NTT DATA Technology Foresight 2025

Evolving today's technology insights into tomorrow's business growth.

Contents

Introduction

Understanding today's technological trends is essential for preparing for tomorrow's business success. The NTT DATA Technology Foresight 2025 report traces the technology patterns that will become business realities, synthesizes complex data and recommends strategies for navigating the next wave of change.

This year’s report identifies five trends to continue watching:

01 Enhanced humans

The synergistic collaboration between people and machines is shaping a future where human potential isn’t limited by time, task or knowledge.

02 Ambient intelligent experiences

Technologies like artificial intelligence (AI), spatial computing and automation are fundamentally changing how organizations connect with their audiences across different touchpoints.

03 Digital sustainability for economic resilience

A new business strategy is emerging where organizations integrate environmental stewardship with economic growth and assign individual and collective responsibility.

04 Cognitive cloud convergence

The seamless integration of advanced cloud computing technologies with AI and human cognitive abilities is empowering organizations to improve operations, enhance decision-making and derive deeper insights from their data in real time.

05 Accelerated security fusion

Capabilities like automated incident response and AI-driven threat detection are enabling organizations to adapt dynamically to emerging threats, ensuring resilience in an ever-changing risk landscape.

Our experts explore how these technologies work, their impact on business and how they may evolve. They also outline some use cases and scenarios across different industries, as well as practical steps you can take right now to start capitalizing on the opportunities that lie ahead.

Trend 1: Enhanced humans

Imagine a future where your potential isn’t limited by time, task or knowledge.

Introduction

"Enhanced humans" describes the synergistic collaboration between humans and machines, where technologies such as artificial intelligence (AI), machine learning (ML) and automation to amplify human capabilities.

Rather than replacing humans, these technologies boost people's productivity and the quality of their outputs while empowering them to handle more complex and value-generating tasks.

Significance and impact on modern work environments

In the future, enhanced humans will revolutionize task execution in the workplace. Human–technological integration will facilitate faster decision-making, lower error rates and inspire innovation.

Specifically, it will reduce the time employees spend daily on unproductive activities.

Studies show that employees devote

20% of their workday to searching for information

28% to managing emails

14% to collaboration

Implementing an enhanced-humans strategy will drastically cut down on this time, delivering significant efficiency gains. For example, reducing the time people spend on searches by **30 minutes** daily could save an organization with **1,000 employees over 1.5 million euros annually.**

Key drivers and technologies

The integration of enhanced humans into the mainstream is driven by the rapid evolution of AI, increased availability of data, advancements in automation and growing implementation of generative AI (GenAI). Central to this are technologies like AI-enhanced software development, virtual assistants, digital avatars (which in their most realistic form evolve into digital humans) and GenAI-powered applications. Together, these technologies enable the integration of AI into daily work, creating new opportunities for employee support and business success.

However, the rise of enhanced humans comes with potential risks. Social impacts include job displacement, widening skills gaps and privacy issues. Technical challenges may include algorithmic bias, security vulnerabilities and increased energy use.

Responsible organizations are preparing themselves to address potential challenges that may arise when integrating AI into their workplaces.

Technical explanation

Enhanced humans refers to the seamless integration of AI technologies to augment human capabilities, especially in the workplace, where they support employees in various capacities:

1. Organizational enablement through AI

The strategic use of AI improves organization-wide processes and decision-making by analyzing large amounts of data. Adoption of AI by business units promotes innovation, enables new business models and creates competitive advantages, making the entire organization more efficient and adaptable.

2. AI-assisted workplace

An AI-powered workplace improves productivity, efficiency and collaboration with tools that automate routine tasks and support employees in their daily work.

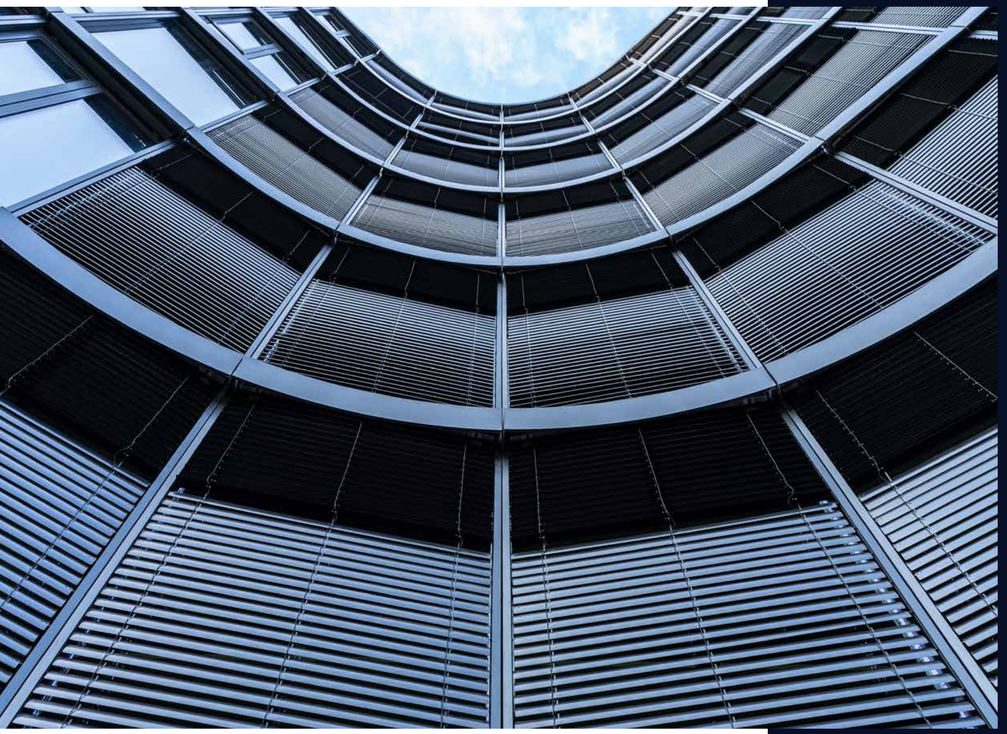
3. GenAI software development

Using GenAI in software development processes, software engineering and AI code-generation streamlines development workflows and reduces the time between concept and deployment.

4. AI safety and compliance

The integration and use of AI tools must comply with regulatory standards to ensure a secure and ethically responsible environment.

> “Ultimately, human–AI integration will create a workforce that’s not just technologically proficient but also strategically empowered to leverage AI for ongoing innovation and performance improvement.



Technology

Leading large language models (LLMs) like GPT-4, Google's Gemini and NVIDIA's Nemotron-3 are increasingly being refined and optimized for diverse applications, including real-time processing and on-device use across industries like education and customer service.

GPT-4o, the latest version of OpenAI's generative pre-trained transformer (GPT), supports multimodal inputs, real-time conversations, memory learning, and advanced translation and emotion detection capabilities.

OpenAI's o1 model, introduced in September 2024, excels in advanced reasoning for complex tasks but operates more slowly and at higher costs than GPT-4o. It has two variants: o1-preview for broad reasoning and o1-mini for coding, math and science. Unlike GPT models, o1 models are trained using reinforcement learning techniques to **"think before they answer",** and they produce long internal chains of thought.

Retrieval augmented generation (RAG) improves LLMs by retrieving relevant external information and integrating it into responses, improving accuracy, contextual understanding and cost-effectiveness. Its applications span customer support, content creation, legal research, healthcare and financial services. However, RAG comes with challenges, such as retrieval quality, and there are ethical issues to consider.

Digital humans (also called AI avatars) are advancing in realism and interactivity, with applications in customer service, entertainment and healthcare that feature capabilities like real-time facial expressions and emotion detection.

Business explanation

The enhanced-humans trend, where AI augments human abilities, signals a major shift for businesses.

Employees are able to maximize their potential and organizations can quickly adapt to a fast-changing market.

The enhanced-humans trend brings several key outcomes that can redefine organizational success:

Increased productivity

By automating routine and time-consuming tasks, employees can focus on higher-value activities.

Improved decision-making

AI-driven data analysis provides deeper insights and predictive analytics, enabling more informed and accurate decision-making.

Accelerated innovation

With AI handling and improving standard operations, organizations can allocate more resources to innovation and development.

Cost efficiency

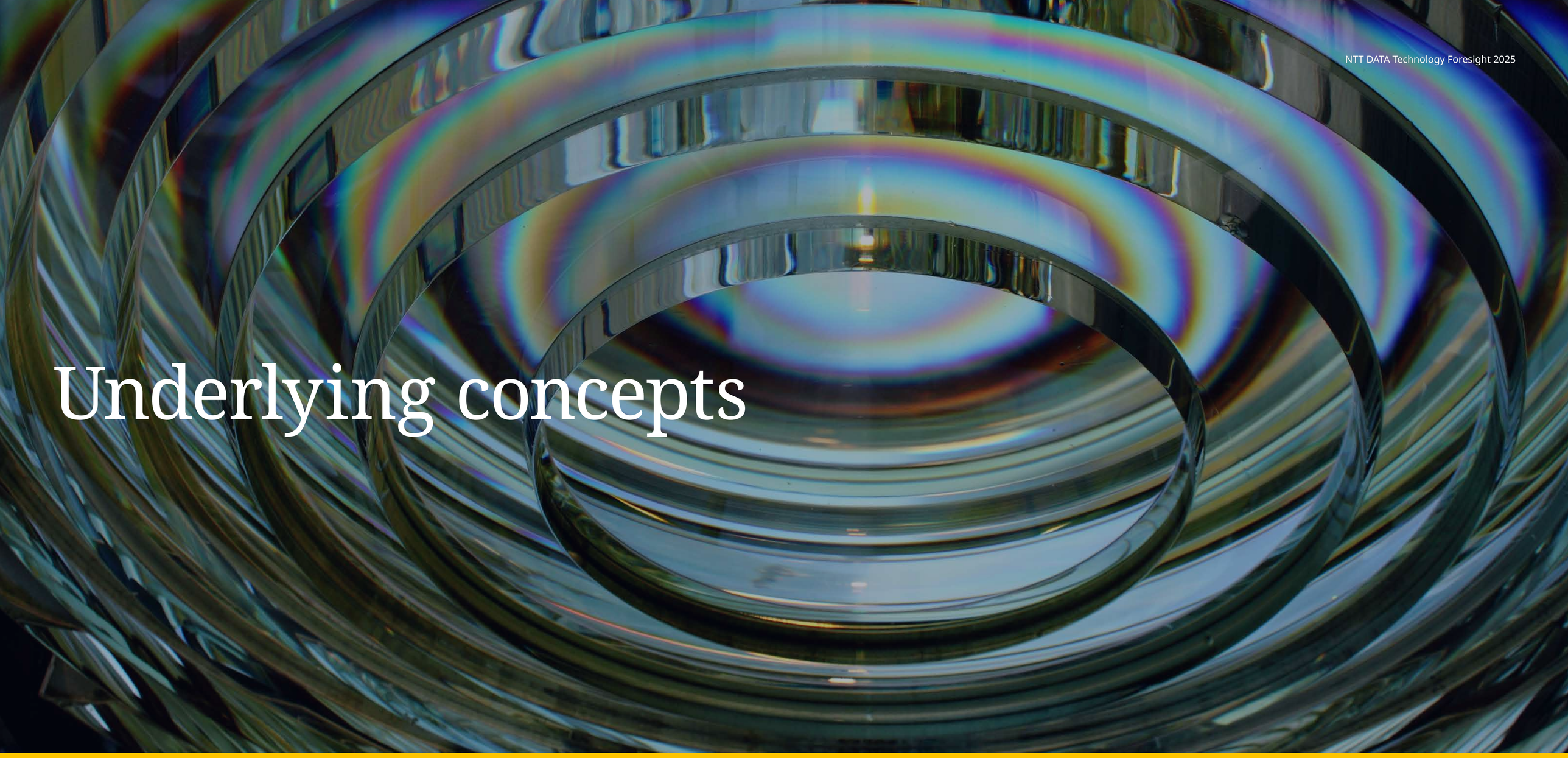
Enhanced humans can lead to significant cost savings through better resource allocation, fewer errors and less time required to complete business processes. These savings can be reinvested into other strategic areas.

Competitive advantage

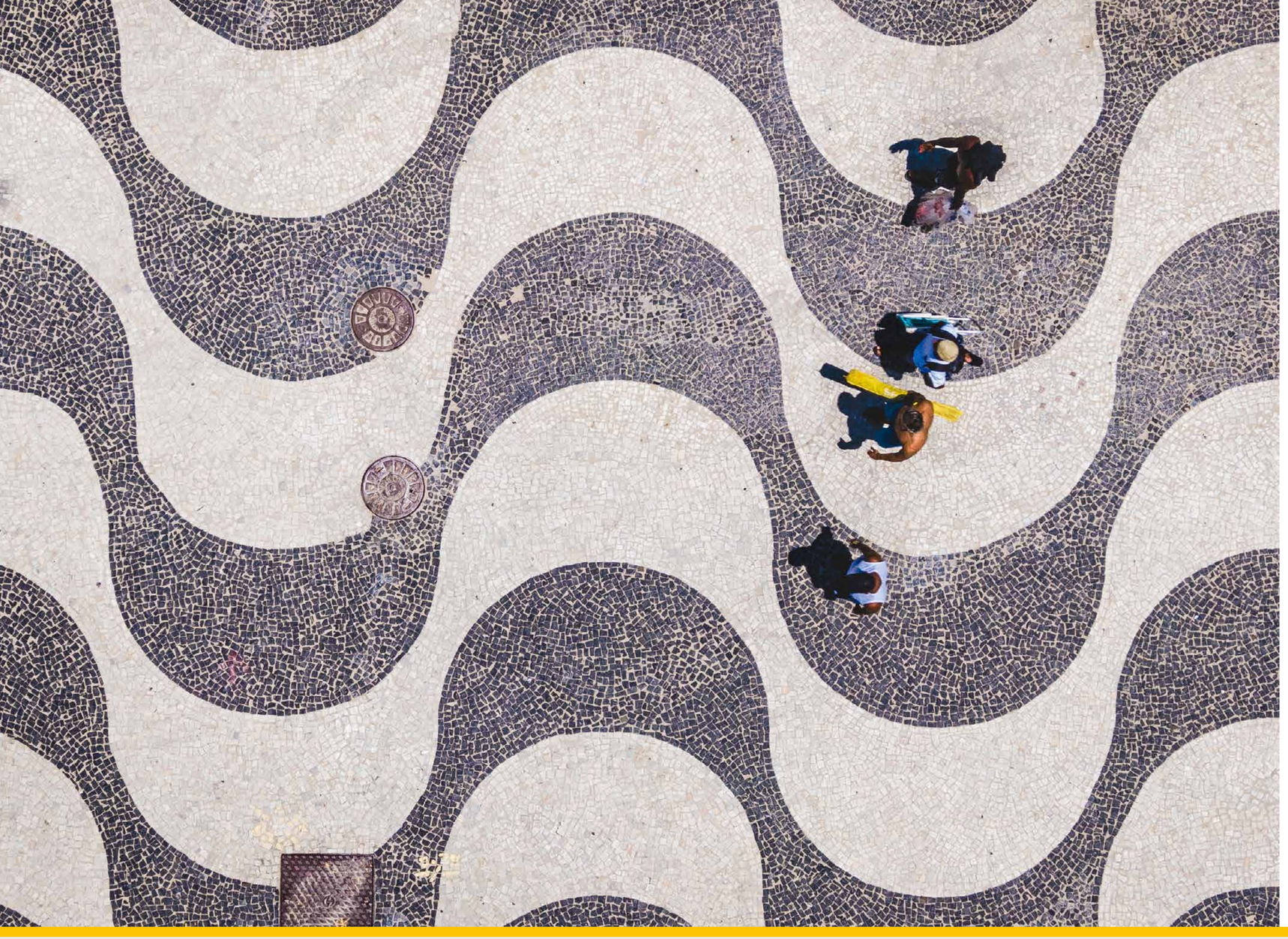
Organizations that integrate AI to augment their employees' abilities will gain a competitive edge through greater agility, responsiveness and capacity to innovate.

Enhanced customer experience

AI can improve customer service by enabling faster and more personalized interactions.



Underlying concepts



Underlying concepts

The transformative trend of enhanced humans is underpinned by several underlying concepts that must be considered to ensure its successful implementation and widespread adoption. Safety, compliance, organizational enablement and technological advancements are the bedrock on which enhanced human capabilities are built. Understanding and mastering these underlying concepts is key to unlocking the full potential of enhanced humans in an organization.

Enhanced humans

AI safety and compliance

- Ethical considerations
- Security gaps and threats
- Explainability and transparency
- Bias detection and reduction
- Technical safety measurements
- Compliance with regulatory requirements

Organizational enablement through AI

- Technological infrastructure and integration
- Data management and governance
- Scaling of AI applications
- Change management and training
- Optimization of business processes
- Strategic decision-making

AI-assisted workplace

- Human–machine collaboration
- Optimization of work processes
- Improved employee support
- Efficient data analysis and decision-making
- Productivity increase

AI-assisted software development

- Automation of software development
- Improved collaboration in the dev team
- Scaling the maintenance of software projects
- Adaption to individual requirements
- Reduction of errors and security gaps
- Compliance with regulatory requirements

Figure 1: Enhanced humans — underlying concepts and supporting trends

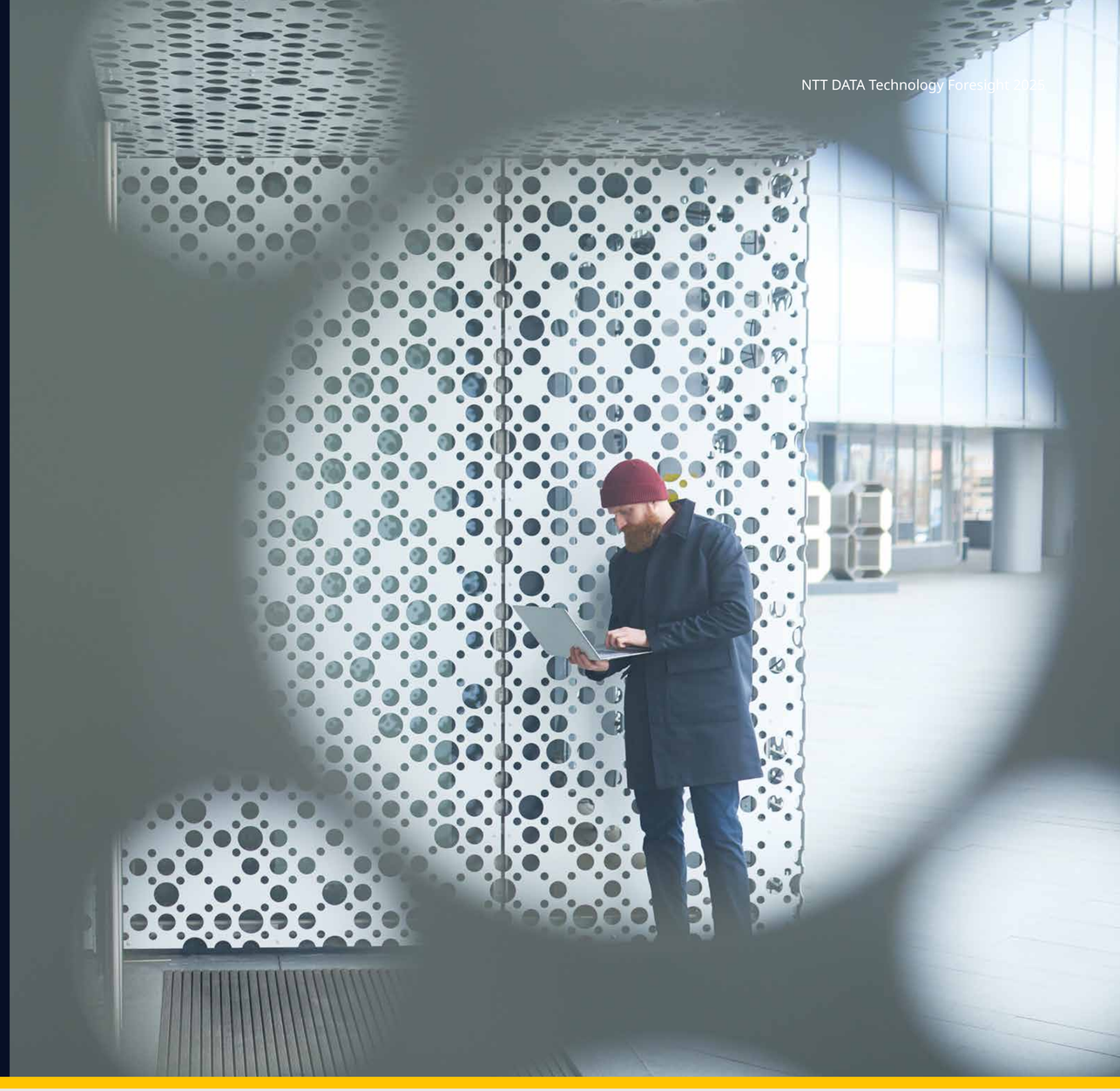
Underlying concepts

AI safety and compliance

AI safety and compliance will be decisive success factors for organizations seeking to expand their use of AI technologies. Organizations must ensure their systems are not only efficient and “fair”, but also legally compliant. Protection against cyberthreats, avoiding bias and discrimination and complying with increasing global data protection laws such as GDPR will all be essential.

Technical measures such as differential privacy, federated learning and bias detection tools will help to minimize these risks. Explainable AI approaches such as SHapley Additive exPlanations (SHAP) and Local Interpretable Model-agnostic Explanations (LIME) will ensure transparent decisions while also providing safeguards against cyberattacks.

> “Organizations that invest in AI safety will protect their reputation, minimize legal risks, promote trust in their AI applications and secure long-term competitiveness.



Ethical considerations

- Looking ahead, responsible AI practices will increasingly integrate ethical principles such as fairness and transparency into AI strategies. This is crucial for both legal compliance and public trust.
- Organizations will need to implement mechanisms that allow for the traceability and algorithmic accountability of their AI systems.

Security gaps and threats

- Adversarial examples are manipulated inputs intended to deceive AI models and will continue to represent a growing security risk. Organizations must take protective measures to prevent these attacks, for example, by cross-checking results with techniques from the field of explainable AI.
- Model drift detection will require regular monitoring for models in operation, helping detect deviations in model performance at an early stage.

Explainability and transparency

- Explainable AI will deliver understandable explanations for AI decisions, improving the acceptance and comprehensibility of AI solutions.
- Tools like SHAP (a game-theory-inspired approach to model explanation) and LIME (a model-agnostic approach to explaining and interpreting AI models) will provide standardized and widely applicable approaches for explainable AI.
- Future AI services will be required to provide explanations at the same speed and quality as the results themselves.

Bias detection and reduction

- Fairness-aware machine learning techniques like bias mitigation algorithms will increasingly prevent systems from making discriminatory decisions. This is crucial for compliance with ethical and legal standards and the acceptance of broader AI adoption.
- Model cards will provide standardized documentation tools and increase the transparency of models by revealing model behavior, including potential biases and the quality of predictions.

Technical safety measures

- Differential privacy techniques anonymize personal data during processing by AI models. This will significantly reduce the risk of data leakage and boost user and customer acceptance for advanced AI functions.
- Adversarial training will increase the resistance of models to manipulation attempts aimed at causing malfunctions in automated processes and decision-making.

Compliance with regulatory requirements

- The EU AI Act defines strict requirements for managing high-risk AI applications, including regular audits.
- Organizations will need to intensify their efforts to ensure their AI solutions comply with these requirements, or risk facing grave legal consequences.
- The National Institute of Standards and Technology (NIST) AI Risk Management Framework guides organizations in identifying, assessing and managing risks associated with AI. This is important for safety and compliance.
- Organizations will also find increasing support for regulatory compliance in the RegTech startup ecosystem.

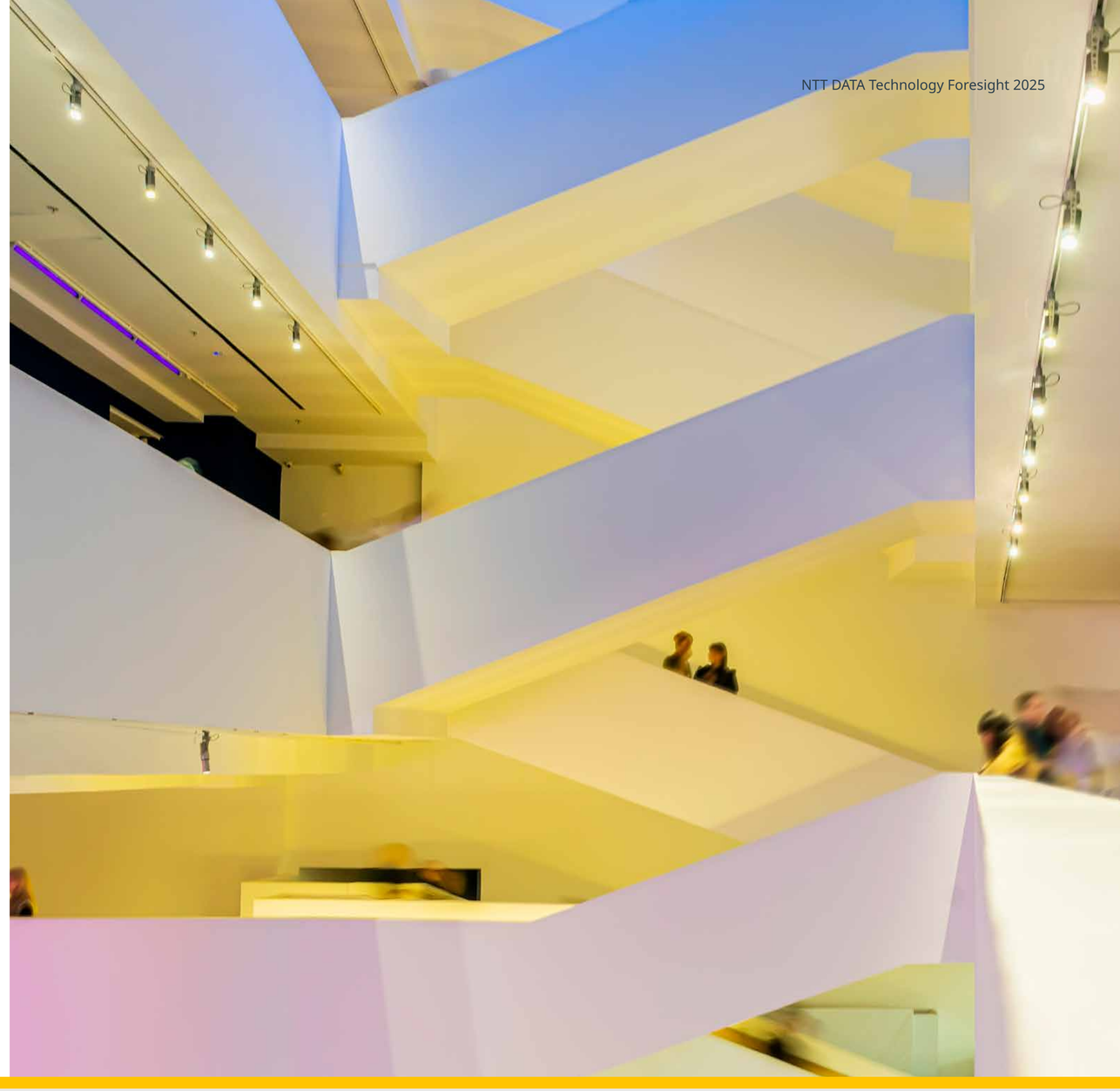
Underlying concepts

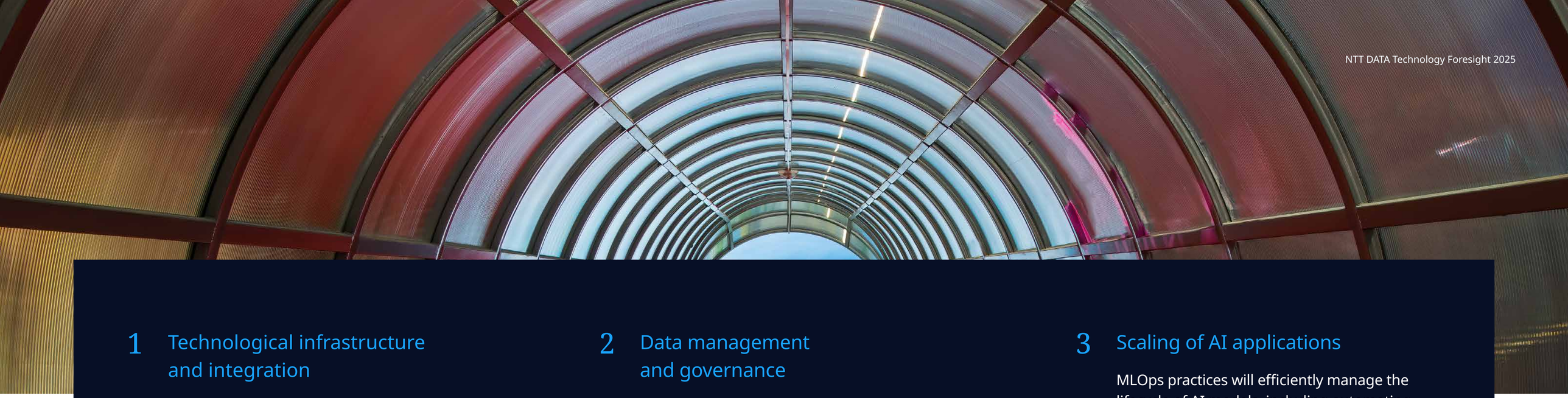
Organizational enablement through AI

Organizational enablement through AI refers to the strategic use of AI to transform culture, people and processes, and hence improve efficiency and inspire innovation. Increasingly, we'll see organizations integrating AI into areas such as human resources, supply chain, financial planning and decision-making processes to create a competitive advantage.

Cooperation and collaboration between humans and machines will be crucial to fully exploiting the potential of AI. This will require effective change management and training to enable employees to work with AI systems.

> "Equally, data management and governance will play a central role in ensuring the quality, privacy and security of data and enabling reliable, data-driven decisions.





1 Technological infrastructure and integration

GenAI will require scalable cloud environments with specialized hardware to process large amounts of data and perform complex model calculations in real time.

A seamless connection to internal data sources, application programming interfaces (APIs) and other systems will be crucial for providing relevant data for training models and integrating GenAI into existing processes and systems.

