. This is how an AI teachers can supplement human teachers' teaching experience with their data analytics capabilities, making tailored and targeted teaching more accessible for more students.

Snapshot from the future: AI teachers for on-demand tutoring

Intelligent twins of teachers will also be able to provide one-on-one tutoring and instruction for students more flexibly than human teachers, allowing teaching to occur outside classrooms and school hours. They can facilitate self-paced learning, provide on-demand explanations of complex course concepts, guide students through step-by-step problem-solving, and serve as a practice partner.[27] This gives students the opportunity to ask a "teacher" questions and receive the guidance consistent with that given

by a human teacher any time they need. This flexibility can spark a new desire to learn and makes private study more effective. It also creates more touchpoints that AI teachers can use to analyze student feedback and study progress, and automatically send alerts on blind spots to either their human teacher or the student themselves, along with recommended study materials. The availability of an on-call 24/7 virtual teacher for each student makes learning easier and faster.

Intelligent twin and holographic technologies also help address uneven distributions of teaching resources by making the knowledge and experience of seasoned teachers available to all. The intelligent twin of a seasoned teacher can create a virtual replica of the teacher that reflects their actual teaching behaviors, knowledge systems, and teaching styles. If additionally equipped with emotional support technology, these AI teachers can track students' moods and provide encouragement, empathy, or questions for thinking as needed.

Learning without bounds: Intelligent twins of classrooms provide easier access to knowledge for students

Experiential learning will be a very important part of future education.[28] By 2035, intelligent classrooms are expected to evolve into intelligent twin classrooms, leveraging immersive technologies such as holography, VR, and AR to provide more vivid and intuitive teaching experiences. These advancements will not only spark students' interest in learning but also improve their learning efficiency. For instance, immersive technologies will be able to enable students to experience digital content in both physical and virtual spaces. Without the constraints of a physical space, these technologies will create more opportunities for collaborative projects and hands-on practice tailored to the needs of children at different stages of the K-12 education system.[29]

Snapshot from the future: Hyper-realistic teaching for immersive experiences

In the future, intelligent twin classrooms will bring hyper-realistic virtual experiences to life, making classroom teaching more interactive and engaging. Immersive technologies can be used to create vivid representations of knowledge that help students more quickly and easily retain new information. Real-time VR and AR teaching modules will augment the physical world by reproducing immersive teaching methods, which will also make learning more fun.

For example, primary school teacher Leticia Ahumada used immersive technologies to deploy game-based teaching activities in her classroom, which resulted in increased student engagement. One of her students remarked that it felt like they weren't just studying history, but living it.[30]

Hyper-realistic virtual teaching can increase student interaction and engagement by providing hands-on experience in more scenarios. Technologies like VR and AR can also simulate high-risk or challenging experiments, that allow students to standardize their activities and deeply understand experiments, without bearing any additional risks. This affordable and repeated approach can be particularly useful for simulated teaching in fields like surgery.

Conclusion

By 2035, advanced ICT will become a major driver of educational transformation and will reshape the entire education ecosystem. AI will be deeply integrated into all aspects of the education process, taking the education sector to new heights.

At that point, more than one billion students worldwide will have intelligent study partners; 50 million intelligent twin teachers will assist in teaching; and over 80% of intelligent classrooms will be upgraded to intelligent twin classrooms. To provide these intelligent services, digital and intelligent infrastructure for the education sector will all need significant upgrade. For a school or area with 10,000 students, computing power demand will increase by 680 times to 68 PFLOPS, network bandwidth will increase 500 times to 500 Gbit/s, and storage demand will increase by 850 times to 68 TB.

Mobility: Experiencing a mobile third space

As 2035 approaches, urban transportation is undergoing a fundamental transformation. The focus of mobility services is shifting from just providing efficient movement to enabling personalized travel experiences that create both value and joy. Driving factors behind this transformation include the emergence of Mobility as a Service (MaaS) platforms and the adoption of new modes of transportation like robotaxis (autonomous taxis) and air taxis. These new technologies are shaping a seamless and intelligent transportation network for the future.

Currently, we need to choose from a range of mobility options, including the metro, buses, and ride-hailing services, based on time, cost, and route considerations. However, in 2035, mobility services will be scenario- and experience-based and provided through MaaS platforms. These platforms will become a "super portal" that aggregates all possible mobility options, and serve as an intelligent agent that truly understands user intents. This new "super portal" will be able to create custom solutions including transportation, entertainment, and office services, based on each user's schedules, preferences, and even current emotional states.

New modes of transportation like robotaxis and air taxis (UAM/eVTOL) will play a key role in this experience-oriented transformation. Robotaxis will create a mobile third space that offers so much more than traditional cars. For example, a robotaxi can serve as a mobile office where you can take a morning meeting on your way to work. It can also become a mobile entertainment room on weekends, making your family journeys more enjoyable. With robotaxis, you will be able to use the time you currently spend on a boring commute to do more valuable things, such as working or spending time with family.

Air taxis, represented by eVTOL (electric vertical take-off and landing) aircraft, will provide a new option for urban mobility. When you need to quickly cross congested urban areas to attend an important meeting, MaaS platforms can arrange a trip combining robotaxi and air taxi travel to guarantee seamless mobility, turning hours of ground travel into just a dozen minutes of air travel. This will not only significantly improve efficiency, but also give users a bird's eye view of beautiful cityscapes.

By 2035, the goal of mobility services will be making every journey a meaningful and valuable part of life, rather than just transporting people from point A to point B. Through intelligent scheduling by MaaS platforms and innovative modes of transportation like robotaxis and air taxis, mobility will be redefined as a new life experience that can be designed to be enjoyable and empowering.

Seamless, intelligent, and sustainable transportation networks for more convenient and efficient mobility

By 2035, with deepening urbanization, megacities worldwide will need to address challenges related to surging mobility demand and aging populations, while also striving to achieve carbon neutrality goals. Fortunately, various innovative transportation solutions are emerging, including highly-autonomous vehicles (Level 4/5), urban air mobility (UAM) aircraft, and super-fast hyperloops. In this era, single modes of transportation will no longer be able to meet complex mobility demand. Instead, a super hub that integrates all transportation resources—MaaS platforms—will become the foundation of urban transportation systems. This super hub will profoundly change the transportation landscape by adopting a range of cutting-edge technologies and integrating with other urban facilities.

Snapshot from the future: Seamless commuting

To address the challenge of serious congestion during peak hours, MaaS platforms will provide one-click mobility services. This will require cloud-based urban digital twins that continuously simulate traffic conditions, as well as AI and quantum computing engines that can find the best solutions for millions of users and vehicles.

After you subscribe to the service, the platform will automatically dispatch an autonomous shared vehicle to your doorstep in the morning, based on your schedule and predicted traffic patterns. The vehicle will drive along a dynamically-adjusted route sent from the cloud in real time through networks with peak speeds as fast as 100 Gbit/s. When the vehicle takes you to a vertical airport (vertiport) in the neighborhood, a shared eVTOL aircraft will be waiting for you. This seamless mobility service that eliminates wait times for passengers will be made possible by collaborative communications with an end-to-end latency of less than 0.5 milliseconds between the vehicle, the eVTOL aircraft, and the vertiport. The aircraft will fly across congested urban areas in just 15 minutes. Then at the landing site, you will see another autonomous vehicle that will take you to the final destination. In addition, you will not need to wait or pay multiple times during the entire process. This will significantly improve commuting efficiency and experiences.

Snapshot from the future: Inclusive mobility for all

Facing the challenge of aging populations, MaaS will provide highly-customized, accessible mobility solutions. For example, senior citizens can use speech recognition functions to easily book a vehicle equipped with automatic seat lifts and health monitoring devices. To ensure safety, the interaction between vehicles and road infrastructure is crucial. When a vehicle approaches an intersection, it can contact road side units (RSUs) through vehicle-to-everything (V2X) technologies to request longer green lights. Then RSU edge compute nodes with up to 1 PFLOPS of processing power will immediately process the request and adjust the traffic light. The entire interaction can be completed within 0.5 milliseconds, ensuring both efficiency and safety.

MaaS platforms can also be connected to healthcare systems to automatically plan and schedule rehabilitation therapy trips. This will rely on an Internet of Things (IoT) with over 10 million connections per square kilometer. Through this IoT network, vehicles, users, medical equipment, and other urban facilities will be closely connected to provide accessible public services for all residents.

Snapshot from the future: Integrated passenger and cargo transportation

To help achieve carbon neutrality goals, MaaS platforms will integrate passenger and cargo transportation networks to reuse resources based on traffic patterns. Autonomous vehicle fleets that serve passengers during the day will turn to support cargo logistics at night. They will automatically drive to logistics centers to load packages and then deliver them to storage lockers in target communities. The scheduling hub for this model will be a city-wide, cloud-based control platform with a storage capacity exceeding 100 exabytes. The platform will use AI to analyze vast amounts of historical and real-time data to accurately predict passenger and cargo transportation demand in different regions, and send instructions to millions of vehicles. This model, with central scheduling, can significantly reduce the total number of vehicles on the road and cut carbon emissions.

In 2035, MaaS will not be just an application that integrates different modes of transportation. Instead, it will provide an operating system for human-centric urban transportation based on AI and digital twin technologies. In the coming years, it will be able to address transportation challenges and make our cities more efficient, equitable, green, and vibrant.

Vehicles with Level 4/5 autonomy: Creating intelligent mobile third spaces and reshaping urban transportation

By 2035, robotaxis, which are currently being used on a trial basis, will play a key role in global urban transportation ecosystems. Their market size will rise to trillions of US dollars, disrupting the traditional mobility service industry. Compared to current B2C ride-hailing services, robotaxis will be run with diverse business models and deeply integrated into other mobility services.

There are several potential mainstream models. First, through a public-private partnership (PPP), robotaxis can complement public transportation facilities like metro and buses to solve the last-mile problem in public transit. Second, they can be used to provide enterprise customers with custom solutions for employee commutes and business travels. Third, original equipment manufacturers or leading operators can build Vehicle as a Service (VaaS) platforms through which third parties can operate standardized robotaxis and relevant O&M systems to provide more diverse services.

The large-scale commercialization of robotaxis will require leapfrog advances in autonomous driving technologies. By 2035, Level 4 autonomous driving will become common in most urban built-up areas and highways. Some leading smart cities may have even begun to deploy Level 5 autonomous vehicles that are capable of handling all driving scenarios. To make that happen, we need three kinds of technology.

- Deeply-integrated, multi-dimensional perception: Vehicle-mounted sensor systems will not be a simple combination of LiDAR devices, cameras, and millimeter-wave radars. Instead, relying on front-end data preprocessing and feature-level image fusion powered by deep learning algorithms, these systems will possess precise perception capabilities to adapt to all speeds, directions, targets, weather conditions (including heavy rain and fog), and scenarios (such as complex urban streets).

- Predictive, interactive decision-making: Instead of passively responding to instructions, robotaxis will be able to think and make decisions like humans. V2X networks will support such decision-making by providing overall traffic information and precise behavior predictions of surrounding traffic participants. As a result, robotaxis will always be able to find the best route, in terms of safety and efficiency, when driving alongside pedestrians and other vehicles.

- Solid redundant safe systems: Robotaxis will need a full set of closed-loop safety systems, from dual backup hardware designs to zero-trust cyber security frameworks, and to real-time remote takeover systems on the cloud for continuous safety assurance. This will allow robotaxis to achieve nearly 100% reliability.

In 2035, driven by mature business models and strong technological capabilities, robotaxis will give rise to a range of disruptive applications, and turn vehicles from a mode of transportation into a mobile third space.

Snapshot from the future: Personalized mobile spaces

Commuters may subscribe to "office cabins" where they can smoothly connect to secure networks to join video conferences on their way to work. Young people may book "entertainment cabins" to enjoy immersive audio-visual gaming experiences. Family may opt for "parent-child cabins" equipped with interactive games and child safety monitoring systems. By enabling these quality work, entertainment, and rest experiences, robotaxis will reshape mobility patterns and allow us to make full use of our times on the way, which have often been wasted to date.

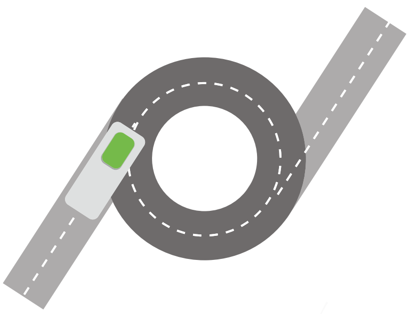
Snapshot from the future: Dynamic public services with real-time responses

In addition to commercial operations, robotaxis will also be widely adopted in urban public service systems. For example, after being connected to urban healthcare systems and equipped with smart diagnostic equipment, robotaxis can serve as "mobile clinics" to provide basic health check-ups to senior citizens with mobility issues at their homes, and then transmit data to community doctors in real time through high-speed networks. During emergencies, robotaxi fleets can be easily scheduled and dispatched to provide pressing public services, such as drug delivery and personnel evacuation, becoming agile terminals of urban emergency response systems.

Snapshot from the future: Real-time retail and services on the go

Robotaxis will create new channels for offline retail and services. For example, when users are about to get off work, they may book robotaxis with "mobile fitting rooms" on e-commerce platforms. Then they can try on new clothes and return those they don't like right on their way home. Food companies can turn robotaxis into "mobile cafes" to provide hot meals at the time and location specified by users. In this way, the shopping pattern will shift from "people finding commodities" into "commodities delivered to people", which will significantly improve shopping experiences and efficiency for consumers.

In summary, by 2035, robotaxis will not be just a mode of transportation. They will have evolved into powerful intelligent mobile terminals that make up an unprecedented urban service network and profoundly change our living spaces, work patterns, and lifestyles.



Conclusion

By 2035, the share of passenger miles traveled (PMT) in private cars will drop by about 15%. Meanwhile, MaaS will become a mainstream platform for mobility services in 80% of key cities across the EU, increasing commuting efficiency by 15%–30%. MaaS will be able to smoothly schedule new modes of transportation like robotaxis and air taxis, and provide personalized and enjoyable travel experiences to reshape mobility patterns. The focus of mobility services will shift from just providing efficient movement to enabling quality travel experiences that create both value and joy.

It is predicted that by 2035, each connected vehicle will require stable bandwidth of 100 Gbit/s and a decrease in end-to-end latency from around 10 milliseconds to sub-milliseconds. The number of IoT connections per square kilometer will reach 10 million, and both vehicles and roadside facilities, including traffic lights and sensors, will become intelligent connected nodes. The edge computing power of modern roadside facilities will increase by two orders of magnitude to reach 1 PFLOPS, and the amount of data that needs to be stored on urban cloud, including data from the driving logs of millions of autonomous vehicle, sensors, and vehicle-to-grid (V2G) power transactions, will leap from petabytes to 100 exabytes.

Diets: From eating enough to eating healthy

As the lifeblood of humanity, food is critical to every country. As outlined by the United Nations in the *State of Food Security and Nutrition in the World 2025* report, about 673 million[31] people around the world are currently afflicted by hunger, and 512 million people could be chronically undernourished by 2030. Food security remains a formidable long-term challenge.

Looking ahead, more and more people will shift from simply eating enough to eating healthy. Daily food choices will go beyond the basic needs of safety, convenience, and nutritional balance. There will be a greater focus on precise and enjoyable diets tailored to individual needs.

Smart farms: Making agricultural production less reliant on the weather

By 2035, smart farms will be the norm in global agriculture. Powered by IoT, AI, and blockchain technologies, farmland will function like a smart agent that reduces the reliance of agricultural production on the weather. More than 80% of farm operations will be completed by drones and robots. Satellite navigation systems will enable precision seeding. LED lights and water culture technologies will significantly increase yields per unit area. This new mode of agricultural production characterized by comprehensive sensing, intelligent decision making, and precise execution will overcome the limitations of geography and climate.

Snapshot from the future: A new form of self-sustaining farm production

In the future, farms will go digital, equipped with a wide range of smart devices. With soil sensors and meteorological instruments, each plot of farmland will be able to act as a smart brain, sensing humidity, light, and temperature in real time. When soil moisture falls below a preset threshold, a drip irrigation system will automatically start and deliver just the right amount of water, ensuring optimal crop hydration while preventing waste.

Farmers will no longer need to patrol fields under the scorching sun. They can simply view data on their phones to determine areas in need of fertilization and times for pest and disease prevention.

In greenhouses, plant growth will no longer rely on natural light. Artificial lighting systems will adjust light duration and intensity based on plant needs, enabling robust plant growth even in off-seasons. Using multi-layer plant racks and hydroponic nutrient solutions, vertical farms will be able to produce vegetables in urban areas throughout the year.

By harnessing technology, smart farms will reshape agricultural production, overcoming the uncertainties of climate and geography and reducing reliance on weather conditions.

Diets tailored to individual needs

The growing integration of genomics, AI, and smart wearables is set to change how we manage nutrition. By analyzing genomic sequencing, epigenetic data, and real-time gut microbiota monitoring results, nutritional systems will be able to pinpoint an individual's metabolic issues such as lactose intolerance or inadequate vitamin D synthesis. This will help create a nutritional model tailored to an individual's specific needs.

In addition, smart wearables like flexible electronic skin and implantable nanosensors will continuously monitor an individual's key physiological indicators, including blood glucose and vitamin levels. Based on the monitoring data, these devices will generate an evolving nutrition profile which can be used to manage nutrition and recommend personalized diets.

Snapshot from the future: Precision nutrition for healthier lives

People will enjoy healthier lives with diet recommendations based on their nutrition profiles and health graphs. For the elderly, dynamic nutritional plans will help optimize protein and calcium intake, preventing muscle loss and reducing the risk of chronic diseases. Children and pregnant women will receive specialized, nutritional guidance for their health and development. Athletes will be able to fine-tune their nutrition based on metabolic predictions, enhancing their performance on the field.

Personalized diets and precision nutrition will significantly change people's lifestyles. By combining scientific insights with individual needs, people will be able to make healthier dietary choices in their daily lives. The key to this change lies in creating a dynamic system that balances diets, physical health, and the environment. Furthermore, the synergy between smart wearables and cloud algorithms will drive a dietary shift from experience-based decisions to data-driven choices.

Conclusion

Looking ahead, smart farms will use technologies like IoT, AI, and blockchains to overcome the limitations of conventional farming, enabling intelligent, precise, and efficient agricultural production. This will be key to ensuring secure, sustainable food production around the world.

In addition, the integration of genomics, AI, and smart wearables will pave the way for personalized nutrition management systems. With tailored dietary recommendations and management, these systems will help individuals stay healthy.

By 2035, the informatization rate of agricultural production will exceed 40% and the grain yield per unit area will increase by 7.8% in China.

Homes: From living spaces to smart environments, enhancing everyday comfort

Intelligent and digital technologies are reshaping every aspect of our lives, including clothing, food, housing, and travel. Profound changes are also taking place in our home life.

In the future, homes will evolve from simple living spaces into smart environments that understand and offer us new levels of comfort. Smart home devices will function as human-like assistants, seamlessly supporting us across different scenarios.

Intelligent cleaning robots will efficiently map out the optimal routes to leave floors spotless. Smart kitchen appliances will prepare nutritious and delicious meals based on our health data and taste preferences. Meanwhile, intelligent housekeeping robots will learn each family member's habits and provide personalized, meticulous care.

Holographic technologies: Transforming homes into truly dynamic, immersive living spaces

By 2035, holographic technologies will be essential to anyone seeking high-quality, truly immersive experiences at home, breaking the physical boundaries of homes, extending them into the digital world, and enabling people to live and work more efficiently. Home entertainment, education, and social interactions will be completely transformed. People will be able to explore the world from the comfort of their homes and communicate or collaborate with others as if they were in the same room.

Snapshot from the future: Embracing new possibilities in life through immersive interactions

Advancements in technologies like spatial sensing, virtual reality, and displays will enable future entertainment and gaming devices to engage all the senses—vision, hearing, touch, smell, taste, and even thoughts. This will facilitate multimodal and emotional interactions between people and devices. These devices will not only simulate and mirror the physical world but also enhance it, enabling people to integrate the virtual with the physical and experience sensations that are either close to or even surpass reality.

XR and holographic technologies will unlock the full potential of home spaces, offering people unprecedented freedom. This will typically require home broadband speeds of over 10 Gbit/s.

We will be able to interact with loved ones across long distances as if they were right beside us, embark on time and space exploration journeys with our children, discuss work with our colleagues across the globe, and immerse ourselves in our favorite sports games and concerts. Homes will become new and dynamic living spaces, constantly evolving to meet a wide range of needs.