2 Data management and governance

Data meshes will support the efficient storage and analysis of large amounts of data and create a basis for data-driven decisions and AI projects. The decentralized architecture of data meshes will enable technical and organizational scalability.

Data governance strategies will need to ensure that data quality, privacy and security measures meet legal and regulatory requirements.

3 Scaling of AI applications

MLOps practices will efficiently manage the lifecycle of AI models, including automating training, deployment, monitoring, maintenance and retraining.

Modular AI architectures will enable organizations to expand and adapt their AI applications flexibly and cost-effectively and increase the speed of adoption of AI.

4 Change management and training

Corporate culture will have to embrace collaboration with AI. Change management, supported by clear communication and employee engagement, will smooth the integration of AI into work processes.

Training initiatives will be essential for preparing employees to work with AI systems, strengthening their digital competence and promoting acceptance.

In this way, AI will become a trusted team member and companion.

5 Optimization of business processes

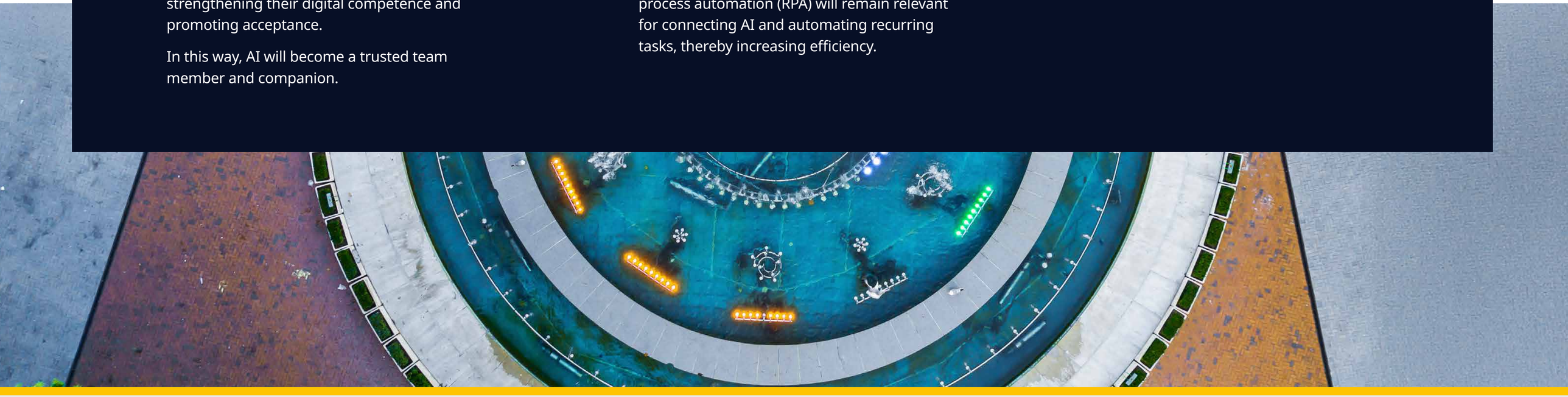
AI will observe and optimize complex business processes based on information automatically retrieved from systems and workplaces. This will shorten processing times and improve overall business performance.

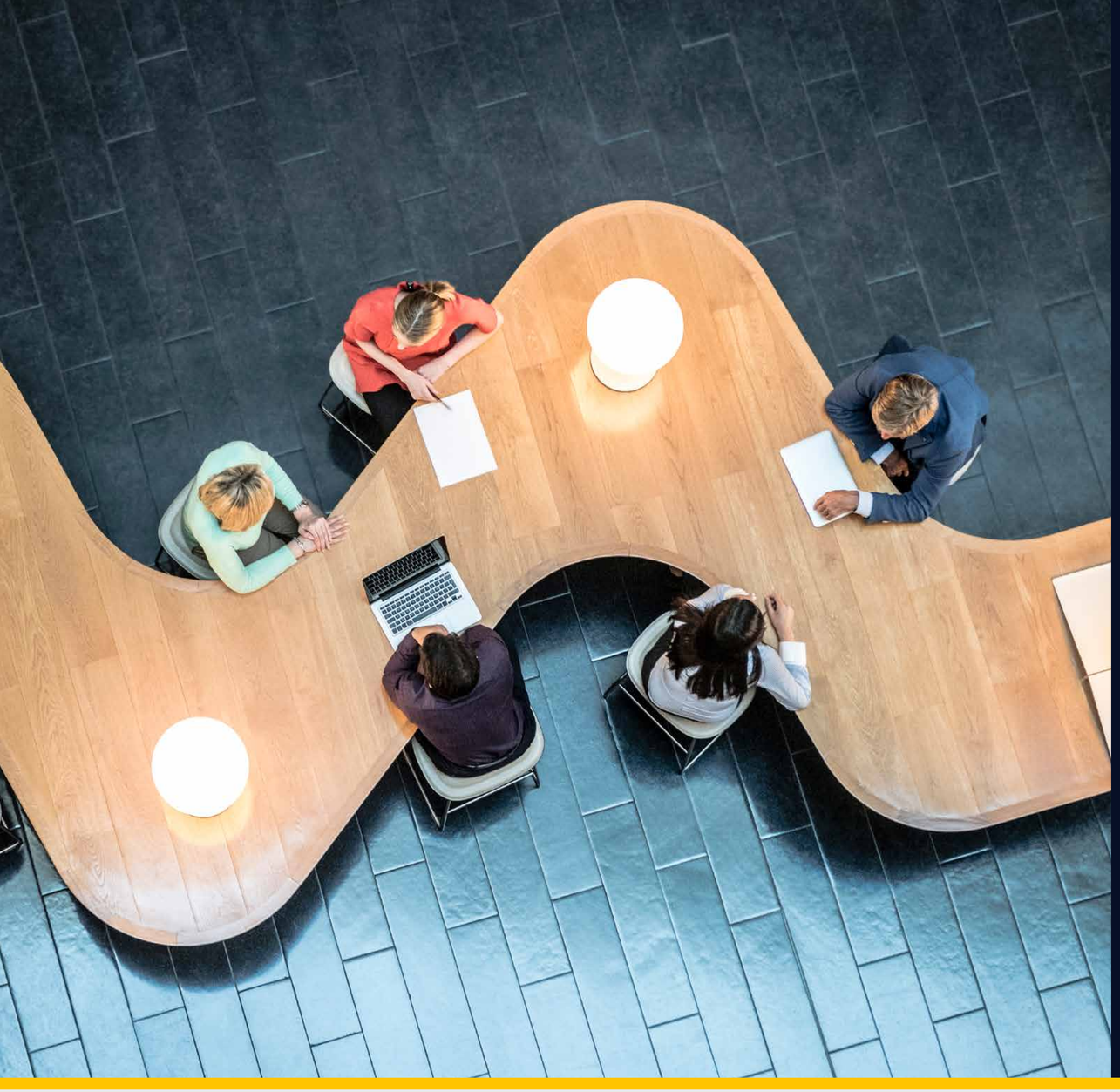
AI will have to be connected to operational systems and processes. Classic tools like robotic process automation (RPA) will remain relevant for connecting AI and automating recurring tasks, thereby increasing efficiency.

6 Strategic decision-making

Predictive analytics will anticipate future trends and customer needs, leading to proactive and informed business decisions.

Data-driven business strategies based on AI will give organizations a competitive advantage and enable innovative business models.





Underlying concepts

AI-assisted workplace

AI-powered workplaces will integrate advanced technologies such as GenAI-powered chatbots and services, predictive analytics and RPA to increase productivity and efficiency. These tools will automate routine tasks such as data and document processing and reporting so employees can spend more time on value-adding activities like face-to-face customer service.

GenAI assistants will play a central role in this by analyzing large data sets, summarizing complex information and generating personalized content. Through natural language interaction, they'll improve access to data and support decision-making.

> “These technologies will also promote human–machine teamwork by supporting employees in their daily work and improving collaboration, for example, by automatically generating meeting summaries and offering suggestions on task prioritization.

Productivity increase

- Automated task management with virtual assistants and chatbots will coordinate routine tasks such as scheduling, email management and data analysis.
- Work environments will adapt to employees' individual needs and preferences by providing recommendations for task prioritization and time management.
- Personalized recommendations will help employees make informed decisions faster and more accurately. Decisions will be better documented and grounded in facts.

Efficient data analysis and decision-making

- Large amounts of data will be analyzed in real time to provide relevant insights that lead to faster and more informed decisions.
- GenAI-powered understanding and processing of natural language will make it easier for employees to access data and analyses, regardless of their technical expertise.
- Data from different sources can be combined without the need for engineers to design new interfaces and data flows.

Improved employee support

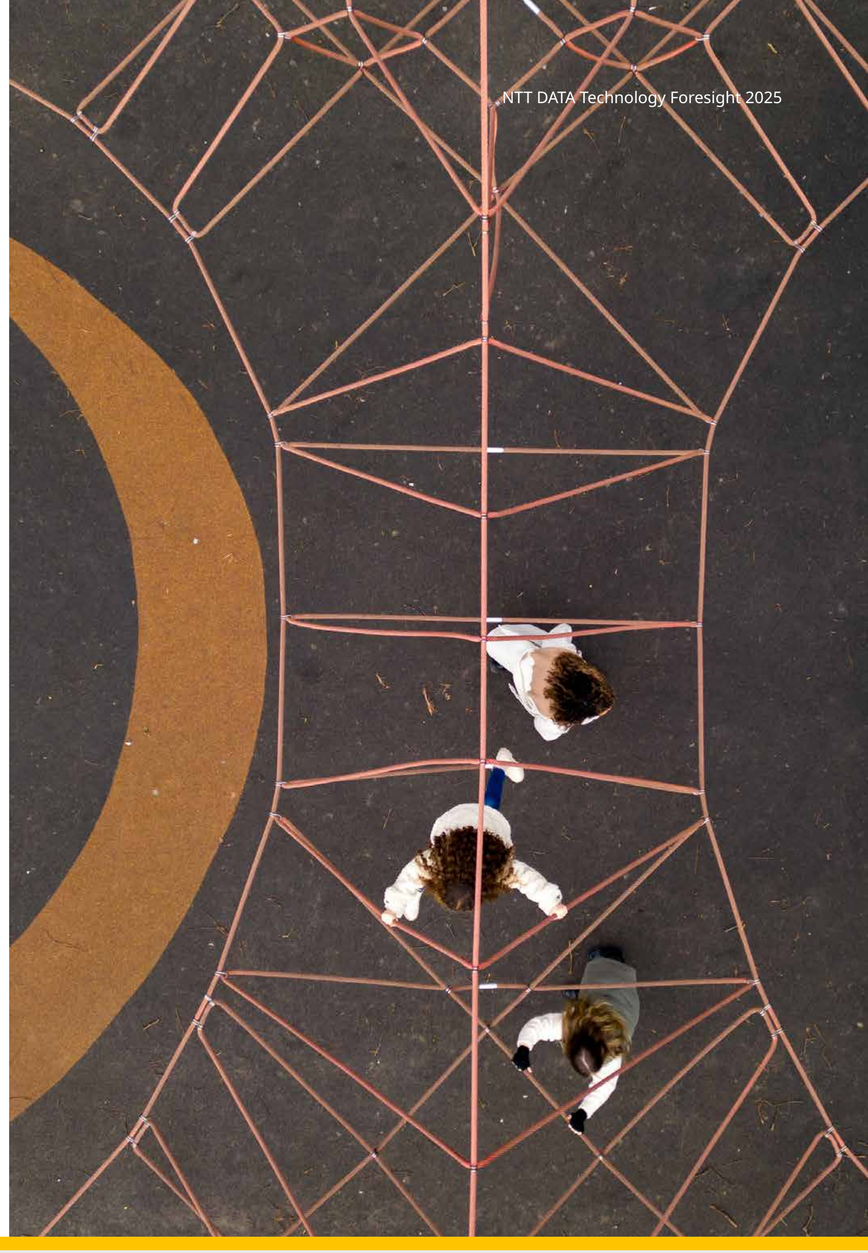
- Support chatbots and digital assistants will provide instant support to employees by answering frequently asked questions and helping solve problems, increasing employee efficiency and satisfaction.
- Learning platforms will automatically create personalized training and development programs that augment employees' skills and address specific needs, based on individuals' current skills and knowledge.
- The collection and consolidation of information from different data sources, based on natural language semantics, will expedite the creation and adoption of effective knowledge-management tools.

Optimization of work processes

- Workflows will be automated and optimized by AI services that autonomously identify and automate repetitive tasks, thus reducing cycle times and increasing overall productivity.
- Intelligent document processing will reach a new level with GenAI: documents can be automatically classified, analyzed and processed, reducing the manual effort involved in training classical AI.
- Creative approaches, concepts and layouts will be generated by drawing insights from large amounts of information, providing inspiration and helping people to overcome creative blocks.

Human–machine collaboration

- Advanced teamwork will emerge from tighter collaboration between humans and machines.
- The computing power and precision of machines will complement human creativity and problem-solving skills. Trusted AI services will provide unbiased and private feedback on team dynamics, boosting team productivity.
- Improved communication systems will analyze and optimize communication patterns, resulting in more efficient meetings, clearer instructions and better information flow within teams.



Underlying concepts

AI-assisted software development

GenAI is revolutionizing software development by automating creative processes and supporting developers in the creation of code, designs and applications. GenAI models will enable organizations to develop software faster and more cost-effectively. Tools such as AI-assisted integrated development environments (IDEs) will provide developers with real-time code suggestions.

Techniques such as transfer learning and reinforcement learning will improve the quality of the generated software components. In addition, GenAI will automate DevOps processes such as continuous integration/continuous deployment (CI/CD) and increase security through AI-driven code analysis and security checks.

> “Collectively, these capabilities will allow organizations to work in a more agile and innovative way.

Automation of software development

- Differential privacy techniques anonymize personal data during processing by AI models. This will significantly reduce the risk of data leakage and boost user and customer acceptance for advanced AI functions.
- Adversarial training will increase the resistance of models to manipulation attempts aimed at causing malfunctions in automated processes and decision-making.

Improved collaboration in the development team

- Intelligent pair-programming assistants will enable seamless collaboration among developers and machines by acting as partners in pair programming and continuously making suggestions for code improvement.
- Collaborative coding platforms will promote collaboration across distributed teams by providing real-time ssuggestions for and corrections to the work of multiple developers. This will maximize consistency in software development efforts.

Scaling and maintenance of software projects

- Automatic refactoring will improve compliance with architecture models and ease the software maintenance burden. It will also reduce technical debt, which is vital when scaling software projects in terms of functionality and team size.
- CI/CD pipelines will be generated based on application code, and integrate intelligent inspection and testing services. This will optimize automated tests and deployments, enabling fast and secure software delivery.

Adaptation to individual requirements

- Models will be trained for discrete industries or use cases, allowing developers to create software solutions tailored to address domain-specific challenges like efficiency, safety and compliance.
- Customizable AI frameworks will allow developers to create software applications that meet specific business needs by easily integrating and customizing existing models and tools.

Reduction of errors and security gaps

- Automated security checks will independently detect and fix security vulnerabilities in code, reducing the risk of cyberattacks and data breaches.
- Models for predictive error detection will anticipate where errors might occur and make suggestions for avoiding bugs, increasing the reliability and stability of software applications.

Innovation and prototyping

- The rapid creation of software prototypes, for example from simple paper sketches, will expedite the innovation process and shorten time to market for new products.
- With AI-powered innovation, developers will be able to create novel features and products that embrace natural interaction and unstructured data, strengthening the organization's competitive advantage.

> AI is reshaping software development, accelerating innovation, enhancing collaboration and tackling complex challenges effectively.

Tech radar

Tech radar for mainstream adoption

In the constantly changing tech landscape, keeping up with the latest developments is essential, not just advantageous.

Continually analyzing technology trends and tracking their evolution will help you anticipate changes and prepare yourself for upcoming shifts.

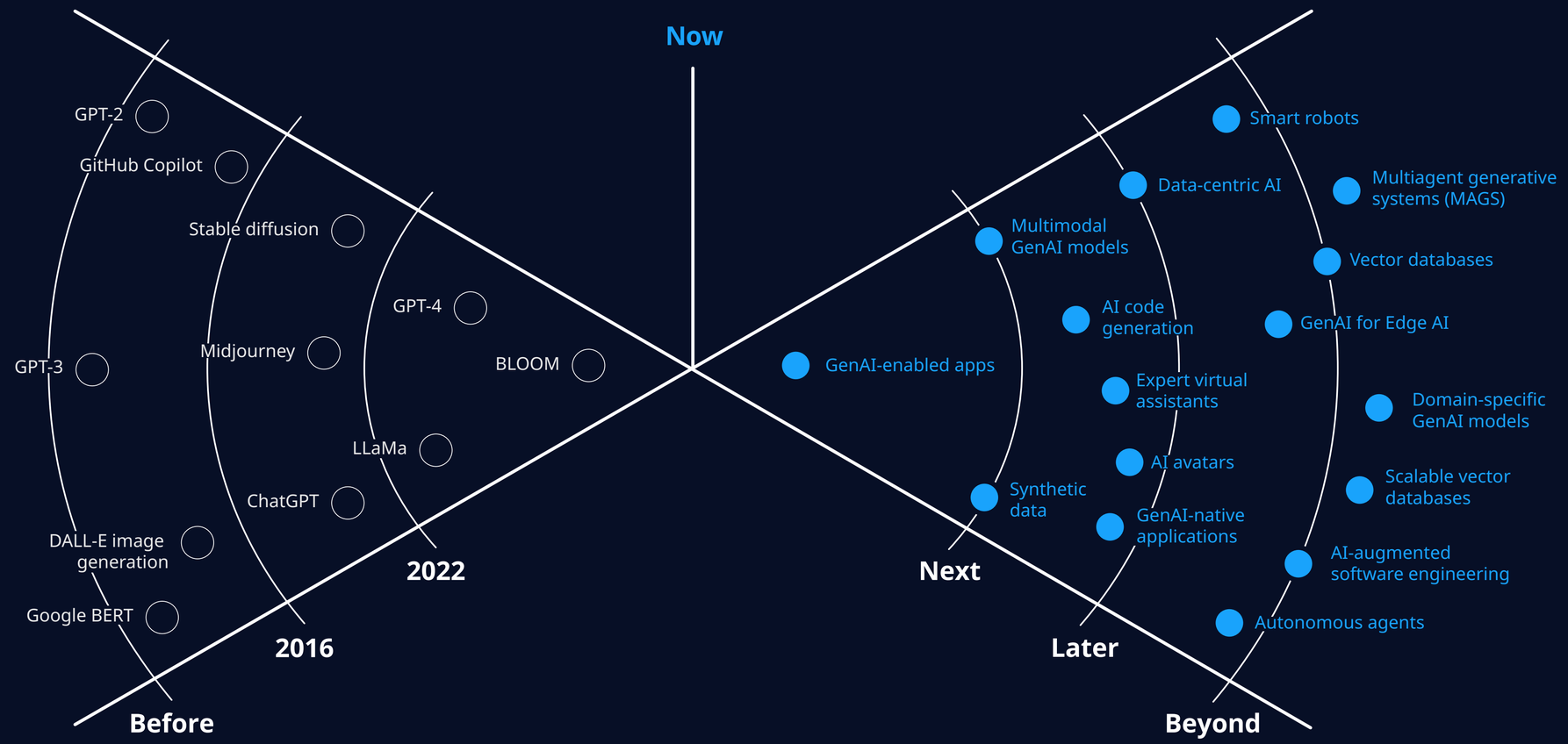


Figure 2: Tech radar — past and future technology

Future tech: now, next and later

A **GenAI-enabled apps**
GenAI-enabled applications enhance the user experience and assist with tasks like generating text, code and images, and enabling autonomous workflows.

B **Multimodal GenAI models**
Multimodal GenAI models process multiple types of inputs and outputs, such as images, text and audio, enabling models to interact across different modalities.

C **Synthetic data**
Synthetic data is artificially generated data used to train AI models, offering solutions in areas such as data scarcity, privacy concerns and regulatory compliance while mimicking real-world data patterns.

D **AI code generation**
AI code generation uses LLMs to generate code based on user prompts, primarily through AI code assistants that are integrated into development environments and support various programming languages.

E **Expert virtual assistants (VAs)**
Expert VAs go beyond traditional VAs by using AI technologies to provide accurate solutions in specialized fields like healthcare and legal, while offering proactive intelligence and multimodal interactions.

F **GenAI-native applications**
GenAI-native applications are built using generative AI technology, designed for specific business capabilities or industries and are often offered as software-as-a-service (SaaS) solutions.

G **AI avatars**
AI avatars are humanlike digital personas created with AI technologies like computer-generated imagery (CGI) rendering, natural language processing (NLP) and emotion AI. They facilitate more immersive and interactive experiences in metaverse and virtual environments.

H **Data-centric AI**
Data-centric AI focuses on improving training data to enhance AI outcomes, emphasizing data quality, privacy and scalability, as opposed to model-centric approaches, which prioritize the development and optimization of AI models.

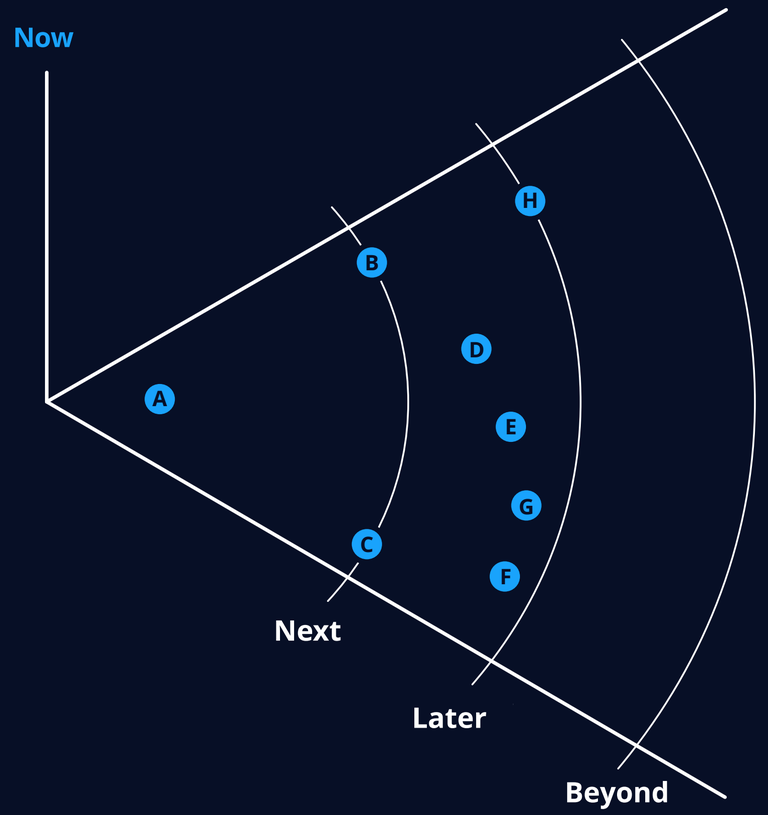


Figure 3a: Tech radar — future technology

Future tech: later and beyond

I **Smart robots**
Smart robots, including unmanned aerial vehicles (UAVs), automated guided vehicles (AGVs) and autonomous mobile robots (AMRs), are AI-powered machines that autonomously perform personal, logistical and industrial tasks.

J **GenAI for edge AI**
GenAI at the edge enables content generation, strategy development and automation based on large data repositories, impacting areas like content creation and employee experience.

K **Autonomous agents**
Autonomous agents are AI-driven systems that independently achieve defined goals by learning from their environment and making decisions without human intervention.

L **Vector databases**
Vector databases store numerical data representations. They are often used in machine learning to search for and compare data points with low latency based on vector similarity.

M **Multiagent generative systems (MAGS)**
MAGS combine software agents and LLMs to simulate behaviors and generate emergent dynamics within multiagent environments.

N **AI-augmented software engineering (AIASE)**
AIASE uses AI technologies like ML and NLP to help software teams create applications faster, with less effort and at a higher standard of quality.

O **Domain-specific GenAI models**
Domain-specific models are GenAI models tailored to specific industries or tasks. They improve performance and reduce prompt engineering needs compared to general-purpose models.

P **Scalable vector databases**
Vector databases enable semantic search by storing embeddings generated by LLMs, allowing for the efficient retrieval and ranking of data in conjunction with custom enterprise information.

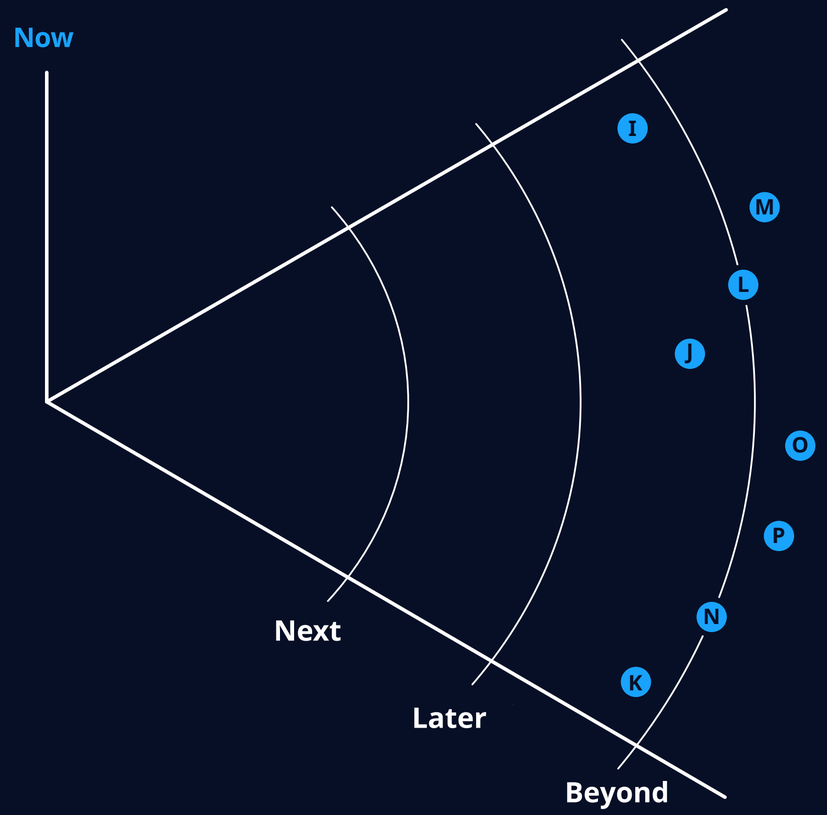


Figure 3b: Tech radar — future technology

R&D highlight

R&D highlight

"tsuzumi"

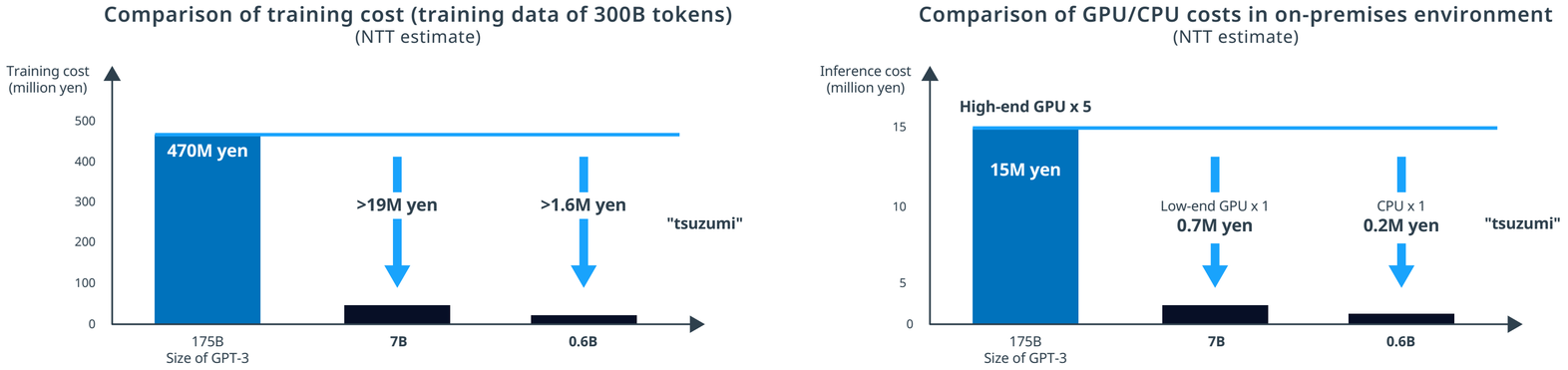
NTT's "tsuzumi" LLM, launched in March 2024, is an efficient and performance-driven solution for sustainable AI.

It has two versions: an ultra-lightweight model with 600 million parameters and a lightweight one with 7 billion parameters, designed to lower computational costs. Unlike larger models like OpenAI's GPT-3, "tsuzumi" allows high-speed inference on a single graphics processing unit (GPU) or even a central processing unit (CPU) for the ultra-lightweight version, making it suitable for businesses needing advanced AI without heavy resource demands.

"tsuzumi" is highly adaptable, allowing precise customizations through adapters for industry-specific needs without extensive retraining. This feature supports fine-tuning for specialized language in sectors like healthcare and finance, reducing computational costs further.

Additionally, “tsuzumi” features multimodal capabilities to process text, audio and visual data, making it versatile for complex tasks like interpreting documents with graphical elements and analyzing medical imaging alongside patient records. Its ability to discern voice nuances is valuable in customer service and counseling, enhancing empathetic responses.

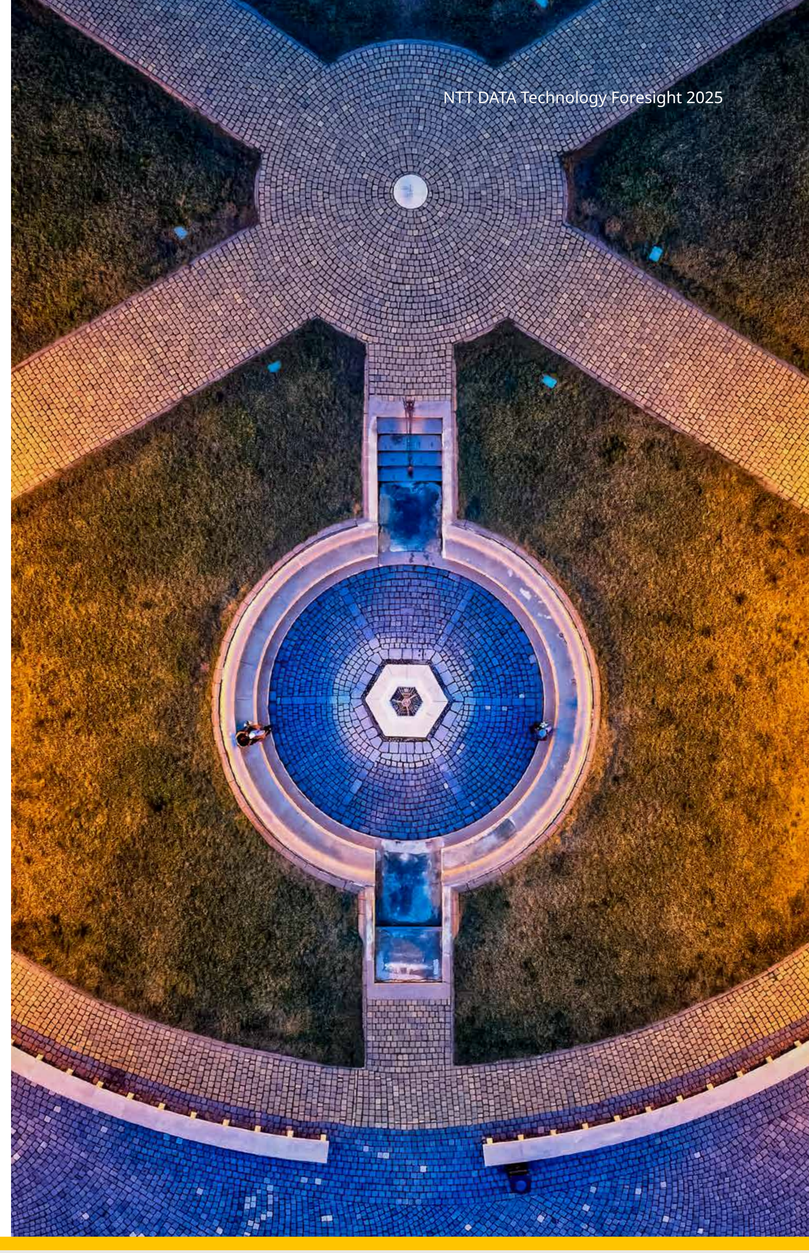
NTT’s research has led to “tsuzumi" being a powerful alternative to larger models, with the benefits of customization and lower operational costs. It represents a significant advancement in AI technology, making high-performance LLMs more accessible while reducing energy consumption and costs.



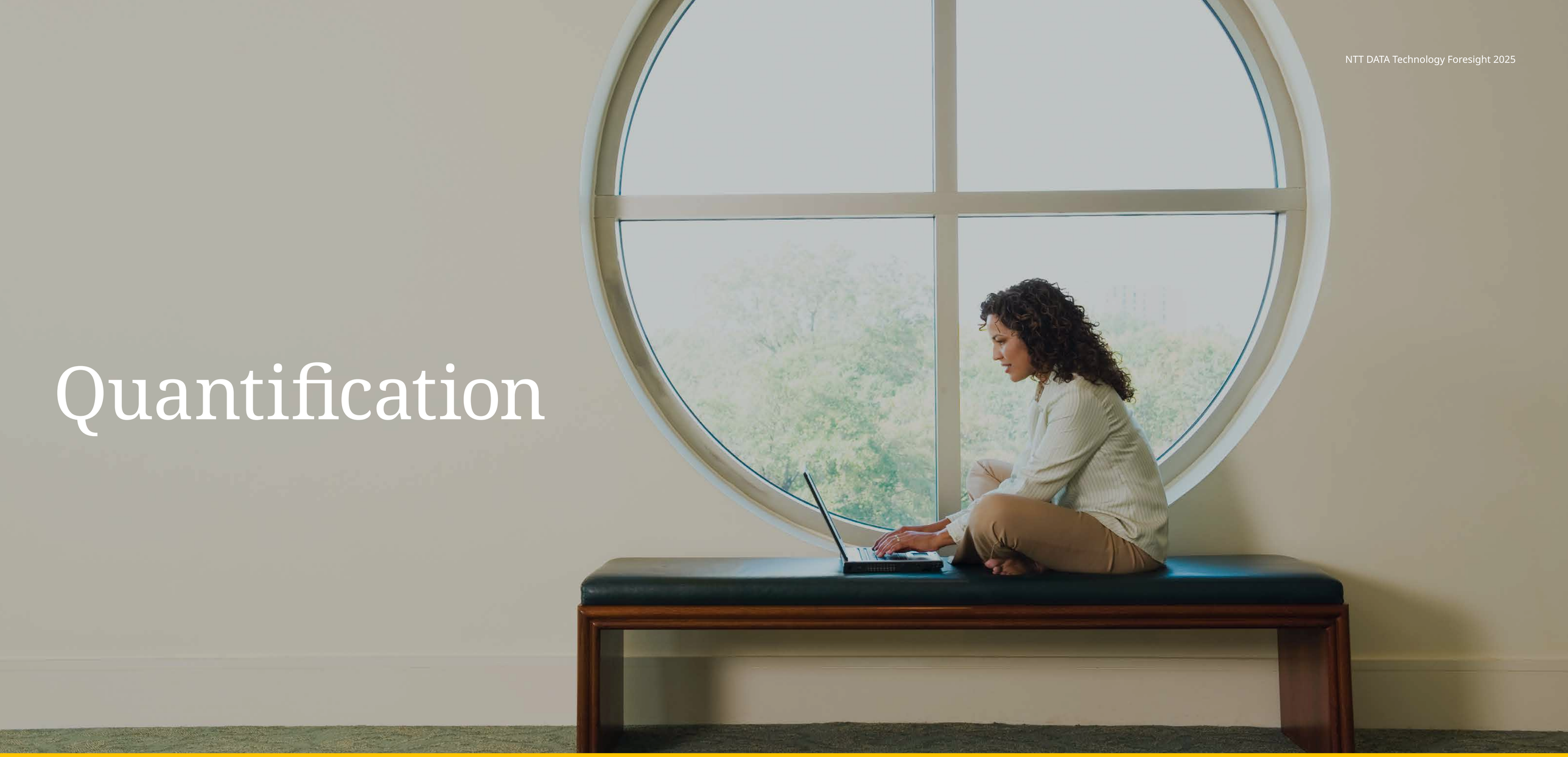
CPU: central processing unit
GPU: graphics processing unit

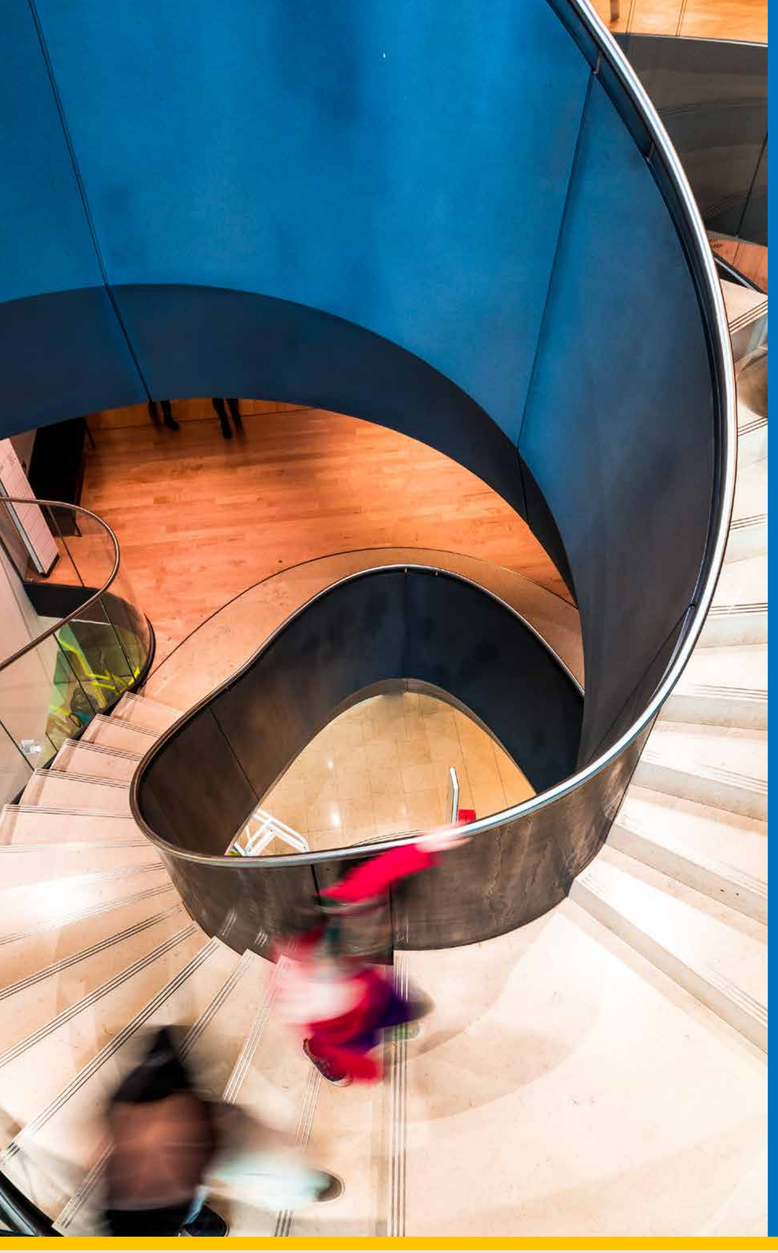
Figure 4: “tsuzumi” comparison for training and inferencing

Adapted from: *NTT Technical Review* Vol. 22, No. 8, pp. 19–25, Aug. 2024



Quantification





Relevant financials

GenAI in software development

Market size, 2024:

$49.8 billion

Market size growth, 2023–2024 (YoY):

+21.46%

Forecast CAGR, 2024–2033:

21.5%

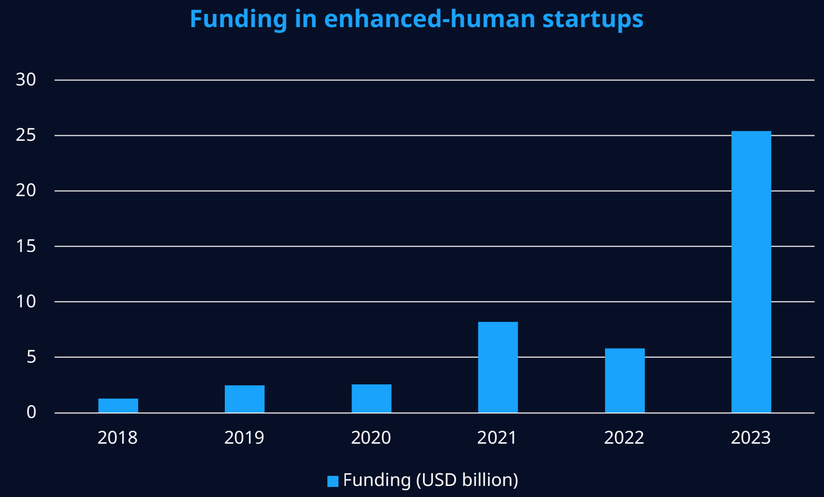


Figure 5: Funding in enhanced-human startups

> 43% of technology leaders are allocating significant budgets to GenAI initiatives.

GenAI adoption rates and benefits

75%
Organizations adopting GenAI

25%
Cost savings (efficiency)

45%
Developers using GenAI tools

40%
Reduction in coding errors

25%
Improvement in software quality

GenAI research and development

15,000*
Patents registered 2023

34,000*
Research papers published 2023

*Approximate figures

Top companies by patent count in GenAI

1. **Tencent** — 2,074 patents
2. **Ping An Insurance Group** — 1,564 patents
3. **Baidu** — 1,234 patents
4. **IBM** — 601 patents
5. **Alibaba** — 571 patents

Use cases

AI companion @Metaverse Garage

Industry: **Automotive**

The AI companion ecosystem transforms automotive experiences by evolving digital assistants into personal concierges who offer timely, data-driven services. This enhances vehicle value, integrates service providers and strategically positions original equipment manufacturers (OEMs) to deliver a seamless, personalized customer journey.

Business value

1. Enable more personalized experiences and added-value services
2. Enhance cross-selling and upselling potential
3. Improve customer loyalty

> AI companions deliver seamless, personalized services, elevating customer experiences and loyalty.

Shopfloor assistant

Industry: **Industry and services**

Shopfloor assistants optimize production processes through real-time instructions, troubleshooting and automated process improvements. This increases efficiency and quality and provides employees with automatic planning and quality assurance.

Business value

1. Cost reduction through process automation
2. Increased productivity through real-time troubleshooting and optimized workflows

Energy trading copilot

Industry: **Automotive**

This solution optimizes energy trading through real-time data analysis, automated transactions and risk management. It improves decision-making, maximizes profits and minimizes risks while automatically monitoring and complying with regulatory requirements.

Business value

1. Optimized earnings through data-driven trading decisions
2. Lower risk and ability to respond faster with automated processes

> “The network engineering copilot streamlines network management with intelligent automation, improving efficiency, reducing disruptions and enhancing resilience.

Network engineering copilot

Industry: **Telecommunications, media and technology**

This copilot optimizes networks through a range of automated functions, including design, real-time troubleshooting, load optimization and security management. It improves operational efficiency, minimizes disruption and strengthens network security by providing intelligent solutions for network issues and optimization.

Business value

1. Cost reduction through more efficient network infrastructure and automated troubleshooting
2. Increased network stability and reliability

GenAI for fraud prevention

Industry: **Financial services**

A GenAI fraud-prevention tool provides real-time anomaly detection, dynamic risk modeling, secure authentication and automated fraud verification. By reducing fraud, minimizing losses and increasing customer security through proactive and accurate fraud detection, it's an essential element of a robust and effective risk management strategy.

Business value

1. Reduction of fraud through proactive detection and prevention
2. Increased customer security and trust through effective risk management

> "GenAI for fraud prevention transforms risk management by enabling real-time insights and dynamic fraud responses.

AI-assisted requirement engineering

Industry: **Cross-industry**

This tool improves efficiency, productivity and quality by gathering, classifying and aligning stakeholder input. It checks consistency, improves accuracy and supports documentation with suggestions and standardization, streamlining the entire requirements management process.

Business value

1. Increased productivity
2. Higher quality of requirements

Datenschutz-Grundverordnung (DSGVO)/General Data Protection Regulation (GDPR) assistant

Industry: **Cross-industry**

This assistant supports the design and implementation of a customizable GDPR companion for employees. It can answer GDPR/DSGVO-related questions based on an understanding of European and German legislation and organization-specific knowledge databases.

Business value

1. Streamlines queries, improving operational and cost efficiency
2. Offers tailored legal assistance

> The GDPR assistant empowers employees with instant, context-aware guidance that bridges organizational and legal expertise.

Use cases

Success case

DACH | Automotive

Business need

Our client sought to quickly and fully exploit the potential of GenAI for GDPR compliance, while alsomanaging risks such as safety, security, compliance, ethics and trustworthiness. The envisaged solution also needed to act as a competent contact for necessary classifications and questions regarding GDPR.

Additional design considerations included adapting the AI model to accommodate different business units' internal processes, a lack of internal AI experts, integration of the solution into the wider internal IT environment and scalability to keep up with the fast pace of innovation.

The goal was to create a stable digital GDPR assistant prototype to present at a customer's trade fair. In addition, an integration and expansion concept was required to show how the prototype could be integrated into an existing IT environment.

Solution

1. **Analysis and conception for the implementation of a GDPR application that uses an AI-based search**

   We analyzed the database provided (documents, transcripts and website content) and designed the technical target image as a basis for a task breakdown for the subsequent implementation phase.

2. **Implementation of the GDPR application based on GenAI**

   We implemented of the GDPR application in the form of a stable prototype.

3. **Development of an integration and extension concept**

   We developed a concept for integrating the solution into corporate IT, identified opportunities to scale and optimize costs, and proposed improvements to language models along with other functional enhancements.

Outcomes

In the future, the client will have a digital GDPR assistant that's expandable, scalable and can be integrated into their existing IT environment. Corresponding concepts were also delivered as part of the project scope.

Technologies

Azure Cloud, Docker, Python

Partner products

Microsoft Azure

Startups

Startup radar

In this section, we review a selection of startups relevant to the enhanced-humans trend, based on our observations, partnerships and investments.

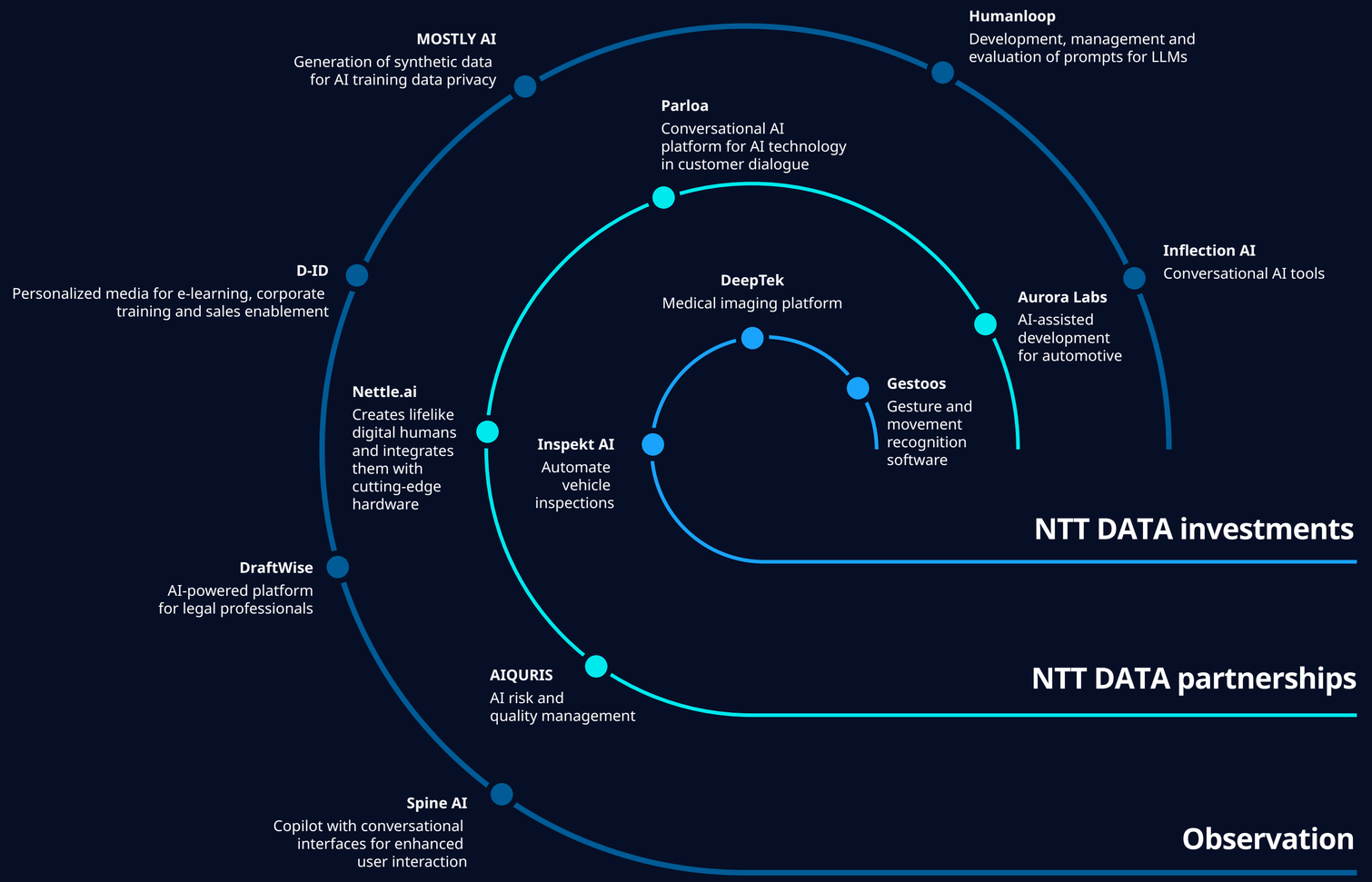


Figure 6: Investment in enhanced-human startups

Startups

Observation

Inflection AI

Founded in 2022 by former leaders of LinkedIn and DeepMind, Inflection AI focuses on developing conversational AI tools. Its flagship product API is designed to augment human–computer interaction through NLP, offering a more intuitive and accessible way to integrate AI into daily tasks.

Stage
Venture-capital backed

Funding
$1.5 billion

Valuation
$4 billion

Industry
Cross-industry

MOSTLY AI

Founded in 2017, MOSTLY AI specializes in synthetic-data generation, critical for AI training and data privacy. Its platform is particularly well suited to industries like banking and telecommunications, where it helps in developing AI models without compromising sensitive information.

Stage
Series B

Funding
$31.1 million

Valuation
Not disclosed

Industry
Financial services; telecommunications, media and technology

DraftWise

Founded in 2020, DraftWise has developed a knowledge management and intelligence platform that supports organizations' technology and compliance requirements. The platform helps law firms draft contracts faster by giving lawyers instant access to their firm's collective knowledge base and existing contracts. Firms can also customize the security architecture according to their requirements.

Stage
Series A

Funding
$28 million

Valuation
$92.93 million

Industry
B2B legal services

D-ID

Founded in 2017, D-ID has developed a platform that uses AI to create highly personalized media, specifically for e-learning, corporate training and sales enablement. The solution allows businesses to create AI-powered conversational agents and AI-generated videos for a more natural and engaging user experience.

Stage
Series B

Funding
$48 million

Valuation
Not disclosed

Industry
Cross-industry

Humanloop

Founded in 2023, Humanloop has developed a platform that trains AI models using less labeled data, allowing engineers and data scientists to move from idea to deployed AI faster, manage prompt development better and improve the evaluation of LLM applications.

Stage
Seed

Funding
$2.7 million

Valuation
Not disclosed

Industry
Cross-industry

Spine AI

Founded in 2023, Spine AI is the developer of an AI copilot with a conversational interface that seamlessly integrates with an organization's existing APIs. It offers robust, stable and hassle-free deployment and integration.

Stage
Seed

Funding
$500,000

Valuation
Not disclosed

Industry
Cross-industry

Startups

NTT DATA partnerships

Aurora Labs

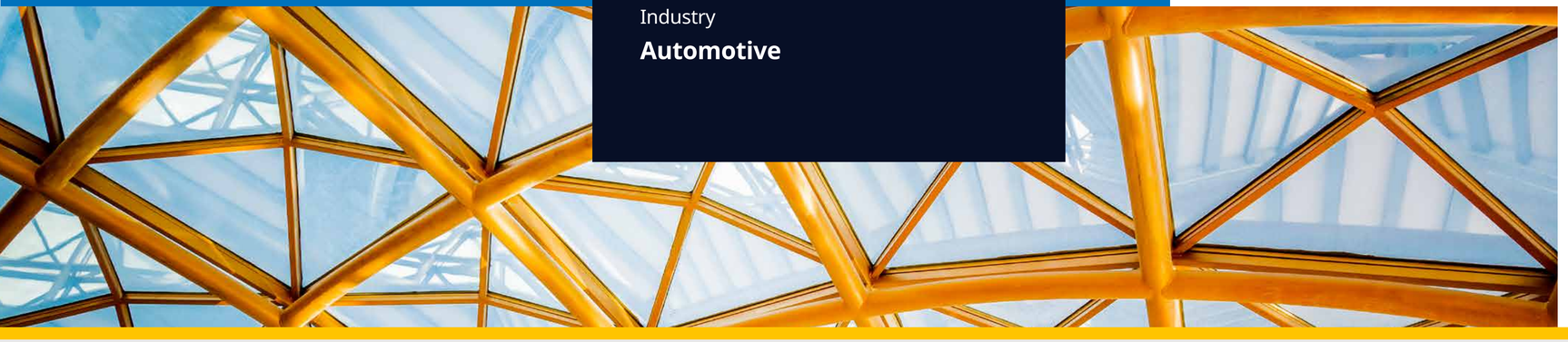
Founded in 2016, Aurora Labs brings AI-based vehicle software intelligence to the entire vehicle lifecycle, from development to testing, integration, quality control, continuous certification and on-the-road over-the-air software updates. Aurora Labs focuses on the embedded systems key to the development of software-defined vehicles. Its solutions enable automotive manufacturers to more efficiently manage software costs and the resources required to develop and manage new vehicle features and mobility services.

Stage
Series C

Funding
$97.1 million

Valuation
Not disclosed

Industry
Automotive



Parloa

Founded in 2018, Parloa has created a conversational AI customer dialogue platform designed to meet increased customer expectations for service quality across more channels. The platform captures and analyzes customer calls and service requests within seconds and automates repetitive tasks. By breaking down data silos and applying unified data training, it allows customers to use multiple service channels simultaneously.

Stage
Series B

Funding
$85.7 million

Valuation
Not disclosed

Industry
Cross-industry

Nettle.ai

Founded in 2018, Nettle.ai creates lifelike digital humans and integrates them with cutting-edge hardware like holographic projectors. These digital humans are customized to represent brands and offer interactive, intelligent conversations powered by advanced NLP. The platform delivers immersive, "phygital" experiences, blending physical and digital realities to engage audiences without the need for additional wearables.

Stage
Seed

Funding
$1.19 million

Valuation
$4 million

Industry
Cross-industry

AIQURIS

Founded by Dr Andreas Hauser and Dr Martin Saerbeck, AIQURIS specializes in AI risk management, compliance and governance, helping businesses safely adopt AI technologies while ensuring regulatory compliance and efficiency for sustainable growth and innovation across industries.

Stage
Series A

Funding
Captive cross

Valuation
Not disclosed

Industry
Cross-industry

Startups

NTT DATA investments

Gestoos

Founded in 2016, Gestoos develops AI-enabled gesture control and behavior recognition applications and ML-enabled gesture recognition solutions for the automotive, consumer electronics and digital space industries. Based in Barcelona, Spain, Gestoos was acquired by PreAct in January 2023.

Stage
Formerly venture-capital backed

Funding
$2.6 million

Valuation
Not disclosed

Industry
Cross-industry

Inspekt Labs

Founded in 2019, Inspekt Labs is the developer of an AI-based inspection platform that automates inspections of physical items using photos and videos. The platform performs quick and consistent inspections of items like cars, bikes, mobile phones, property and more, enabling users to easily conduct damage assessments, asset valuations, claims assessments and fraud detection.

Stage
Seed

Funding
$720,000

Valuation
Not disclosed

Industry
Insurance; logistics

Deeptek

Founded in 2017, Deeptek has developed an AI system that provides decision support for the radiology industry. The system offers services like teleradiology services, radiology optimization platforms and community outreach programs, enabling radiologists to reduce their workload and expedite the diagnosis process.

Stage
Series A

Funding
$10 million

Valuation
Not disclosed

Industry
Healthcare

> Startups in AI are not just disrupting industries; they are blending innovation with scalability to redefine how we work and live.

Future scenarios

As industries transform, new value chains emerge and technological advancements grow exponentially, companies must navigate complex, evolving landscapes.

Future scenarios and GenAI-powered personas allow organizations to explore possible futures by simulating realistic business environments, and minimize risk through scenario-based planning.

Uncertainties represent what we cannot know, but identifying them can reduce the risks of blind spots down the road.

Future scenarios

Uncertainty: regulatory response

The regulatory lag

What if regulation struggles to match the pace of AI development?

As AI fuels the enhanced-human initiative, it will create a vibrant environment for breakthrough innovations and spur growth and opportunities across various sectors. However, regulatory frameworks governing AI's responsible use may not be updated at the same speed. Advancements in augmenting human capabilities could continue unchecked until regulations eventually catch up to provide the necessary safeguards.

Islands of oversight

What if the regulatory spotlight shines brightest on finance and healthcare?

Given the higher levels of regulatory attention on finance and healthcare, these sectors could lead the way in safely integrating AI and set exemplary standards for enhanced-human technologies. This concentration of oversight will ensure that AI enhancements in these critical areas maximize benefits like improved patient care and financial security, establishing models for other sectors to follow.

However, because other sectors don't initially receive the same level of oversight, the application and benefits of AI in enhancing human abilities may be uneven across different industries.

Future scenarios

Uncertainty: impact on employment

The upskilling divide

What if the upskilling race creates champions and stragglers in society?

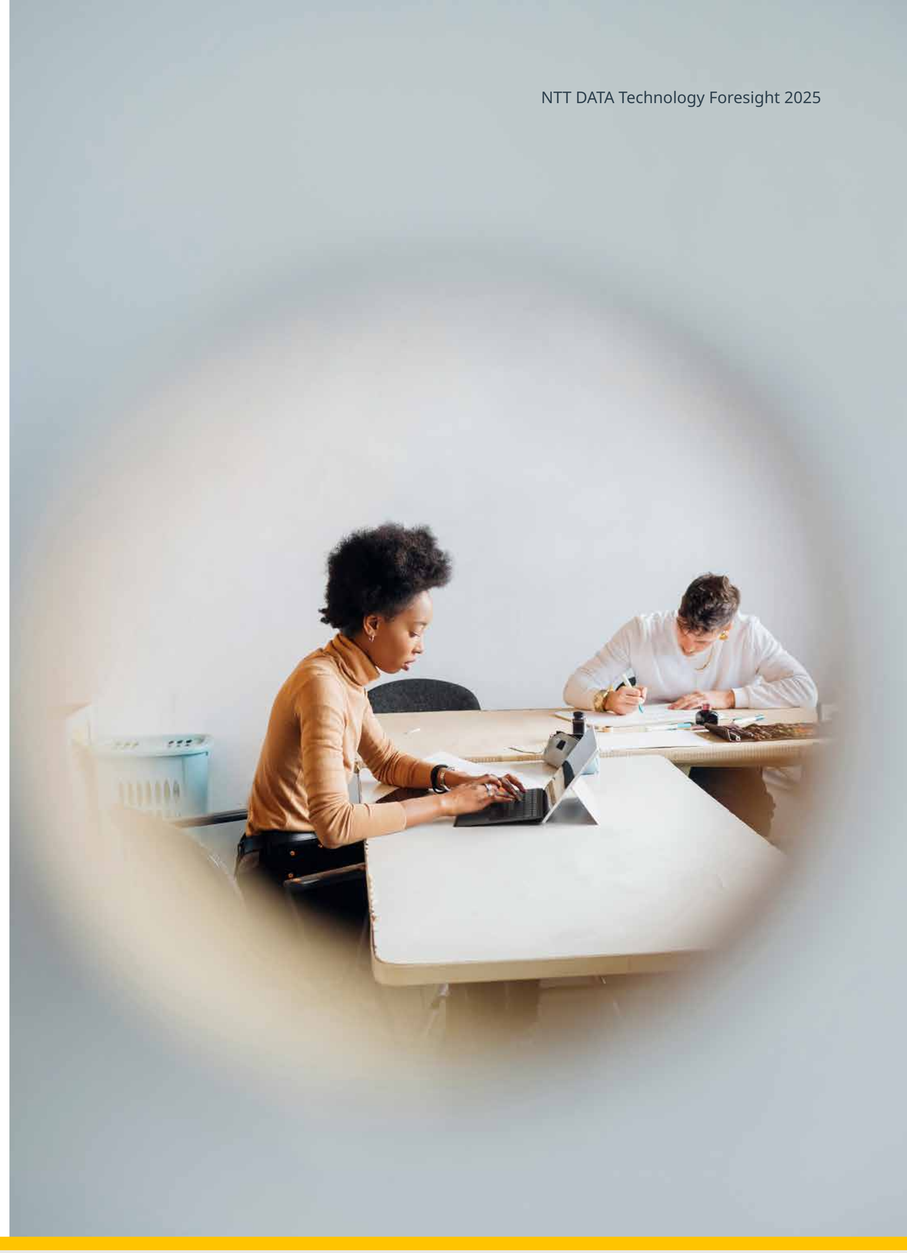
As industries integrate AI, the divide between those who are given the opportunity to enhance their skills and those who aren't could deepen, impacting social equity. This challenge highlights the need for comprehensive, accessible training programs that ensure all members of society can benefit from enhanced-human technologies, not just those already at an advantage. It also underscores the importance of fostering an inclusive environment where every individual has the potential to thrive in an AI-augmented future.