Holographic technologies will break the boundaries of time and space, transforming homes into living platforms that seamlessly blend entertainment, work, learning, and social interactions. They will bring the digital world into every home to open up new exciting possibilities for everyday life.

Intelligent robots: Joining us as new family members

By 2035, intelligent robots will become integral to many homes. As AI and distributed sensing technologies become increasingly integrated, robots will evolve into intelligent entities that can perceive and make decisions. They will not only be seamlessly integrated into every aspect of our lives, but also offer emotional companionship, becoming new family members.

Snapshot from the future: More efficient and supportive home life with intelligent robots

Thanks to rapid advancements in AI, foundation models, sensing, and communications technologies, intelligent robots will be able to understand, reason, and adapt to the physical world. By leveraging multimodal interaction technologies—which combine natural language, vision, and touch—these robots will communicate with people in a seamless, human-like way.

Through device-cloud synergy, these robots will access vast amounts of knowledge and as much computing power as they need. Combined with sensitive, safe bionic designs and energy-efficient technologies, these robots will be able to handle a wide range of household tasks with ease.

Looking ahead, intelligent robots will become indispensable companions in family life, providing personalized experiences for each family member.

As intelligent robots become part of our homes, they will profoundly change people's daily lives. They will act not only as efficient housekeepers handling everyday chores, but also as considerate companions providing emotional support.

These robots will be able to tutor children, personalizing teaching plans and making learning engaging. These robots will also accompany the elderly, monitoring their health status and providing timely alerts.

By continuously learning the voice, emotions, and preferred gestures people use in their interactions with family members, these robots will proactively adjust the home environment, recommend entertainment content, and even bring people a cup of tea at the right temperature when they are tired.

Intelligent robots will free people from daily chores, allowing them to spend more time on emotional engagement and creative work. As a result, people will feel happier and enjoy a higher quality of life.

In 10 years, over 90% of homes in China will have intelligent robots. These robots will handle household chores and offer emotional companionship, enhancing the overall comfort of home life.

Conclusion

In the future, homes will evolve from simple living spaces into smart environments that understand us. Holographic technologies will transform homes into truly dynamic, immersive living spaces. Additionally, intelligent robots will become an integral part of every family, allowing people to enjoy a more efficient, personalized, and comfortable life.

It is predicted that more than 60 million XR devices will be sold annually by 2035. Domestic humanoid robots will move from technological validation to initial commercialization, with their primary functions evolving from basic household chores to multifunctional home assistants. The penetration rate of humanoid robots in middle-class households is expected to exceed 10% by 2035.

Manufacturing: Design for manufacturing, intelligent manufacturing, and manufacturing as a service

The transformation of the manufacturing industry will continue to be shaped by cost reduction and quality improvement, as well as by evolving consumer trends. Over the next decade, the two trends that will dominate this transformation are: increasing demand for personalization and customization, and the growing emphasis on quality and emotional value.

Consumers are increasingly seeking highly customizable product options and configuration diversity. For instance, in the automotive industry, a single Toyota model that only had a handful of configurations ten years ago now offers 300 to 1,000 configurable options. Top-tier models often offer over 5,000 configuration combinations. This reflects the market's growing expectation for deep personalization.

At the same time, consumers are increasingly prioritizing product quality and experience. Products like Pop Mart's Labubu have resonated strongly with the market by offering distinctive emotional value, demonstrating a growing willingness among users to pay for products that deliver affective experience. Similarly, companies like Haier and Midea have launched specialty washing machines designed for infant clothing, in order to meet heightened expectations surrounding health, safety, specialized functionality, and ease-of-use.

These increasing demands are driving digital transformation at manufacturing enterprises, impacting everything from industrial processes and technology adoption to policy frameworks. Industrial AI is now being adopted and implemented. As demonstrated at the Hannover Messe 2025, the flexible manufacturing factory co-developed by Siemens and Audi has been put into production. The facility leverages an integrated industrial AI development platform to centrally coordinate production requirements, enabling a highly flexible manufacturing operations. Another example is embodied intelligence, which is achieving early application breakthroughs in specific manufacturing scenarios, such as the robot demo that appeared at the World Artificial Intelligence Conference (WAIC), and has shown practical functionality in handling repetitive, rule-based operations like transport and sorting.

The manufacturing industry is transforming from "mass standardization" to "mass personalization," and moving further toward a future characterized by "service-oriented, intelligent, and adaptive" manufacturing. The deployment of industrial AI and embodied intelligence not only tackles production line flexibility and labor shortages, but also forms a technological foundation for next-generation manufacturing systems. These capabilities enable sensing, decision-making, and execution throughout the entire production chain, which, in turn, make it possible to both rapidly respond to consumer's personalized demands and deliver high-quality experience.

We anticipate three main paths for development in the manufacturing industry over the coming decade thanks to the convergence of emerging technologies and these market trends. The first path is design for manufacturing (DFM) where production lines will leverage digital mapping of the physical world and simulation-based optimization to advance toward adaptive switching by 2035 (for example, producing cars one day and appliances the next). Deeply integrating AI into product design tools will help achieve this kind of "design-ready manufacturing." The second path is Intelligent Manufacturing, where embodied AI machines use self-sensing and self-learning capabilities (such as autonomous predictive maintenance) to improve human-machine collaboration throughout production. The third path is Manufacturing as a Service (MaaS) that can bridge gaps between customers and manufacturers by increasing order lifecycle visibility. With MaaS, customers can modify their demands (such as color or dimension specifications) within clearly specified time windows, which increases the transparency and control of every order, making it comparable to real-time food delivery tracking.

The central impetus behind these future paths for manufacturing is the transition away from the supply-side emphasis on cost reduction and efficiency improvement towards the demand-driven focus on personalization and quality. This transition will be enabled by advanced technologies including industrial AI, flexible production, and embodied intelligence.

Design for manufacturing: From a technological vision to a new industrial paradigm by 2035

By 2035, the R&D paradigm in manufacturing will undergo a revolutionary transformation to enable DFM. This will reduce product development cycles from the current months or even years to mere weeks or days, and lower R&D costs. Virtual simulation and validation will replace over 90% of physical prototyping stages and cut prototyping costs by more than 70%. It will also improve resource utilization, achieving almost 100% material utilization and cutting energy consumption during R&D by over 60%.

Product performance boundaries will be substantially extended. AI-powered generative design and multidisciplinary optimization are projected to enhance a number of key performance metrics, such as the driving range per charge on new energy vehicles and the thrust-to-weight ratio of aero-engines which are both expected to increase by 30% to 50%.

Mass customization is expected to become standard during manufacturing, as these technologies will be able to design tens of thousands to millions of personalized configurations without sacrificing production efficiency. More importantly, the pace of innovation is also expected to accelerate exponentially. Thanks to digital twins and continuous learning, manufacturing systems will achieve optimal design and immediate manufacturability, establishing a fully autonomous "design-manufacture-learn" cycle.

Snapshot from the future: A closed-loop system for collaborative design optimization

In the future, the new product design process will undergo a number of changes that will decrease repetitive engineering workloads by more than 90%. This breakthrough will be achieved thanks to cloud-based powerful computing platforms and AI capabilities. Manufacturing systems will be able to use deep learning algorithms deployed on the cloud to emulate design data, topological structures, and mechanical principles in order to quickly generate initial model proposals that satisfy predefined functional and spatial constraints. Intelligent enterprise services will then provide the compute needed for large-scale model training, which can improve the scope and efficiency of the design process.

The next critical stage, optimization and simulation, will then achieve AI-aided multi-physics simulation by coupling computation across multiple physical fields, including computational fluid dynamics, structural stress, thermal transfer, and electromagnetic compatibility. Powered by AI-driven automated optimization, manufacturing systems can conduct in-depth analysis and iterative refinement of initial models. Leveraging real-time cloud rendering and simulation, the systems can precisely simulate product behavior under real operating conditions and autonomously adjust design parameters to identify the optimal balance between function and performance, ensuring outstanding reliability of the final product.

Following model optimization and finalization, rapid prototype validation can be performed using an industrial IoT platform, 3D printing workshops, and cloud-based equipment management solutions. Low-latency and high-reliability networks will be needed here to ensure high-speed transmission and processing of the digital models. Additive manufacturing allows seamless, integrated molding of complex structural sample parts, supporting the trial production of functional prototypes in very short timeframes. This approach considerably shortens the R&D cycle, reduces trial-and-error operations that drive up cost, and increases the agility of subsequent design feedback and modification.

Intelligent manufacturing solutions also benefit mass production by enabling a seamless transition from lab to factory. Industrial networks built on advanced connectivity can ensure real-time production data transmission and processing. The Huawei Industrial Cloud Platform, for example, supports the hyper-integrated molding technology that combines previously separate components and processes into a unified system. This allows complex parts to be manufactured in a single molding operation through innovative structural design and material techniques, Industrial IoT platforms can also be used to digitalize production management, simplifying processes, cutting material waste, and reducing assembly steps. This improves efficiency and lowers unit costs in large-scale production.

DFM will be one way for us to restructure the manufacturing value chain through digital and intelligent technologies. It will allow us to transform our traditionally linear "design-to-production" sequence into a closed-loop system of collaborative optimization in both design and production. As digital twin, AI, and industrial IoT technologies continue to advance, more factories will achieve adaptive production line reconfiguration and build more synergies between product design and production by 2035, ultimately steering the industry toward greater flexibility, efficiency, and precision.

Intelligent manufacturing: Redefining production paradigms with technological breakthroughs

By 2035, the era of intelligent manufacturing is expected to be in full swing. Key performance indicators will clearly demonstrate the depth and reach of intelligent transformation in the manufacturing sector. Labor productivity is expected to increase by over 60%, overall equipment effectiveness (OEE) will top 90%, product defect rates will drop to below 0.05%, and first-pass yield will exceed 99%. At the same time, production costs are expected to decrease by 40%, energy efficiency will improve by 35%, and carbon emissions will be reduced by 50%. Digitalization of manufacturing is expected to approach 100%, IoT device coverage will reach 95%, AI application rates will surpass 85%, and predictive maintenance will achieve full coverage. These indicators will not only gauge the effectiveness of intelligent transformation, but also reflect the fundamental shift that will occur in manufacturing from automation to true intelligence that enables more efficient, high-quality, and sustainable production.

Snapshot from the future: Embodied agents as "production partners" with autonomous decision-making capabilities

Intelligent factories in the future are expected to demonstrate a fundamental shift from automation to intelligence, elevating the human-machine relationship from conventional "tool operation" to genuine "cognitive partnership." This transition will be underpinned by comprehensive advances in connectivity, computing power, and cloud infrastructure, which together form a robust foundation for intelligent manufacturing.

Embodied agents built on a synergistic device-edge-cloud architecture will become "production partners" with autonomous decision-making capabilities. Robotic arms equipped with high-performance chips and industrial communication modules will be able to leverage edge computing to process multi-sensor data in real time. With the additional help of a cloud-based digital twin platforms for continuous training and optimization, they will be able to achieve minute-level switching between tasks such as welding and precision assembly. Dexterous AI-powered robotic hands controlled via ultra-low-latency networks will also be able to adapt their grip strength to prevent material deformation,

making them more suitable for flexible and high-precision operations.

In high-end manufacturing, optical connectivity will deliver more stable and reliable networking for cleanroom environments. This will allow embodied agents on an industrial IoT platform to carry out high-purity operations such as semiconductor wafer transport and chip packaging. These agents will also be able to use AI-powered big data analytics to more accurately sense environmental changes and quickly initiate non-destructive cleaning procedures in situations such as when microscopic particles are detected on the surface of a wafer. In fields like new energy battery manufacturing, agents backed by an industrial IoT platform will be able to autonomously coordinate production stages, executing complex tasks like electrode coating and cell assembly in real time while leveraging cloud-based intelligent decision systems to promptly respond to unexpected events.

The role humans play throughout these processes will slowly become that of global orchestrators. A "one operator per factory" paradigm will emerge thanks to high-speed industrial networks and the technologies they power. Global orchestrators will use cloud-based digital twin platforms to coordinate multiple agents across production, operations, and logistics. Engineers will also benefit, using mixed reality (MR) interfaces to design agent workflows in immersive 3D digital twin environments. This "what you see is what you get" (WYSIWYG) orchestration approach can be further enhanced by cross-factory knowledge graphs, while agents can continuously grow by synchronizing their operational experience in real time through the cloud with a globally shared manufacturing process database.

Intelligent manufacturing is achieved by using intelligent hardware and disruptive technological innovation to equip the entire production chain with end-to-end capabilities in perception, decision-making, and autonomous optimization. This transformation will be able to drive a strategic shift from conventional production toward highly autonomous, deeply flexible, and globally efficient operations. There are two essential technological enablers that will be needed to achieve intelligent manufacturing: embodied intelligence and artificial intelligence. Together, they can substantially improve production line iteration and establish a continuously evolving, next-generation intelligent manufacturing system.

Manufacturing as a service: Redefining the synergy between industrial customers and enterprises

By 2035, the MaaS model is expected to eliminate the traditional separation between producer and consumer in advanced industrial systems. MaaS enables end-to-end transparency and real-time interaction that can move the primary operation model within the manufacturing sector away from reactive order fulfillment towards a full-lifecycle collaborative co-creation paradigm.

This shift would improve overall customer experience and fostering a new service-oriented manufacturing model by significantly increasing both the involvement of customers within the manufacturing process, and their decision-making authority.

This new model's achievements can be measured through several key indicators. The indicators that measure customer involvement include the customer design collaboration rate, which

is expected to exceed 80% by 2035, and the requirement iteration response speed, which is expected to drop to less than 24 hours in that same timeframe. Process transparency can be measured by manufacturing process data openness, which will reach over 95%, and the realization of real-time order source tracing. Collaboration efficiency will be measured by how long it takes to complete a customized order, which can be shortened by 50%, and dynamic resource configuration matching rates, which will likely exceed 90%. Customer value will be measured by customer satisfaction, which is expected to increase to over 90%, and repeat customization rates, which will jump to 75%. Finally, service-oriented transformation will be measured by service revenue, which has the potential to account for over 60% of manufacturers' total revenue by 2035, and platform ecosystem integration exceeding 80%. Together, these indicators can be used to track the fundamental shift within the manufacturing sector from linear production-delivery systems to an open, collaborative, and capability-sharing paradigm.

Snapshot from the future: An open, collaborative, and capability-sharing paradigm for manufacturing

The automotive production is often looked to as a prime example of modern manufacturing. In it, we have already seen the beginning of a new collaboration model between customers and automakers. A full-stack technological foundation in networking, computing, and cloud capabilities is supporting this shift and enabling these manufacturers' transition away from one-way delivery towards end-to-end collaborative and sustained service.

Under this new collaborative model, the initial project phase where customers traditionally only submit design requirements, will be completed by specialized teams and a cloud-based virtual collaboration environment. This environment will run on a global high-speed, low-latency, and high-fidelity network, and will allow designers to collaborate in real time. The cloud's substantial computing capacity will allow for the rapid processing of large-scale design data, enabling the concurrent simulation of multiple complex options as well as iterative refinement. Rather than passively receiving information, customers will also be able to take on a more active role during critical design reviews to ensure alignment on design targets and continuous optimization, as the system makes the process fully visible.

During production, networking and IoT technologies can be used to enable fully connected intelligent factories. Low-latency networks will allow all data, from raw material supplier data to real-time HD video of key processes such as welding and battery assembly, to be transmitted seamlessly to customer devices. If each vehicle being produced is assigned a unique digital identity, their full-lifecycle production and quality data can be uploaded and tracked in real time to the cloud. This would allow customers to monitor the production of their order instantly by scanning a code. Using cloud-based big data and AI, even minor deviations in production data would also be detectable, so that manufacturers can be immediately alerted and proceed to rapid root-cause analysis and resolution. Customers are kept fully informed throughout this process, enabling potential issues to be addressed transparently at the earliest stage possible.

During delivery, customers would also be able to use an Internet of Vehicles (IoV) platform and high-precision location services to monitor their vehicle's location, energy consumption, and automated predictive maintenance alerts directly from their personal devices. Throughout the usage phase, edge computing nodes and cloud AI can work together to analyze live vehicle data, also enabling automakers to provide proactive services in addition to reactive after-sales support. Such services include predictive maintenance scheduling and performance optimizations based on actual usage patterns. This ongoing interaction between the manufacturer and the customer deepens their collaboration and enable joint development and enhanced product iterations. The entire customer journey moves beyond a traditional one-off vehicle purchase, and becomes a sustained, service-oriented partnership driven by cloud and connectivity technologies.

At its core, the MaaS model represents a shift in the role of manufacturers from product producers to service providers. By integrating customers into the end-to-end production process through technological enablement and paradigm innovation, MaaS establishes a new form of industrial partnership centered on service, collaboration, and user experience. Over the next decade, as this model matures and gains adoption, it has the potential to greatly improve manufacturers' ability to fulfill individualized needs while minimizing supply-demand mismatches. It will also change the competitive landscape as manufacturers shift their focus from traditional capacity and cost optimization to service quality and experience enhancement. Ultimately, this service-oriented approach will create a mutually beneficial relationship between customers and manufacturers, injecting new vitality into the transformation and upgrade of the manufacturing industry.

Conclusion

By 2035, ICT technologies are expected to be deeply embedded into the entire manufacturing process, fundamentally transforming R&D, design, production, and supply chain operations. In R&D and design, the convergence of quantum computing and generative AI will make "what you think is what you develop" a standard practice. Engineers will use brain-computer interfaces to run simulations that once took months in just minutes. AI will serve as a "digital inventor," opening up unprecedented frontiers in innovation by autonomously making discoveries like new superconducting materials and synthetic cell designs. In production and manufacturing, embodied agents operating under a synergistic device-edge-cloud architecture will enable extreme flexibility, with robotic arms being able to switch processes in seconds, and automated guided vehicles (AGVs) handling millimeter-scale material delivery. Over 90% of tasks will be converted to automated commands, elevating human to the role of "global orchestrators" who define and manage digital twin workflows through mixed-reality interfaces. Supply chains will evolve into seamlessly intelligent land-sea-air networks operated by end-to-end decision systems that can dynamically optimize procurement and logistics plans, reduce demand forecast errors, and slash transportation costs.

Top 3 key indicator predictions:

In R&D and design, the core focus of transformation will be on direct model-to-data integration in order to enable seamless transition from design to manufacturing. The penetration rate of intelligent model applications in enterprises above designated size of key industries is expected to reach 70% by 2028, and 90% by 2035, marking AI's evolution from an assistant tool to a "digital inventor." By 2035, the future architecture will be defined by generative data models and globally autonomous AI self-optimization. AI computing power is projected to grow from 10–20 PFLOPS to 300–500 PFLOPS, a 20 to 30 times increase, while HPC core counts will expand from 30,000–50,000 to 2–5 million, a 50–100 times increase.

In production and manufacturing, the focus of transformation will be on AI-enabled equipment and embodied intelligence to achieve large-scale customized flexible production. Robot density is projected to reach over 1,000 units per 10,000 employees by 2035, a significant rise from around 300 in 2025, reflecting structural changes to manufacturers' operations models and enhanced production flexibility driven by embodied agents. The future architecture will evolve into a triad of human orchestration, embodied agent collaboration, and autonomous task execution by intelligent machines. IoT connections are expected to grow to 0.5–1 million, a 30–50 times increase, while network speeds will reach 5–10 Tbit/s, representing an over 1,000 times improvement. Annual AI computing power is set to reach 10 million PFLOPS at the edge, and 3 million PFLOPS on the cloud and in data centers, marking an over 2,000 times expansion.

In delivery and service, the entire process from order placement to fulfillment is expected to become fully transparent and customizable, with customers able to modify configurations within predefined cycles and actively participate in the manufacturing process. Such systems would enable second-level responses to customer requests, minute-level intelligent production scheduling, and hour-level delivery period predictions. The future architecture will evolve toward real-time AI-powered process across orders, production, supply chain, and logistics. To support this, computing power will need to expand from 40 PFLOPS to 2,000–3,000 PFLOPS, a 50–80 times increase, while storage capacity will need to grow from 120 PB to 3,000 PB, representing a 25 times increase.

Finance: AI redefines financial productivity, ushering in a new era of smart financial services

Moving from "VIP-centric" to "client-centric" financial services

Over the past 10 years, global financial institutions have actively implemented digital transformation and integrated financial services into medical, food, housing, travel, and other daily life scenarios. Through precise client insights and omnichannel collaboration, financial institutions can now design product and marketing strategies based on client segments, but are struggling to provide truly-personalized services. In fact, 80% of financial resources are channeled to serve VIPs, which account for just 20% of all clients.

Over the next 10 years, AI will bring a structural rather than a phased change to finance, and agents will act as every client's "financial confidant", offering 24/7 highly-personalized support throughout the client's entire service journey. In addition, both business and service models will be reshaped, causing a shift from "investing 80% of resources to serve 20% of clients" to "introducing agents to provide every client with highly-personalized financial services ". Entry points for interactions will also be transformed, moving from passive clicks on mobile banking Graphical User Interfaces (GUIs) to active interactions with Natural User Interfaces (NUIs). Meanwhile, risk control models will shift from "expert + data" decision making to "knowledge + agent" decision making. Organizations will be restructured, with new talent and new forms of organization emerging, such as "one person, one team" and "one position, one agent". Ultimately, highly-personalized experiences will better address clients' pain points, achieving a leap from "VIP-centric" to "client-centric" financial services.

In addition, AI is rapidly empowering financial operations from end to end. In domains like tech, inclusive, and green finance, a new "human + agent" collaboration model is emerging. Under this model, agents can precisely identify intents and distribute client requirements to account managers, creating an insight competency center where agents can distill expertise in domains like inclusive and tech finance. Agents can empower all those in key positions within financial institutions, including account managers, credit managers, and managerial and operational staff. These people can leverage AI to reshape processes and organizations, and thus improve both the quality and efficiency of financial services and business operations.

Towards 2035, financial institutions will embed their capabilities like payment, settlement, wealth management, intelligent risk controls, and identity authentication into all kinds of third-party intelligent ecosystems based on Model Context Protocols (MCPs). Additionally, financial agents will collaborate with healthcare, travel, and education agents to dynamically plan tasks, making intelligent financial services available everywhere.

Agents providing highly-personalized services

By 2035, AI will be embedded into every financial transaction, transforming financial services from passive response to proactive companionship. Each client will have their own agent that helps optimize their financial decisions, and more importantly, understands their needs and serves as their trusted wealth partner. For example, agents will be able to dynamically adjust their clients' investment portfolios to address unexpected market fluctuations, automatically recommend the optimal loan solutions, predict personal investment risks, and recommend suitable insurance plans. Finance will no longer only provide products and tools, but will become a smart partner in life, designing highly-personalized services for all.

Snapshot from the future: AI enters every transaction, serving as a "financial confidant" for every client

Over the next 10 years, financial institutions will deliver seamless, intuitive, and predictive service experience. Acting as a super, interactive interface through which proactive banking services are provided, "financial confidants" will be deeply integrated into the life of every client.

Seamless and natural interaction via user interfaces: Acting like a friend, a "financial confidant" will be able to initiate conversations through multimodal and contextual AI interaction, alongside holographic projections, AR glasses, or in-car systems. A "confidant" will also be able to sense emotions, communicate in the right tone, and transform complex financial data into intuitive 3D landscapes to support a client's decision making.

More predictive and resonant product recommendations: A "financial confidant" will be able to model a client's financial personality, build dynamic knowledge graphs, and intelligently analyze travel, consumption, and other daily activities, to quantify a client's financial personality. A "financial confidant" will also be able to proactively offer services before needs arise, precisely predict a client's potential needs, and make financial recommendations (e.g., child-raising funds) based on the client's browsing history. A "financial confidant" will also be able to sense client values and make the corresponding recommendations. For example, a "financial confidant" may recommend green investments to environmentalists, thus adding a human touch to its services. Meanwhile, products will be seamlessly integrated into consumption scenarios, with the optimal installment plan provided during payment.

Dynamic, forward-looking, and highly-personalized risk controls: A "financial confidant" will make risk controls each client's financial "shield". Financial institutions can leverage reinforcement learning to develop agentic AI models for risk controls, and make precise risk predictions based on specialized risk control knowledge. Based on data such as a client's income, health, and career prospects, a "financial confidant" can dynamically make highly-personalized risk control decisions. Furthermore, based on situational intelligence, a "financial confidant" can approve transactions (e.g., travel spending), proactively warn a client about future financial risks (e.g., tight cash flows), and propose preventive measures.

Highly-personalized operations as a client's wealth collaborator: A "financial confidant" will be able to dynamically adjust a client's investment portfolios to align with their life goals (e.g., property purchase and education). Through decentralized, multi-agent communication and collaboration, and based on Agent to Agent (A2A) security protocols, a "financial confidant" will be able to share data and allocate tasks across institutions and domains. For example, bank agents may collaborate with medical agents to design health insurance plans. Acting as an integrated financial manager, a "confidant" will be able to automatically optimize the interest rates of a client's loans, manage subscriptions, and plan taxes. When a client sets goals (e.g., "financial freedom at 45"), their "confidant" will be able to formulate and execute a complete set of dynamically adjustable lifetime financial plans, and regularly analyze related progress.

Intelligent compliance and privacy protection: "Financial confidants" will create an "invisible shield" for every client. By using technologies like federated learning and differential privacy for end-to-end data encryption, "financial confidants" can dynamically adjust privacy protection levels based on situations, to proactively guard against potential data risks. This gives clients absolute control over their own data, while meeting global compliance requirements as stipulated in documents like the *General Data Protection Regulation* (GDPR). Clients can adjust the weight of AI proposals or disenable specific functions, truly realizing intelligent financial services characterized by available but invisible data.

As we move towards 2035, we will see intelligent computing inferences embedded into every interaction and every transaction. In the risk and wealth management domains, general AI models will become more specialized. Furthermore, data systems will evolve towards knowledge systems, rapidly making implicit knowledge explicit to support precise decision making. Blockchains will become unified property right and authentication management platforms intended for agents...All these will come together to form the new infrastructure of smart finance. Every 1,000 "financial confidants" will demand 1 PFLOPS of computing power to support client-intent understanding and dynamic task planning, and these "confidants" will also demand 30-terabit storage capacity to memorize contextual information gained from interactions with clients.

Secure and resilient financial infrastructure safeguarding every transaction

Over the next 10 years, agents will be able to handle all aspects of financial services but may face all kinds of risks regarding tech, ethics, and compliance. Therefore, an all-domain risk control framework must be established to ensure client-facing applications are secure, reliable, and compliant with laws and regulations. Financial services will shift from manual invocations that typically require more than 10 seconds between clicks to agent-powered invocations that can be executed at a rate of 100 per second. Devices and clouds frequently interact, and inference streams are transmitted in real time. Data transmitted over networks in real time has extended beyond structured data to also include long text for risk control inferences, meaning a 10-fold increase in data traffic. In addition, real-time transaction anti-fraud requires 24/7 availability of strategy inference services. Intelligent inference infrastructure is shifting from deployment in a single data center to active-active or multi-active deployment across multiple data centers, which will ensure the high availability of interactions and transactions reshaped by agents.

Meanwhile, financial institutions will very likely face attacks powered by AI and quantum computing. Hackers are building AI-powered virus creation pipelines, in an attempt to allow viruses to camouflage in over 100 layers, evolve within minutes, and penetrate financial defenses. Virus agents will also have the ability to launch offensives in a distributed manner, through collaboration on tasks like reconnaissance, penetration, and horizontal movement. Impacted by AI and quantum computing, a new financial security paradigm and a new financial immune system need to be developed. When financial systems become too complex to regulate, it will be necessary to build a dual-layer protection system that comprises an algorithmic immune system and a quantum security foundation; it will also be necessary to establish agent security protocols and standards to ensure the security of financial transactions. By 2035, financial security will enter a "self-immune" stage, with self-adaptive resilience and security architecture.

Snapshot from the future: Multi-active architecture for intelligent computing will ensure that AI-native services are always online and that quantum and AI self-immunity technology can help ensure transaction security

Building resilient infrastructure, from multi-active general-purpose computing to multi-active intelligent computing: Financial institutions must build new and resilient infrastructure architectures to drive the rapid growth of agent-handled transactions via dual-mode mobile devices capable of both general-purpose and intelligent computing. Ultra-high-bandwidth distributed transmission networks and adaptive routing will support 10-fold data traffic growth in three types of scenarios: transactions, interactions, and inferences. On the cloud side, the upgrade of intelligent computing towards active-active or multi-active architecture will ensure that both inference and agent platforms are always online.

Building a domain-wide quantum security network: To address quantum computing attacks, financial institutions need to build quantum-native financial infrastructure that connects the central banks, commercial banks, and key nodes via metropolitan Quantum Key Distribution (QKD) networks in a quantum entanglement state, thus forming highly-secure key distribution channels. By integrating QKD with Post-Quantum Cryptography (PQC), financial institutions can create a dual shield of unconditional security at the physical layer and flexible authentication at the network layer. By introducing quantum chips to data center routers, optical transmission networks, automatic teller machines (ATMs), and mobile teller terminals, financial institutions will be able to fully quantize data center nodes and edge computing nodes, thereby ensuring that all network connections in and between data centers, office parks, branch outlets, and payment terminals are covered by quantum.

Issuing legal identity proofs and creating pre-warning and prevention space for every agent: By performing blockchain quantum immunization upgrades and defining Post-Quantum Digital Identities (PQ-DID), financial institutions can create unforgeable cross-border digital identity systems that will eliminate the risk of identity impersonation under quantum computing. Through the real-time mirroring of every agent operation in digital twin systems, financial institutions can preemptively perform simulation verifications to prevent agents from going insane or losing control. The third-generation PQC-based distributed ledger can record every agent operation and decision, and perform dynamic authentication and blockchain notarization for every application call.

Building an all-domain AI risk control framework: Financial institutions need to build a three-dimensional risk control system for all client-facing applications, covering domains like tech, ethics, and compliance. With model hallucination governance, supply chain security reviews, and the prevention of new types of attacks at the center of everything they do, financial institutions need to build reliable technological foundations that can support agent operations. By adopting a mechanism that prevents privacy breaches, defines scopes of responsibilities, and traces accountability, financial institutions can guarantee agent reliability. Financial institutions should ensure that data flows comply with regulatory rules for AI-powered finance and that business operations comply with applicable laws and regulations. Ultimately, risks at every step, from underlying models to upper-layer applications and from internal governance to external regulation, will be controlled, ensuring that agents are secure, reliable, and compliant while providing innovative services.

Building an "AI vs AI" financial immune system: Through a globally-shared "malicious agents' behavioral fingerprint database", financial institutions can analyze the behavioral patterns of agents (e.g., API calling sequences and resource-occupation characteristics) to share threat-related information across institutions.

Financial institutions can then deploy "defensive agents" to combat "offensive agents" in real time, using Generative Adversarial Networks (GANs) to simulate offensive paths, dynamically update detection models, and automatically identify the chains of root causes for offensives. For example, financial institutions can use cause-effect graphs to determine whether frequently-occurring trading anomalies are caused by market fluctuations or AI viruses.

Towards 2035, the bandwidths of financial institutions that can be protected by QKD/PQC will increase from 1 to 5 Gbit/s in core links to more than 100 Gbit/s in full-domain coverage, thus realizing quantum security across all domains. Meanwhile, computing demand of agents will increase from 1 PFLOPS to 100 PFLOPS to support "defensive agents" in combating "offensive agents". The ratio of general-purpose to intelligent computing deployed will increase from 9:1 in 2025 to 5:5 in 2035, thus supporting the integration of AI into every interaction, every transaction, and every risk-control decision.

Conclusion

Once every individual has a digital financial avatar that understands their values, risk philosophy, and even intergenerational inheritance needs, finance will return to its roots – a tool to help people achieve their life goals, rather than nothing but cold data and transactions. Realizing this will require financial leaders, technology pioneers, policymakers, and ethicists to work side by side and build a new paradigm of "computing finance with a human touch". Advanced ICT technology will undoubtedly become a key pillar to support the development of global financial services. By reshaping business models with AI-native applications, and by building highly-available multi-active inference architectures and quantum security centers, financial institutions will be able to provide more personalized and efficient financial services to more people.

By 2035, the agents of top financial institutions will process more than 100,000 transactions per second, with the amount of computing used during intelligent investment research reaching 1.5 YFLOPS, and with the real-time latency of risk monitoring supported by quantum computing reduced from 1 second to 50 microseconds, an improvement of three orders of magnitude compared to 2025. Infrastructure is set to undergo a transformation from being centered around general-purpose computing to being centered around intelligent computing.

Electricity: Revolutionizing power systems with renewable energy

The ever-growing demand for electricity is a pivotal issue for the global energy transition and social development. This demand reflects the inherent requirements of economic growth and technological advancement, driving diverse transformations, including adjustments in the energy mix and progress toward environmental sustainability. By 2035, global electricity consumption is projected to surge from 28 trillion kWh in 2024 to 40 trillion kWh. Electricity generation will no longer rely primarily on conventional fossil fuels such as coal and natural gas. Instead, the installed capacity of renewables is expected to exceed 70%, with solar and wind power alone accounting for 60% of this share and contributing over 50% of total energy output. As the levelized cost of electricity (LCOE) for renewables drops to below 1 cent due to technological advances, solar and wind will play a dominant role in the energy mix, further enabled by large-scale breakthroughs across the energy storage industry.

On the power grid side, a synergy between transmission networks, distribution networks, and microgrids will facilitate intelligent energy dispatching. Dispatching in milliseconds across regions will balance energy supply and demand through quantum computing and digital twins technologies for all voltages and domains. AI technologies and high-precision weather data will improve the accuracy of short-term and long-term prediction of renewable power and loads. The number of nodes participating in power flow and transient calculation on the entire network will increase from hundreds to millions, enabling flexible supply and demand control.

On the load side, the electricity consumption of global data centers will soar from 420 billion kWh in 2024 to 1.5 trillion kWh, and the number of electric vehicles (EVs) will grow from 64 million to 350 million. Hundreds of millions of EVs will participate in power grid peak shaving using the vehicle-to-grid (V2G) technologies of smart chargers.

For energy storage, the extensive adoption of grid forming technology will be key to solving the challenge of output fluctuations of renewables. Output fluctuations can be suppressed in real time to ensure that renewable power is as stable as thermal power. By 2035, renewable energy will have completely transformed the operational logic of power systems. Digital and AI for Science (AI4S) technologies will be thoroughly integrated into production systems, becoming essential to new power systems.

Enabling all-scenario grid forming with solar PV and energy storage

Solar and wind power are indispensable to addressing the climate crisis and driving the energy transition worldwide. They are becoming the most cost-effective energy sources worldwide. However, the growth of solar and wind power results in grid integration challenges. Innovative technological breakthroughs like the convergence of solar PV and energy storage and all-scenario grid forming are transforming power systems from rigid architectures made up of conventional synchronous generators to flexible ecosystems centered on renewables. These breakthroughs will address the spatiotemporal and technical misalignment of energy generation and consumption. This will help overcome renewable integration challenges and enable the low-carbon transformation of power systems.

Snapshot from the future: Solar PV and energy storage continue to converge and are both reaching grid parity.

PV technologies are being developed at an unprecedented speed. Breakthroughs are being

made in cell technologies and in intelligent manufacturing processes. The LCOE of the PV industry has been reduced by more than 90% over the past decade, approaching US$2 cents/kWh. Tunnel oxide passivating contact (TOPCon) cells have significant advantages in ROI, technological maturity, and industry support systems. They are poised to become a major industry option as their production capacity expands rapidly over the next five years. After that, TOPCon and perovskite tandem cell technologies will continue to reduce the LCOE, which will fall below US$1 cent/kWh.

Innovative chemical energy storage technologies like lithium-ion batteries are seeing rapid iteration and increasing industrialization. The cost of lithium-ion battery energy storage systems has decreased by nearly 85% in the past decade, with the levelized cost of storage (LCOS) falling below US$4 cents/kWh. It is predicted that by 2030, the LCOS will fall to less than 3 cents/kWh or as low as below 2 cents/kWh, which is lower than the cost of pumped storage. Lithium-ion batteries will become one of the most cost-effective energy storage technologies.

Energy storage systems will function as flexible and efficient electricity reservoirs. This will not only suppress the intermittent fluctuations of PV power generation, but compensate for the difference in electricity demand in peak and off-peak hours. These systems will ensure power supply stability from the source to the load, which will significantly improve the value and reliability of PV power generation in the energy supply system. Solar-storage synergy will create a powerful complementary effect, unlocking vast potential for application expansion, market penetration, and industrial development.

Snapshot from the future: All-scenario grid forming will solve the global challenges of renewable energy integration.

As renewables begin to make up a greater proportion of the energy mix, flexible regulation resources in power systems will be rapidly consumed. This will present challenges in power system balance and safety as well as power grid stability. These challenges will hinder the development of renewables worldwide. Among numerous grid stabilization technologies, grid forming is the only approach that can simultaneously implement inertia emulation, proactive voltage/frequency control, and adaptation to all types of power sources. Power electronics and digital technologies are being deeply integrated to turn grid forming into a pivotal technology for highly coordinated renewable power plants. Grid forming technology enables renewable power plants and energy storage systems to develop grid support capabilities similar to those of conventional synchronous generators. This enables proactive control of grid frequency and voltage stability, which helps renewable power plants shift from passive adaptation to active formation. All-scenario grid forming technology allows entire power systems to generate, transmit, and distribute electricity more efficiently.

Along the Red Sea in Saudi Arabia, Huawei helped a customer build the world's largest microgrid based on solar PV and energy storage. The microgrid delivers reliable green power to the region and promotes energy mix innovation. It is equipped with a 400 MW PV system and a 1.3 GWh energy storage system for stable independent grid forming. For power transmission, grid forming technology accurately suppresses voltage fluctuations and frequency deviations during grid integration of renewables. This enhances the stability of long-distance power transmission. For energy consumption, grid forming technology enables fast responses to disturbances in the distribution network, which reduces the impact of voltage sags and frequency fluctuations.

According to the International Energy Agency

(IEA), grid forming technology functions as an operating system for grid integration of renewables, and the progress of carbon neutrality hinges on its application. Grid forming technology is quickly becoming standardized. It is predicted that by 2028, a comprehensive standards system covering devices, grid connection, and O&M will be established. And from 2030, grid forming technology will be applied on a large scale worldwide. By 2035, the technology will cover all applications of power generation, transmission, distribution, and consumption, becoming a mandatory requirement of grid connection for PV, wind power, and energy storage equipment.

Significant advancements are also being made in the development of PV modules, wind turbine blades, lithium battery performance, and grid forming and digital technologies. By 2035, the global cumulative installed capacity of PV and wind power will exceed 1.2 trillion kW, accounting for more than 60% of the global installed power capacity. And the installed capacity of electrochemical energy storage is predicted to exceed 8 billion kWh, which will provide substantial support for flexible grid regulation. PV, wind power, and energy storage will become the dominant electricity sources worldwide, accounting for more than 50% of the global power supply.

Managing watts with tokens to boost power quality

Power grids are underlying infrastructure for energy production, transmission, distribution, and consumption. As the scale and proportion of renewables increase, distributed PV, high-power chargers, V2G, and energy storage equipment on the load side will continue to develop. Consequently, power grids will face numerous challenges, including increasing supply and demand fluctuations, growing technical complexity, diverse safety risks, and delayed digital transformation. An architecture that integrates digital twins and AI4S technologies must be established to facilitate critical services like power grid dispatching and engineering scheduling. This will enable rapid response of power grids for output power and load forecasting, power flow calculation, and transient calculation.

Digital technologies and AI will be essential to new power systems. AI4S will play a key role in all applications of power systems.

For grid dispatching, load and renewable power forecasting will facilitate the formulation of short-term (15-minute) to mid- and long-term (monthly) power generation plans. Multi-objective optimization will empower safe grid operation. Power flow and transient calculation of main nodes will support grid status simulation. Additionally, simulation and power flow calculation on the distribution network will facilitate the management of large-scale distributed PV systems, coordinated charging of large numbers of EVs, and bidirectional interactions of microgrid resources. This will ensure the balance and stability of distribution network transformer districts. In 2024, the penetration rate of weather and power forecasting in global wind, solar, and hydro power plants was approximately 1.04%, and that of load forecasting was less than 17%. By 2035, the former will likely reach 100%. This will be essential for the comprehensive flexible control of renewable power for carbon neutrality. The number of power grid topology training nodes used for electromechanical transient calculation will soar from less than 300 in 2024 to about 1 million, covering all voltage ranges and elements. We will need 300,000 times more efficient electromagnetic transient simulation and calculation than that in 2024.