Elastic instability

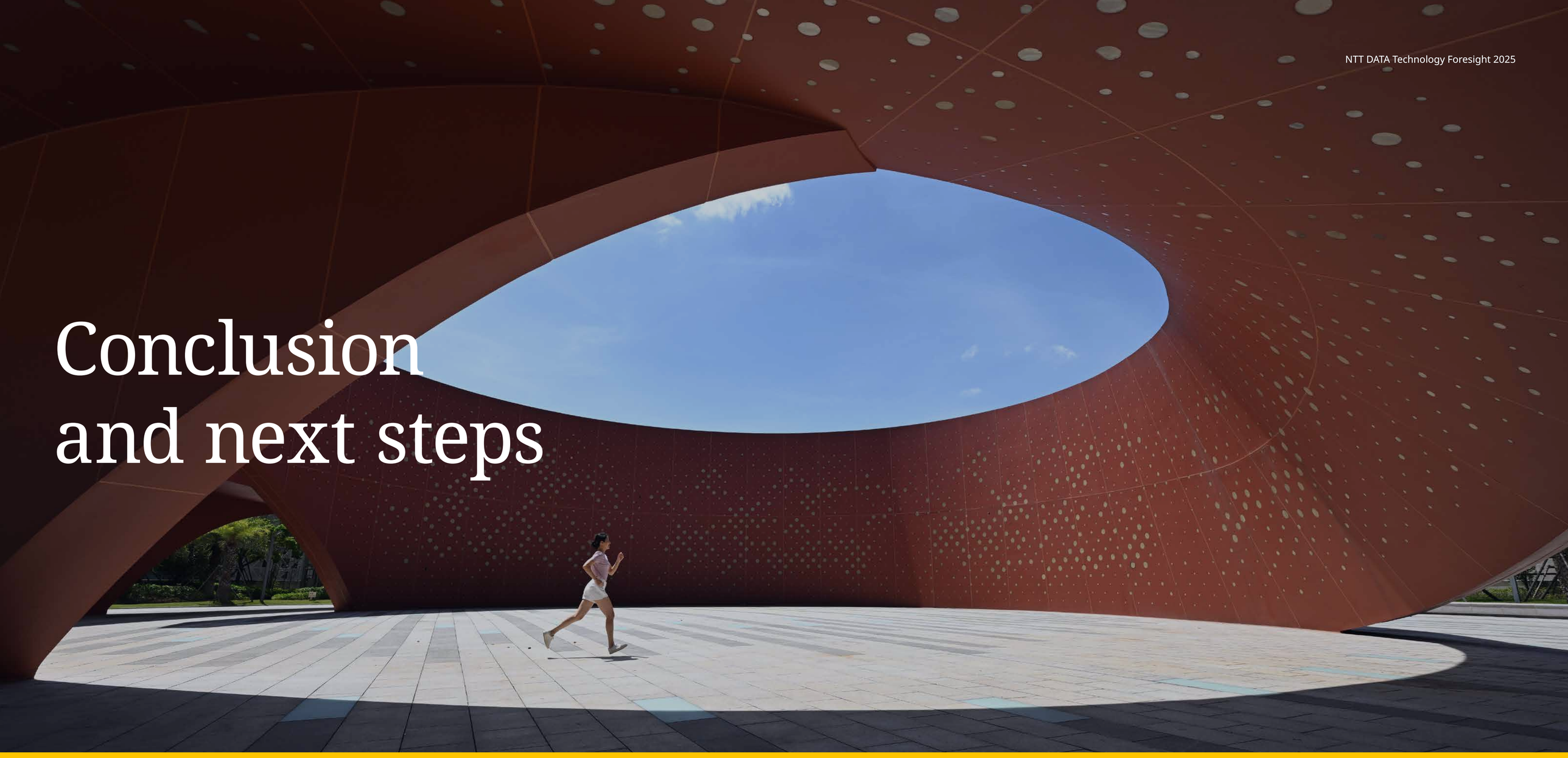
What if GenAI fuels a booming yet precarious gig economy?

While the expansion of the gig economy through AI may introduce challenges to job security, it will also introduce opportunities for greater flexibility and diversity that support personal and professional growth. This new landscape will require a rethink of traditional employment models and the introduction of innovative work structures that balance flexibility with stability to benefit a broad range of workers.

> “ Exploring scenarios like regulatory lag or the upskilling divide highlights the pivotal choices ahead.



Conclusion and next steps



Conclusion and next steps

Think about this

Given the rapid pace of AI advancements, staying ahead will require constant adaptation and the integration of the latest tools and techniques.

How do you keep up with the speed of AI innovation? What is your GenAI ecosystem?

As concerns regarding AI ethics and bias increase, organizations must ensure they have transparent and explainable AI systems and comply with new regulations governing the use of these systems.

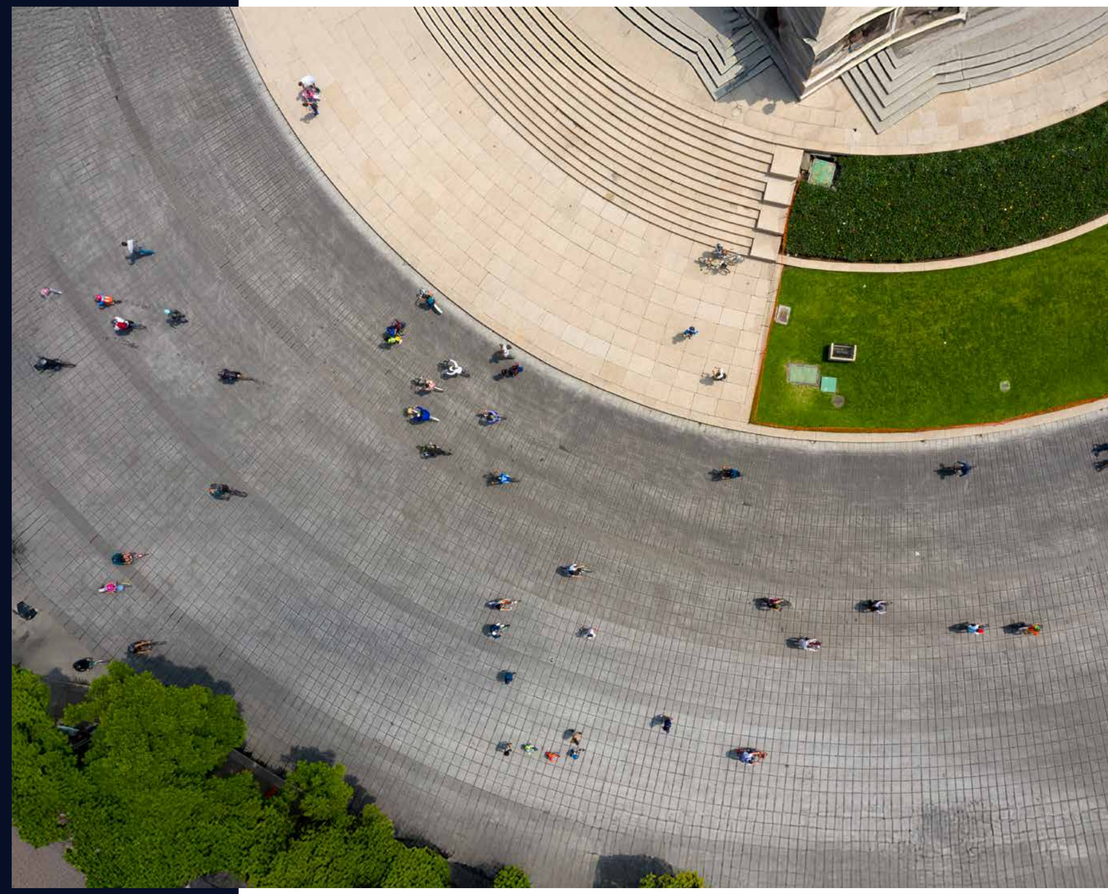
How do you bring transparency to your AI systems?

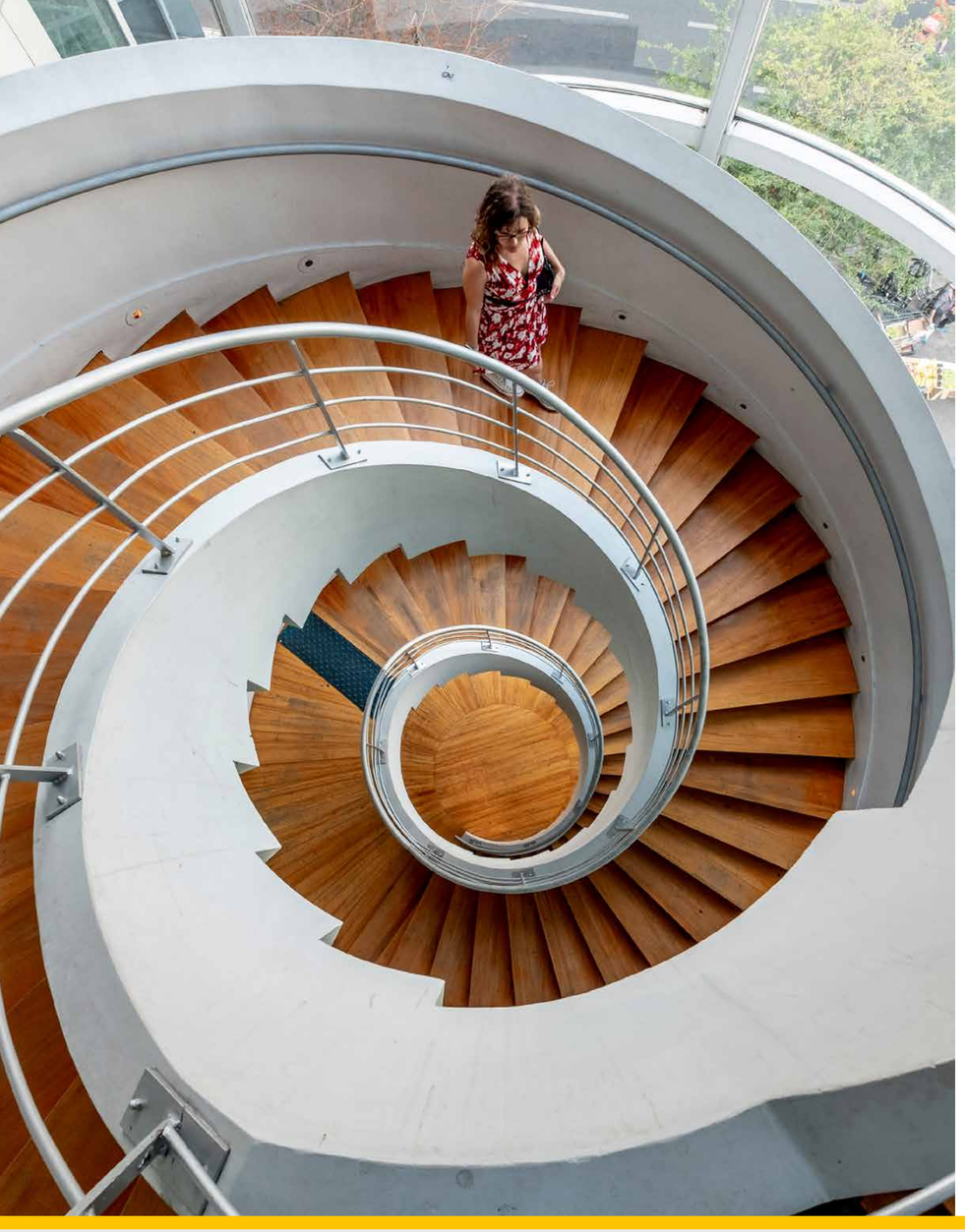
Enhanced-human technologies do not replace people but enhance their abilities. Critical thinking and targeted questioning will remain essential.

How do you train juniors if there are no easy or routine tasks?

Ownership of AI models and the distribution of value from AI services raise critical questions about control and equity in the evolving digital landscape.

Who owns AI models, and how do we share the value generated by AI services?





Conclusion and next steps

Do this next

5 minutes

Prioritize key workflow bottlenecks

Identify the top three processes or workflows that frequently reduce the speed of operations (for example, manual data entry, lengthy approvals). These areas are ideal for immediate, targeted AI enhancements.

5 days

Deploy a GenAI chatbot for internal queries

Set up a GenAI chatbot prototype that assists employees with routine internal queries, such as accessing data or policy information. This will immediately reduce the time people spend searching for information, and lay a firm foundation for broader AI adoption.

5 months

Launch a cross-departmental AI-enablement program

Initiate a program to train a small group of employees from different departments on how they can use AI tools in their specific roles. Focus on creating AI “champions” who can encourage the adoption of the technology among their colleagues and help refine use cases. This will set the stage for the scalable integration of AI throughout the organization.

Contact information

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Trend 2: Ambient intelligent experiences

Envision unlocking personalized customer journeys at every touchpoint, transforming interactions into lasting relationships.

Introduction

Ambient intelligent experiences are redefining how customers and brands interact across different touchpoints and reshaping customer engagement.

Driven by technologies like AI, spatial computing and automation, these experiences fundamentally change how organizations connect with their audiences. Beyond improving customer service, they help organizations proactively anticipate needs, optimize interactions and nurture meaningful emotional connections — crucial for building customer satisfaction and loyalty.

Significance and impact on business

Some 73% of customers cite experience as a key factor in their purchasing decisions. Organizations that strategically embrace this trend can reduce churn and cultivate dedicated brand advocates, strengthening their reputation and deepening customer trust.

Key drivers

Ambient intelligent experiences are made possible by several critical elements. AI-driven chatbots facilitate real-time, responsive interactions, offering efficient support. Predictive analytics helps businesses anticipate customer preferences and tailor their offerings. Omnichannel strategies create a seamless experience across all touchpoints, ensuring consistency in engagement. Hyperpersonalization — using data insights to meet individual needs — will be vital for fostering deep, immersive interactions. Connected products will blend their physical and digital features into a single, consistent and natural flow of interactions.

As the future unfolds, data privacy concerns and personalization fatigue may present challenges, underscoring the need for ongoing innovation to keep pace with evolving customer expectations. Businesses that invest in advancing ambient intelligent experiences will set new benchmarks in customer satisfaction, driving sustainable growth.

Technical explanation

Ambient intelligent experiences transform business–customer and product–user interactions by using advanced technologies to create integrated, personalized and intuitive interactions across platforms. This shift is built on key concepts that enable businesses to anticipate and meet customer needs effectively:

1. Natural user interfaces (NUIs)

Utilizing gestures, voice and touch, NUIs create intuitive experiences that simplify digital interactions, making them more human-centric and accessible.

2. AI-driven customer interfaces

These interfaces use machine learning to analyze behavior in real time, adapting to user needs and providing personalized interactions through natural language understanding and emotion detection.

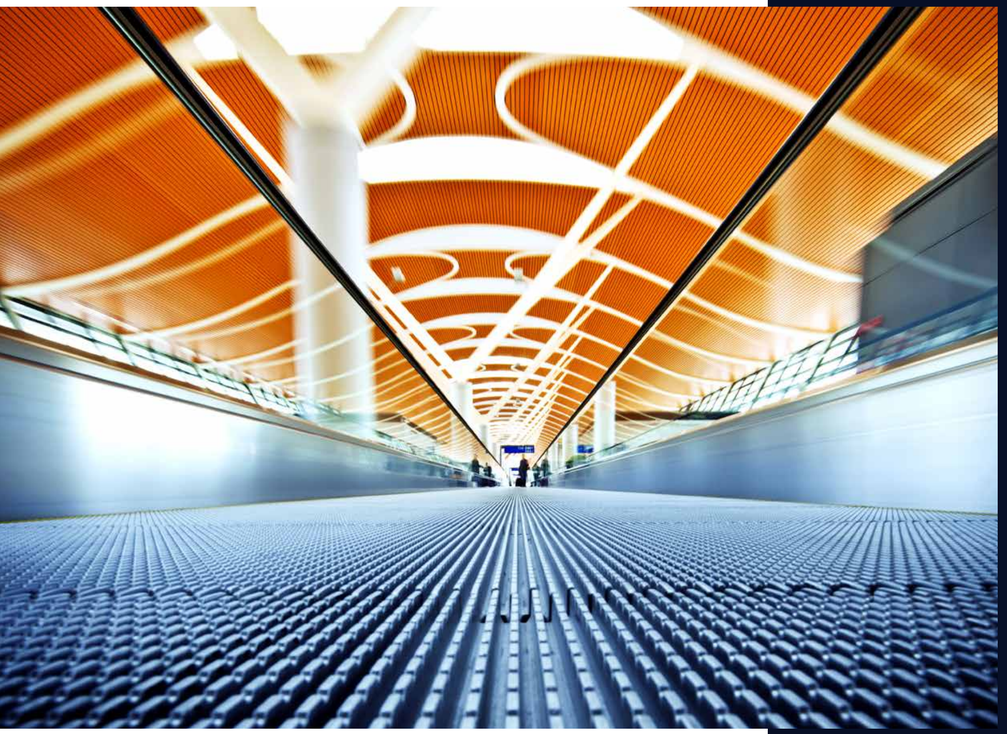
3. Intelligent personal assistants (IPAs)

AI-powered assistants provide conversational support, recommendations and solutions across platforms, improving user engagement with seamless, real-time assistance.

4. Omnichannel integration

Omnichannel integration unifies customer data and interactions across all touchpoints, supporting smooth transitions between platforms and improving engagement.

> By applying these concepts, organizations can deliver adaptive customer journeys that boost customer satisfaction and loyalty, and build a competitive advantage through immediate, relevant interactions in an evolving digital world.



Technology

Emotion AI and sentiment analysis technologies capture user emotions through voice, facial and behavioral data, enabling real-time adaptation to customer sentiment. Cogito AI, for example, detects stress in voice signals during support calls, helping organizations tailor responses in the moment and enhance customer satisfaction.

Recommendation engines use advanced ML models to dynamically tailor content, products and services based on user behaviors and preferences. Inflection AI's Pi represents the latest in recommendation technology, offering personalized, contextually relevant interactions that evolve based on conversation history and user needs.

Speech and gesture recognition brings intuitive control and interaction capabilities by interpreting voice commands and gestures in real time. Google's Project Starline uses 3D imaging for natural, holographic conversations, while Ultraleap's Leap Motion Controller delivers precise, touch-free gesture control in virtual reality/augmented reality (VR/AR) spaces, enhancing accessibility and engagement.

Smart sensors and radio frequency identification (RFID) technology enable real-time data collection and tracking across physical and digital touchpoints, improving the flow of information throughout the customer journey. Advanced RFID systems and smart sensors capture location, movement and engagement patterns, allowing businesses to seamlessly connect in-store and online behaviors.

Business explanation

The ambient intelligent experiences trend represents a significant transformation in how businesses interact with customers and streamline operational processes. It uses advanced technologies to create cohesive, intuitive and personalized interactions across various platforms.

By focusing on user-centric design and intelligent automation, organizations can boost engagement and satisfaction while increasing efficiency.

Ambient intelligent experiences can redefine customer experience and operational success in several areas:

Improved customer engagement

By integrating AI and ML, businesses can analyze customer behavior in real time and tailor interactions to meet individual needs, preferences and expectations.

Enhanced operational efficiency

Seamless experiences minimize process friction, enabling faster response times and smoother transitions between different touchpoints. This efficiency can significantly reduce operational costs and improve service delivery.

Data-driven insights

The continuous collection and analysis of customer data across various interfaces provides organizations with valuable insights that can inform strategy, product development and marketing efforts.

Personalization at scale

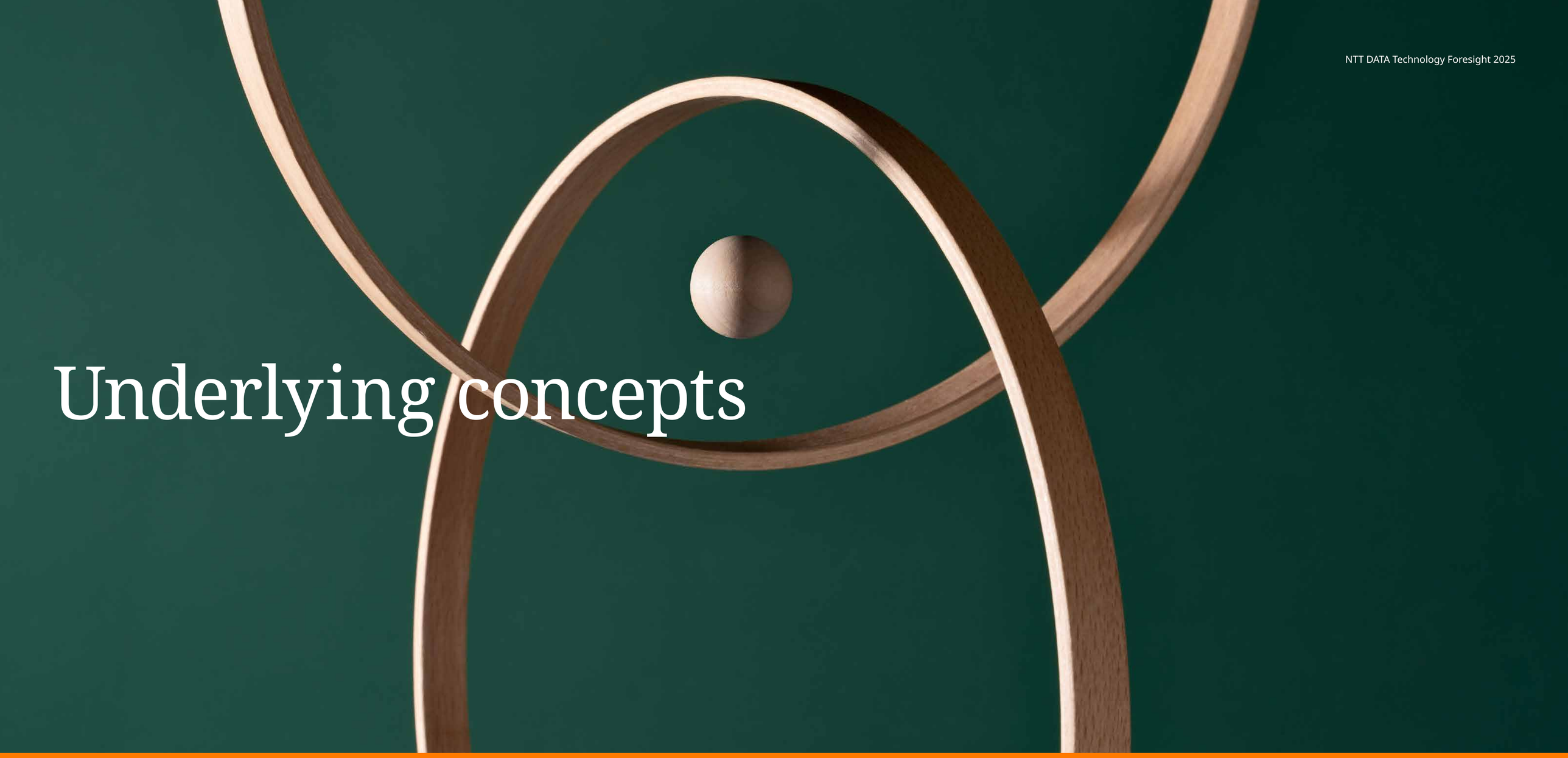
With intelligent systems, businesses can automate personalized content and offers, ensuring each customer receives relevant experiences that foster loyalty and retention.

Ease of use

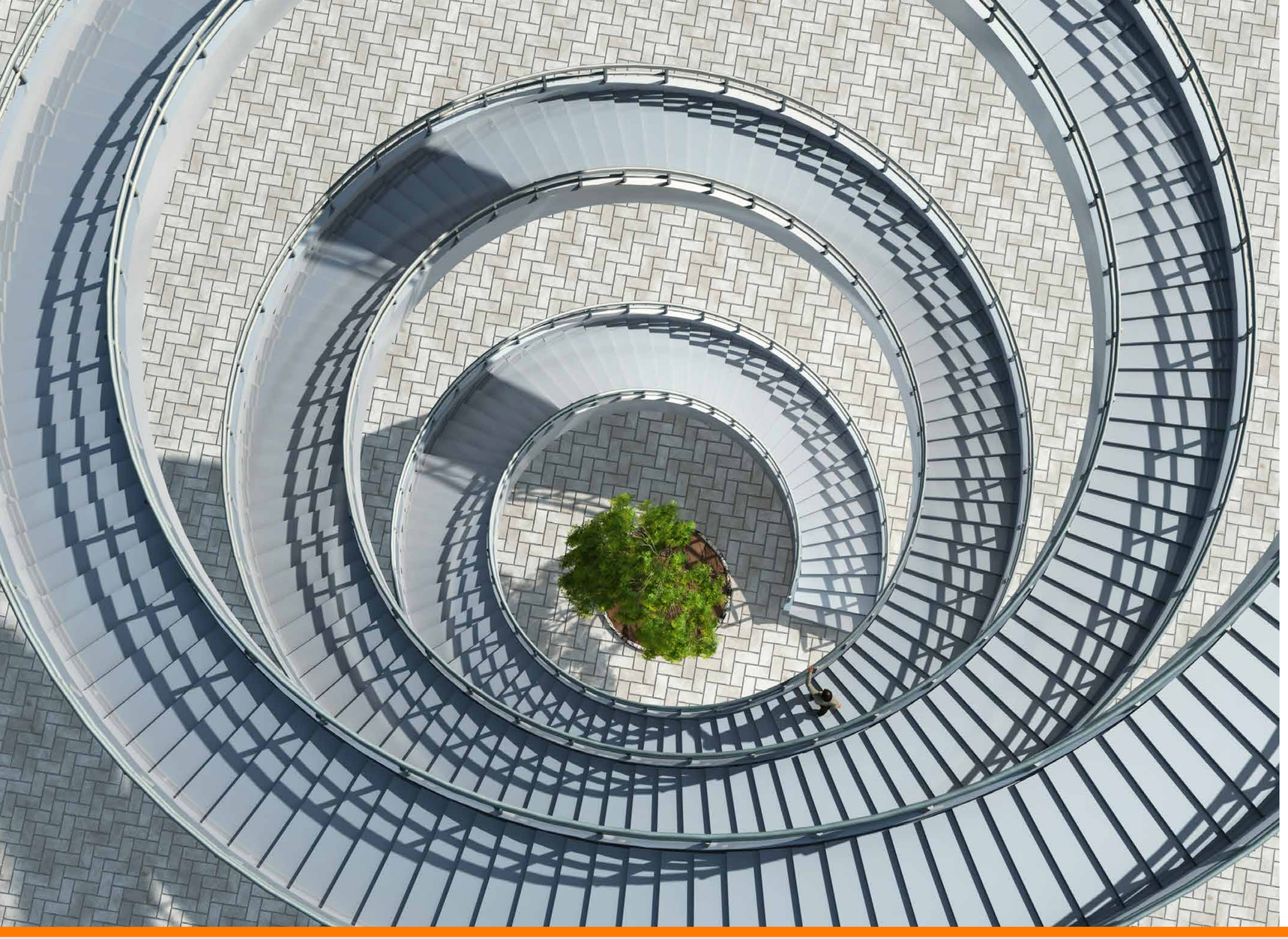
When a product's physical and digital features are blended, natural interactions with a product (for example, touch and gestures) can trigger contextually relevant digital functions, resulting in reduced training requirements, fewer handling errors and a more frictionless experience.

Competitive differentiation

Organizations that successfully implement ambient intelligent experiences will distinguish themselves in the marketplace, attracting more customers and building their brand reputation.



Underlying concepts



Underlying concepts

Ambient intelligent experiences are characterized by the seamless combination of intuitive user interfaces, AI-powered customer engagement tools, smart virtual assistants and cross-channel integration. The result is an effortless and unified interaction that anticipates user preferences, offers tailored solutions across multiple platforms and stays aligned with evolving customer expectations and market dynamics.