For O&M, big data and AI technologies will replace manual expertise to sense and predict the real-time status of devices, enabling predictive maintenance at the component, device, and system levels. Video and AI will replace human eyes to identify damage caused by human or other unpredictable external forces, enabling preventive management at the environment, operation, and emergency levels. In 2024, the penetration rate of intelligent device O&M was less than 1%, and the coverage rate of relevant job positions was below 0.5%. It is predicted that by 2035, predictive O&M will cover 110 kV/10 kV main devices for power generation, transmission, and transformation, and the coverage rate will rise to 60%. Predictive device O&M will integrate data from diverse sources, such as temperature, voiceprint, vibration, and oil & gas detection, as well as multimodal large models. This will drive the upgrade from scheduled inspection to 24/7 inspection for all domains and improve the fault prediction accuracy from less than 85% to over 95%. The coverage rate of digital twins personnel in remote plants, high-risk operations, and disaster prevention and emergency response will jump to 90%.

For engineering and construction, AI will be fully integrated into diverse production settings like infrastructure construction, maintenance, live-line operations, and troubleshooting of transmission and distribution networks. AI engines will optimize quantitative constraints like objectives and rules as well as variable constraints like personnel, materials, tools, and environments to generate optimal project construction, production, and business support plans.

For electricity trading, increased renewables

penetration and the intensified power system fluctuations will accelerate electricity market cycle evolution. The market is transitioning from day-ahead to intraday and real-time trading. Responses in minutes and fluctuations lasting seconds are becoming critical to new power systems. This transformation will increase the integration of AI technologies into markets. Driven by AI technologies, electricity trading will increase from less than 1% of the market in 2025 to 72% by 2035.

Ubiquitous IoT and reliable communication will be fundamental to the digital and intelligent development of power systems. AI works systematically based on high-quality data. Ubiquitous IoT and communication are the prerequisites for high-quality data, AI, and application-based value delivery.

Data is derived from ubiquitous IoT. Data space connects diverse parties through IoT technologies, providing continuous, reliable, and multidimensional data for AI based on consensus rules (such as secure sharing and compliant transfer). It establishes a trusted mechanism for data exchange between businesses, enterprises, and ecosystems. This helps eliminate stakeholder concerns about data exchange.

Communication is essential to protection. It is also critical to automation, informatization, and digitalization of production, and AI enablement. We need a future-proof communication network that encompasses a smart and robust transmission network, a converged medium-voltage network, a transparent low-voltage network, and plant campuses. The transmission network must implement dual-plane communication with 99.9999% reliability and response in microseconds or milliseconds. The medium-voltage network must be converged and offer 99.99% reliability and response in milliseconds through "optical + 5G" hardware isolation and short slicing. The low-voltage network must implement transparent communication with 99.9% reliability and response in seconds. Wired and wireless networks must be combined on plant campuses to ensure 100% coverage. Only in this way can we meet the diverse needs of AI applications for latency and transmission bandwidth.

The future intelligent world will run on electricity. Large-scale development of renewables will present analysis and decision-making challenges for new power systems. To address these challenges and prevent accidents like the Iberian Peninsula blackout, we need to transform from electromechanical transient simulation to electromagnetic transient online simulation for all domains and voltages to ensure effective, accurate, and rapid performance. It is predicted that by 2035, the number of grid topology computing nodes will grow to millions and the computing efficiency will be improved 300,000-fold. Moreover, we need breakthroughs in predictive maintenance to ensure device safety in power generation. When prediction accuracy increases from 85% to 95%, multimodal predictive maintenance at the device and system levels will enable proactive maintenance of devices and extend their service life.

Electrification will ignite a global transportation revolution

Transportation electrification and automotive electrification are pivotal to the global energy transition and sustainable development. The transportation sector is rapidly shifting from conventional fossil fuels to electricity around the world. The expansion of charging network infrastructure and the development of high-voltage fast and ultra-fast charging technologies are transforming the user experience. This change from lining up for charging to charge-and-go is making EVs more convenient than ever, spurring decarbonization across the transportation sector. EVs and charging infrastructure have evolved from electrical loads to an integral part of power systems. The synergy of vehicles, chargers, and the power grid creates a dynamic and mutually beneficial integrated ecosystem of traffic and energy systems. This ecosystem flexibly responds to the diverse charging needs of EVs (such as time-of-use intelligent dispatching and priority assurance for emergency charging). Moreover, it enables EVs to participate in peak shaving and voltage and frequency regulation of the power grid through technologies like coordinated EV charging and V2G. This enables elastic support for the safety and stability of the power grid. By turning loads into resources, transportation and energy systems are evolving from one-way supply to two-way enablement. This evolution will unleash the benefits of cross-system collaboration for low-carbon development while meeting user energy needs.

High-voltage fast and ultra-fast charging will improve EV user experience. Evolving technologies are pushing the performance boundaries of fast and ultra-fast charging for lithium-ion batteries. 10C and higher batteries will be widely adopted by 2035, thanks to revolutionary improvements in charging speed. Mature technologies for high-voltage ultra-fast charging are also driving a qualitative leap in charging efficiency. With each charging session shortened to below 5 minutes, charging EVs will be as convenient as refueling gasoline vehicles. New technologies will not only eliminate range anxiety, but bridge the gap in charging efficiency between EVs and gasoline vehicles. This will pave the path for the comprehensive electrification of transportation. The global penetration rate of passenger EVs is predicted to exceed 60% by 2035. China will lead the global electrification, with a penetration rate of over 80%. Mature technologies for high-rate batteries and high-voltage fast and ultra-fast charging are clearing major obstacles for large-scale application, which is enabling electrification for diverse applications in addition to passenger vehicles.

In the field of construction machinery, the electrification and intelligence of excavators and loaders will be thoroughly coordinated. Intelligent systems will accommodate the precise control characteristics of motor drives to significantly improve efficiency and reduce safety risks through functions like unmanned operations and remote surveillance. It is predicted that by 2035, the electrification rate of construction machinery will exceed 40%. Electric construction machinery will become the top choice for mining and construction.

Electric heavy goods vehicles (HVGs) powered by large-capacity batteries and megawatt charging technologies will break through the limitations of range and charging. They will rapidly expand from medium- and short-distance as applications like urban delivery and port short-haul to long-distance trunk transport for logistics. The global penetration rate of electric HVGs is predicted to exceed 50% by 2035. The penetration rate will exceed 80% in regions like China with favorable policies and sufficient infrastructure.

In the shipping field, electrification and autonomous driving are converging. The combination of electric power systems and intelligent navigation technologies will reduce carbon emissions from inland and coastal transportation, and boost transportation efficiency and navigation safety through functions like route optimization and automatic obstacle avoidance. It is predicted that the electrification rate of inland ships will exceed 30% by 2035. The rapid adoption of high-power charging infrastructure is the key to breakthroughs in these areas. Fast and ultra-fast charging networks will be ubiquitous. The total number of high-power chargers worldwide is predicted to exceed 15 million by 2035. More than 30% of these chargers will be fast and ultra-fast chargers, each with over 400 kW of

power. These chargers will efficiently charge diverse electrical equipment, creating a positive cycle of technology breakthrough, application-specific implementation, and infrastructure support.

Vehicle-charger-grid synergy will drive vehicle-grid integration (VGI). By 2035, the number of EVs worldwide will exceed 350 million. Power grid dispatching and management will be extremely difficult if large numbers of EVs are charged haphazardly. According to experts from the State Grid Corporation of China (SGCC), without an effective vehicle-charger-grid synergy mechanism, uncoordinated charging of EVs may lead to an increase of 153 million kW in the peak load within the region covered by SGCC by 2030, equivalent to 13.1% of the peak load within the region during the same period. Sudden and concentrated increases in load will not only compromise the stability and reliability of power supply services, but cause safety hazards such as overload and voltage fluctuations of power grid devices, challenging power system safety management. Technologies and mechanisms like V2G and coordinated charging are needed to address these risks. By dynamically matching the charging behavior of EVs with the load characteristics of the power grid, we can ensure that users' charging needs are met while preventing power system overload. Doing so will ensure power grid safety in the face of high EV penetration.

As renewables like PV, wind power, and energy storage continue to improve in cost-effectiveness and grid forming capacity, campuses, commercial complexes, and communities are shifting to a model of microgrid-based energy independence. The microgrids powering this shift feature a synergy of source-grid-load-storage. V2G technologies can be used to convert large numbers of EVs into distributed energy storage resources to establish a flexible pool of mobile energy storage. When the grid load peaks or the renewable energy yield within a campus becomes insufficient, EVs can supply power to the grid or campus to alleviate power supply pressure. Charging can be started when the grid load is low and the renewable energy yield is at its peak, preventing renewable energy waste and reducing the dependence on thermal power plants for peak shaving. This bidirectional interaction on the load side adds flexibility to energy adjustment, improves the efficiency of local renewable energy integration, and enhances the stability of coordinated operations between the microgrid and the main grid.

We predict that by 2035, more than 50% of global charging infrastructure will be able to respond to grid demand and dynamically regulate charging behavior based on power supply and demand. Additionally, 30% of new EVs will be equipped with V2G functionality and become grid resources. Evolving from technical feasibility to large-scale application, V2G will inject synergy into distributed energy systems.

Automotive electrification is accelerating the shift from fossil fuels to renewables. Chargers will gradually replace gas stations, and critical infrastructure will be built to integrate urban transportation into energy networks. While supplying energy to EVs, chargers will function as flexible loads and energy storage facilities for power grids. Eventually, they will become hubs for connecting traffic flows and energy flows. Transportation electrification will be closely coupled with flexible dispatching of smart grids and holographic collaboration of digital twin cities. This will shape a new landscape that integrates energy, transportation, and information. Transportation is shifting from fossil fuel consumption to renewables, and cities are evolving from siloed systems to collaboration across all domains. Collaboration across industry boundaries will change how we live and work and enable sustainable development.

Greener tokens with electricity-computing synergy

The functional boundaries of AI are expanding disruptively, driven by falling computing costs, surging data availability, and breakthroughs in algorithms and models. Dual infrastructure systems supporting this transformation are becoming increasingly mature. Large numbers of AI servers in large-scale computing centers are running around the clock to handle complex AI tasks. Additionally, small data centers are rapidly penetrating into the urban fabric, like nerve endings in the human body. With them, AI can work closer to physical applications and implement data response and local processing in milliseconds. Intelligent computing data centers or AI DCs are becoming one of the most energy-intensive sectors. Their high-density computing units and continuous cooling systems consume much more energy than traditional data centers. It is predicted that the electricity consumption of global data centers will increase fourfold in the next decade. An example of how electricity demand is driving the transition to renewable energy is the direct connection between data centers and PV plants or wind farms. This transition is accompanied by the dynamic matching of computing and electricity, like with AI-based energy efficiency optimization and demand response dispatch. These shifts are transforming the production and consumption logic of global energy systems.

Energy is essential to AI. Coordinated development of green electricity and computing is not just necessary, but inevitable. Large AI models like GPT are evolving rapidly, with an exponential increase in parameter scale and exponential growth in computing demand. Although models like DeepSeek continue to achieve technical breakthroughs in computing efficiency, computing supply struggles to keep up with demand thanks to rapidly developing applications like autonomous driving, industrial metaverse, and intelligent decision-making. In 2024, global data centers consumed about 420 billion kWh of electricity, roughly 1.5% of global consumption. With an annual growth rate of 14%, data center consumption is projected to surpass 1.5 trillion kWh in the coming decade, making up nearly 4% of global consumption. AI needs to balance explosive computing demand with the global green transition. We need to substantially reduce carbon emissions while expanding computing capacity.

Green computing power is being rapidly coupled with computing nodes as renewables like PV, wind power, and energy storage see significant improvement in cost-effectiveness, stability, and flexibility. At utility-scale renewable power plants, zero-carbon data centers can be directly powered by renewables like PV, wind power, and energy storage. In this business model, renewable power is integrated and consumed locally, eliminating the losses and costs that result from long-distance power transmission. Moreover, clean power is directly supplied for computing traffic, significantly reducing computing costs. More importantly, the model enables 100% clean power consumption, slashing carbon emissions by over 80% compared to traditional data centers and striking a balance between computing growth and carbon reduction. We predict that this electricity-computing synergy model will be widely adopted in the next decade. By 2035, 80% of electricity supplied to global large data centers will be green power, and short-distance coupling models like direct supply of green power will make up 30% of the market. This will enable the AI industry to transform from carbon-intensive expansion to green and intelligent development.

Integrated innovation on direct DC power supply will transform data centers into energy routers Power supply to traditional data centers involves

multiple levels of conversion within the AC power grid: AC power is converted from high voltage to low voltage through an uninterruptible power system (UPS), and then converted to the DC power needed for servers. About 10% to 15% of energy is lost during this conversion process. AC frequency fluctuation and harmonic interference can lead to device faults, which hinder energy efficiency and system stability. The shift to renewables is enabling a high-voltage direct current (HVDC) direct supply model based on the flexible DC architecture of PV, wind power, and energy storage for greener computing power consumption. Underlying this transformation are three critical breakthroughs.

First, efficiency improvement: HVDC (such as ±400 V and ±800 V) systems significantly simplify AC-DC conversion and adapt to the characteristics of DC power sources like PV power systems and energy storage systems to ensure seamless access to different energy sources. Consequently, the energy utilization of the entire chain from PV power generation to chip computing in data centers is improved to over 70%, far exceeding the 55%–60% of the traditional "AC power grid + UPS" model. Additionally, power usage effectiveness (PUE) is reduced from 1.5–1.8 to below 1.1, maximizing energy efficiency with zero redundancy.

Second, dynamic symbiosis: Thanks to flexible DC architecture, data centers can transform from electricity consumers into energy routers. Real-time matching between computing demand and the supply of PV, wind, energy storage, and grid power enables dynamic collaboration between renewables and computing loads. When PV and wind power output is excessive, data centers proactively increase elastic loads like those for AI training to consume the surplus power through energy storage systems. When the power supply is insufficient, data centers reduce non-critical computing, and then energy storage systems discharge electrical energy to support other loads of the power grid.

Third, closed-loop control: The "computing + peak shaving" model establishes a closed-loop control system for computing and electricity.

Data centers will no longer adapt to the power grid passively. Instead, they will proactively participate in energy network control, improving local renewable energy integration and enhancing the resilience of the power system. In this way, the power source, grid, load, storage, and computing will collaborate as an organic whole. By 2035, 30% of new AI DCs will use the "HVDC + green power supply" architecture. This transformative architecture will not only redefine the energy logic of data centers, but turn computing infrastructure into hubs for connecting renewables and the digital economy. This will enable zero-carbon computing on a large scale.

As critical energy-intensive infrastructure that delivers powerful computing, data centers are undergoing a paradigm shift from traditional passive power consumers to active and flexible participants in the power system. They are becoming hubs for connecting renewable energy generation, storage, and consumption. Data centers deliver significant value in two key ways: As the computing foundation for electric power digitalization, data centers use technologies like AI algorithms and digital twins to enable power grid dispatching optimization, device status warning, and renewable output forecasting through powerful computing. This facilitates intelligent and targeted upgrading of the power system.

As flexible loads with elastic adjustment capabilities, data centers respond to changes in power grid supply and demand through dynamic dispatching of computing power (such as off-peak operation and load shifting). Data centers increase the computing load to consume green power when the renewable power output peaks, and reduce the non-critical computing load to ease electricity demand. In this way, they safeguard the stability of the power grid that integrates a high proportion of renewables. Through bidirectional interactions between computing and electricity, data centers will become hubs for energy system collaboration, facilitating the integration of renewables into the digital economy.

Conclusion

By 2035, power systems will have evolved into dynamically balanced, highly intelligent energy ecosystems. This will drive low-carbon development while ensuring reliable power supply. When night falls, PV panels will start automatic cleaning, wind turbines will adjust blade angles accurately, energy storage plants will store energy effectively, EVs will be charged in a coordinated manner based on intelligent dispatching, and data centers will dynamically adjust computing and electricity. The power systems will operate efficiently and seamlessly, fueling a more sustainable future.

Logistics: AI drives intelligent transformation and high-quality, precise delivery across the global logistics supply chain

By 2035, intelligent logistics will have become the control hub of the global supply chain, and the integration of cutting-edge information technologies and intelligent equipment will reshape logistics systems. AI will be employed to ensure that all goods are precisely delivered to specified destinations from the optimal departure location at the optimal time, through the most appropriate carrier and transportation mode. Such enhancements will help create an efficient, green, and reliable logistics ecosystem.

In the transportation industry, autonomous trucks will use an AI-driven dynamic route optimization system to analyze multi-dimensional data, such as traffic flow, weather conditions, and energy consumption, in real time and automatically select the optimal route. Additionally, intelligent collaborative control technology will be employed so that vehicles in the same fleet can track each other at centimeter-level precision, effectively reducing wind resistance and energy consumption and realizing a 60% lower empty running rate. In terms of cross-border logistics, unmanned ships will use the AI-powered maritime cloud platform to integrate real-time global shipping data, plan the safest and most economical routes, and intelligently avoid harsh sea conditions and congested ports. This will significantly improve the efficiency and reliability of cross-border transportation. Furthermore, in the end-distribution phase, drones and unmanned vehicles will form a collaborative intelligent distribution network. Within such a network, drones will be responsible for transporting high-value goods and emergency medical supplies by air. Meanwhile, unmanned vehicles will take advantage of multi-source sensing technology to realize precise ground distribution. Together, they will form an efficient last-mile solution.

In the warehousing industry, intelligent warehousing robots will use 5G-A networks to achieve millisecond-level responses. These self-learning robots will be capable of optimizing warehousing operation processes in real time and dynamically adjusting sorting paths, thus improving sorting efficiency by five times and reducing processing cost per item by 60%. Furthermore, the intelligent warehouse management system will seamlessly interconnect with the transportation network for automatic inbound and outbound goods processing, intelligent stocktaking, and precise inventory control, forming an efficient and collaborative logistics node operation system.

When it comes to logistics supply chains, in-depth collaboration will be achieved throughout the E2E intelligent decision-making system. This will be possible as AI streamlines the entire process from demand forecast, procurement management, warehousing scheduling, transportation and distribution, to terminal services, achieving autonomous operation across more than 90% of decision-making nodes. The system will then be capable of real-time simulation, deduction, and self-learning, enabling it to predict risks and launch emergency solutions before market fluctuations occur, significantly enhancing supply chain resilience and adaptability. In addition, quantum sensing and edge intelligent computing technologies will be combined to cover more than 90% of high-value logistics scenarios, supporting the creation a full-process, AI-powered quality control system. Within this system, multi-source sensors will monitor the location, temperature, humidity, and vibration of goods in real time, and digital twin technology will enable high-precision status identification and intelligent intervention. Furthermore, blockchain technology will ensure the authenticity and reliability of full-link data, reducing the damage rate of high-value goods, such as perishables and medical supplies, to less than 0.1%.

These technological innovations will drive intelligent logistics to evolve from auxiliary tools into a fully intelligent logistics control hub. By building a trusted data space for logistics, we can shatter data silos, promote the efficient flow of data across organizations and industries, and form a win-win ecosystem for industry collaboration, thereby supporting the development of the global intelligent economy.

AI drives the dynamic optimization of logistics and transportation combinations for the optimal allocation of global resources

In 2035, the logistics and transportation system will evolve into a single and highly-intelligent organic system. As the core driving force behind this, AI will dynamically optimize transportation combinations to optimize the allocation of global logistics resources. The entire logistics network will function as a highly-collaborative intelligent control hub capable of coordinating the global flow of goods in real time to ensure that goods always complete their journeys in the most efficient, economical, and environmentally-friendly manner.