Ambient intelligent experiences

Natural user interfaces

- Enhanced user experience
- Adaptive contextual awareness
- Interaction modalities
- User-centric design
- Design philosophy and principles

AI-driven customer interfaces

- Intelligent feedback analysis
- Predictive customer service
- Adaptive interface evolution
- Omnichannel engagement
- Personalized marketing automation
- Enhanced customer analyticcs

Intelligent personal assistants

- Immersive cross-platform experiences
- Dynamic decisions support
- Natural and engaging interactions
- Personalized and contextual assistance

Omnichannel integration

- Seamless customer experience
- Digital–physical convergence
- Business transformation
- Innovation and insight

Figure 7: Ambient intelligent experiences — underlying concepts and supporting trends

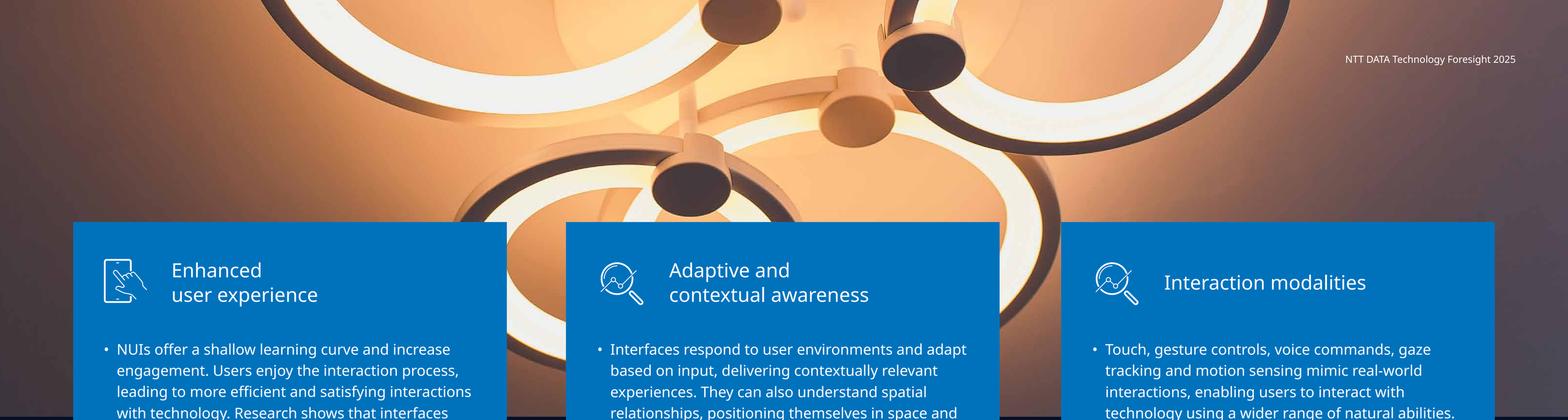
Underlying concepts

Natural user interfaces

Natural user interfaces (NUIs) facilitate intuitive human–computer interactions by drawing on natural human abilities such as touch, gesture and voice. These interfaces minimize the learning curve, allowing users to engage with technology without extensive training. By improving user experience and accessibility, NUIs can broaden market reach and create a competitive advantage. They're applicable across various sectors, including customer service, retail, healthcare, manufacturing and education.

NUIs present a significant opportunity for improving user engagement and operational efficiency in a rapidly evolving digital landscape.

> "However, organizations must carefully consider user needs, ongoing technological developments, and potential challenges such as development costs and privacy concerns.



Enhanced user experience

- NUIs offer a shallow learning curve and increase engagement. Users enjoy the interaction process, leading to more efficient and satisfying interactions with technology. Research shows that interfaces designed for emotional engagement increase user retention rates significantly.
- The deep integration of the Apple Pencil in iPadOS demonstrates how natural interactions can enhance user experiences. By allowing users to write, draw and navigate with precision and fluidity, the Apple Pencil transforms digital tasks into intuitive and enjoyable processes, showcasing the power of performance aesthetics to drive engagement.

Adaptive and contextual awareness

- Interfaces respond to user environments and adapt based on input, delivering contextually relevant experiences. They can also understand spatial relationships, positioning themselves in space and time for more fluid interaction.
- We estimate that most internet-connected devices will be context-aware by 2025, allowing for smarter, more personalized user experiences. This shift is already transforming the automotive industry, where in-car systems can adapt to drivers' preferences and driving habits, making vehicles smarter and safer.

Interaction modalities

- Touch, gesture controls, voice commands, gaze tracking and motion sensing mimic real-world interactions, enabling users to interact with technology using a wider range of natural abilities. For example, the latest developments in speech recognition allow systems to process speech with up to 95% accuracy, nearly matching human capabilities.
- Gaze-tracking technology, once considered futuristic, is now being implemented in devices like VR headsets, allowing users to navigate and select content simply by looking at it. These natural interaction methods reduce reliance on traditional input devices, making engagement with technology more fluid and accessible to diverse user groups.

User-centric design

- Interfaces will need to be intuitive and reduce cognitive effort by leveraging natural human skills. The goal is to make interactions feel seamless and allow users to focus on content without noticing the interface itself.
- Studies show that reducing visual complexity can improve task performance by up to 20%. This emphasizes the importance of simplicity in design.
- Apple Vision Pro exemplifies design simplicity, combining spatial computing with a minimalist interface. By enabling users to interact with content using natural gestures, voice and eye tracking, Vision Pro minimizes cognitive effort and distraction, embodying the essence of seamless and intuitive design.

Design philosophy and principles

- Direct manipulation, content serving as the interface, and logically extending objects to enhance functionality are all shaping NUI design. Subtle design elements guide users through interactions, creating intuitive, context-aware environments. This approach taps into human instincts and abilities, making interactions feel natural and engaging.
- Emotional design is becoming increasingly vital in shaping user and customer experiences, particularly as AI technologies evolve. This approach focuses on how users feel when interacting with products and services and aims to create positive emotional responses that boost satisfaction and loyalty.

Underlying concepts

AI-driven customer interfaces

AI-driven customer interfaces revolutionize how businesses engage with customers by delivering personalized and efficient interactions. These interfaces incorporate voice of the customer (VoC) applications and sentiment analysis to collect insights, enabling organizations to elevate customer experiences based on real-time feedback. They can anticipate customer needs and evolve over time, improving service delivery and boosting user satisfaction. By maintaining consistent engagement across diverse channels, including social media, these interfaces cultivate stronger brand loyalty.

> AI-driven customer interfaces empower organizations to meet increasing customer demands for relevance and immediacy, thereby driving satisfaction and fostering business growth in a competitive environment.

1 Intelligent feedback analysis

AI-driven interfaces excel at collecting and analyzing customer feedback through VoC applications. These systems utilize sentiment analysis to understand customer emotions and opinions, providing businesses with valuable insights. A continuous learning process enables organizations to refine their services and create more personalized, satisfying customer journeys, ultimately improving customer satisfaction and loyalty.

For example, major banks use AI to analyze customer feedback from surveys and social media. This allows them to tailor services like loan recommendations and fraud prevention.

2 Predictive customer service

Businesses can anticipate customer needs and behaviors by leveraging AI to identify trends and optimize interactions. This predictive capability enables proactive problem-solving and personalized recommendations, reducing customer frustration and improving the overall experience. As these systems evolve, they will become increasingly adept at anticipating customer requirements, allowing organizations to stay one step ahead in meeting expectations.

Retailers like Amazon use AI to manage inventory more effectively, ensure popular products are always available and optimize shipping times.

3 Adaptive interface evolution

AI-driven customer interfaces are evolving based on user behavior, becoming more intelligent and tailored over time. This adaptive nature ensures that interactions become more efficient and satisfying as the interface learns from past experiences and adjusts its responses accordingly. The result is a continuously improving customer experience that becomes more personalized with each engagement.

Music-streaming services like Spotify adapt to users' evolving preferences, updating personalized playlists to reflect recent listening trends.

4 Omnichannel engagement

AI-driven customer interfaces extend beyond traditional channels to include social media monitoring and management, ensuring consistent engagement across all customer touchpoints. By maintaining a cohesive presence across platforms, businesses can build stronger brand recognition and customer trust. This comprehensive approach allows for a seamless customer journey, regardless of the chosen interaction channel.

Retailers like Zara integrate online inventory data with in-store availability and analyze social media activity to predict demand trends, optimizing stock levels in real time. Before visiting a store, customers can check the app to see if items are in stock.

5 Personalized marketing automation

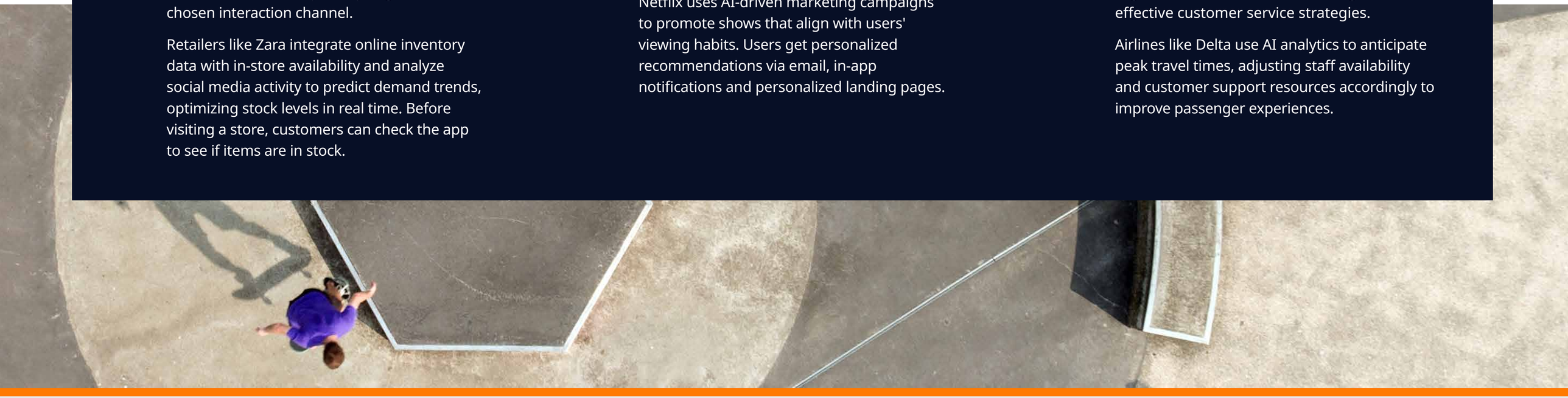
Through-channel marketing automation uses AI insights to deliver cohesive and personalized experiences across different marketing avenues. This ensures that customers receive relevant content and offers tailored to their preferences and behaviors, increasing the effectiveness of marketing efforts and improving customer engagement.

Netflix uses AI-driven marketing campaigns to promote shows that align with users' viewing habits. Users get personalized recommendations via email, in-app notifications and personalized landing pages.

6 Enhanced customer analytics

AI-powered customer service analytics provide deep insights into customer behavior, preferences and emotions. These analytics help businesses continually refine their services, optimize customer interactions and make data-driven decisions to improve overall customer satisfaction. By understanding customer needs at a granular level, organizations can create more targeted and effective customer service strategies.

Airlines like Delta use AI analytics to anticipate peak travel times, adjusting staff availability and customer support resources accordingly to improve passenger experiences.



Underlying concepts

Intelligent personal assistants

Intelligent personal assistants (IPAs) use advanced AI to provide personalized, context-aware support in various personal and professional scenarios. These AI-driven platforms, including generative conversational AI and AI avatars, offer natural, engaging interactions that adapt to user preferences and market conditions in real time, enhancing decision-making and user experiences.

> By integrating with immersive technologies like the metaverse and addressing crucial ethical considerations, IPAs are poised to revolutionize customer engagement, operational efficiency and human–computer interaction across multiple industries.

Personalized and contextual assistance

- IPAs leverage generative conversational AI to provide highly personalized support. These systems learn from interactions, adapting to user preferences and context over time. This enables IPAs to offer tailored assistance in various scenarios, from daily tasks to complex queries, improving user experience in both personal and professional settings.
- For example, Google Assistant integrates with productivity tools like Google Calendar and corporate scheduling applications, helping users manage their schedules seamlessly across devices and platforms.

Natural and engaging interactions

- AI avatars and enterprise conversational AI platforms enable more human-like interactions between users and technology. By using advanced NLP, IPAs can engage in interactive conversations, making technology more accessible and user-friendly. This approach significantly improves user engagement and satisfaction across multiple enterprise platforms.
- For example, AI avatars in virtual meetings can translate conversations in real time, breaking down language barriers and enhancing global collaboration.

Dynamic decision support

- IPAs incorporate contextualized real-time pricing, allowing for dynamic adjustments based on customer context and market conditions. This capability extends beyond simple task execution, enabling IPAs to provide valuable decision support in areas such as purchasing, financial planning and resource allocation, adapting in real time to changing environments.
- Online investment platforms use digital advisors to monitor market changes and notify users of opportunities, offering guidance based on real-time data.

Immersive cross-platform experiences

- Integrating IPAs into immersive technologies, such as the metaverse in manufacturing, creates new possibilities for customer experiences. These assistants can guide users through virtual spaces, allowing for interactive product exploration and support. This approach blends the digital and physical worlds, enhancing customer engagement and decision-making processes across various platforms.
- For example, virtual shopping assistants in metaverse retail spaces can help users "try on" clothing in a digital space, providing a unique shopping experience that blends virtual and physical realities.

Evolving roles and ethical considerations

- As IPAs become more sophisticated, their roles are expanding from simple task executors to intelligent companions and collaborators. This evolution raises important ethical considerations, including privacy concerns, data security and the need for transparency in AI decision-making. Addressing these aspects is crucial for building trust and ensuring the responsible development of IPA technologies.
- Companies like Apple focus on data privacy and aim to build trust through transparency, for example, by allowing users to manage the information digital assistants can access.

Underlying concepts

Omnichannel integration

Omnichannel integration is a comprehensive business strategy that seamlessly unifies customer experiences across multiple digital and physical platforms. It uses AI-powered commerce solutions and metaverse-ready networks to create consistent, personalized interactions while driving digital transformation through dedicated initiatives and product innovation based on customer insights.

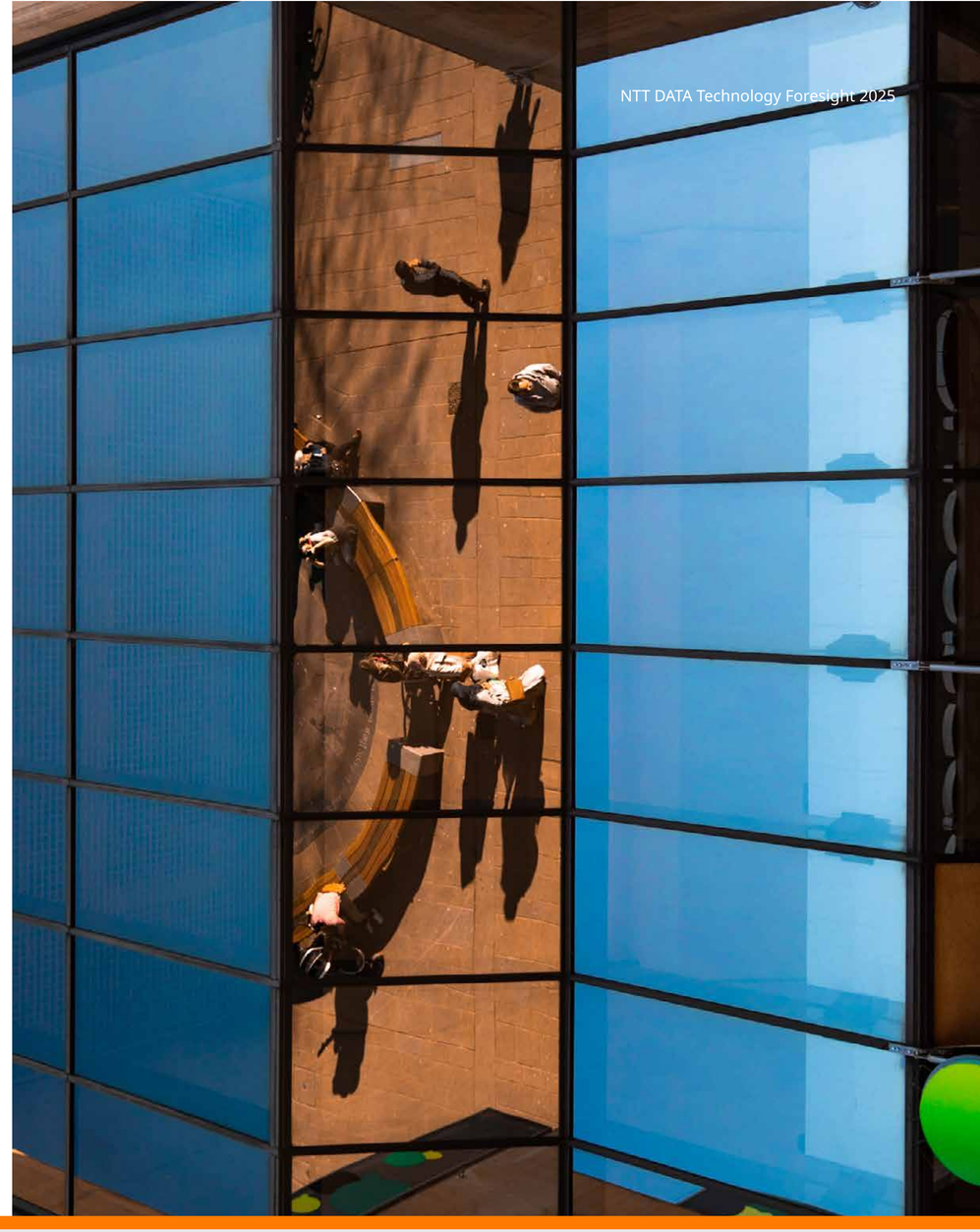
> “This approach enables businesses to adapt to evolving consumer expectations, providing a cohesive brand experience that transcends traditional boundaries between online and offline channels.

Seamless customer experience

- Omnichannel integration focuses on providing a consistent and fluid customer journey across all platforms. AI-powered commerce solutions ensure that customers have a uniform experience, whether they're shopping online, in-store or through mobile apps.
- For example, McDonald's uses geolocation data in its mobile app to offer personalized promotions and allow customers to place orders directly from their tables. This turns self-service into service while lowering operational costs, as meal production can be optimally sequenced.

Digital–physical convergence

- This theme emphasizes the creation of metaverse-ready networks that support immersive experiences spanning both digital and physical environments. The goal is to blur the lines between online and offline interactions, offering a cohesive brand experience across all touchpoints.
- Retailers like Sephora use AI-driven AR tools, such as their Virtual Artist, to let users try on makeup virtually before purchasing, bridging the gap between online browsing and in-store experiences.

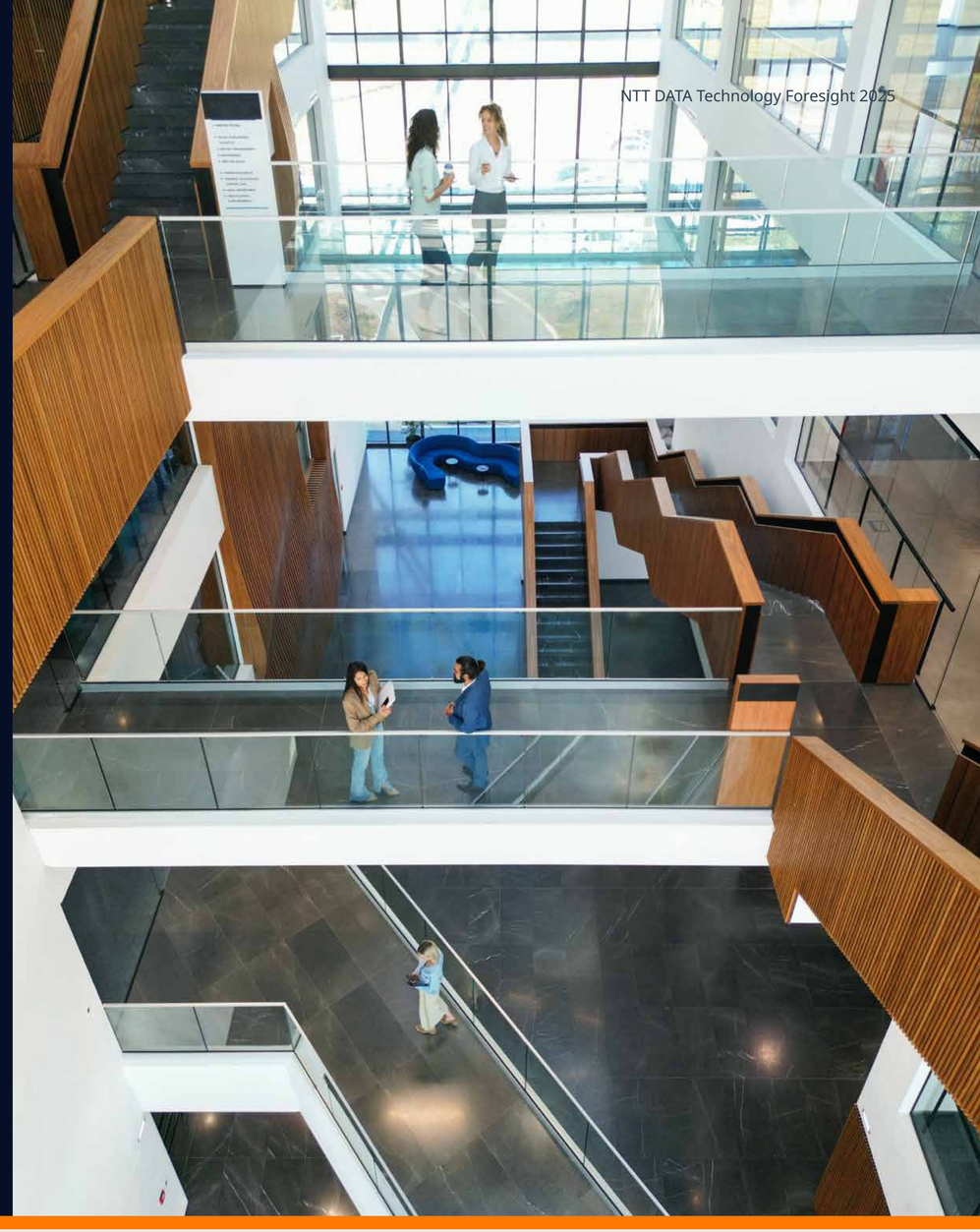


Business transformation

- Successful omnichannel integration requires significant organizational change. Digital transformation officess should therefore lead initiatives to help businesses adapt and provide unified, AI-powered customer experiences. This involves aligning various departments and processes to create a cohesive omnichannel strategy.
- Nike's loyalty program integrates data from online and in-store purchases, allowing customers to earn rewards for activities like workouts and creating a unified brand experience across different touchpoints.

Innovation and insight

- With AI-powered product innovation platforms, businesses can continuously improve and adapt based on customer insights and trends. By analyzing data from various channels, organizations can develop more targeted and relevant offerings to stay ahead in a competitive omnichannel landscape.
- Netflix adapts its recommendations based on users' viewing habits across devices, offering a consistent experience whether customers are streaming on their phones, tablets or smart TVs.



Tech radar

Tech radar

In the constantly changing tech landscape, keeping up with the latest developments is essential, not just advantageous.

Continually analyzing technology trends and tracking their evolution will help you anticipate changes and prepare yourself for upcoming shifts.

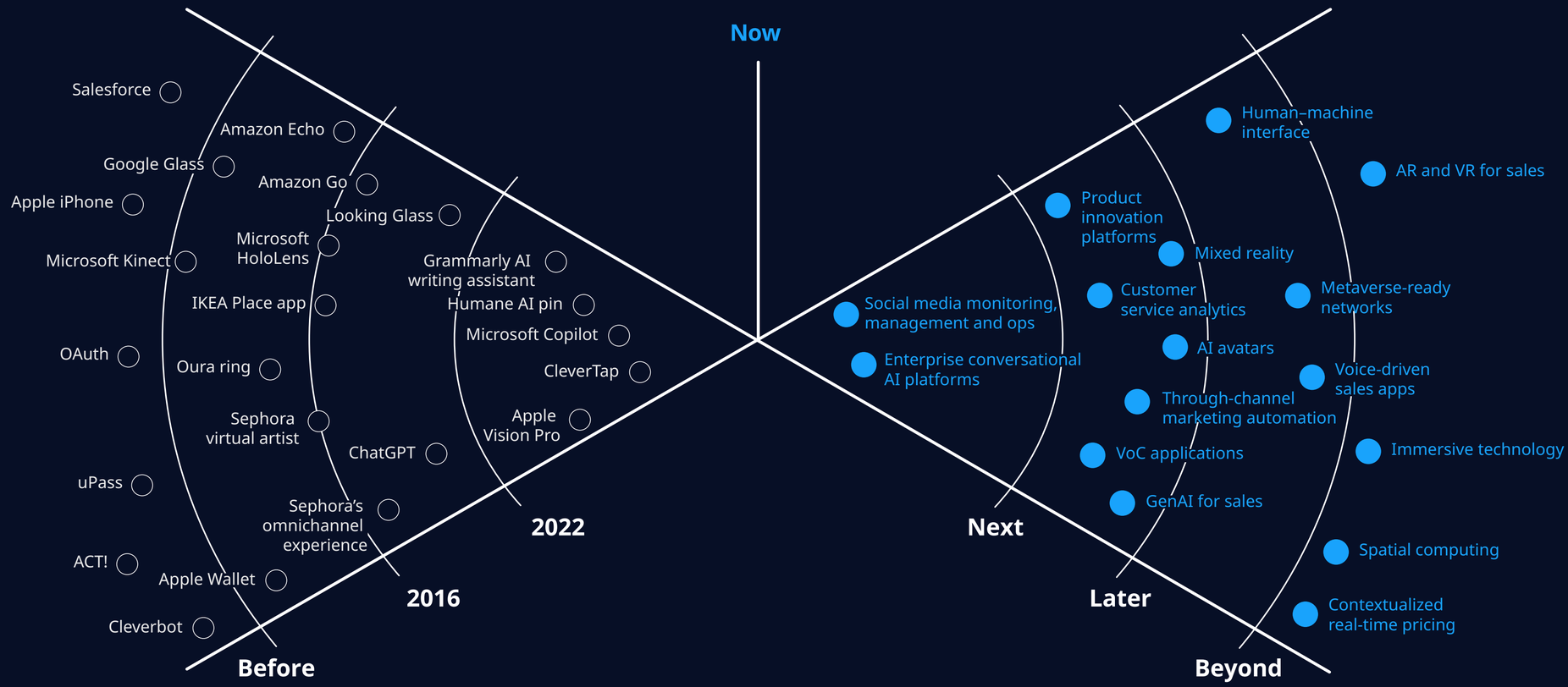


Figure 8: Tech radar — past and future technology

Future tech: now and next

A **Social media monitoring, management and operations**
These tools support social media strategies and facilitate engagement between organizations and their audiences.

B **Enterprise conversational AI platforms**
Enterprise platforms create scalable chatbots and virtual assistants using no-code tools for diverse use cases like customer service and IT automation.

C **Product innovation platforms**
Cloud-based platforms enable continuous product innovation through collaborative IT infrastructure.

D **Customer service analytics**
Analytics combining real-time and historical data optimize customer interactions and improve service delivery.

E **VoC applications**
These applications integrate feedback channels to provide actionable insights from direct and indirect customer feedback.

F **GenAI for sales**
AI creates content and strategies by learning from existing data, aiding customer engagement and training.

G **Through-channel marketing automation**
These solutions streamline content distribution and marketing execution across partner networks.

H **Mixed reality**
This digital experience that blends real and virtual elements and enables interaction through devices like smartphones, tablets and headsets.

I **AI avatars**
AI avatars are human-like digital personas created with AI technologies like CGI, NLP and emotion AI. They facilitate more immersive and interactive experiences in metaverse and virtual environments. AI avatars include virtual influencers, which are autonomous, interactive digital humans.

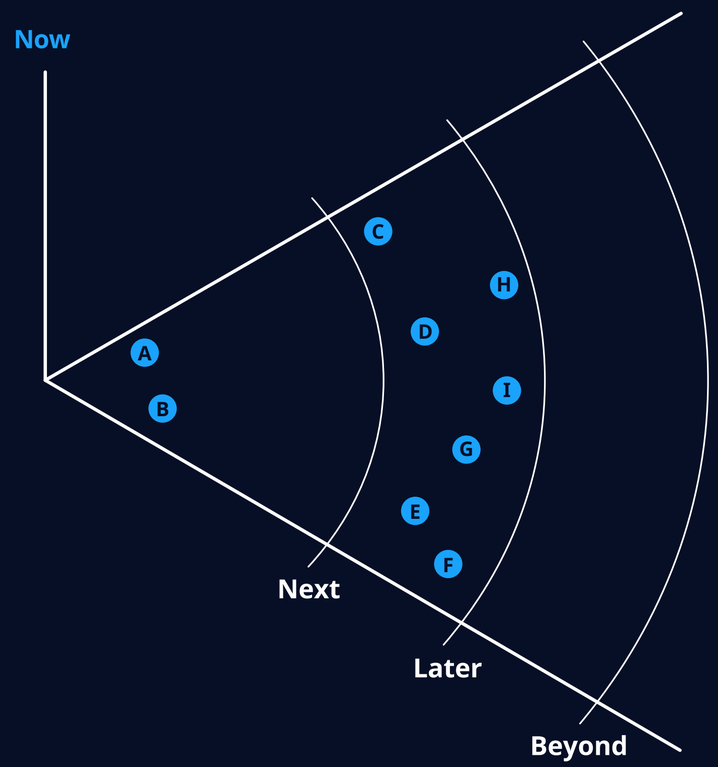


Figure 9a: Tech radar – future technology

Future tech: later and beyond

J **Human–machine interfaces**
Interfaces in autonomous vehicles use screens and voice assistants to communicate with passengers and other road users.

K **Voice-driven sales apps**
These sales apps use conversational interfaces and AI to streamline processes like ordering, check-out, data retrieval and record management.

L **Metaverse-ready networks**
These networks provide the low latency and high bandwidth needed for immersive digital experiences in the metaverse.

M **AR and VR for sales**
AR overlays digital information onto reality, while VR immerses users in digital environments for enhanced sales experiences.

N **Immersive technology**
Technologies like AR, VR and MR blend digital and physical worlds to enhance user experiences.

O **Spatial computing**
Computing environments integrate physical and digital objects, essential for immersive digital content.

P **Contextualized real-time pricing**
Pricing can be dynamically adjusted in real time based on factors like demand, competition and customer loyalty.

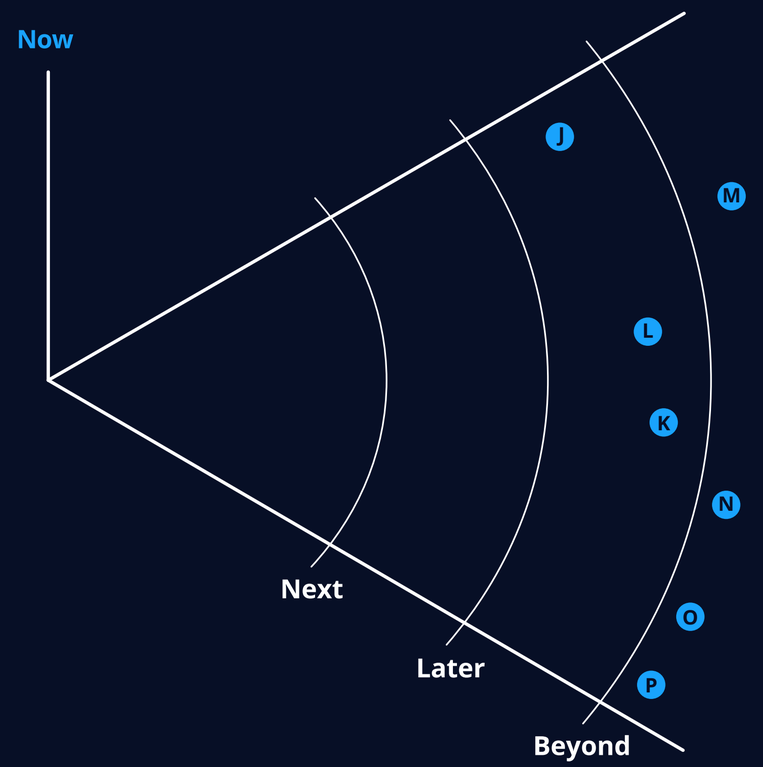
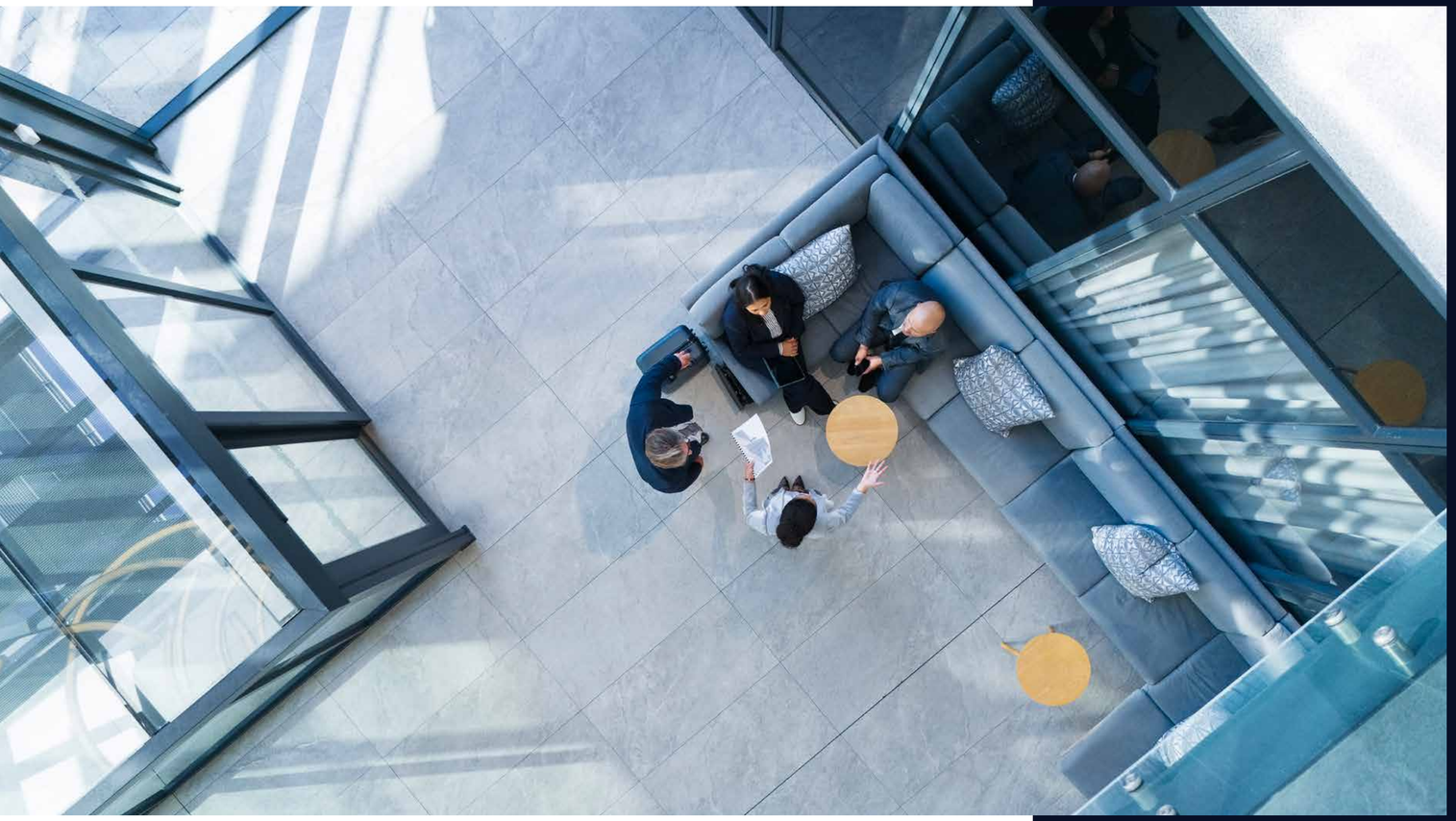


Figure 9b: Tech radar – future technology

R&D highlight



R&D highlight

Nurturing true humanity

NTT Human Informatics Laboratories leads the way in creating innovations that integrate the real and digital worlds to augment human experiences.

Its guiding mission is to develop technologies based on a human-centered approach that respects and enhances a range of human functions. This vision encompasses six key human characteristics — senses, sensitivities, thoughts, behaviors, body and environment — and translates them into data to enhance information and communication processing.

The Laboratories' key research efforts align with the evolving landscape marked by the emergence of GenAI, the advanced miniaturization and accuracy of brain-computer interfaces, and broader societal shifts such as disillusionment with the metaverse and postcapitalism.

In response, they've highlighted several critical actions:

- Accelerate research using general-purpose AI with different approaches to understanding the brain as both a "black box" and a "white box".
- Explore the essential and universal value of the metaverse.
- Promote research that's closely aligned with humanistic disciplines.

The Metaverse Project envisions a future where wellbeing is ubiquitous. It strives to merge the real and cyber worlds through ultrareal virtual spaces and avatars with identity and autonomy. The goal is to:

- Transcend space–time and physical constraints to enable a wide range of immersive experiences that aren't confined to a single metaverse.
- Promote individual wellbeing and improve societal integration by enabling richer, more meaningful encounters and exchanges within virtual environments.

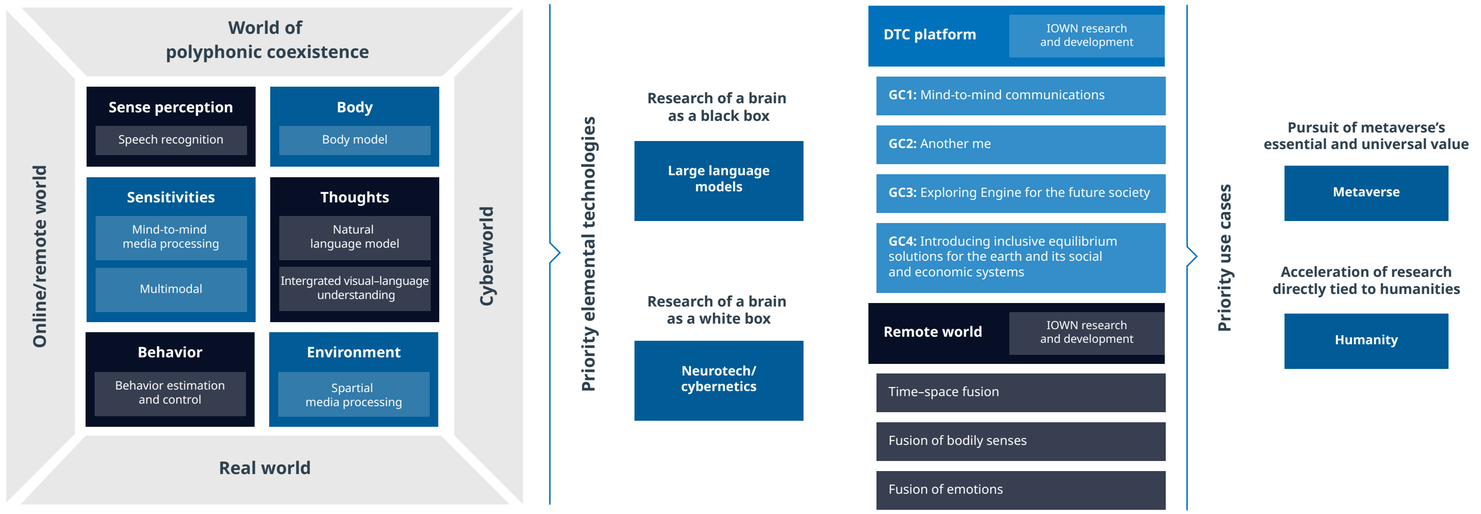
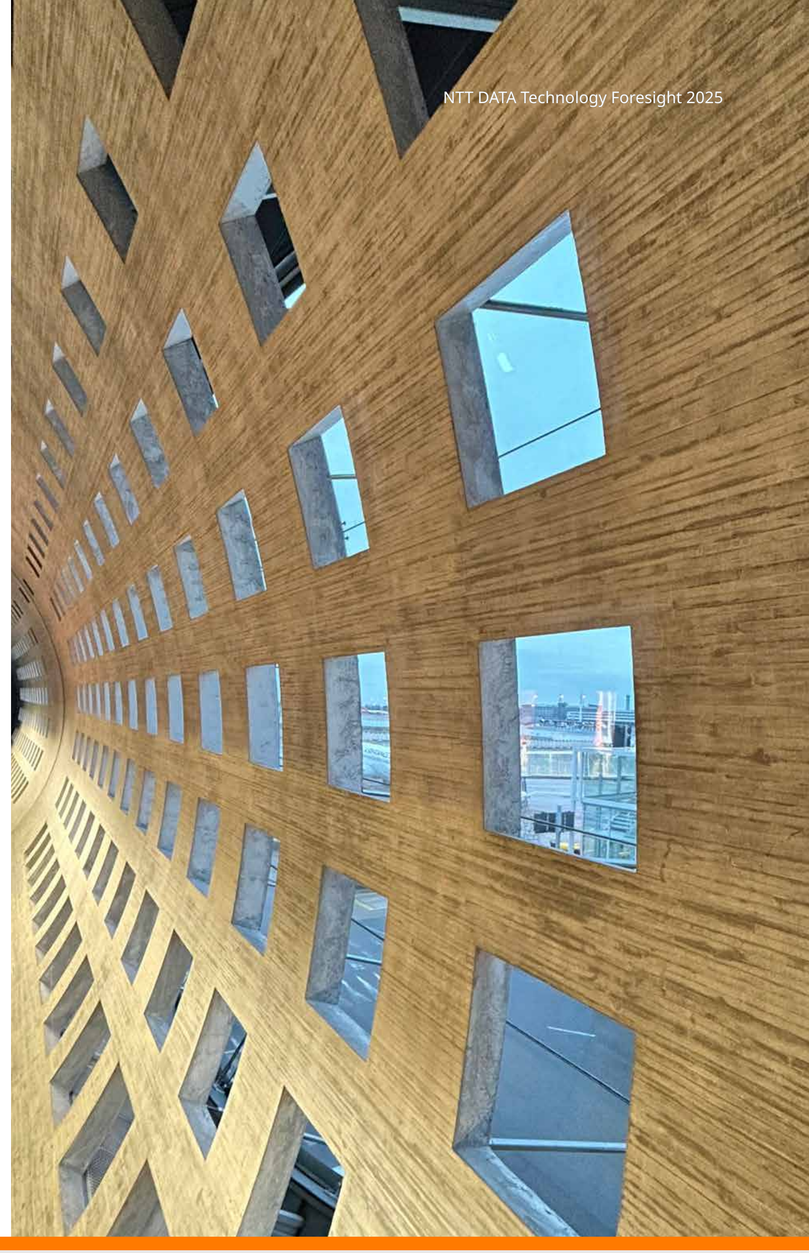


Figure 10: NTT Human Informatics Laboratories' key research

Adapted from: *NTT Technical Review* Vol. 22 No. 4 Apr. 2024



Quantification

Relevant financials

Ambient intelligent experiences

Market size, 2024:

$82.8 billion

Market size growth, 2023–2024 (YoY):

+24%

Forecast CAGR, 2024–2030:

22.7%

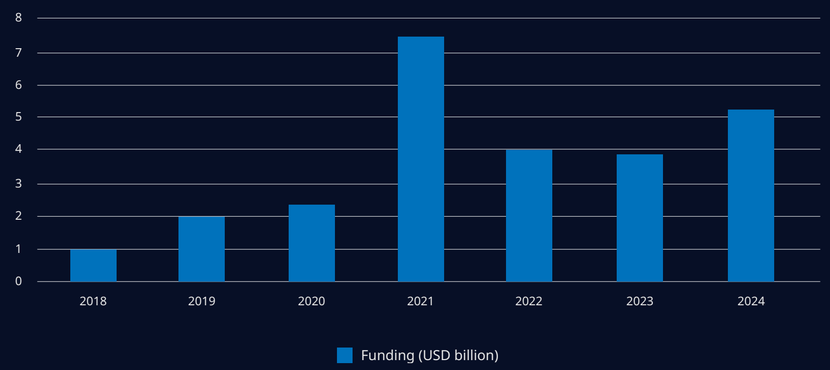


Figure 11: Funding in ambient intelligence startups

> 51% of respondents prefer advanced chatbots, a defining feature of intelligent customer experience, for immediate response.

Impact of AI on ambient intelligent experiences

In the next two years,

70%

of CX leaders plan to integrate GenAI into many of their touchpoints.

75%

of consumers who have experienced GenAI believe the technology will completely change how they interact with companies in the next two years.

Nearly

90%

of contact centers report measurable improvements in complaint-resolution speed and call-volume processing using AI.

Companies using NLP for sentiment analysis have seen a

20%

increase in customer satisfaction and a **25% reduction** in customer service costs.

Research shows that Chatbot-led customer service interactions cost

30%

less than agent-led interactions.

Research and development

2,500*

Patents registered 2023

390,000*

Patent applications pending worldwide

*Approximate figures

Use cases

AI-powered predictive maintenance for cars

Industry: **Automotive**

Manufacturers leverage AI to provide proactive maintenance alerts and automated service scheduling. This keeps vehicle owners informed and engaged, reduces the need for reactive maintenance and improves the overall customer experience.

Business value

1. Competitive advantage in reliability and new features
2. Minimize vehicle downtime
3. Enhance customer trust, for example, by automated alerts
4. Improve service frequency
5. Reduce service costs for owners and dealerships

> “AI-powered maintenance keeps customers informed and worry-free, setting a new standard for reliability.

Digital twins for enhanced retail operations

Industry: **Retail**

Digital-twin technologies create a virtual replicaof retail environments, enabling retailers to simulate scenarios like store layout changes, product placements and customer flow. Analyzing this data improves stores’ performance and customer experiences, and helps retailers make informed inventory and marketing decisions.

Business value

1. Use data to improve decision-making and uncover insights
2. Improve inventory management and reduce stockouts
3. Increase operational efficiency and performance

AI-driven emotional intelligence

Industry: **Cross-industry (B2C)**

With advancements in NLP, sentiment analysis and facial recognition, AI can increasingly detect customer emotions. This emotional awareness helps brands address not only customer queries but also the emotional context behind them, fostering more empathetic, human-like interactions.

Business value

1. Better assess the need for human intervention
2. Improve and evaluate patients' psychological wellbeing in healthcare
3. Achieve greater retail effectiveness

AI-assisted home energy management

Industry: **Energy**

A smart interplay between predictive analytics and GenAI helps customers manage their energy usage more efficiently. The technology analyzes individual consumption patterns and continuously offers tailored advice using natural language.

Business value

1. Lower energy bills by optimizing usage
2. Personalize advice to foster customer loyalty
3. Promote sustainable consumption
4. Balance demand to ease grid strain and enable "prosumer-based" smart grids

> "AI-assisted energy systems empower customers with advice for smarter consumption and seamless integration with future smart grids.

Use cases

Success case

DACH | Automotive

Digital customer twin

Business need

Our client wanted to provide customers with personalized offers and services in both online and live settings. Suboptimal data quality, primarily a result of disparate and duplicate data sources and human error, hampered its ability to do so.

Solution

NTT DATA implemented a cloud-based solution for customer data management based on Dabelia, our digital-twin customer platform.

Dabelia automatically merges customer master data from different systems, delivering a complete and accurate rendering of every customer data record. A database collects account and contact data from sales and after-sales systems and supplements it with additional customer-specific information.

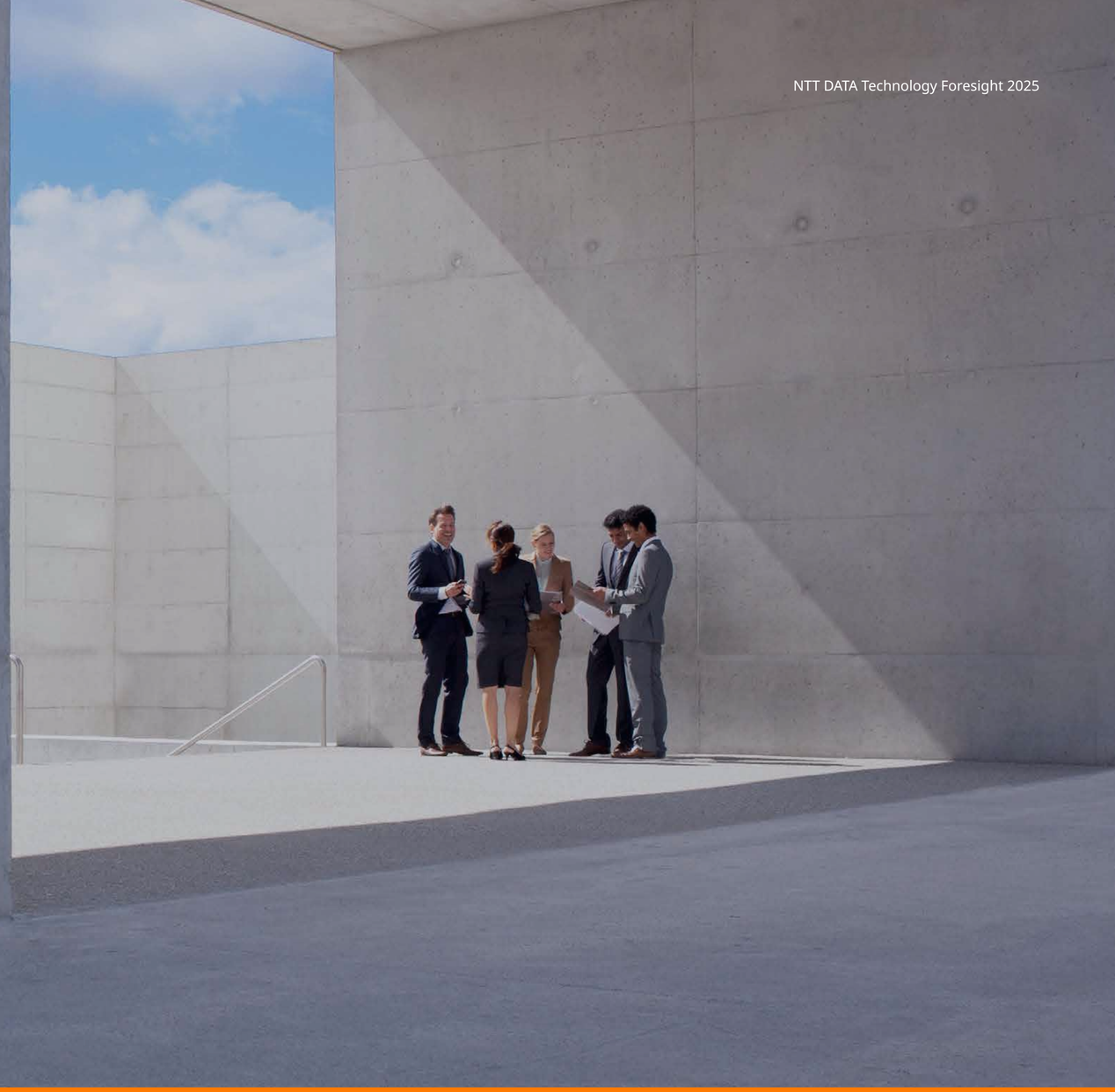
Outcomes

Thanks to its digital customer twin and accurate, transparent and easily accessible data, the client is well positioned to develop personalized offers and services and reduce service costs. The new solution also aligns with GDPR processes, serves as a database for self-service functionalities and delivers the best possible data quality for sales and after-sales processes. Additionally, the solution's powerful automation features have reduced data-handling costs and effort.

Technologies

Azure Cloud, Docker, Python

Startups



Startup radar

In this section, we review a selection of startups relevant to the ambient intelligent experiences trend, based on our observations, partnerships and investments.

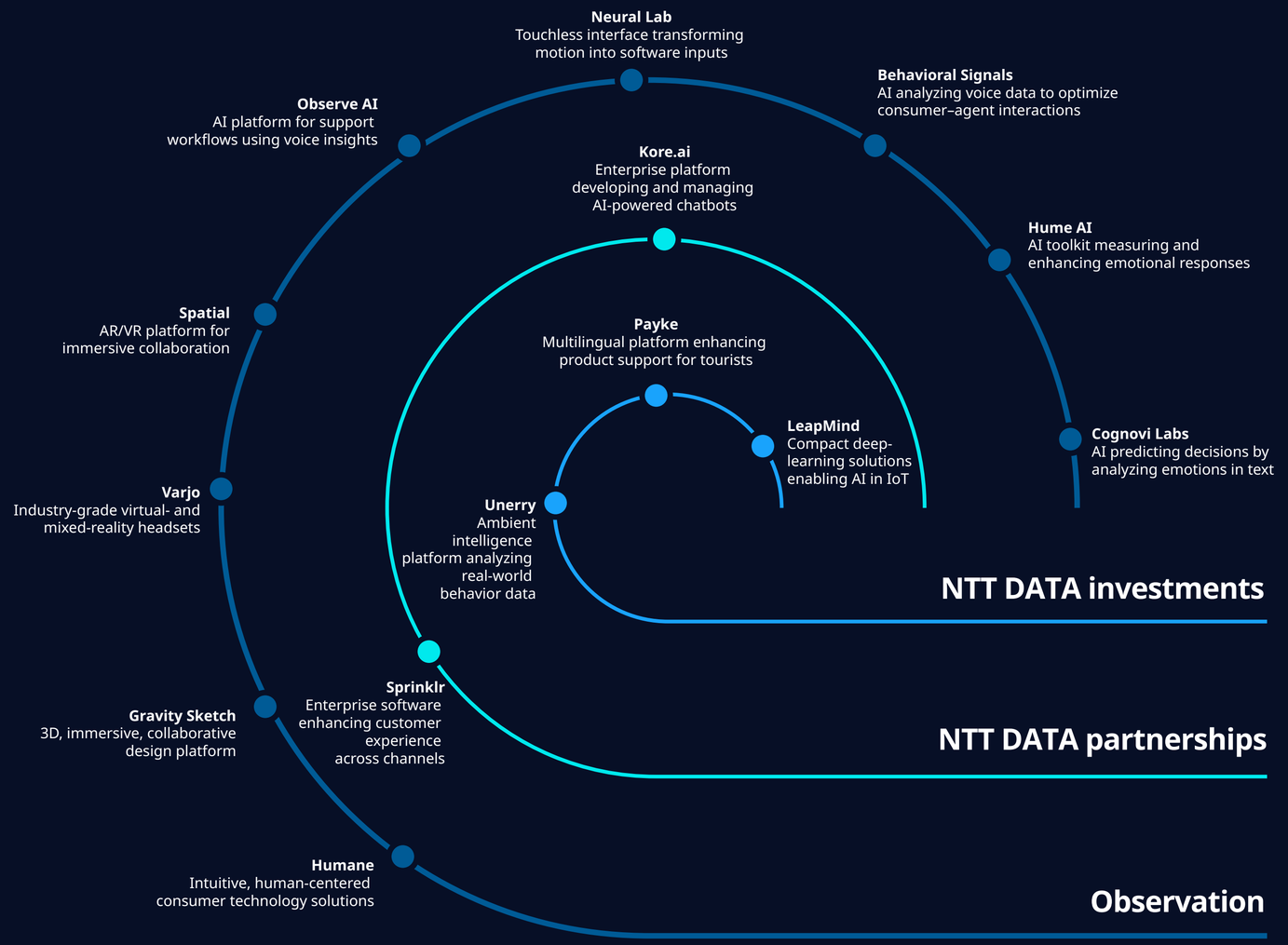


Figure 12: Investment in ambient intelligent experiences startups

Startups

Observation

Humane

Founded in 2017, Humane is a platform that creates and sells consumer hardware, software and services that feel familiar, natural and humane.

Stage
Series C

Funding
$230 million

Valuation
$850 million (2023)

Industry
Cross-industry

Gravity Sketch

Founded in 2014, Gravity Sketch provides 3D design and collaboration tools for the technology sector. Its core offerings include immersive 3D sketching and design software that allows designers to create, communicate and share their ideas in a virtual studio environment. The software is used in the transportation, industrial design, product design and concept art sectors.

Stage
Series A

Funding
$38.66 million

Valuation
Not disclosed

Industry
Cross-industry

Varjo

Founded in 2016, Varjo develops virtual- and mixed-reality headsets for professional use across various industries. Its products are designed to deliver experiences with photorealistic visual fidelity and are suitable for training, design and research applications. Varjo's headsets, including the XR-4 series, offer features such as gaze-driven autofocus and are available in secure editions for classified environments.

Stage
Series D

Funding
$162 million

Valuation (approximate)
$400 million

Industry
Cross-industry

Spatial

Founded in 2016, Spatial has developed an AR/VR platform for collaboration in virtual environments, specifically immersive remote workspaces.

Designers, marketers and business teams use this platform for seamless virtual collaboration.

Stage
Series A

Funding
$30 million

Valuation
Not disclosed

Industry
Cross-industry

Observe.AI

Founded in 2017, Observe.AI applies deep learning and NLP to automate support workflows. Its voice AI platform gives agents feedback on customer sentiment and guides them through customer calls by providing recommendations for the next steps.

Stage
Series C

Funding
$213.12 million

Valuation
$500 million–$1 billion

Industry
Cross-industry

Neural Lab

Founded in 2021, Neural Lab has developed a patent-pending hardware-neutral touchless user interface that uses any camera to turn motion into inputs for any software application, on any device. Use cases include critically sterile environments, shared public devices and mixed-reality immersion for gaming or training. The products improve the limitations of the traditional mouse-keyboard-controller combination and many more.

Stage
Pre-seed

Funding
$100,000

Valuation
Not disclosed

Industry
Cross-industry

Behavioral Signals

Founded in 2016, Behavioral Signals (Behavioral Signal Technologies, Inc.) develops technology to analyze human behavior from voice data. With AI-MC, their flagship product, enterprises can automatically match customers to agents best suited to them, using voice data and emotion AI. This improves the overall performance and outcomes of contact center conversations, leading to higher productivity.

Stage
Series A

Funding
$7 million

Valuation
Not disclosed

Industry
Cross-industry

Hume AI

Founded in 2021, Hume AI provides an AI toolkit to measure, understand and improve how technology affects human emotion. Organizations use Hume's science-backed API to measure human expressive behavior in images, videos, audio and text, and build applications that better predict users' intents, preferences, experiences and outcomes.

Stage
Series B

Funding
$67.7 million

Valuation
Not disclosed

Industry
Cross-industry

Cognovi Labs

Founded in 2016, Cognovi Labs has developed a proprietary AI solution that integrates deep ML with behavioral psychology to measure emotions from textual and transcribable data to predict people's decisions and help shape the outcome. Cognovi's psychological AI scientifically anticipates human decisions and provides prescriptive tools to change outcomes, from accelerating revenues and increasing prescription growth to identifying future threats.

Stage
Series A

Funding
$8.9 million

Valuation
Not disclosed

Industry
Cross-industry

Startups

NTT DATA partnerships

Sprinklr

Founded in 2009, Sprinklr provides enterprise software for customer experience management. The solution helps brands understand the conversations that matter most on channels such as social media, messaging, blogs and review sites. Companies like Microsoft and McDonald's rely on Sprinklr to manage customer experiences at scale.

Stage
Series A

Funding
$429 million

Valuation
Not disclosed

Industry
Cross-industry

Kore.ai

Founded in 2014, Kore.ai has developed an enterprise conversational and GenAI platform to help organizations design, develop, test and manage chatbots for internal or customer-facing business scenarios. The platform, no-code tools and solutions deliver end-to-end customer and employee experiences — from automated to human-assisted — and build GenAI-enabled applications. Kore.ai takes an open approach, allowing organizations to choose the LLMs and infrastructure that best meet their needs.

Stage
Series D

Funding
$223.5 million

Valuation
Not disclosed

Industry
Cross-industry

Startups

Investments

Unerry

Founded in 2015, Unerry specializes in ambient intelligence infrastructure and big data analytics, particularly through its Beacon Bank platform. It collects and analyzes real-world behavioral data to enhance retail digital transformation and support smart-city initiatives, processing billions of location logs monthly.

Stage
Series A

Funding
$5.4 million

Valuation
Not disclosed

Industry
Cross-industry; financial services

LeapMind

Founded in 2012, LeapMind makes deep learning “small and compact” and accessible across a broad spectrum of applications, evolving the Internet of Things (IoT) into the “Deep Learning of Things (DoT).” LeapMind specializes in providing ultralow-power AI inference accelerators and deep-learning technology for model-weight reduction, enabling advanced data processing in environments previously unsuitable for AI.

Stage
Incubator/accelerator

Funding
$45.5 million

Valuation
Not disclosed

Industry
Cross-industry

Payke

Founded in 2014, Payke provides multilingual support solutions for products and services used by inbound tourists. Its platform allows users to scan barcodes on products, and displays information in multiple languages. It also provides tools for analyzing inbound consumer data.