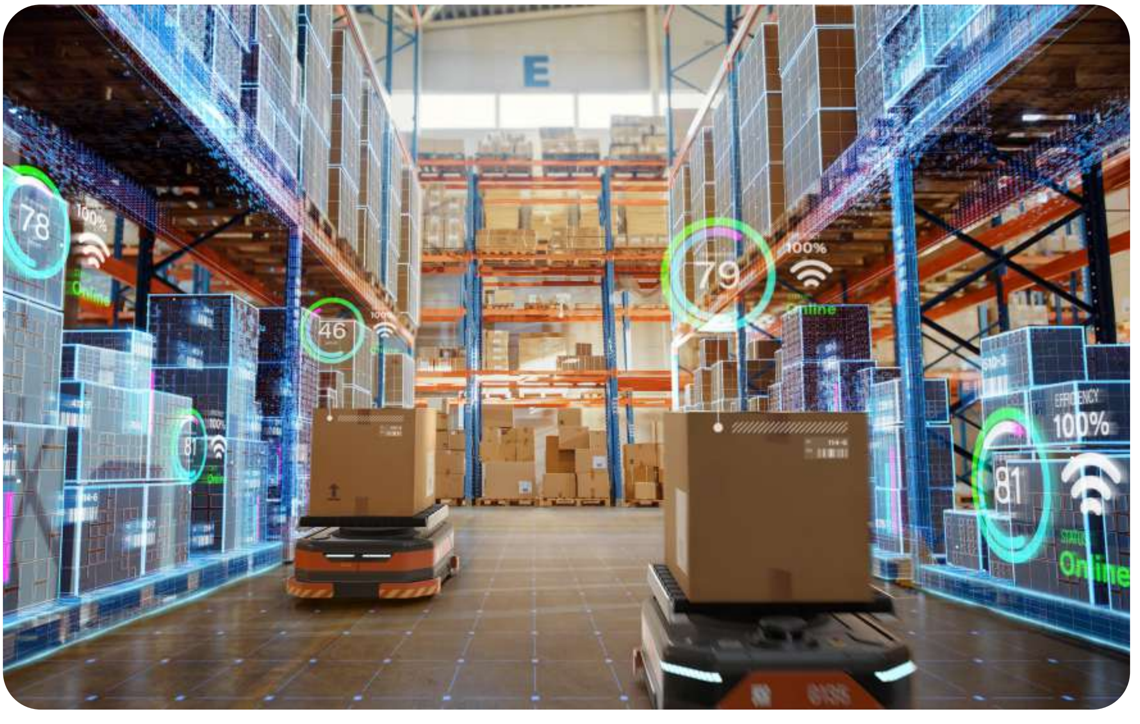
Snapshot from the future: AI-driven dynamic optimization of transportation combinations in multimodal logistics networks

In this new paradigm, the AI-driven dynamic optimization system will constantly re-schedule the operations of the global transportation network for maximum efficiency. The system will integrate multi-dimensional real-time data, such as that related to satellite-tracked meteorology, real-time road conditions, port ship queues, and global carbon tax policies, and use deep neural network algorithms to calculate optimal transportation solutions. This capability for dynamic optimization will greatly reduce the probability of delays in the logistics system, significantly reduce empty running rates, and boost transportation efficiency to never-before-seen levels.

In terms of trunk transportation, autonomous truck fleets will employ vehicle-to-everything (V2X) communications technology to realize intelligent and collaborative operations. Under the unified scheduling of the AI system, these vehicles will be capable of automatically forming the optimal fleets, effectively reducing wind resistance and energy consumption. The system will also dynamically adjust driving routes and speeds based on real-time road conditions and changes in the weather, thus ensuring safe and efficient transportation.

In cross-border logistics scenarios, unmanned ships will take advantage of the global AI-powered maritime cloud platform to implement autonomous navigation and intelligent scheduling. Such ships will be able to achieve the real-time analysis of global shipping data, automatically avoid harsh sea conditions and congested ports, and identify optimal routes. The system will include carbon emissions as a core decision-making indicator and proactively select the most environmentally-friendly navigation solutions to significantly reduce environmental impact during transportation.

The end-distribution network will also be intelligently upgraded, with the drone distribution system being responsible for transporting high-



value goods and urgent medical supplies, and implementing precise delivery through the low-altitude urban logistics network. Autonomous distribution vehicles will implement multi-source sensing technology to accurately identify traffic signals and obstacles, thus enhancing driving safety and improving distribution efficiency. The air-ground collaborative intelligent distribution system will then provide an efficient solution for last-mile delivery.

The multimodal transport system will introduce a highly collaborative intelligent feature, with AI systems breaking the boundaries of traditional transportation and intelligently combining multiple transportation modes, such as highway, railway, aviation, and water transportation, based on real-time requirements. The system will also have the ability to dynamically evaluate the efficiency of different transportation solutions and adjust policies in real time to ensure transportation quality and improve overall benefits.

By 2035, the AI-driven dynamic optimization of transportation combinations will completely reshape the logistics industry to achieve the optimal allocation of global resources. The logistics system will achieve unprecedented efficiency, reliability, and sustainability through intelligent transportation combinations, unmanned driving technology, and end-distribution innovations, ultimately providing solid support for global economic development.

Wide adoption of intelligent warehousing robots forms closed-loop and unmanned "perception-decision-execution" warehouses

In 2035, the warehousing system will fully enter the intelligent era. The large-scale popularization of intelligent warehousing robots is set to transform traditional warehouses into intelligent warehousing centers that possess autonomous operation capabilities. Such robots will employ advanced perception systems, intelligent decision-making algorithms, and precise execution mechanisms to form a complete "perception-decision-execution" closed loop, revolutionizing warehouse operations.

Snapshot from the future: AI-driven closed-loop and unmanned "perception-decision-execution" warehouses

At the perception level, warehousing robots will be equipped with a multimodal perception system. Through the integration of visual sensors, lidar, and depth cameras, these robots will be able to detect the warehouse environment, goods status, and operation progress in real time. Additionally, every shelf and goods item will be equipped with IoT sensors to create a digital warehousing environment. Sensing data can then be transmitted to the central processing system in real time over the high-speed network, providing data support for intelligent decision-making.

At the decision-making level, the AI scheduling system will serve as the brain of warehousing. Supported by deep-learning and reinforcement-learning algorithms, the system will be able to analyze warehouse status in real time and dynamically optimize operation processes. This means that when the system receives an order, AI will immediately calculate the optimal pick

path, robot scheduling solution, and operation time sequence. The system will also be capable of self-learning through the continuous analysis of operation data, allowing it to continuously optimize the decision-making model and improve warehousing operation efficiency.

At the execution layer, multiple types of robots will collaborate. The autonomous mobile robot (AMR) will be responsible for goods transportation and transfer, and possess autonomous-navigation and obstacle-avoidance capabilities. Picking robots will achieve accurate goods grabbing and sorting through intelligent visual recognition and robotic arm control, while inventory management robots will automatically perform stocktaking and goods-location optimization. Supported by 6G networks, these robots will be able to respond in sub-milliseconds and precisely collaborate.

The intelligent warehousing system will significantly improve efficiency in many areas, which will translate to greater warehousing benefits. Compared with traditional manual warehousing, robot warehousing will improve operating efficiency by three to five times, increase order processing speeds by 400%, and reduce the cost to process each single item by 60%. Furthermore, warehousing-space utilization will jump by more than 50%, and inventory turnover will significantly improve. In addition, robot warehousing will be able to support 24/7 uninterrupted operation, ensuring the high availability of warehousing services.

Fully closed-loop unmanned warehouses will also realize a high degree of flexibility. The intelligent system will be capable of automatically adjusting the working modes and operation processes of robots based on the characteristics of order fluctuations. During promotional seasons or peak hours, the system will dynamically optimize resource allocation to guarantee stable and efficient warehousing operation. This flexibility in terms of operation modes will greatly boost the adaptability and operating efficiency of the warehousing system.

The popularization of intelligent warehousing robots is also expected to bring changes to management methods. Digital twin technology will be employed to enable management personnel to monitor warehouse operation in real time in a virtual environment, predict potential problems, and intervene in advance. Additionally, the intelligent management system will be able to automatically generate operation reports, provide data insights and optimization suggestions, and help managers make better-informed decisions.

In 2035, the wide adoption of intelligent warehousing robots will mark a new stage of development in the warehousing industry. By building a closed-loop and unmanned "perception-decision-execution" warehouse system, warehousing operation will reach new levels of intelligence, efficiency, and flexibility, laying a solid foundation for modern logistics systems and enabling the entire supply chain to continuously develop and become increasingly intelligent and efficient.

AI drives quality control and source tracing throughout the logistics supply chain

In 2035, the quality control and source tracing system of the logistics supply chain will achieve a revolutionary leap forward. The in-depth integration of AI and cutting-edge technologies will transform the quality control of the entire logistics process, from traditional manual spot checks to intelligent, full-chain quality control, leading to the creation of a quality assurance system that covers the entire supply chain.

Snapshot from the future: AI-driven high-quality logistics quality control systems

The combination of quantum sensing and edge AI will ensure the quality of high-value logistics. Each transport vehicle will be equipped with a quantum sensor in order to achieve atomic-level environment monitoring and capture minute changes regarding parameters such as temperature, humidity, and vibration in real time. Edge AI devices will also perform real-time data analysis and decision-making locally for millisecond-level responses. Such technology combinations will cover more than 90% of high-value logistics scenarios, reducing the damage rate of sensitive goods such as perishables and medical supplies to less than 0.1%, and reducing economic losses by more than US$200 billion each year. The intelligent monitoring system will make use of precise environment management and control throughout the logistics process, with multimodal sensing devices monitoring more than 20 environment parameters in real time. When an exception is detected, the system will immediately invoke the autonomous control mechanism.

In cold chain logistics, the AI temperature control system will be able to predict trends in temperature changes and preemptively adjust temperatures for ±0.1°C precision. This means goods will always remain in the optimal storage state. By employing blockchain technology, every item will be assigned a unique digital identity, allowing data to be recorded across the entire logistics process, from raw material procurement to sales. Such data will then be stored using distributed ledger technology to ensure that information cannot be tampered with or traced. Consumers will then have the option to scan the QR code of a product to view its complete circulation record and quality-test report. By taking advantage of big data analysis and machine learning algorithms, the system will be able to predict potential quality risks and send warnings before problems even occur. This predictive quality management will reduce the occurrence rate of quality problems by more than 85%. Furthermore, the system will collect quality data from across the entire logistics chain, perform in-depth analysis using AI algorithms, identify the root causes of quality issues, and automatically generate improvement suggestions to form a closed loop.

In 2035, the quality control system of the logistics supply chain will be fully digitalized and intelligent. The AI-driven, full-process quality monitoring system and the blockchain-enabled source tracing system will not only greatly reduce quality costs faced by enterprises, but significantly improve consumer experience and brand trust, thus providing solid support for the high-quality development of modern supply chains.

Conclusion

In 2035, intelligent logistics will achieve three AI-driven breakthroughs. In the transportation phase, the AI-driven dynamic optimization system will analyze multi-dimensional data in real time to implement the optimal allocation of global resources, reducing empty running rates by 60% and carbon emissions per unit of goods by 45%.

In the warehousing phase, intelligent robots will enter full-scale adoption to form closed-loop and unmanned "perception-decision-execution" warehouses to improve operating efficiency by three to five times and reduce processing costs by 60%. In terms of quality control, quantum sensing and edge AI technologies will cover 90% of high-value scenarios, reducing the damage rate of perishable and medical supplies to just 0.1% and cutting related annual losses by more than US$200 billion.

The combination of these transformations will build an efficient, transparent, and reliable modern logistics system. AI will not only implement intelligent upgrades at every stage of logistics, but use the blockchain-powered source tracing and intelligent warning system to ensure that quality across the entire process is controllable and traceable.

It is predicted that by 2035:

(1) 90% of global trunk lines will need 10^6 decisions per second, and the computing power will increase by 300 times from 1 EFLOPS to 300 EFLOPS.
(2) Four robots and 20 AMRs will need to be deployed in every 10,000 square meters of a fully automated, unmanned warehouse. The warehouse will need to be fully covered by 5G-A, with the network bandwidth increasing by 50 times from 3 Gbit/s to 140 Gbit/s, and the network latency decreasing by 50 times from 50 ms to 1 ms.
(3) AI-powered quality control will be realized throughout the logistics chain, requiring over 20 sensors (of temperature, light, and vibration) for each single batch of medical supplies transported. The number of global cold-chain IoT devices will increase by 100 times from tens of billions in 2025 to trillions in 2035.

Logistics has already evolved from an auxiliary tool to core infrastructure that supports the global supply chain. Now, as we look to the future, an intelligently upgraded logistics system will bring about significant improvements to operating efficiency, greatly reduce costs and environmental impacts, and inject new momentum into economic development.

Mining: Intelligent mining resource exploration and office mining to reshape mine production

The mining industry is indispensable to the prosperity and development of humanity. From the Stone Age to the Industrial Revolution, and then to the Information Age, every major leap in our civilization has been heavily reliant on mineral resources. The International Energy Agency (IEA) predicts that, despite the accelerated adoption of renewable energy, fossil fuels will still constitute over 60% of the global energy mix by 2035, with demand for key resources such as oil, natural gas, lithium, and copper remaining high.

Modern mining development currently faces a range of complex scientific, technological, and environmental challenges. With shallow resource deposits gradually depleting, extraction from deep underground, the deep sea, and geologically-complex areas has become inevitable. Globally, 70% of undiscovered oil and gas resources are estimated to lie in deep or ultra-deep formations. By 2035, deepwater oil and gas production is expected to account for 25% of total offshore output. Around this same time, it is predicted that traditional extensive development models will be increasingly unable to meet demands for safe and efficient resource extraction.

Today, advanced technologies, such as quantum computing and nanotechnology, are developing into foundational capabilities for oil and gas extraction, while digital and intelligent technologies are accelerating their deep integration with oil, gas, and mining techniques. Additionally, exploration, development, and production activities in the oil, gas, and mining fields will rely on governance and predictive analysis grounded in accessible geological and production data. AI technology is also gradually evolving from a supporting tool into the core driver of the industry's transformation. Over the past three decades, technological innovations

ranging from 3D seismic imaging to nanosensors have incrementally improved; over the next decade, AI is expected to deliver a qualitative leap, fundamentally redefining the technical frameworks and competitive dynamics of the oil, gas, and mining industry.

By 2035, intelligent technologies will have reshaped the mining landscape throughout the entire exploration, extraction, and production chain, achieving technical breakthroughs in geological visualization, factory-style mining, and unmanned production.

During drilling operations, diagnostic drill bits will send back data in real time, which AI systems can then analyze to dynamically calibrate models and optimize drilling trajectories. Ultimately, these advancements will lead to a closed-loop holographic exploration system of data acquisition, high-performance computing and modeling, AI interpretation, and drilling feedback, advancing petroleum exploration from highly fragmented surveying to crust CT scanning.

Oil and gas extraction will also be revolutionized through a closed-loop system of downhole technologies that span from reservoir stimulation to end-stage treatment. A new "downhole factory" development model will emerge, through which technologies such as high-precision intelligent fracturing, in-situ upgrading, nano oil displacement agents, and downhole oil-water separation systems will work in concert. Such innovations will surpass the limits of single-well recovery efficiency, lower operational costs, and fundamentally transform traditional extraction paradigms.

Offshore oil and gas production are set to enter an era of intelligent subsea factories, defined by a transition to a fully-subsea-integrated system characterized by automation, intelligent operations, remote control, and unmanned capabilities.

Meanwhile, onshore production will rely on digital twin technologies to achieve full lifecycle management and control. This will involve millions of IoT nodes dynamically optimizing production parameters in real time, and 5G-A/6G network-based intelligent remote centers coordinating the global production chain, thus minimizing the need for human intervention in high-risk areas. This will ultimately give rise to a new operational paradigm characterized by zero on-site manpower in production environments.

More efficient smart mineral exploration

Snapshot from the future: AI-driven intelligent geological exploration will significantly improve efficiency and accuracy

The exploration business is undergoing a paradigm shift from traditional methods to intelligent approaches, with the deep integration of AI technologies reshaping the entire geological exploration workflow. By 2035, the exploration industry will enter the era of holographic crustal visualization, forming a closed-loop system encompassing data acquisition, quantum modeling, AI interpretation, and drilling feedback. AI-powered geological exploration will lie at the heart of this transformation. The ongoing integration of quantum computing, intelligent sensing, and real-time feedback mechanisms is facilitating a revolutionary leap from geological interpretation to crustal understanding.

Meanwhile, exponential data growth and real-time transmissions are raising requirements for enhanced storage, greater computing capabilities, and high-speed network bandwidth.

Data acquisition: Building an integrated real-time data foundation across sky, land, wells, and sea

Over the next decade, the exploration business will establish a fully-coordinated, all-domain, and all-terrain collaborative network for data acquisition. Autonomous seismic node deployment will be realized through fleets of autonomous vehicles and drone swarms on the ground, while wireless, full-coverage marine detection will be enabled through Autonomous Underwater Vehicles (AUVs) ad hoc networking.

Furthermore, downhole nanosensors will be combined with quantum gravity gradiometers to create micrometer-scale monitoring layers, and thus create a four-in-one real-time data chain. This technological system will be able to overcome the physical constraints of traditional manual deployment and cable-laying vessels, compressing exploration cycles from months to weeks. Ultimately, this will form an intelligent and self-evolving neural exploration network, boasting comprehensive sensing and autonomous collaboration.

Moreover, the data acquisition in AI-powered geological exploration will rely on the application of intelligent sensing technologies in order to increase detection radius and fill in the blind spots of conventional methods. Therefore, the look-ahead-while-drilling and deep-reading logging-while-drilling technologies will play increasingly critical roles in reservoir description and geosteering while drilling, as they enable more extensive, accurate, farther-reaching, and faster detection. The look-ahead-while-drilling and deep-reading logging-while-drilling technologies use acoustic and electromagnetic sensing to expand detection ranges from the current tens of meters to several hundred meters around wells, and even up to thousands

of meters between wells. This will effectively bridge the detection gap that has traditionally existed between conventional logging and inter-well seismic surveys. The technologies will transmit subsurface data in real time during drilling, creating diagnostic drill bits to realize live formation scanning. Simultaneously, satellite remote sensing and drone spectral scanning will be initiated to enable wide-area coverage of surface geological features. The resulting massive multi-source datasets, including seismic, drilling, and remote sensing information, generated by these technologies will then provide high-precision inputs for subsequent modeling.

For example, the deep-reading logging-while-drilling technology is capable of capturing fluid distributions and reservoir boundaries near wells in real time through the use of electromagnetic or acoustic sensors, thus enhancing 3D formation awareness. This will result in an integrated data foundation that not only improves acquisition efficiency but optimizes sensor deployment through AI algorithms, thereby reducing human errors and guaranteeing data completeness and timeliness.

By 2035, a single multi-source integrated exploration project is expected to acquire petabyte (PB)-level raw data, while real-time transmission of the diagnostic drill bit data will rely on comprehensive downhole 5G-A/6G network coverage. Edge computing is also expected to play a key role by helping to alleviate backhaul bandwidth pressure.

Data processing: Quantum-computing-driven high-resolution modeling

In the data processing phase, huge volumes of seismic, drilling, and satellite remote sensing data will be rapidly processed by quantum computing chips, greatly accelerating the completion of reservoir inversion computations, which traditionally took months. This will lead to a dramatic increase in the resolution of 3D geological models.

Quantum computing chips possess ultra-high parallel processing capabilities. Utilizing the constant transmission of PB-level exploration data through subsea fiber-optic arrays, the AI hubs integrated with quantum computing chips can execute inversion workflows that traditionally required months in just hours. These systems will simultaneously integrate satellite monitoring, UAV-based hyperspectral scanning, and downhole nanosensor networks, to form a dynamically updated geological metaverse.

In elastic wave imaging technology, breakthroughs will overcome the limitations of conventional acoustic methods. Both P-waves and S-waves will be integrated into data acquisition, while leveraging full-waveform inversion (FWI), to realize full-wavefield imaging that will significantly enhance reservoir prediction. This process will be further supported by compressed sensing seismic acquisition, which uses optimized irregular sampling strategies to reduce data redundancy and improve imaging efficiency.

For example, Elastic Full-Waveform Inversion (EFWI) software will apply vector signal processing to generate high-fidelity subsurface images, laying a solid foundation for AI-driven geological interpretation.

Industry experience shows that seismic data processing typically requires 10–15 times more storage than the volume of raw data. It is predicted that by 2035, the cumulative annual data volume for a single oilfield will jump from PB-level to exabyte (EB)-level. Similarly, computing demands for EFWI are expected to escalate from PFLOPS to EFLOPS. This exponential data growth is accelerating the adoption of AI-based pre-processing and compression techniques, in a bid to ease storage pressure.

The application of quantum computing will not only accelerate inversion but optimize model parameters, resulting in more geologically-accurate reservoir characterizations, thus improving exploration accuracy at the source.

Seismic interpretation: AI-driven, centimeter-level intelligent interpretation

The seismic interpretation phase is at the very core of AI-powered geological exploration, where AI enables centimeter-level fault identification and reservoir prediction. Here, AI-based seismic interpretation will leverage deep learning and machine learning algorithms to automatically process seismic attribute data, allowing for centimeter-level detection of faults and lithofacies classification. This will significantly reduce the accuracy limitations associated with manual interpretation, enabling direct prediction of oil and gas distribution from 3D volumes through big data analysis.

For instance, multi-layer neural networks embedded within interpretation platforms will generate probabilistic lithofacies volumes, quantifying geological uncertainty and thus enhancing drilling success rates. It is predicted that by 2035, the error rate of AI geological modeling-based exploration target recognition in commercial applications will drop from the traditional 15%–20% to less than 5%.

AI systems will also integrate multidisciplinary datasets, such as well logs and geological survey data, into intelligent geoscience platforms, enabling collaborative analysis and dramatically reducing interpretation cycles. This will lead to far more accurate evaluations of exploration targets, lower the risk of ineffective drilling operations, and ultimately mean more reserves and increased production.

Real-time validation: Closed-loop feedback and dynamic optimization

The real-time validation phase will use AI systems to achieve model self-calibration and drilling trajectory optimization, ensuring closed-loop exploration management. Diagnostic drill bits will send back formation data during drilling. The AI system can compare it with the predictions of models in real time to dynamically adjust parameters. For example, the look-ahead-while-drilling technology can work with underground sensors to pinpoint "sweet spot" locations in real time, guiding drill bits to the precise location of the target formation. To ensure drilling trajectory and improve drilling efficiency, the edge computing system must respond in real time (through dynamic modeling) with a latency of less than 100 ms. The remote real-time intelligent control center can use 5G/6G and IoT to process on-site data and generate optimization instructions, enabling automated geosteering adjustments. This feedback mechanism will not only validate the model's accuracy, but enhance its predictive capability through machine learning iterations. This will enable crust CT scanning, which marks a shift from passive reaction to proactive insight.

In short, end-to-end AI geological exploration will revolutionize exploration. Data collection will form an integrated foundation, quantum computing will accelerate high-resolution modeling, AI interpretation will enable precise analysis, and real-time feedback will allow closed-loop optimization. Together, these changes will enable the transformation of oil and gas exploration from discrete snapshot-based surveying to a continually evolving crust CT scanning. This will allow a complete overhaul of the traditional paradigm characterized by long manual interpretation cycles and poor accuracy. Not only will this improve resource discovery efficiency, but it will significantly reduce exploration costs, which is conducive to sustainable energy development.

Reshaping operations for green, unmanned mining

The intelligent transformation of mining has already begun: Autonomous driving in open-pit mines is nearly mature. By the end of September 2024, 1,642 intelligent mining faces had been established nationwide in China, and over 1,000 unmanned mining trucks and robots had been deployed, covering 20% of all mining operations. However, complex underground settings still require manual decision making. Unmanned mining trucks have been deployed in only less than 5% of these settings, equipment coordination accuracy is insufficient, and data silos remain unresolved. There is still long way to go before inherent safety goals can be achieved.

Looking ahead, the main goal of unmanned mining areas will be the elimination of the high-risk factors for miners, such as collapses and explosions, with a target of zero fatalities. According to the Innovation Action Plan of Energy Technological Revolution (2016–2030) released by the National Development and Reform Commission and National Energy Administration of China, intelligent coal mining will be achieved by 2030, with most key coal mining areas having unmanned mining faces. By 2035, mining operations will be fully automated, with unmanned on-site production becoming the norm. China University of Mining and Technology predicts that China will have largely transitioned from manual mining operations by 2040. To achieve this goal, full automation must be implemented across mining operations, transportation, and safety monitoring.

Snapshot from the future: Autonomous operational ecosystems

By 2035, mines will have evolved into ecosystems with fully autonomous operations across the entire production process. The deep integration of quantum sensing networks and AI hubs will enable full automation across the lifecycle of

geological exploration, excavation, transportation, and safety monitoring.

Intelligent excavation: Millimeter-level precision extraction and adaptive control

The excavation process will be executed with bionic robotic arms and intelligent equipment. Transparent geological models will be used for autonomous collaboration between equipment, which will enable 100% automation in mining operations. Robotic arms can integrate a multispectral vision system and force feedback devices to scan rock fracture distribution with LiDAR (recognition accuracy of 0.1 mm). Combined with data from hydraulic pressure sensors and using inertial navigation technology, they can dynamically adjust cutting trajectories, making traditional experience-based judgment obsolete. This will enable coal mining machines to autonomously avoid obstacles in complex geological conditions, which can significantly improve extraction efficiency. Meanwhile, high-precision blasting technology will use 3D laser scanning to locate weak layers in the rock, with AI algorithms dynamically calculating the amount of explosives needed. This will enable directional energy release, which can reduce ore loss while minimizing disturbance to the surrounding rock. This will allow mines to shift from partial automation to full-scale independent decision-making, making manual mining operations a thing of the past.

Unmanned transportation: Dynamic scheduling and collaborative operation network

By 2035, autonomous driving will cover all mining settings, transforming assisted transportation into full-scale unmanned transportation. The transportation process centers around fleets of unmanned mining trucks and aims to form a dynamic scheduling network. Unmanned trucks and loaders will be coordinated using the Cellular-V2X technology. The vehicle-loader collaboration algorithms will be used to enhance efficiency to ensure 24/7 non-stop operations. Unmanned mining trucks equipped with integrated LiDAR-mmWave radar sensing systems can achieve real-time obstacle avoidance with response times in the milliseconds enabled by 5G-A/6G private networks. The cloud-based AI hub powered by deep reinforcement learning algorithms can comprehensively analyze ore grade, equipment status, and energy consumption data. This will allow trucks to take dynamically optimized routes, avoid obstacles, and transport materials efficiently.

The belt conveyor system will also go intelligent. Online monitoring of belt status and loads can improve scheduling and prevent faults. Sensors installed on belt conveyors can continuously monitor belt wear, material flow, and material composition. In the event of an abnormality, the system can automatically trigger an alert and take corrective action to ensure conveyor system stability. Currently, unmanned transportation pilot programs are limited to open-pit mines. By 2035, this technology will cover underground tunnels up to 50 km long, with centimeter-level navigation precision. It is predicted that unmanned mining trucks will be deployed for all open-pit mining operations and over 50% underground mining operations by 2035.

Safety monitoring: Surveillance and risk alerts across the mining area

Safety monitoring will transition from passive response to proactive alerting. The optical quantum sensing network can monitor micro-seismic waves with nanotesla-level sensitivity, providing enough time for rock burst warnings, which is a critical safety requirement. Explosion-proof inspection robots can use laser spectroscopy for second-level detection of gas leaks. The remote control center can use VR to map the underground environment in real time, allowing operators to remotely operate equipment as if playing a real-time video game. This will eliminate the need for human entry into hazardous areas.

While the current safety monitoring system can issue dust alerts, siloed systems cause response delays. By 2035, a fully responsive mechanism will be formed. Rock burst alerts will directly trigger mining robotic arms to avoid obstacles, and the exceeding of dust limits will trigger mining trucks to slow down. Emergency response times will be reduced from hours to minutes, turning the vision of zero safety accidents into a reality. Fixed positions underground will be fully covered by inspection robots. Robots will redefine the production chain. It is predicted that robots will fully replace human workers in 100% of high-risk settings by 2035.

The deep integration and collaborative optimization of mining, transportation, and safety monitoring is transforming the intelligent mine into a complete autonomous operational ecosystem. This system will enable fully automated operations across the entire production process. The deep integration of quantum sensing networks and AI hubs will create mining AI agents with autonomous perception, decision-making, and execution capabilities. We will see a comprehensive shift from labor-intensive to technology-intensive mining. This will be a new paradigm of global sustainable mining that will make manual mining operations obsolete.

Conclusion

By 2035, mines will have achieved technical breakthroughs in geological visualization, factory-style mining, and unmanned production. By then, geological exploration will have transitioned from AI interpretation to holographic crustal visualization. Error rates for AI modeling target recognition will drop from the current 15%–20% to less than 5%, with fault identification accurate to the centimeter. Mining will overcome limitations of traditional exploration, which is highly fragmented. The data volume of individual explorations will increase 1,000-fold from PBs to EBs, and computing requirements will also increase 1,000-fold from PFLOPS to EFLOPS with the upgrade of EFWI. This will enable high-resolution modeling and real-time feedback. Edge-based while-drilling dynamic modeling latencies will be reduced to less than 100 ms, achieving second-level data transmission from diagnostic drill bits. This will be enabled by 5G-A/6G and edge computing.

Mining operations will move beyond manual mining and transition to full-scale automation. The entire process of mining, transportation, and safety monitoring will be automated, with bionic robotic arms achieving millimeter-level precision in cutting through quantum torque sensing technology. Autonomous driving in open-pit mines is predicted to rise from 20% to 100%, and the adoption of unmanned mining trucks in underground mining operations is predicted to increase from less than 5% to 50%. Mining truck fleets will achieve centimeter-level navigation and millisecond-level coordination through 5G-A/6G private networks. The rock burst alert system integrated with autonomous obstacle avoidance devices will reduce emergency response times from hours to minutes, bringing safety incidents close to zero. Robots will fully replace human workers in 100% of high-risk settings.

This leap in computing power (EFLOPS), storage capacity (EB level), and latency (millisecond level) will power the transformation of the industry from labor-intensive to technology-intensive mining. It will enable breakthroughs in resource development efficiency and inherent safety. This is not only a technological innovation, but a significant stride towards an era of full-scale intelligent mining.

Cities: AI for the autonomous evolution of cities

Cities are the representation of the boundless aspirations of humanity. They serve as the core engines and pivotal nodes of global development. Two enduring characteristics of cities are high population density and endless expansion. During the Industrial Era, technologies like steam engines and railways overcame spatial constraints to extend urban boundaries from central districts to suburban areas. The underlying logic of urban evolution became clear: concentration for efficiency and expansion for development. In the intelligent era, this logic has been further activated by technological innovation and industrial upgrading, with concentrated development remaining the defining characteristic of future cities.

Populations, resources, and functions are highly concentrated in both large cities and smaller, well-planned cities. World-class urban clusters like New York City, London, Tokyo, Beijing, Shanghai, and Shenzhen continue the "concentration for efficiency" model and attract continued inflows of high-end talent. Smaller cities create competitive advantages through differentiated positioning, cultivating distinctive industries and quality living environments that appeal to people with high lifestyle expectations. The share of the global urban population is projected to rise from 56% in 2021 to 62% by 2035. In China, the urbanization rate is expected to reach 74% by 2035.[32] The increasingly networked population distribution highlights the urgent need to identify key focal points for achieving urban industrial collaboration and a balanced provision of public services.

New technologies are accelerating the blurring of urban boundaries. Spatially, the boundaries between cities, as well as between urban and rural areas, are becoming increasingly blurred. Functionally, cities are evolving from self-sufficiency to differentiated, complementary functions for different cities. For governance, boundaries are shifting from administrative jurisdictions to problem-oriented governance

units. The gradual dissolution of urban boundaries also raises the question of how cities can maintain their uniqueness amid convergent development.

With the widespread application of intelligent sensors, intelligent service terminals, digital service platforms, and robots, service models like on-demand and seamless services are redefining both the efficiency and human experience of human-machine collaboration. The efficiency of technology complements human judgment, jointly driving the upgrading of urban functions and shaping future cities where humans and machines work synergistically. Technological transformations have turned theoretical ideas into tangible realities, unlocking limitless possibilities for future cities. At the same time, human-machine symbiosis requires a careful balance in the division of labor, trust, and safety between humans and machines.

AI is reshaping how cities develop in the intelligent era, using its foundational capabilities to overcome bottlenecks in urban development. Guided by value creation and aimed at resolving major challenges, AI establishes a technological framework that empowers cities, providing them with leverage points, practical footholds, and mechanisms for balance. Autonomous perception, autonomous intelligence, and autonomous evolution have become shared goals for cities worldwide. Future cities will no longer passively respond to risks. Instead, they will use autonomous perception to automatically identify and report risks. Cities will operate with autonomous intelligence to meet human needs, responding to situations flexibly and efficiently rather than relying on hierarchical commands. This will enable faster and smarter responses to human needs. Through autonomous analysis and contingency plan optimization, cities will achieve autonomous evolution across perception, understanding, decision making, and execution, maintaining operational resilience and sustainable development in the face of change. This will further the development of AI-centered future cities. According to the International Data Corporation (IDC), global digital transformation spending grew at a CAGR of 15.4%.[33] Cities worldwide are progressing toward a shared intelligent future at varying paces, becoming testing grounds for comprehensive smart transformation. The level of intelligence is also becoming a key benchmark for urban development.

City-level AGI for infinite intelligence in new AI cities

The accumulation and application of AI technologies are closely aligned with the development needs of cities. Significant technological breakthroughs have been achieved, with algorithms gradually moving beyond heavy reliance on large-scale data toward enhanced autonomous reasoning. It is predicted that by 2035, 70% of the world's population will live in cities. Traditional management paradigms are insufficient for addressing the complexity of megacities. As living organisms, cities are becoming increasingly intelligent, evolving symbiotically with smart technologies. AI is already widely applied across urban services, governance, and safety, making cities more human-centric, livable, and safe. For the essential settings of digital and intelligent cities, AI will move beyond isolated applications to be seamlessly integrated into all aspects of urban life and work. In cities, every resident, moment, and task will be supported by a dedicated AI agent. This citywide adoption of AI indicates the evolution from specialized intelligence toward general intelligence. In other words, city-level AGI will begin to take shape. AI agents are predicted to reach 82% penetration across industries by 2035, becoming critical infrastructure that supports both efficient city operations and quality urban lifestyles.

Snapshot from the future: Urban service agents making cities more friendly with personalization and proactive response

The deep integration of intelligent technologies with urban services is painting a vivid picture of the city life of tomorrow. Over the past decade, cities have evolved from fragmented individual systems to holistic, collaborative networks, fundamentally reshaping how residents engage with their urban environments. Urban services are undergoing a profound shift from individual needs to the coordinated management of collective needs. This transformation goes beyond the traditional "point-to-point" model of service delivery. Each city is now treated like a living organism, and all its constituent parts need to be considered. Urban needs are evolving from singular, concrete service offerings to digital and virtualized demand spaces. For example, communities are using AI to establish service platforms for elderly care. These platforms monitor the health of elderly residents using things like video and wristbands, and provide comprehensive services like housekeeping, meal delivery, and medical escort. For personalization, micropower sensors monitor the vital signs of seniors living alone. When an urban service agent detects abnormal readings, it will notify an embodied AI care robot to monitor the situation. The agent will also assess whether medical intervention is needed by referencing the senior's health record history and trigger emergency alerts if necessary.

Whether for personalized basic household services or shared services at the city level, these needs can be efficiently addressed through the collaborative response of virtualized demand spaces. In cross-departmental collaboration, urban service agents break down data silos, integrate data from different departments, and enable real-time data sharing and coordinated service delivery. This allows residents and businesses to access services without having to navigate multiple departments, creating a convenient, efficient, and friendly urban service ecosystem.

Snapshot from the future: Urban governance agents making cities more livable with autonomous micro-governance

1. Urban micro-governance: Intelligence in the details

In modern urban governance, people remain the core unit of management, overseeing tasks such as waste-sorting supervision, dispute mediation, facility inspections, and emergency response. However, limitations in human resources and capacity often result in insufficient inspection frequency and make micro-level hazards difficult to detect. This hinders overall response efficiency. The traditional "low-density" governance model is inadequate for refined governance.

AI and embodied AI promise to overcome the bottleneck of governance density. Using building units, buildings, and communities as the smallest governance cells, these technologies establish perception and execution networks that extend beyond human capabilities. In Shanghai's Putuo District, nearly 1,000 community workers use an AI-assisted community worker app to quickly access accurate policy interpretations and similar case references. This has improved response times by 70%.[34] In Shenzhen's Mumianling Community, inspection robots equipped with smoke and fire detection algorithms perform 24/7 intelligent patrols.[35] In the communities of the Wuhan East Lake Hi-tech Development Zone,

high-frequency governance scenarios like objects being thrown from heights, electric scooters entering elevators, and seniors living alone are now intelligently identified and automatically addressed. As a result, safety incidents have decreased by 53.6%, building hazard inspection efficiency has improved tenfold, and inspection labor costs have been reduced by 71.4%.[36]
AI is redefining governance density through technological empowerment, enabling urban governance to achieve greater precision and reach.

With the rise and large-scale application of AI agents and embodied AI technologies, urban micro-governance supported by embodied AI robots is poised to enable finer-grained governance than traditional grids. In communities and buildings, a multi-stakeholder co-governance system fosters a micro-governance model characterized by human-machine symbiosis, where humans and embodied AI robots collaborate seamlessly. The number of embodied AI robots per square kilometer is projected to exceed 50 by 2035.

2. Future-oriented holistic urban governance

The concept of holistic urban governance encompasses preventive policies, proactive execution, and autonomous evolution.
Holistic governance is ideal for risk prevention in megacities, as it offers cross-domain collaboration, dynamic perception, and citywide response. Urban metaverses that integrate the physical and digital worlds can serve as technical foundations for holistic governance. For example, Singapore reconstructed the entire city in the metaverse block by block with extremely high precision.[37] South Korea launched the Metaverse Seoul platform in Seoul, on which people can access public services and resources in an immersive VR environment.[38]

Urban metaverses use virtual and digital technologies to create accurate digital representations of physical-world cities. Management elements like city events and components in the physical world can be updated in a digital city operation center using digital twin technology. Instructions and intentions in the virtual world can be accurately executed in the physical world in real time through urban governance agents, forming a new digital and intelligent governance model.

Using the metaverse, the governance status of the physical world is automatically synchronized, modeled, and enabled in the virtual world. Subtle changes like traffic signal adjustments, waste management facility additions, and pipe network pressure fluctuations in the physical world are automatically synchronized to the virtual platform through the sensor network across the city. After receiving the data, the virtual world starts modeling autonomously. The model's outputs and embodied AI technologies then will empower the physical world to take actions, contributing to automatic reconstruction of the spatiotemporal logic of urban governance. This significantly improves governance efficiency.

Snapshot from the future: Shifting from passive response to proactive defense with urban safety agents

Public safety in modern cities has evolved from passive response in individual domains to systematic risk prevention and control across domains. According to the research at the University of Tokyo, a fire at a subway station in a city of 10 million can result in the breakdown of services across an area of 12 square kilometers if emergency fire response is delayed by 10 minutes. The resulting economic losses can reach millions of dollars per minute.[39] The focus of safety management in the intelligent era is shifting to a preemptive approach. In Türkiye, AI is being used to enhance wildfire prediction and prevention. A model based on optimal resource allocation has been developed to predict wildfires in advance. This model can have a prediction accuracy of up to 80% and can predict wildfires 24 hours before they occur.[40]

Urban safety management is becoming increasingly intelligent as technology advances. AI will transform from an assistant to a decision-maker, from passive perception to autonomous decision making, and from instruction-based command to task- and target-based command. A joint research team of Waseda University and the University of Tokyo have developed an AI-based urban waterlogging disaster prediction system for rainstorms in Tokyo. The system can predict areas waterlogged by rainstorms 20 minutes in advance and update the data every five minutes, helping reduce the impact of rainstorms.[41] In the future, urban safety agents will no longer operate as isolated technical systems. Instead, they will be integrated into the "immune system" of cities, enabling citywide sensing, autonomous decision making, and cross-domain collaboration. Urban safety will shift from passive response to proactive defense, heralding a new era of intelligent evolution.

By 2035, cities will evolve from centralized intelligent hubs for data aggregation, analysis, and AI-assisted decision making to multi-dimensional embodied agents with intelligent sensing, decision making, and execution units. Like a human, the agents will be able to perform both data collection and task execution as well as intelligent control with their "hands and feet". Their "brains" will be capable of holistic thinking, dynamic planning, and intelligent collaboration. In this way, cities will become intelligent in all aspects, enabling sustainable development, improving quality of life for all, promoting economic prosperity, and ensuring urban safety.

City data driving a prosperous intelligent economy

As a new production factor, city data is playing an increasingly important role in city operations and development. According to international data agency Statista, the total volume of data worldwide will increase by about 35 times by 2035 compared with 2020.[42] City data is crucial in many ways: City managers can analyze citywide data to inform their decisions and optimize resource allocation. Enterprises can gain insights into market trends and update their production and marketing strategies based on consumption data. In the public service domain, public data can be used to improve service accuracy. Furthermore, the in-depth analysis and cross-domain integration of city data will promote the digital and intelligent transformation of cities, accelerate the development of the intelligent economy, and become the key driver of urban innovation and competitiveness.