Stage
Series B

Funding
$10.79 million

Valuation
Not disclosed

Industry
Retail

Future scenarios

As industries transform, new value chains emerge and technological advancements grow exponentially, companies must navigate complex, evolving landscapes.

Future scenarios and GenAI-powered personas allow organizations to explore possible futures, simulate realistic business environments and minimize risk through scenario-based planning.

Uncertainties represent what we cannot know, but identifying them can reduce the risks of blind spots down the road.

Future scenarios

Uncertainty: technological integration and interoperability

The ambient symphony

What if all your devices and platforms worked together seamlessly, making technology invisible and effortless?

As devices and platforms become fully interoperable, users will be able to transition smoothly between digital environments. AI assistants, AR/VR and IoT will blend into a unified, intuitive experience, making the technology nearly invisible. As a result, users can enjoy frictionless interactions without loyalty to any single ecosystem.

Islands of innovation

What if your digital world was confined to one technology ecosystem, locking you into innovative but isolated experiences?

If technology companies build highly personalized but closed ecosystems, consumers will be immersed in isolated, optimized experiences that offer deep integration within each brand's platform but make switching between systems difficult. This will fuel competition but could stifle cross-platform innovation.

Future scenarios

Uncertainty: consumer acceptance and behavioral changes

Empowered trust

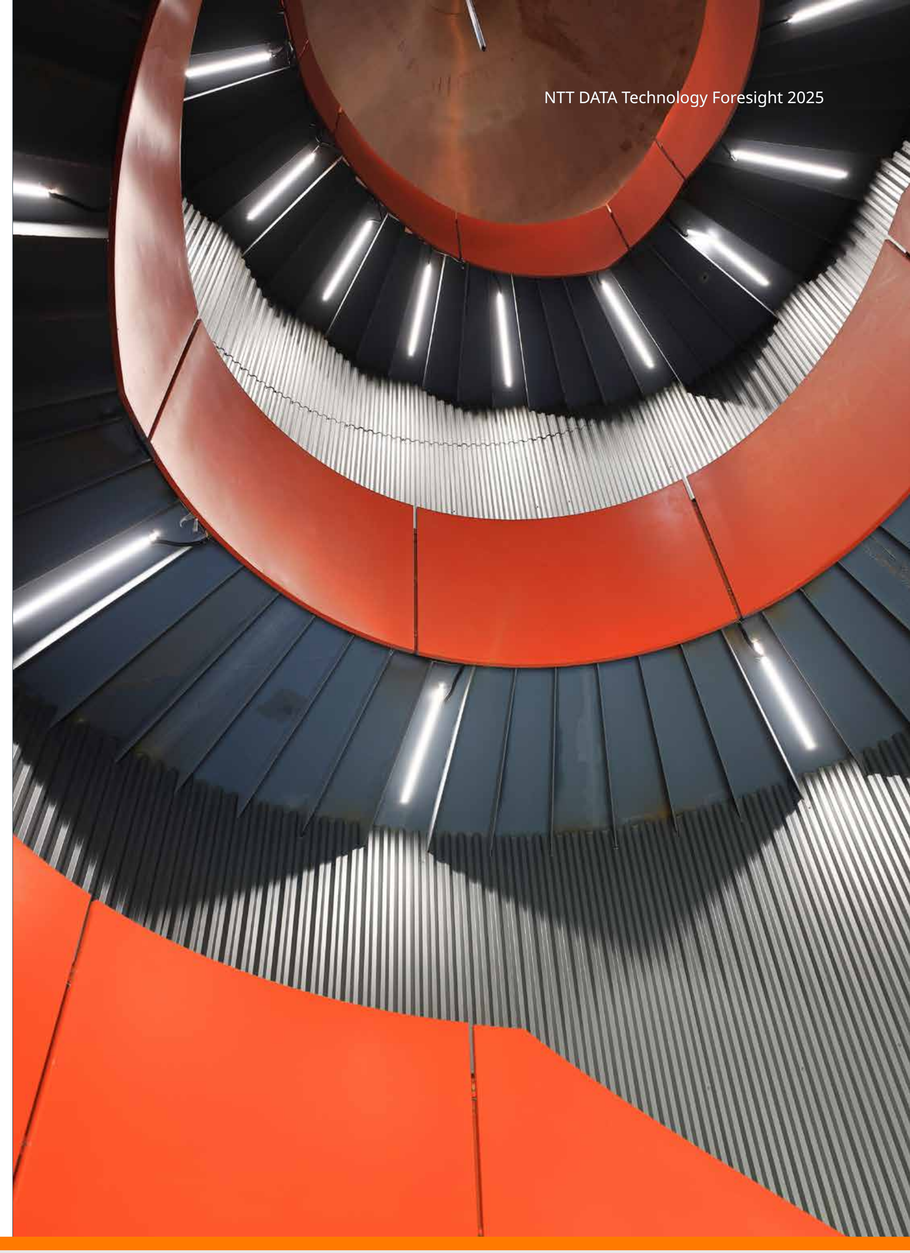
What if your personal data became the currency for trust, and control over privacy was the key to deeper digital experiences?

Some consumers may choose to engage with AI and immersive technology only if they have full control over their data. Organizations will need to be transparent and offer opt-in features for each interaction. In this scenario, trust becomes the cornerstone of engagement, with users demanding strict privacy standards and customizable AI experiences.

Echoes of intimacy

What if AI assistants became emotional companions, offering comfort but creating new dependencies?

AI assistants may evolve into emotional companions, offering advice, comfort and deep personalization. People could begin relying on them for decision-making and emotional support, creating new dependencies. While many will embrace this bond, ethical concerns about manipulation and the loss of human connection will arise.



Conclusion and next steps

Conclusion and next steps

Think about this

As technology creates more seamless and intuitive interactions, organizations must integrate these tools to meet evolving customer expectations.

How effectively are you using NUIs, emotion AI and omnichannel platforms to enhance user engagement?

With personalization driving customer loyalty, real-time data processing and sentiment analysis are essential.

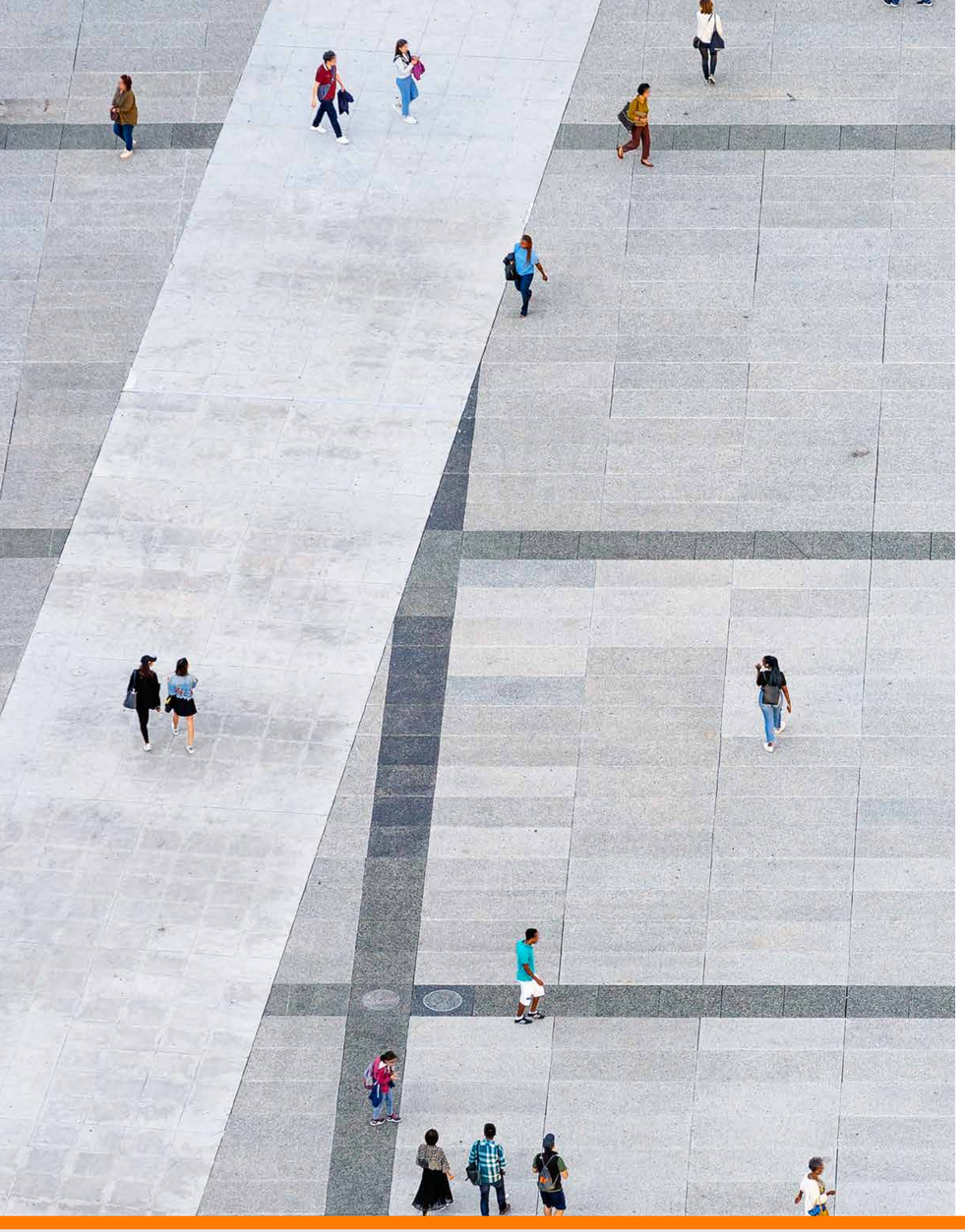
Are your systems equipped to process behavioral data instantly and adapt interactions based on real-time insights?

Ambient intelligent experiences are designed to improve interactions and empower brands to provide relevant, meaningful engagement.

How does your strategy ensure human-centric experiences that feel both intuitive and personal?

Ownership and data privacy concerns become more complex with integrated platforms.

How will you secure customer data while providing cross-platform consistency and personalized support?



Conclusion and next steps

Do this next

5 minutes

Identify high-impact touchpoints

Focus on the top three customer touchpoints that would benefit most from personalized, adaptive responses (for example, support chat or product recommendations). These should serve as the basis for implementing ambient intelligent experiences.

5 days

Set up a sentiment-responsive system

Prototype a customer support system that adjusts interactions based on real-time sentiment analysis, ensuring service responses align with the customer's emotional state.

5 months

Create a cross-functional CX innovation team

Establish a team tasked with identifying opportunities for AI-driven customer experience (CX) improvements. This team can refine use cases, promote platform adoption and deliver a seamless experience across departments.

Contact information

Experts | Ambient intelligent experiences (Customer experience)

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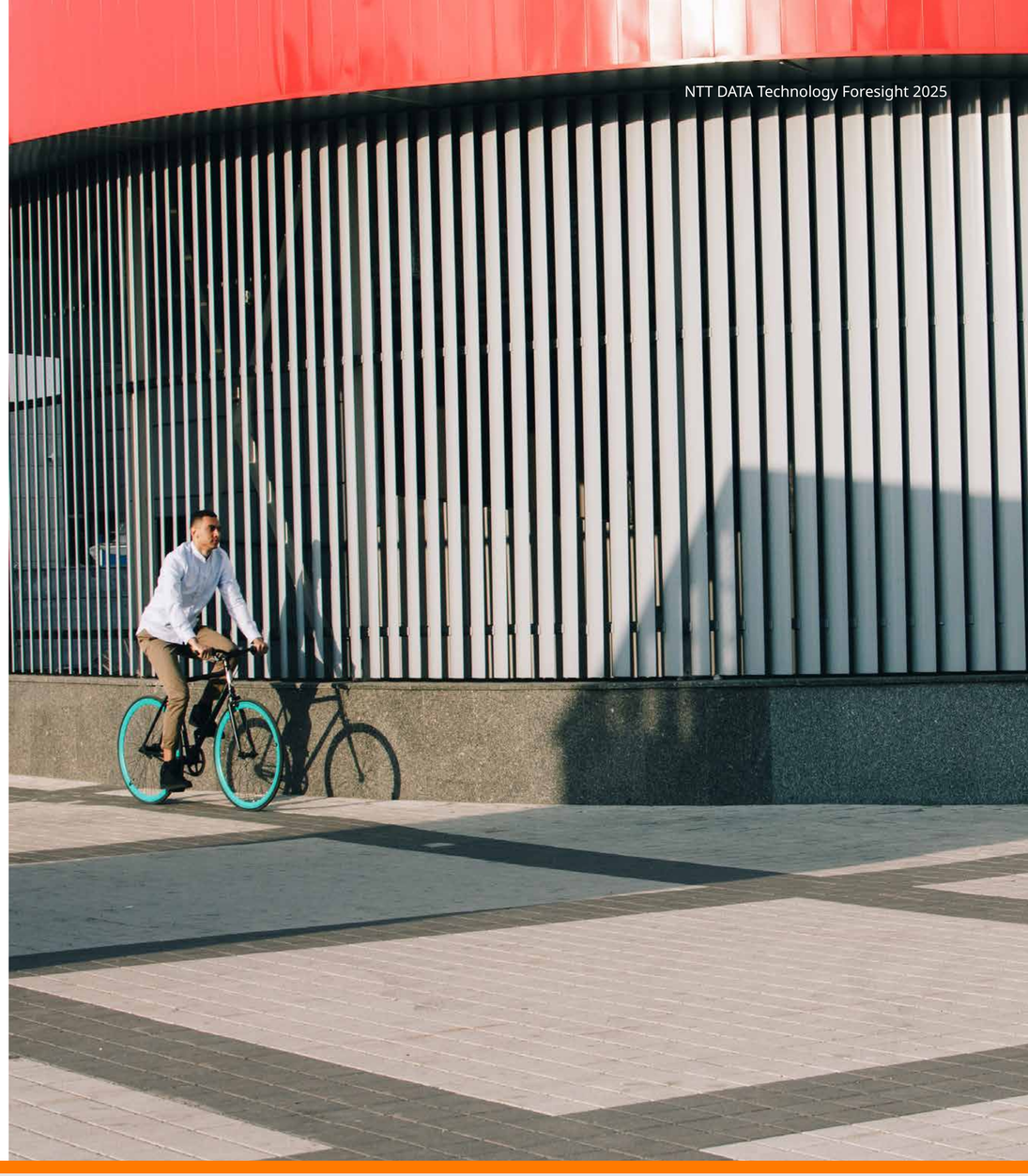


Trend 3: Digital sustainability for economic resilience

Envision resilience redefined by technology, harmonizing people, planet and prosperity.

Introduction

Digital sustainability for economic resilience is emerging as a critical part of modern business strategy, with organizations integrating environmental stewardship with economic growth.

This approach encompasses environmental, social and personal dimensions and follows the principle of ownership, fostering individual and collective responsibility. By adopting digital sustainability practices, organizations can improve their resilience, meet rising consumer expectations for ethical operations and contribute to global social equity and ecological balance, securing their long-term success.

Significance and impact on business

Digital sustainability not only supports ecological balance but also builds economic resilience, allowing organizations to adapt to shifting market demands and regulations. Studies reveal that businesses embracing sustainable practices see a boost in efficiency of up to 20%, along with significant reductions in operational costs, demonstrating the tangible benefits of integrating sustainability into core business strategies.

Key drivers

Technological advancements in AI, IoT and blockchain support digital sustainability by enabling efficient energy management, real-time environmental monitoring and greater supply chain transparency. These technologies empower organizations to amplify their sustainability initiatives, maintain competitiveness and address growing consumer demand for eco-conscious practices.

Digital sustainability introduces complex challenges, including balancing environmental justice with social equity, mitigating over-reliance on technology and navigating regulatory complexities. At the same time, it presents significant opportunities through inclusive solutions, resilient technologies and data-driven optimization that enable organizations to progress toward their sustainability goals.

Collaborative innovation across sectors offers the potential to foster long-term resilience, driving both economic and environmental progress.

Technical explanation

In the face of pressing global challenges in a multi-polar world, such as climate change and resource depletion, digital sustainability is emerging as a foundation for building economic resilience. Key components include:

1. Digital optimization for energy and resources

Systems integrate IoT networks and AI-driven analytics to monitor and manage energy and resource flows in real time. These optimizations feed into predictive models used by resilience frameworks, ensuring a seamless connection between efficiency and readiness.

2. Human and territorial resilience

Data from sensors and digital twins, processed via ML, predicts and mitigates natural disaster risks. This ensures human and economic resilience by protecting supply chains and resources.

3. Economic resilience

Transparent and decentralized asset tracking stabilizes supply chain operations. Using digital optimization and circular economy principles, it supports sustainability by ensuring equitable access to resources during crises or disruptions.

4. Social and individual sustainability

Privacy-preserving methods and behavioral algorithms maintain individual wellbeing while addressing societal goals. These systems contribute data to align personal outcomes with societal resilience and environmental stability, supporting systemic sustainability efforts.

5. Systemic, integrated sustainability

Holistic platforms aggregate insights from economic and social systems to form an interconnected governance structure. Tools like systems mapping and simulations evaluate interdependencies, ensuring long-term sustainability and alignment.

> “Digital sustainability is rapidly shaping the future of economic resilience by integrating advanced technologies to improve resource usage, inspire innovation in circular-economy models and manage environmental impacts more efficiently.

Technology

Trusted data spaces enable a secure and interoperable data exchange between organizations, using advanced encryption and governance frameworks to promote transparency, improve collaboration and optimize resource usage while complying with data sovereignty regulations. This boosts operational efficiency, fosters innovation and supports sustainability goals across industries.

Smart grids integrate digital technologies such as sensors, IoT devices and AI algorithms to optimize the distribution and management of electric power. Through real-time data collection and dynamic demand response, these grids enhance the efficiency of energy use, minimize transmission losses, balance load more effectively and ease the integration of renewable energy sources.

Sustainable data centers use advanced cooling technologies, energy-efficient hardware, renewable energy, virtualization and dynamic resource allocation to reduce their environmental impact and carbon footprint, promoting greener cloud computing and supporting economically resilient business practices.

Remote sensing technologies employ high-resolution satellite and aerial imaging systems, along with advanced data processing algorithms, to monitor environmental and resource conditions. By analyzing multispectral and hyperspectral data, these platforms provide precise information on climate patterns, vegetation health, water resources and land usage, enabling accurate forecasting and informed decision-making that's essential for improving resource management and enhancing sustainability and economic resilience.

Business explanation

Digital sustainability for economic resilience integrates sustainability principles with advanced technologies, enabling organizations to achieve economic success while reducing their environmental impact. This megatrend is radically changing business operations through innovative solutions that enhance resource efficiency, boost transparency and drive ethical practices. By embedding sustainability into core strategies, organizations contribute to environmental health, build resilience and position themselves for long-term growth.

Key principles address current challenges while fostering a sustainable future:

For individuals

- Access to sustainable products empowers informed choices aligned with personal values.
- People enjoy a better quality of life through healthier environments and reduced ecological harm.

For companies

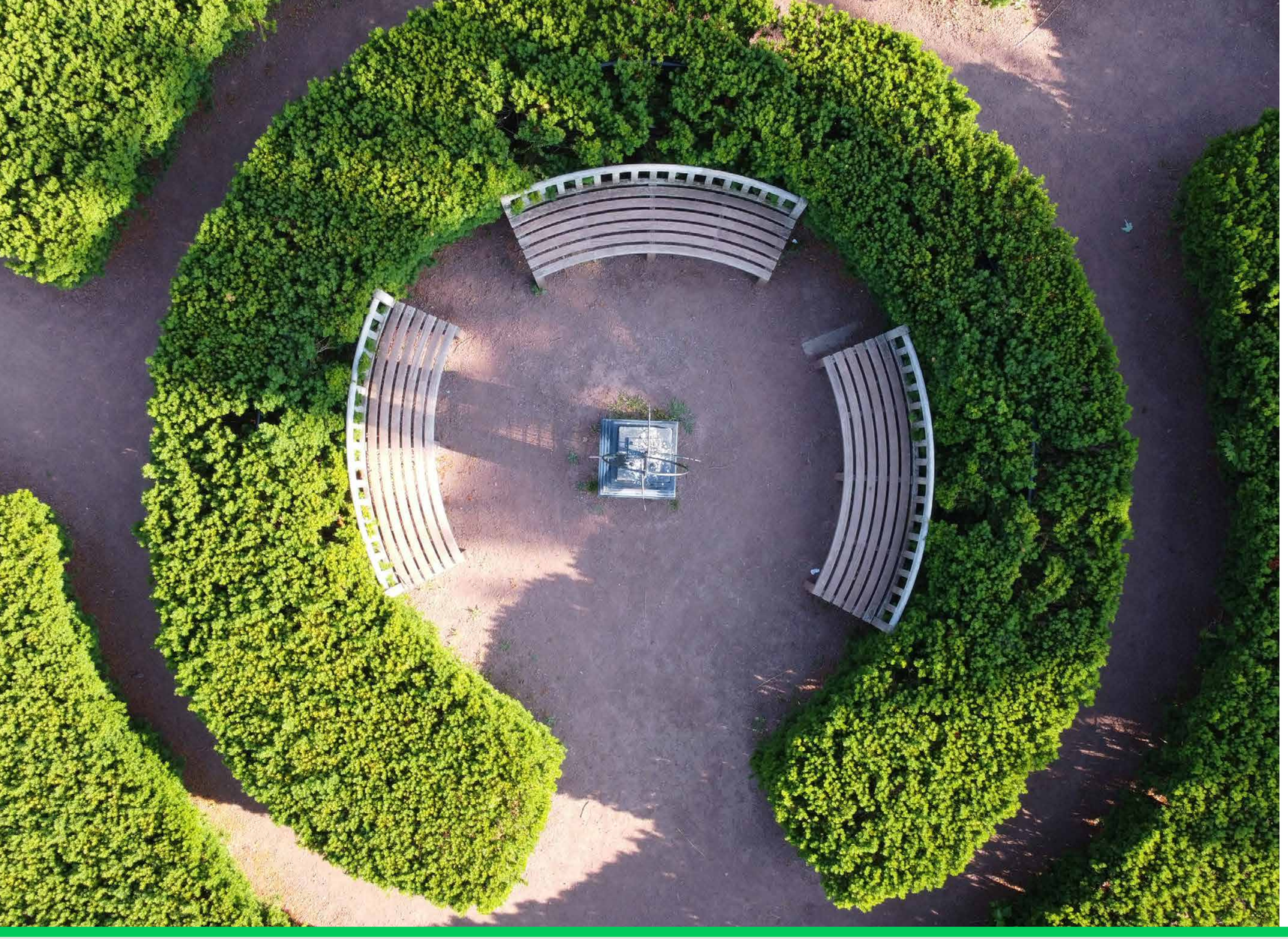
- Sustainable practices lead to significant cost savings and operational efficiencies, such as reduced energy and material waste.
- Organizations gain a competitive advantage through the ability to access sustainable finance and attract socially responsible consumers and investors.
- They can also achieve measurable reductions in greenhouse gas emissions and conserve natural resources.

For society

- Drives greater social equity through inclusive access to sustainable opportunities.
- Encourages innovation by aligning technological advancements with environmental goals.
- Promotes economic stability by fostering resilient and equitable growth for all stakeholders.

By leveraging digital technologies such as AI-driven analytics, blockchain for transparency, and IoT-enabled resource management, organizations can amplify their impact, aligning profitability with sustainability to create shared value for individuals, businesses and society.

Underlying concepts



Underlying concepts

This megatrend represents a pivotal shift in how organizations integrate sustainable practices with digital innovations to ensure long-term viability and adaptability in an increasingly interconnected world. As the urgency for environmental action grows, organizations must prioritize digital sustainability to remain competitive and responsible.

This approach is built upon several key pillars. Understanding these foundational aspects is essential for grasping the full scope of the megatrend, as they serve as the framework for achieving sustainable economic resilience in an increasingly digitized world.

Digital sustainability for economic resilience

Digital optimization for energy and resources

- Energy-system simulation
- Autonomous predictive maintenance
- Advanced energy storage
- AI-enhanced energy management
- New processing and network needs

Human and territorial resilience

- Distributed environmental monitoring
- Disaster prediction and management
- Urban design
- Resource tracking
- Crisis management

Economic resilience

- Climate risk assessment
- Learning and upskilling
- Energy management
- Inclusive and sustainable finance
- Transparent and circular supply chains

Social and individual sustainability

- Privacy enhancement
- Mental-health consultancy
- Gamification for inclusivity and sustainability
- Transparency within ethical AI
- Digital democracy

Systemic, integrated sustainability

- AI-supported remote teams
- Business optimization with policy simulations
- Enhanced business insights through systems mapping
- Improving sustainability tracking
- Resilience monitoring

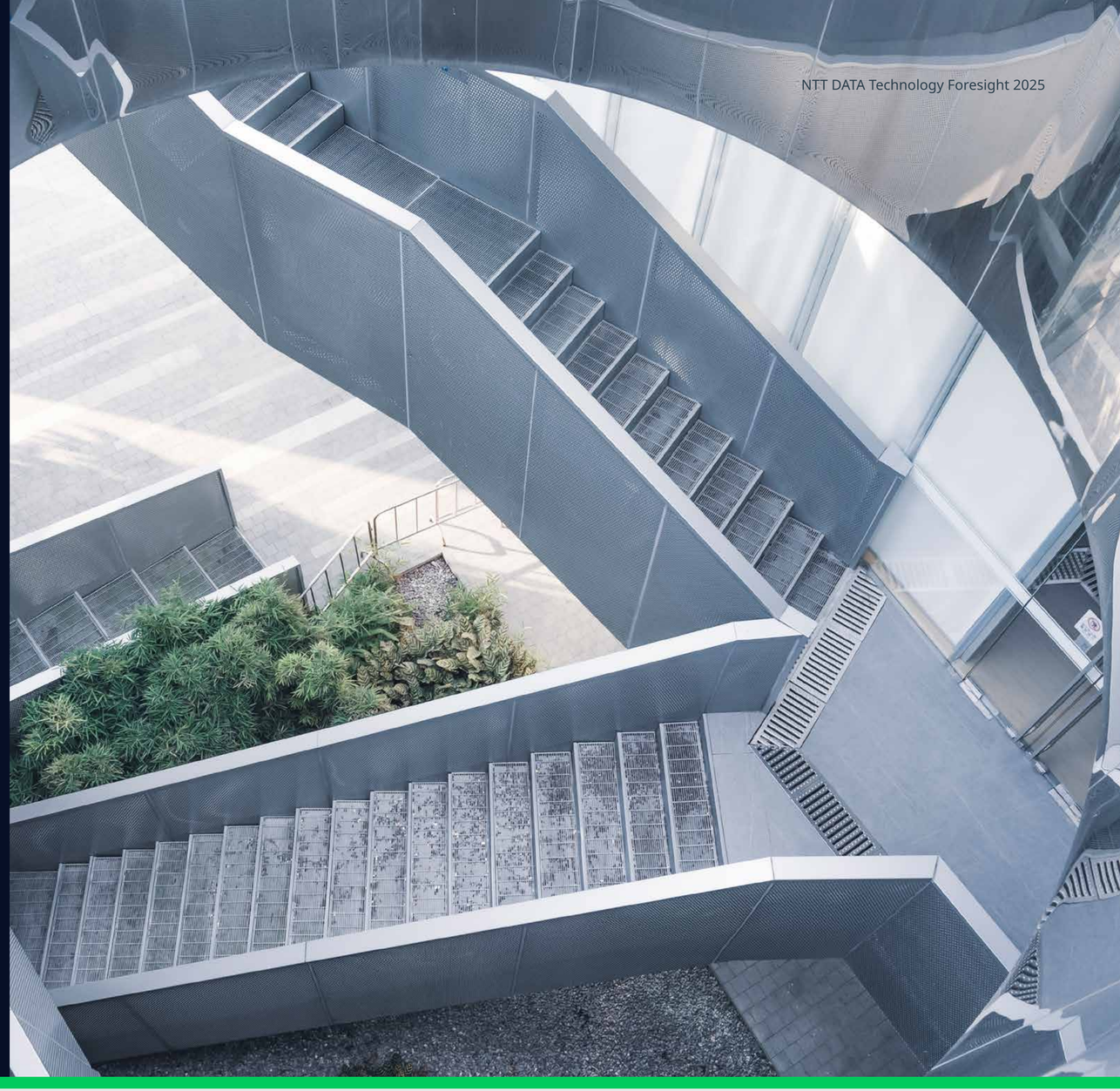
Figure 13: Digital sustainability for economic resilience — underlying concepts and supporting trends

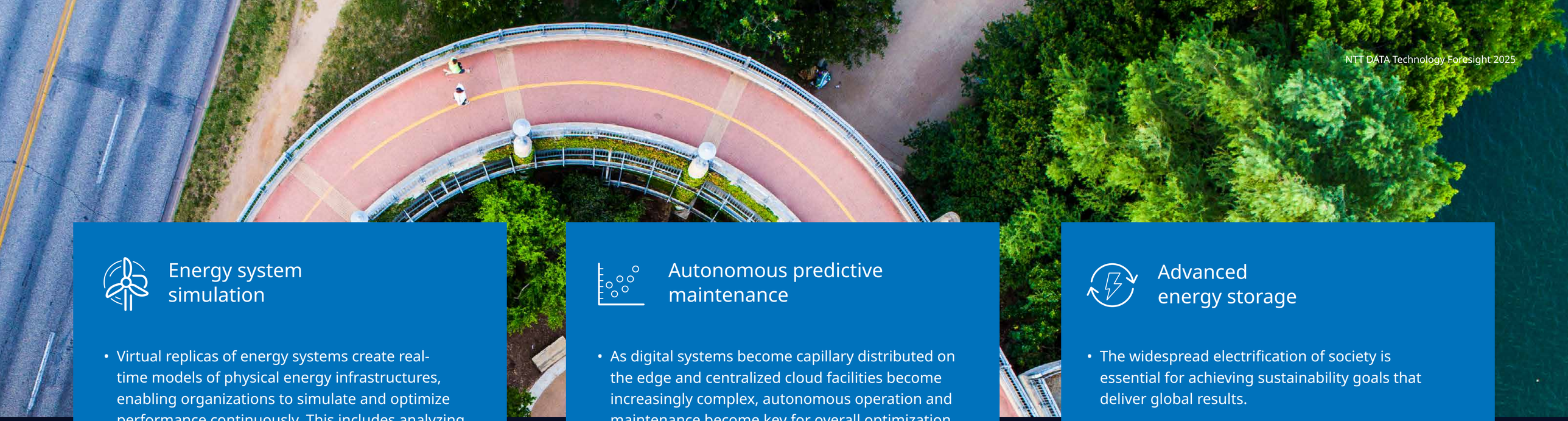
Underlying concepts

Digital optimization for energy and resources

Digital optimization for energy and resources focuses on using advanced technologies to improve sustainability in organizations. This approach integrates sustainability targets with stakeholder engagement and responsible consumption practices, improving the efficiency of energy and resource management. By prioritizing regulatory compliance, economic impact and social responsibility, businesses can lay the foundation for a sustainable future while optimizing resource use.