Snapshot from the future: A data space for every person, enterprise, and city

Data space is a concept emerging from the transformation from "land dividends" to "data dividends". In the context of the digital economy and the reconstruction of production factors and resource allocation, a trusted data space system is the key driver of industry collaboration and service transformation. A trusted data space cannot be constructed without the integrated development of communication networks, computing facilities, data ecosystems, trusted services, and security technologies. This space creates value by enabling the orderly flow of distributed and unstructured data.

As a global pioneer in trusted data spaces, the EU has built 160 trusted data spaces in 2024, covering domains like healthcare, energy, and transportation.[43] Japan has launched the Ouranos program aimed at innovation in emerging industries, urban public services, electric vehicles and batteries, and financial transactions.[44] At the Suzhou International Data Port in China, digital trade and cross-border data circulation are being developed. System innovation, infrastructure upgrade, and platform support at the port are stimulating economic growth in the region and the world at large.[45]

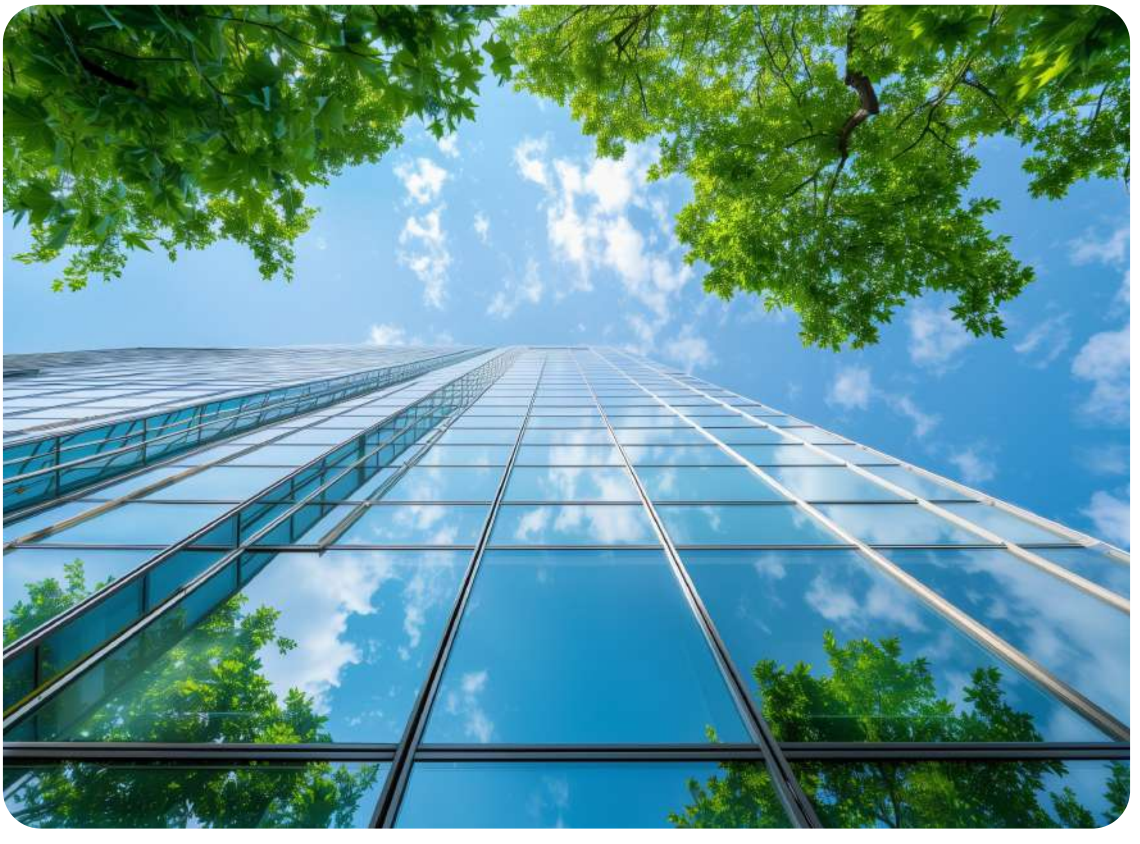
In the future, data will become a key production factor for city development, and trusted data spaces will be critical for connecting people, enterprises, and cities. As the data in different domains is connected through trusted data spaces, public services will be provided proactively instead of reactively, enhancing residents' well-being. Enterprises will use trusted data spaces to offer services through the secure collaboration model of "data available but invisible", improving operational efficiency. Cities will use trusted data spaces to break intercity data barriers and support efficient cross-domain linkages and collaborative development. This data-driven development model will lay the groundwork for the sustainable development of cities.

Snapshot from the future: Intelligent supply of data products to meet emerging data needs

Data needs are emerging through diverse methods at the underlying level, forming a pattern driven by both user-defined needs and AI-perceived needs. User-defined needs encompass explicit data needs and implicit scenario-based needs. The former largely consists of the precise needs that enterprises and organizations express based on their business objectives. For example, financial institutions need structured data like enterprise credit investigation and transaction records to prevent risks. The latter is largely made up of data needs hidden in business scenarios. For example, when planning traffic governance solutions, city managers need to build comprehensive analysis models based on data like population migration and weather changes.

AI-perceived needs refer to potential needs identified through advanced data chain technologies and AI algorithms. Multi-dimensional data graphs constructed using blockchain and big data technologies weave fragmented data scattered across different domains into an organically interconnected data chain network. Each data node is a traceable and verifiable value unit. On this basis, the foundation model uses technologies such as graph neural networks and natural language processing to dynamically mine and intelligently analyze data graphs, and automatically identify needs that are difficult to detect with conventional methods.

When user-defined needs and AI-perceived needs are parsed through intelligent algorithms, instructions are accurately pushed to a data factory in milliseconds. As the "hub" of data products, the data factory can dynamically schedule citywide data resources within seconds using an automatic orchestration engine. In addition, the data factory can automatically complete data cleaning, feature extraction, and model training. It can convert raw data into diverse data service products like visualized reports, prediction and analysis models, and intelligent decision-making systems. Finally, using an intelligent recommendation algorithm and data sandbox technology, these customized



products will break through the limitations of time and space to fulfil user needs accurately, securely, and compliantly. This will enable closed-loop management of data throughout the process from production to delivery, and significantly improve the circulation and service efficiency of the data element market.

Snapshot from the future: Cross-region circulation of trusted data beyond the physical boundaries of cities

As the digital economy sweeps across the globe, data will go beyond the physical boundaries of cities to circulate across regions. Using trusted data probes deployed across these regions, the system will proactively and dynamically probe such data in real time. As the digital economy becomes an increasingly important part of society, an efficient and normalized operation model is maturing for establishing property rights, pricing, and circulating personal, business, and city data. In this way, data will become core assets for businesses and other organizations. Just like how businesses get publicly listed for equity trading, data holders will be able to organize and evaluate their legally and compliantly owned data assets and bring them to the market for trading. By 2035, the global data trading market will be worth US$812 billion.

Let's look at how data will be used to improve business operations in three sectors.

Finance: The difficulties and high costs of financing are common challenges for small and medium-sized enterprises (SMEs). To address this, privacy computing technology will be used to integrate information such as enterprise tax continuity, social security coverage stability, and energy consumption activeness in an encrypted environment. This will help to create a multi-dimensional credit model that can rigorously assess enterprise operation risks while protecting their data privacy. Based on the assessment results, banks can quickly grant loans to SMEs that have authentic business needs but lack traditional collateral, making financing easier for SMEs.

Manufacturing: With data systems at the equipment, workshop, enterprise, and industry levels, enterprises are no longer restricted by internal data silos. Instead, enterprise data will be shared, coordinated, and circulated across regions and enterprises through an industrial Internet platform. Design teams will obtain component specifications and process standards from the global supply chain in real time to optimize product design. Manufacturing shops will adjust production schedules through collaboration with enterprises across the supply chain according to changes in market demand. Suppliers will accurately arrange material delivery based on the real-time inventory data of manufacturing enterprises.

Logistics: A highly intelligent and efficient logistics network system is taking shape. Based on real-time inventory data and order information, intelligent algorithms will be used to optimize the allocation of logistics resources, enabling refined management from transportation route planning and vehicle scheduling to warehousing facility usage. Automated equipment driven by data-based commands will be able to store, sort, and distribute goods within seconds, greatly improving logistics efficiency. With deep analysis and optimization of warehousing data, warehousing space can be better utilized to reduce logistics costs.

Intelligent infrastructure for a digital future

With city-level AGI on the horizon, intelligent infrastructure is becoming the key to addressing governance challenges and supporting AGI applications. The way cities expand is constantly evolving, and the focus of urban development is shifting towards digitalization and intelligence.

Currently, the focus of global digital infrastructure construction is transitioning from function development to intelligent collaboration, demonstrating new features like deep integration, intelligent citywide sensing, and dynamic collaboration. We believe that intelligent urban infrastructure will evolve in three areas. The first is terabit quantum communications, which connect cities with ultra-high speed and superior security. Ubiquitous connectivity helps break physical barriers between computing nodes and aggregate scattered computing resources for collaboration and interaction, unlocking the potential of cities. The second is citywide sensing, which provides city managers with multi-dimensional and high-granularity bases for decision making by capturing the operating status of the city in real time. The third is a city operating system, which integrates digital resources across the city so that domain-specific systems can autonomously collaborate and city operations can be dynamically optimized. Combined, these three areas serve as the foundation of city operations. They can provide end-to-end support for the digitalization and intelligence of cities by enabling a closed loop from secure data transmission and real-time city status sensing to intelligent resource scheduling.

Snapshot from the future: Terabit quantum communications covering every corner of the city

1. 3D communications networks for ultra-fast citywide connectivity

China has built the world's largest and most advanced 5G network. By 2025, there were 4.8 million 5G base stations nationwide.[46] F5G 10-gigabit optical networks are already serving as the backbone of urban connectivity, providing 10 Gbit/s access for homes and businesses while being widely adopted in city infrastructure.

In wireless communications, the terahertz (THz) frequency band will become a new target for high-speed, low-latency communications. The International Telecommunication Union (ITU) has designated the 0.12 THz and 0.22 THz bands for next-generation terrestrial wireless communications and inter-satellite communications, respectively.[47] With ultra-large bandwidth, the THz band will be the key to terabit communication speeds. In wired communications, optical module technology is rapidly evolving, targeting single-channel rates of coherent 1.6 Tbit/s with 400 GHz channel spacing.[48] The all-optical network architecture will lay a solid foundation for connectivity in a digital and intelligent world. In the UK, a research team from Aston University has achieved a transmission speed of about 400 Tbit/s on a 50-kilometer-long single-core optical fiber.[49] In China, the world's first 1.2 Tbit/s backbone for the next-generation Internet has already connected Beijing, Wuhan, and Guangzhou over a total length of more than 3,000 kilometers.[50]

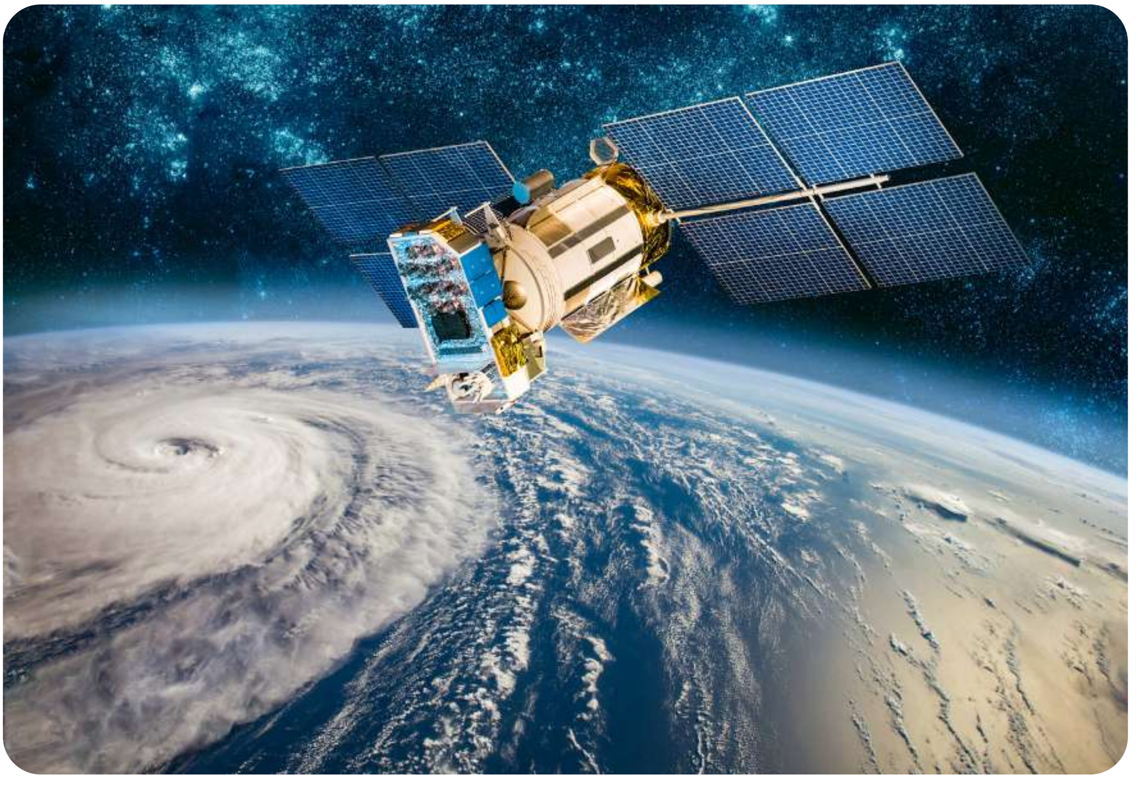
Satellite communication technology has seen breakthroughs in recent years. Smartphones can now directly access satellites to make calls. The Tiantong-1 satellite mobile communication system is already applied to automotive communications. Through collaboration with automobile manufacturers, the satellite system is making in-vehicle communications even more powerful. Satellite communications will also play an essential role in emergency rescue. When terrestrial communication networks are damaged by natural disasters, emergency communication channels can be quickly established through satellites to ensure unimpeded rescue commands.

10 Gbit/s wireless communications, 10 Gbit/s optical communications, and satellite communications work together to deliver seamless, ultra-fast urban connectivity. Citywide connectivity is underpinned by optical fiber networks that transmit data at terabits per second per wavelength. By 2035, urban connectivity will become even more advanced, efficient, and integrated, as it will be powered by core networks delivering over 1.6 Tbit/s speeds and core metro network switching nodes with up to 150 Tbit/s capacity.

2. Quantum communications for communication security

Security is essential for intelligent urban infrastructure. Quantum communications can implement security features grounded in physical theory and can play an important role in the security of urban connectivity. Quantum communications are a form of communication that uses quantum mechanics principles to manipulate quantum states. It has the potential to revolutionize information security, as it is the only communication method rigorously proven to be unconditionally secure, meaning it is an effective solution to information security issues.[51] This unconditional security means that encryption technology no longer needs to depend on algorithm intensity. Secure data transmission is no longer a mathematical assumption, but is now provable by physical laws.

For intelligent urban infrastructure, quantum communications will be the secure backbone of critical information networks, providing reliable solutions for future communication security. This will inject new momentum into the adoption of



quantum communication technology worldwide. Quantum communications are already being used in multiple areas, such as government services and urban operations, to ensure information security. Encrypted communication links based on quantum key distribution (QKD) will be established for physical infrastructure such as urban power grids, traffic signal systems, and energy dispatch centers. For example, in Internet of Vehicles (IoV) systems, communications between autonomous vehicles can go through quantum channels to ensure ultimate security in command transmission. This will protect vehicles from cyber attacks and eliminate security risks for intelligent transportation. China has built the Beijing-Shanghai Backbone Network for quantum-secured communications, connecting multiple important cities and enabling QKD over thousands of kilometers. The UK has also experimented with long-distance quantum-secure data transmission. It is estimated that by 2035, the quantum communications market will be worth US$13.49 billion, a quantum leap from US$1.37 billion in 2024.[52]

3. Networks for computing: Enabling on-demand compute flows

IDC projected that, by the end of 2025, the global volume of data would exceed 180 ZB, 1,000 times the combined data of all printed books throughout human history.[53] Computing power will be the key to organizing such massive amounts of unordered data.

Computing power for cities will be delivered not only by data centers. City components, vehicles, consumer devices, and wearables can all serve as compute nodes for scheduling on demand. Every digital component will be able to deliver intelligent computing power and become "cell" nodes or even "atom" nodes of urban AI agents. Theoretically, upgrading all existing city components of a medium-sized city with computing power will add billions of floating-point operations per second (GFLOPS) to the total compute supply. For instance, citizens in Barcelona only need to download a dedicated app to share unused computing power on their phones. This facilitates the processing of urban environment monitoring data. It is predicted that by 2035, the computing power needed by humanity will be 100,000 times that in 2025. By then, every enterprise, individual, and city component will be enabled by AI.

The scheduling of computing power, regardless of the form, relies on intelligent lossless networks. Optical transmission technology features ultra-low bit error rate design and a dynamic routing redundancy mechanism. This enables a reliable high-speed digital channel for remote scheduling of computing power to ensure zero packet loss and minimal delay during data transfer across nodes. Intelligent optimization can be achieved using AI algorithms that sense computing loads, link status, and service requirements across networks.

By 2035, we will see a vast computing network ecosystem covering over 99% of cities. Through this comprehensive urban computing network, remote computing power will enable local inference across scenarios. Additionally, urban apps can be developed and run without concern for where computing power originates. Computing power can be invoked remotely for virtually seamless and on-demand computing.

Snapshot from the future: Empowering cities with intelligent sensing to stay in sync with their every beat

1. Nanocomposite sensing: Empowering all facets of resilient cities

Sustainable development is a critical aspect of urban planning, and issues like energy consumption and environmental degradation can be exacerbated by city expansion. In a smart city, sensors need to be deployed for urban management, environment monitoring, traffic guidance, and other applications. The power consumed by these sensors alone in a typical megacity is conservatively estimated at billions of kilowatt-hours per year, or tens of millions of tons of carbon emissions annually.[54] There is an urgent need to use cutting-edge technologies to design solutions for energy conservation.

Nanocomposite sensing technology can help sensing devices conserve energy using semiconductor nanoparticles that absorb visible light and convert kinetic and thermal energy into electrical energy. Biodegradable polymer matrices can minimize the carbon footprint of sensor disposal. The Chinese Academy of Agricultural Sciences has developed the world's first intelligent monitoring system for nonpoint-source pollution and developed eco-friendly sensing materials that can be used to identify and capture pollutants more efficiently. The materials are more than five times stabler than traditional adsorbents, enabling over 90% sensing accuracy.[55]

With the maturity of manufacturing processes and scenario-based applications, nanocomposite sensing technology will be able to monitor and analyze data in real time in diverse areas of urban management. The technology will enable interoperability and data sharing between systems, improve operational efficiency and management, and help achieve sustainable development. This will make city life more convenient, comfortable, and safe.

2. Citywide intelligent sensing of things and self-healing: Transition to autonomous evolution

There is an urgent need for efficient and intelligent management models for massive population flows, traffic management, and infrastructure O&M to meet the needs of real-time targeted urban governance. Traditional management methods characterized by manual inspection and delayed data feedback are no longer sufficient. Cities are increasingly eager for intelligent sensing of things and self-healing.

Cities are still inconceivably vulnerable to abrupt destructive attacks. Major megacities around the world are implementing resilient city strategies using smart sensors. City planners in Tokyo, Japan have installed a large number of sensors on bridges, buildings, underground pipelines, and other types of infrastructure to monitor the structural soundness of infrastructure in real time.

In this way, city authorities can be alert to changes and take maintenance measures quickly.[56] An intelligent energy sensing program has been launched in London, UK. Sensing devices like smart meters are used to monitor the electricity consumption of residents and enterprises in real time. Based on the sensor data, power supply strategies can be dynamically adjusted to ensure energy stability and efficiency.[57] In the future, intelligent devices deployed and connected to urban networks will be able to automatically report their models, functions, locations, and other information to a management system. The devices will autonomously determine data transmission paths and assign tasks based on the environmental and device conditions. By 2035, the total number of IoT connections worldwide will reach 100 billion. Devices in cities will become increasingly adept at automatic detection and autonomous connection. These devices will form autonomous intelligent IoT sensing systems that will improve public safety and quality of life.

Snapshot from the future: Digital operating systems for flexible resource allocation and more efficient municipal services

Digital operating systems for cities will integrate cloud-network, computing, algorithm, data, component, and application resources. These systems will also enable intelligent decision making and collaborative execution. The operational logic of urban physical space will be converted into a computable, malleable digital model that allows cities to transition smoothly from traditional governance to intelligent and adaptive development. Shenzhen, China now has a digital operating system that dynamically and accurately manages all digital resources and allocates these resources for collaborative services.[58] U-City in Seoul, South Korea, has integrated a sensor network, government cloud platform, supercomputing resources, and data from different fields like transportation, energy, and environmental management into a unified digital resource management hub.[59]

A digital operating system for cities will be like a large and well-organized digital warehouse. It will break down barriers between industries and government authorities in cities. It will connect to IT platforms through unified standard interfaces to implement seamless sharing and collaborative innovation related to digital resources.

Digital operating systems for cities will evolve to become more adaptive and collaborative. The southbound architecture of these systems will orchestrate and schedule resources across physical boundaries based on constantly evolving needs. When IoT devices upload data intensively, the system will automatically and preferentially allocate computing power from edge nodes to the data source and cloud storage for backup. This prevents single-node overload while ensuring response efficiency through flexible resource allocation.

The northbound architecture will reconstruct apps, deeply understand and dynamically respond to user needs, orchestrate and invoke resources, and dynamically arrange human-machine interaction interfaces based on user intent. In this way, apps will be completely independent of physical hardware and exist in the cloud resource pool as digital services. When city managers analyze data on city operations, the digital operating system can automatically retrieve data based on the city managers' concerns and recommend optimization solutions. The system will follow the principle of minimal cognitive load when seamlessly embedding technologies into the decision-making process.

Conclusion

By 2035, intelligent technologies will be more than standalone tools, but work together in a symbiotic partnership. These technologies will permeate the very fabric of urban life, transforming cities from collections of functions into adaptive living organisms. With city-level AGI as the blueprint, data as the connection between city-level AGI and urban infrastructure, and intelligent infrastructure as the foundation, cities will be able to intelligently transform. By 2035, urban computing networks will achieve 99% coverage, AI agents will reach 82% penetration across industries, and the global data trading market will be worth US$812 billion.

Over the next decade, cities will evolve into living organisms capable of autonomous perception, autonomous intelligence, and autonomous evolution. This will usher in a new stage of citywide business model-based, data value-oriented, and intelligent development. City-level AGI will enable intelligent interaction and autonomous intelligent services across domains through the use of AI agents. Business models will be integrated across areas like governance, services, and public safety. With data as the connection between city-level AGI and urban infrastructure, cities will dismantle departmental and hierarchical silos, unleash the value of data assets through their circulation, and make data value creation a new engine for urban development. Intelligent infrastructure will be deployed across cities, providing comprehensive support for autonomous decision making and collaborative city operations. Smart technology will lay a solid foundation for city operations and improve quality of life for all urban residents.

Symbiosis with AI

Making AI sustainable

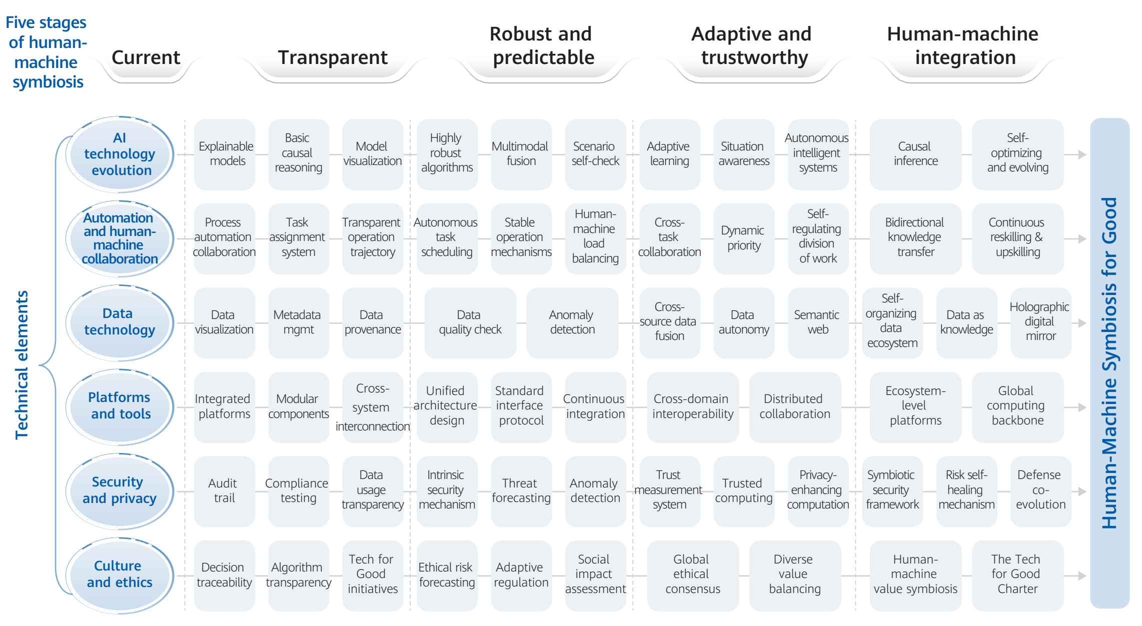
AI is transforming every aspect of our lives, homes, and businesses at an unprecedented rate, and it will become a catalyst for future societal change. However, the shift of AI from the digital realm into the physical realm presents significant challenges for humanity:

(1) Technological imbalance and digital divides: The benefits of AI may be concentrated in a small number of countries and companies, creating a new divide between the AI haves and AI-have-nots and even exacerbating social inequality.

(2) Ethical risks and value alignment: AI agents currently make decisions without transparency or explainable reasoning. When AI systems evolve towards greater autonomy, aligning their values with human values will become a critical challenge.

(3) Security: In an intelligent world where everything is connected, AI systems will face growing risks of cyber attacks, and many of these risks are amplified with AI.

Navigating these challenges requires a systematic approach to balancing rapidly evolving technologies and governance frameworks. Huawei proposes a systems engineering framework aimed at building a future where AI is used for good. This system draws on systems engineering theories as well as the AI roadmap developed by INCOSE and SERC, featuring five waves of development towards human-machine co-learning.



Human-Machine Symbiosis for Good – Systems Engineering Framework

Promoting AI for good through a human-centric approach that factors in ethics and security

AI ethics: Making AI for good part of AI values

AI is more than just a technical product. It is a reflection of our values. Initially, the main focus of AI ethics was to prevent harmful behaviors and discriminatory practices. That was why clear boundaries were delineated for technology use. As AI capabilities continue to expand, ethical standards are beginning to encompass explainability, traceability, and accountability. These standards will provide a clear understanding and effective regulation of AI decision-making processes.

When AI reaches a certain level of autonomy, the ethical framework must be updated to include value alignment and cultural inclusivity to mitigate technological biases or monocultural impact on diverse communities. In a human-machine symbiosis model, AI would collaborate with humans to develop wisdom for long-term development. AI ethics is about ensuring AI serves humans, not the other way around.

AI cyber security: Building trustworthy AI systems

AI cyber security is the foundation of using AI for good. It hinges on three fundamental pillars: ICT infrastructure security, single-agent security, and multi-agent security. Governance is also key to ensuring AI cyber security.

ICT infrastructure security

ICT infrastructure will need to embed a security framework rooted in post-quantum cryptography to keep up with advances in quantum computing. In particular, critical ICT infrastructure will need to ensure three types of security: integrated computing security, integrated network security, and integrated energy security.

- Integrated computing security entails creating a trusted confidential computing environment to make every computation confidential.
- Integrated network security means ensuring full-link security for communication and data flows between intelligent computing units to make every communication secure.
- Integrated energy security focuses on flexible scheduling of energy supply and secure energy system management by integrating functional safety with network security to ensure continuous and stable system operations.

Single-agent security

Single-agent security must be ensured throughout the lifecycle of any agent, from model training to inference and application. It must cover different levels like data security, model security, content security, application security, and O&M security. Single-agent security can help ensure reliable and autonomous decision making of AGI and embodied AI. Each agent should have trusted identity and content identifiers to ensure their actions are auditable and calls are traceable. To counter emerging cybersecurity threats, it will be essential to develop AI-driven active security defense systems to create highly adaptive and evolving immune mechanisms.

Multi-agent security

Multi-agent collaboration will become the new norm in future human-machine symbiosis. We need to embed trusted identifiers in each agent while ensuring communication security and data privacy during collaboration between agents. A systematic framework is needed for privacy protection, consensus building, and conflict resolution. This framework needs to address key concerns like data privacy, collaborative decision-making efficiency, and resource allocation optimization. The aim is to foster a stable, efficient, and trustworthy ecosystem for human-machine symbiosis.

AI cyber security governance

AI cyber security relies on comprehensive governance throughout its lifecycle. There needs to be a robust management system that integrates systematic security engineering principles and technologies into every stage, from research and development to operations. This holistic approach can ensure that AI systems remain secure from the initial stages of model training and inference through to their use. It's crucial to strike a balance between AI development and governance.

AI for all: Bridging digital divides for faster sustainable development

The rapid growth of AI is enabling transformative changes, but also presenting new challenges: widening digital divides, increasing regional disparities, and growing ethical risks. The entire world is working together to find a solution. Many leading organizations have released documents on how to manage AI, including the UN's Global Digital Compact[60] and the joint statement from the Paris AI Action Summit[61]. These guidelines provide a clear roadmap for global AI development: a digital future that is human-centric, inclusive, open, sustainable, fair, safe and secure.

The UN's Global Digital Compact aims to close digital divides between and within States and advance an equitable digital environment for all, which is essential to achieve the Sustainable Development Goals. Similarly, the Paris AI Action Summit's joint statement advocates for inclusive and sustainable AI for people and the planet, and prioritizes promoting AI accessibility to reduce digital divides.

AI will become the infrastructure of the intelligent world, just like how highways, railways, and communications networks are the infrastructure of the industrial world. A human-centric approach to AI is key to making the benefits of technology accessible to all and driving sustainable development worldwide.

Inclusive AI for inclusive growth

Inclusive AI means that AI benefits everyone regardless of race, gender, region, economic status, or educational background. By 2035, AI for all will no longer be a nebulous vision, but a reality. We will see AI being increasingly used in areas like education, healthcare, and accessibility services. This will drive inclusive growth and sustainable development.

In education, for example, personalized AI learning plans, intelligent tutoring systems, and remote education programs will improve access to learning resources and opportunities for underserved groups and communities. This will help narrow the education gap in developing countries.

AI-powered bionic prosthetics and brain-computer interfaces will enhance social inclusion for people with disabilities, while embodied AI—intelligent elderly care robots in particular—will help elderly people live better, a pressing need for the world's aging populations.

AI will also expedite drug discovery and development, enable early diagnosis and prevention, and enhance clinical decision support systems, offering affordable technical solutions to underserved regions.

Sustainable AI for green development

However, the massive energy demands of AI systems will put a strain on our planet. To truly bring the benefits of AI to all, we need to consider its energy consumption and environmental impact from the very outset. We need to minimize the environmental footprint of AI by developing more energy-efficient algorithms and hardware, using renewable energy sources, and optimizing data center cooling systems.

AI can also play a pivotal role in the global green transition. In the energy sector, AI can optimize power grids and enhance utilization of renewable energy sources. In transportation, AI can improve logistics and traffic flow while reducing carbon emissions. In agriculture, AI can enable precision farming, which helps conserve precious water resources. Additionally, AI can assist in environmental monitoring and disaster early warning, promote more efficient and sustainable use of natural resources, help fight climate change, and foster harmony between humans and nature.

Technology and governance for inclusive AI

To make AI accessible to everyone, we need a two-pronged approach that balances technological advancement and governance efficiency.

On one front, we need to make AI easily accessible and user-friendly. This means bridging infrastructure and skill gaps and making AI as readily available as water and electricity. Our education systems need to keep up to equip everyone with AI skills. This can be achieved through the provision of basic digital literacy, specialized technical training, and lifelong learning.

On the other front, when it comes to AI governance, particular emphasis should be placed on mitigating gender, racial, linguistic, and other forms of discrimination, as well as algorithmic bias in AI deployment and application. Our goal is to make AI accessible to all people and regions. By fostering partnerships, cross-industry collaboration, and shared innovation, we can accelerate the global adoption of AI and bring everyone into the digital world.

Moving forward, AI will become more deeply integrated into every home and industry. However, to ensure this technology fosters collaboration and progress rather than conflict and division, we need to embed inclusivity, ethics, and security into the systems engineering framework for human-machine symbiosis aimed at building a future where AI is used for good. We must make AI for good a fundamental principle from the start, rather than a mere afterthought. Doing good with AI is not a byproduct of AI; it is the core objective of AI. This approach is key to ensuring humans and AI agents co-exist and thrive and paving the way for a civilized intelligent world.

References

1 "Life expectancy projections," https://ourworldindata.org/grapher/future-life-expectancy-projections?tab=table&time=2025..2035.

2 "Global Healthspan-Lifespan Gaps Among 183 World Health Organization Member States," https://jamanetwork.com/journals/jamanetworkopen/fullarticle/2827753?widget=personalizedcontent&previousarticle=0.

3 "Noncommunicable diseases," https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases.

4 "Revision of World Population Prospects," https://population.un.org/wpp/.

5 "Care Provider Targets Over a Million Visits in January, to Aid Government Promise to Cut NHS Wait Times," https://www.businesswire.com/news/home/20230110005110/en/Cera-Care-Provider-Targets-Over-a-Million-Visits-in-January-to-Aid-Government-Promise-to-Cut-NHS-Wait-Times.

6 "Cera software rolled out across NHS," https://healthcaretoday.com/article/cera-software-rolled-out-across-nhs.

7 "Genomic data in the All of Us Research Program," https://www.nature.com/articles/s41586-023-06957-x.

8 "Imaging-guided bioresorbable acoustic hydrogel microrobots," https://www.science.org/doi/10.1126/scirobotics.adp3593.

9 "ElliQ in the News," https://elliq.com/pages/press.

10 *Virtual wards and hospital at home,* https://researchbriefings.files.parliament.uk/documents/POST-PN-0744/POST-PN-0744.pdf.

11 "How AI Assists With Staffing, Scheduling and Once-Tedious Task," https://consultqd.clevelandclinic.org/how-ai-assists-with-staffing-scheduling-and-once-tedious-tasks.

12 *Global Initiative on Digital Health,* https://www.who.int/publications/m/item/global-initiative-on-digital-health.

13 UNESCO, *Global education monitoring report, 2024/5, Leadership in education: lead for learning,* https://unesdoc.unesco.org/ark:/48223/pf0000391406.

14 UNESCO, *Global report on teachers: addressing teacher shortages and transforming the profession,* https://www.unesco.org/en/articles/global-report-teachers-addressing-teacher-shortages-and-transforming-profession.

15 China's Ministry of Education, *2024 National Education Development Statistical Bulletin,* http://www.moe.gov.cn/jyb_sjzl/sjzl_fztjgb/202506/t20250611_1193760.html.

16 OECD, *Class size and student-teacher ratios,* https://www.oecd.org/en/topics/class-size-and-student-teacher-ratios.html.

17 State Council of China, *Guidelines on deepening the implementation of the AI Plus Initiative,* https://www.gov.cn/zhengce/content/202508/content_7037861.htm.

18 UNESCO, *Flexible strategies for ensuring quality learning outcomes in curriculum, pedagogy, and assessment in Asia-Pacific during the COVID-19 pandemic,* https://www.unesco.org/en/articles/flexible-strategies-ensuring-quality-learning-outcomes-curriculum-pedagogy-and-assessment-asia.

19 UNESCO, *Futures of Education,* https://www.unesco.org/en/futures-education.

20 Jerome Bruner, *The Process of Education*

21 UNESCO, *AI and education: guidance for policy-makers,* https://unesdoc.unesco.org/ark:/48223/pf0000376709?posInSet=1&queryId=bb28fa42-59e2-4777-8010-3f9f6dc8582f.

22 arXiv, The Art of SOCRATIC QUESTIONING: Recursive Thinking with Large Language Models, https://arxiv.org/pdf/2305.14999.

23 arXiv, *Enhancing Critical Thinking in Education by means of a Socratic Chatbot,* https://arxiv.org/abs/2409.05511.

24 Beijing Normal University, *Human-machine collaborative teaching: path design based on virtual avatars, digital twins, and educational robot scenarios,* https://openedu.sou.edu.cn/upload/qikanfile/202311231142207081.pdf, Beijing Normal University.

25 Stanford University, *AI-Driven Virtual Teacher for Enhanced Educational Efficiency: Leveraging Large Pretrain Models for Autonomous Error Analysis and Correction,* https://scale.stanford.edu/genai/repository/ai-driven-virtual-teacher-enhanced-educational-efficiency-leveraging-large.

26 McKinsey & Company, *How artificial intelligence will impact K–12 teachers,* https://www.mckinsey.com/industries/education/our-insights/how-artificial-intelligence-will-impact-k-12-teachers.

27 University of Michigan, *Ross School part of Virtual Teaching Assistant pilot program,* https://record.umich.edu/articles/ross-school-part-of-virtual-teaching-assistant-pilot-program/.

28 Kevin Kelly, *2049: Possibilities of Next 10000 Days*

29 ITIF, *The Promise of Immersive Learning: Augmented and Virtual Reality's Potential in Education,* https://itif.org/publications/2021/08/30/promise-immersive-learning-augmented-and-virtual-reality-potential/.

30 Microsoft, *Immersive Experiences in Education — New Places and Spaces for Learning, 4,* https://www.microsoft.com/en-us/education/msdownloads/MicrosoftEducation_Immersive_Experiences_Education_2019.pdf.

31 *State of Food Security and Nutrition in the World 2025*

32 "The New Pattern of Urban Development in 2035", published on *Research Bulletins*, Guanghua School of Management, Peking University.

33 https://www.iotworld.com.cn/html/News/202411/402c54c47175fa45.shtml.

34 https://www.sohu.com/a/906561832_121106854.

35 https://www.digitalchina.gov.cn/2024/xwzx/szkx/202412/t20241225_4950901.htm.

36 https://www.toutiao.com/article/7521673663268995584/?upstream_biz=doubao&source=m_redirect.

37 https://www.sohu.com/a/559484583_120624328.

38 https://zhuanlan.zhihu.com/p/599852973.

39 "Case Studies of Typical Metro Fire Accidents and Preventive Measures in and Outside China".

40 https://www.cnblogs.com/EasyDarwin/p/18535144.

41 China Meteorological Administration, https://www.cma.gov.cn/2011xwzx/2011xqxkj/qxkjgjqy/201905/t20190530_525986.html.

42 "Strategic Game Situation and China's Countermeasures in Digital Globalization".

43 *Global Digital Economy White Paper (2024).*

44 "Data Spaces Radar Cases".

45 "Typical Cases of Citywide Digital Transformation in Cities (21)".

46 Information and Communications Development Department, Ministry of Industry and Information Technology of China.

47 https://tech.sina.cn/2020-05-31/detail-iirczymk4545539.d.html.

48 Huawei, "Future All-optical Network Architecture and Key Technologies".

49 https://www.toutiao.com/article/7389190027647713830/?upstream_biz=doubao&source=m_redirect.

50 https://www.xinhuanet.com/mrdx/2023-11/14/c_1310750475.htm.

51 Chinese Academy of Sciences https://www.cas.cn/cm/201711/t20171124_4624257.shtml.

52 Business Research Insights, "Quantum Communication Market Report (2025 To 2033)".

53 https://juejin.cn/post/7506455412754546739.

54 CEADs.

55 https://iqstap.caas.cn/xwdt/kydt/64e19772408a418eaca7dcf3c854ccc1.htm.

56 https://www.sohu.com/a/636412648_121123925.

57 "Inside the UK's smart metering projects".

58 "Action Plan for Building Shenzhen into a Digital Twin Pioneer City (2023)" issued by the Shenzhen Municipal People's Government.

59 "U-City White Paper" issued by South Korea.

60 UN's Global Digital Compact, https://www.un.org/zh/documents/treaty/A-RES-79-1-Annex-I

61 The joint statement from the Paris AI Action Summit https://www.elysee.fr/en/emmanuel-macron/2025/02/11/statement-on-inclusive-and-sustainable-artificial-intelligence-for-people-and-the-planet

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