> Together, these subtrends demonstrate how digital optimization fosters smarter, more sustainable energy and resource management practices, aligning with broader sustainability goals essential for organizational success.





Energy system simulation

- Virtual replicas of energy systems create real-time models of physical energy infrastructures, enabling organizations to simulate and optimize performance continuously. This includes analyzing the topology of renewable power sources and a thorough historical and predictive analysis of energy production and consumption patterns.
- Using techniques such as digital twins, organizations can improve decision-making, increase operational efficiency and reduce their energy costs faster and with less risk.

Autonomous predictive maintenance

- As digital systems become capillary distributed on the edge and centralized cloud facilities become increasingly complex, autonomous operation and maintenance become key for overall optimization, helping improve service quality and reducing waste. Next-generation networks such as 6G, smart grids and industrial plants harness the capabilities of predictive AI.
- This proactive approach enables utility companies to reduce downtime and ensure reliable energy distribution, providing users with an uninterrupted power supply. Manufacturers can monitor machinery in real time to anticipate maintenance needs, prevent costly breakdowns and achieve higher efficiency and lower maintenance costs.

Advanced energy storage

- The widespread electrification of society is essential for achieving sustainability goals that deliver global results.
- When combined with the increased use of renewable power sources, this brings a sharper focus to energy storage. Next-generation, eco-friendly batteries and solutions will be needed for nearly every aspect of society.
- People can reduce their energy costs and become energy-independent through renewable systems like solar panels and home energy storage, as seen in the growing market for residential energy solutions.

AI-enhanced energy management

- Energy production and distribution are moving away from traditional models dominated by large power plants that rely on fossil fuels.
- The rise of smart grids (which manage diverse and unpredictable renewable sources) and small modular nuclear reactors, and the potential for nuclear fusion will require substantial support from AI for effective development and management.
- For instance, a community with solar panels and wind turbines can use AI to optimize energy distribution, maintaining stability by predicting production fluctuations and utilizing stored energy as needed.

New processing and network needs

- Sustainability hinges on waste reduction and resource optimization, necessitating advanced processing and lower energy consumption.
- For example, strategically placing data centers in cooler regions can reduce reliance on energy-intensive cooling, significantly lowering overall energy use.
- Coupled with innovations like photonic integrated circuits, these strategies illustrate how organizations can enhance efficiency, cut costs and minimize environmental impact.
- Embracing concepts like smart manufacturing further promotes these goals while advancing production with a smaller ecological footprint.

Underlying concepts

Human and territorial resilience

Human and territorial resilience refers to individuals' and communities' ability to adapt, recover and thrive in the face of environmental, social and economic challenges. This concept focuses on building the strength and adaptability of populations and their infrastructures to respond to crises. It's often referred to as "community and infrastructure robustness."

> To enable this level of proactive and integrated resilience, it's crucial that organizations embrace several key approaches.

1 Distributed environmental monitoring

The availability of low-cost sensors equipped with low-power onboard computing resources allows for the massive deployment of IoT smart devices over territories.

The goal is to collect real-time data on environmental conditions, such as air quality and humidity, to gain insights that support proactive resource management and risk mitigation.

For instance, real-time air-quality monitoring can alert residents to pollution spikes or hazardous conditions, allowing them to take necessary precautions, such as staying indoors or using air purifiers.

2 Disaster prediction and management

Utilizing AI algorithms to analyze extensive data sets allows organizations to anticipate and respond to natural disasters more effectively, improving community preparedness and resource allocation.

AI solutions improve situational awareness and reduce response times during emergencies, saving lives and resources while promoting resilient infrastructures and community safety. This technology appeals to socially responsible consumers and can significantly reduce economic losses through better preparedness and timely interventions.

3 Urban design

Virtual replicas of physical environments enable urban planners to simulate and optimize city infrastructure and services, enhancing decision-making and promoting sustainable development. This technology improves resource allocation and urban planning efficiency, creating more livable spaces while appealing to consumers who value smart-city innovations.

Digital twins of various complex systems deployed in cities will allow predictive and generative AI to act safely and efficiently while providing administrators with valuable systemic insights.

4 Resource tracking

Increasingly, consumers and businesses expect transparency and accountability in supply chains. They want assurance that resources are ethically sourced and sustainably managed.

Meeting these expectations requires traceability to reduce fraud, foster trust and promote responsible practices.

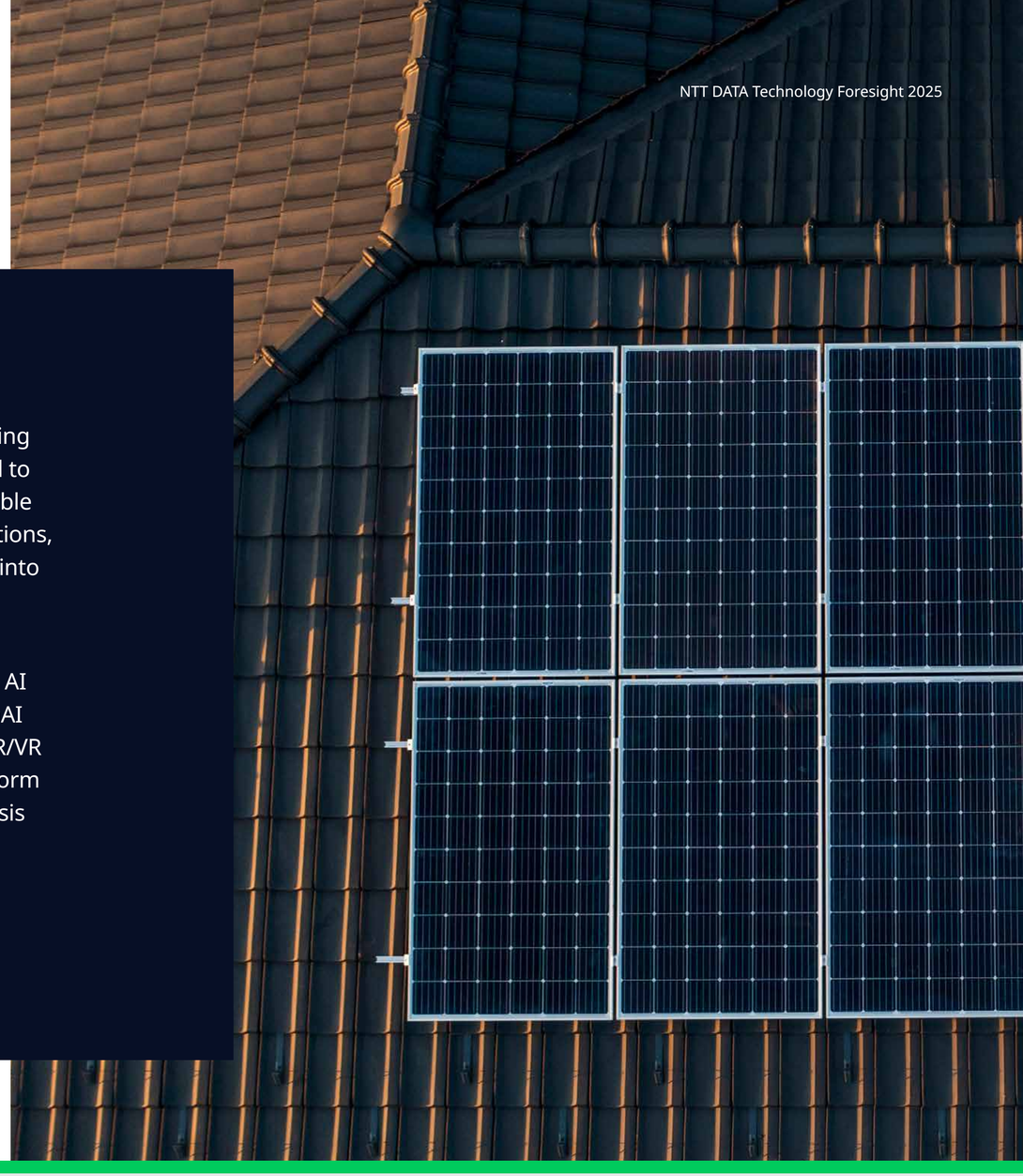
This also supports operational efficiency and cost reduction, as streamlined supply chains can significantly improve performance.

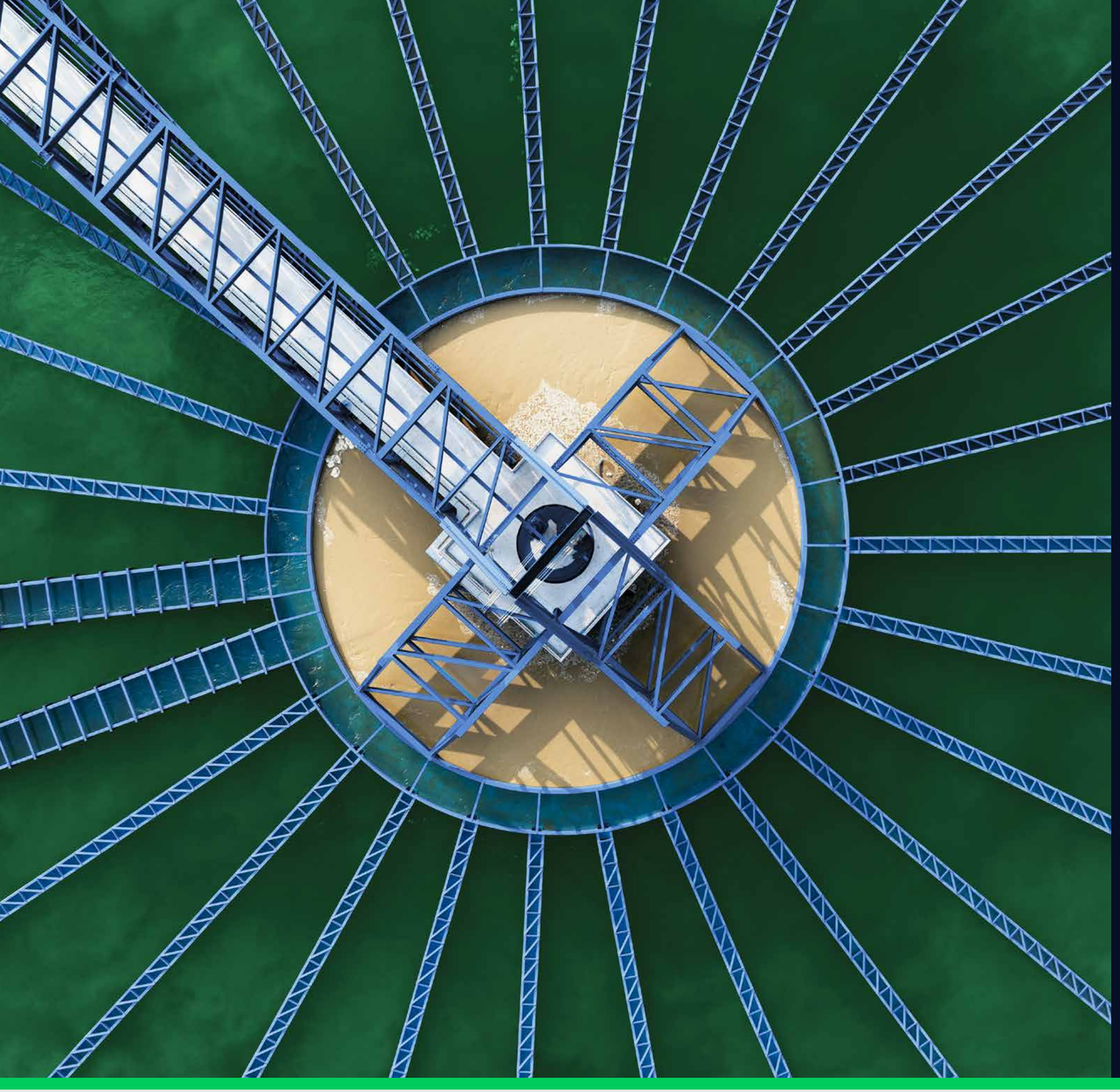
Blockchain technology is a key enabler, offering a secure and transparent way to verify each transaction, enhancing accountability and bolstering the credibility of sustainability claims throughout the supply chain.

5 Crisis management

Real-time data availability is crucial during crises. Large amounts of raw data need to be turned into useful and easily accessible information. Additionally, in crisis situations, information needs to be swiftly turned into insights that enable people to make informed decisions.

Together, IoT data collection, predictive AI that generates actionable insights, GenAI that provides recommendations and AR/VR that visualizes real-time scenarios will form the foundation for future innovative crisis management platforms.





Underlying concepts

Economic resilience

Economic resilience refers to organizations’ and communities’ ability to withstand and recover from economic shocks while maintaining sustainable operational practices.

Adopting resilient practices not only attracts environmentally conscious consumers but also strengthens an organization's overall economic resilience by enhancing stability, trust, competitiveness and adaptability in a fluctuating market.

> “ Establishing a comprehensive framework requires organizations to bring together several key practices.

Transparent and circular supply chains

- As consumers demand transparency in supply chains, there's a need for solutions that ensure ethical sourcing and sustainability. Clear traceability builds trust and reduces fraud. Adopting circular economy principles — like resource efficiency and closed-loop systems — minimizes environmental impacts.
- Blockchain technology enhances the secure verification of transactions, boosting the accountability and credibility of sustainability claims and ultimately fostering loyalty among environmentally conscious consumers.
- A study found that 94% of consumers are more likely to be loyal to a brand that offers complete supply chain transparency.

Inclusive and sustainable finance

- The rising demand for financial inclusion highlights the need for solutions that improve access to financial services for underserved populations.
- Intelligent financial-accessibility tools empower consumers to manage their finances and secure loans, fostering greater economic participation.
- At the same time, sustainable finance initiatives, like green loans and environmental, social and governance (ESG)-focused funding, promote environmental responsibility. By offering personalized financial advice and tailored products, these solutions build people's financial freedom while supporting a sustainable future.

Energy management

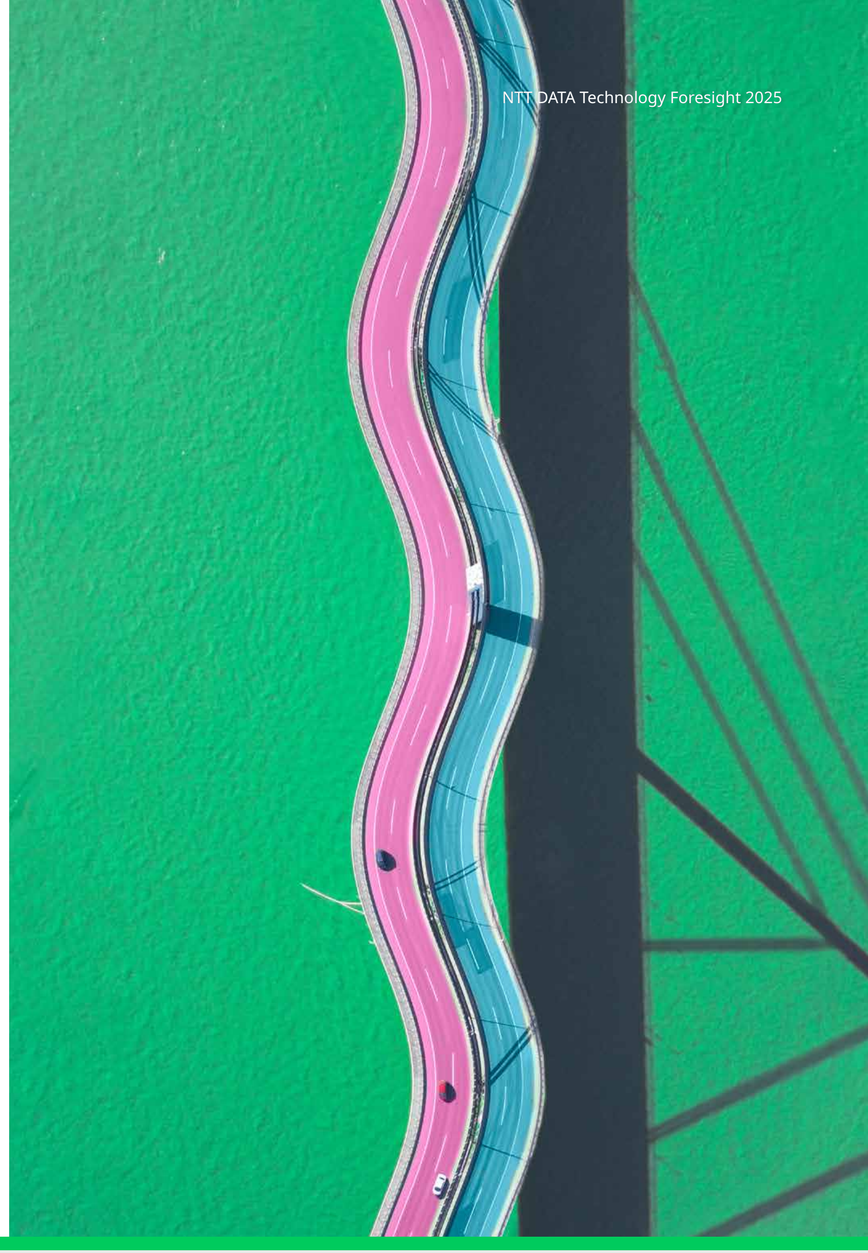
- As businesses increasingly prioritize sustainable practices, there's a growing need for solutions that optimize the use of renewable energy sources.
- Platforms for renewable-energy management help organizations integrate sustainable energy, enhance efficiency, reduce costs and minimize their carbon footprint.
- By adopting these technologies, organizations can improve their operational sustainability and contribute to a greener environment.

Learning and upskilling

- In today's evolving job market, organizations need a skilled workforce that can adapt quickly.
- Digital learning platforms provide personalized skill enhancement, with AI delivering adaptive, tailored learning paths.
- Microlearning programs featuring bite-sized modules boost employee retention and engagement and allow people to build their skills at their own pace.
- This fosters adaptability and innovation and improves organizations' economic resilience amid market shifts.

Climate risk assessment

- As organizations experience the impacts of climate change, they need tools that can help them anticipate environmental risks and vulnerabilities.
- Predictive analytics can help organizations proactively manage their climate-related risks. By analyzing historical weather patterns and socioeconomic data, this technology helps businesses enhance supply chain reliability and optimize resource allocation.
- For example, agricultural companies can optimize planting schedules based on weather forecasts, while insurance firms can enhance their risk assessments by developing tailored policies for clients facing climate threats.



Underlying concepts

Social and individual sustainability

Fostering wellbeing, community engagement and equitable access to resources is vital for building resilient societies. Understanding the interconnectedness of tools and platforms enables informed decision-making and responsible technology use, empowering individuals and communities.

> Collectively, these approaches promote ethical practices and resilience in an increasingly digital world.

Privacy enhancement

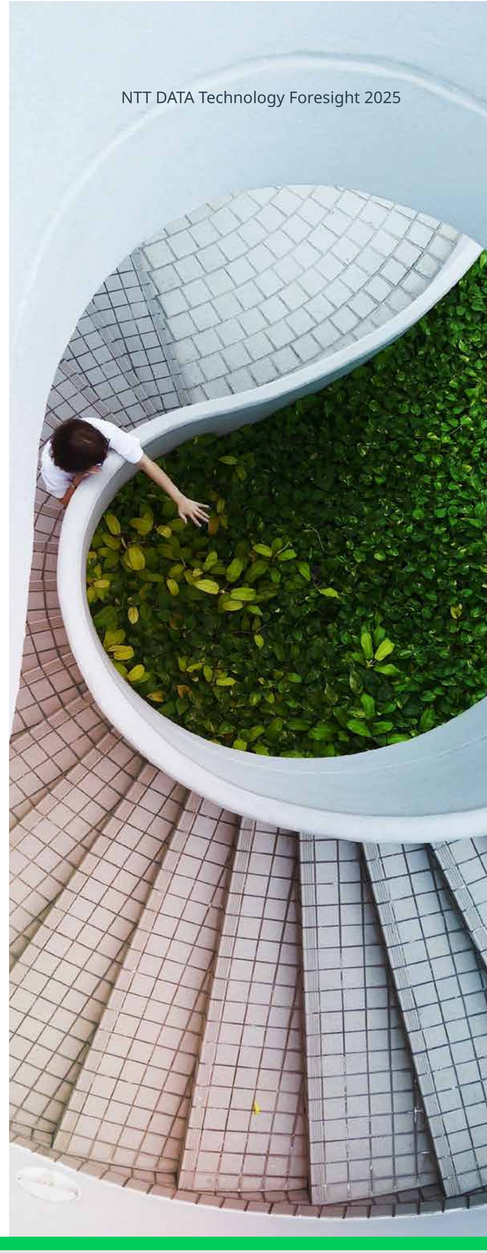
- Concerns about data breaches and privacy are on the rise, creating an urgent need for technologies that safeguard personal information.
- Privacy-enhancing technologies (PETs) meet this demand by protecting data, reducing the risk of breaches and fostering customer trust.
- These solutions not only enhance user privacy but also promote responsible data management, critical for a sustainable digital ecosystem.
- By adopting PETs, businesses can improve their reputation, ensure compliance with privacy regulations and protect users' personal data.

Mental-health consultancy

- The growing demand for mental-health support highlights an urgent need for tools that promote individual wellbeing.
- Intelligent wellness applications use AI to provide personalized resources and interventions, such as mood tracking and cognitive behavioral therapy techniques, empowering users to proactively manage their mental health.
- Researchers from IBM and the University of California found that AI algorithms can detect mental illnesses with a 63 to 92% accuracy, depending on the AI technique and the quality of training data.

Gamification for inclusivity and sustainability

- Digital tools for skill development are increasingly addressing global challenges like inclusivity and sustainability.
- These platforms break down access barriers by offering flexible, scalable solutions for underserved communities, ensuring equal skill enhancement opportunities. Their digital nature also reduces reliance on physical resources, supporting environmental sustainability.
- For example, gamified learning platforms use engaging mechanics like rewards to motivate learners.
- One company reported a 50% increase in employee engagement, demonstrating the social and environmental impact of these tools.

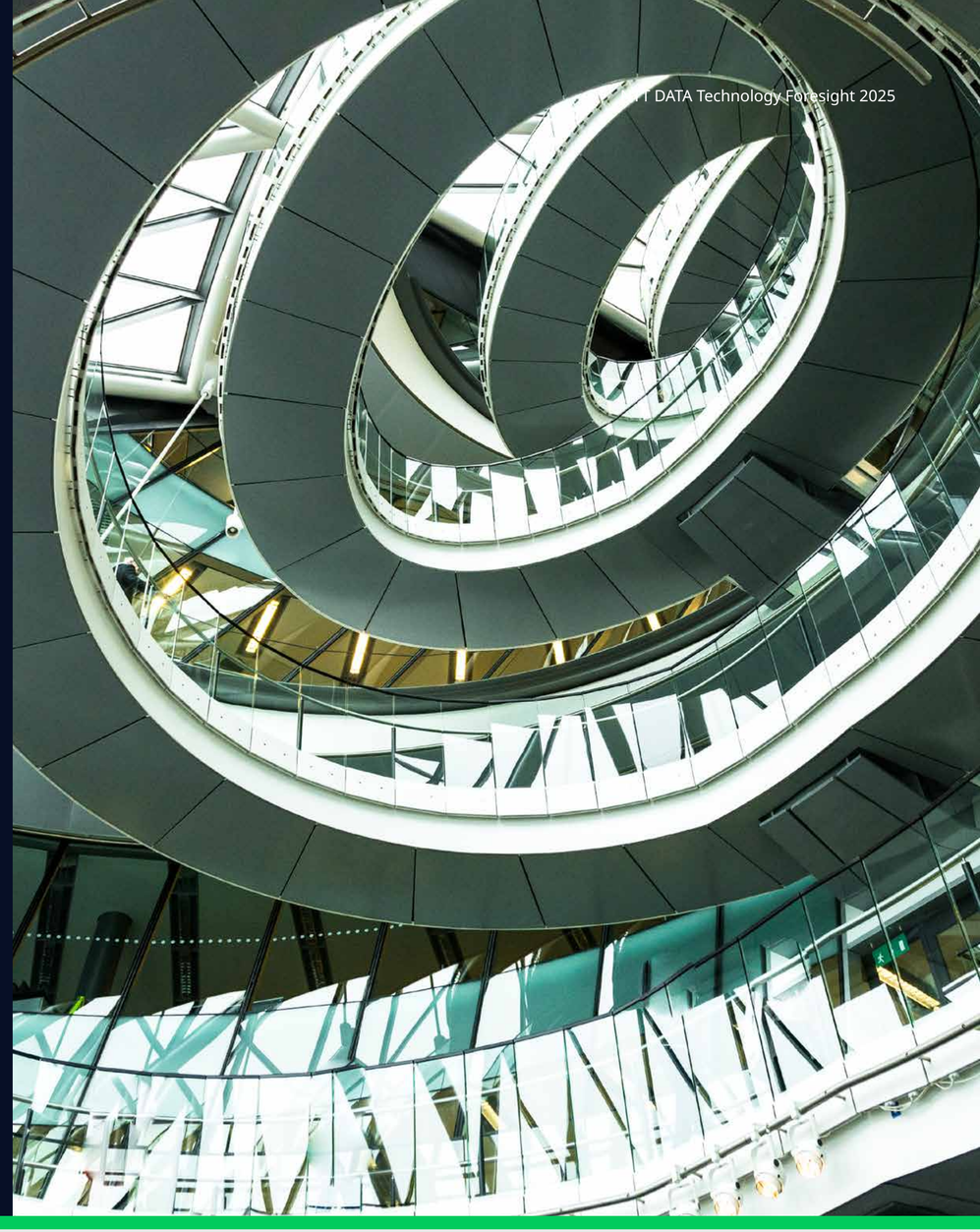


Transparency within ethical AI

- The increasing reliance on AI systems underscores the need for transparency in decision-making. Transparency tools for ethical AI enhance our understanding of how decisions are made.
- This builds trust among users in sensitive areas such as hiring, loan approvals and healthcare diagnostics.
- This accountability promotes responsible AI use and supports a fair digital landscape where individuals feel informed and valued. The concept of "explainable AI" emphasizes the importance of clarity in automated decision-making, empowering users and building community trust in technology.

Digital democracy

- As communities seek to enhance democracy and civic participation, they need technologies that facilitate public engagement.
- Technology solutions for public engagement empower users by providing access to policy information and facilitating discussions, ensuring their voices are heard.
- These platforms enable participation in online polls, virtual town-hall meetings and petitions, making civic engagement more inclusive.
- By representing diverse perspectives, these tools foster community involvement and strengthen democratic processes.



Underlying concepts

Systemic, integrated sustainability

Systemic, integrated sustainability recognizes the interconnectedness of social, environmental and economic systems to develop cohesive solutions. Often referred to as "comprehensive sustainability," this approach highlights the need to address multiple dimensions simultaneously to achieve lasting impact and resilience in communities and ecosystems.

> Integrating these systems promotes a comprehensive understanding of sustainability that fosters lasting solutions and strengthens community resilience.

1 AI-supported remote teams

In today's interconnected work environments, efficient communication and streamlined project management are essential for high-impact tasks.

Effective collaboration tools boost productivity and reduce project turnaround times, facilitating innovation and progress toward sustainability goals.

AI technology helps by automating tasks and conducting data analysis.

Remote-work policies reduce employees' daily commutes, helping organizations lower their carbon footprints. To coordinate remote teams and combat "Zoom fatigue", AI-enhanced platforms automate routine tasks and optimize workflows, supporting productivity and sustainability objectives.

2 Business optimization with policy simulations

Organizations need to assess the impact of various policy decisions and scenarios for effective governance and strategic planning.

Strategic forecasting tools provide digital platforms that enable users to visualize potential outcomes, supporting informed decision-making.

These tools conduct "what-if" analyses, exploring different scenarios to evaluate their potential effects. This enhances organizations' ability to navigate complex challenges and make data-driven decisions.

3 Leveraging systems mapping for impact

Understanding the complexities of systems and their interrelationships is crucial for informed decision-making and driving meaningful change.

Systems-mapping tools visualize these intricate systems, showing how different components interact, leading to more informed decision-making.

These tools identify points for intervention, enabling effective strategies for change. For instance, nonprofits can map social factors affecting community health to target interventions. Businesses can analyze supply chain dependencies to optimize their operations. By clarifying system dynamics, systems mapping empowers organizations to make informed choices that lead to impactful outcomes.

4 Improving sustainability tracking

As the demand for environmental impact transparency increases, organizations need reliable methods for tracking sustainability metrics. Blockchain offers a solution by enabling the secure and transparent tracking of environmental data, ensuring that sustainability claims can be verified and trusted.

For example, the Blockchain for Climate Foundation's BITMO Platform enables carbon credits to be issued and exchanged as tokens on the Ethereum blockchain, with each token representing one ton of carbon dioxide equivalent. This system ensures an immutable and auditable record of carbon offset transactions, promoting trust and efficiency in carbon markets.

5 Resilience monitoring

The need for enhanced resilience in various environments is driven by the increasing risk of disruptions, including natural disasters and system failures. Systems that leverage IoT devices and AI address this need by collecting and analyzing data for improved monitoring and response.

These systems provide users with real-time insights into potential disruptions, enabling them to take proactive measures to mitigate risks. By empowering users with data-driven insights, these technologies facilitate more efficient decision-making and bolster community preparedness, ultimately contributing to greater resilience.

Tech radar

Tech radar

In the constantly changing tech landscape, keeping up with the latest developments is essential, not just advantageous.

Continually analyzing technology trends and tracking their evolution will help you anticipate changes and prepare yourself for upcoming shifts.

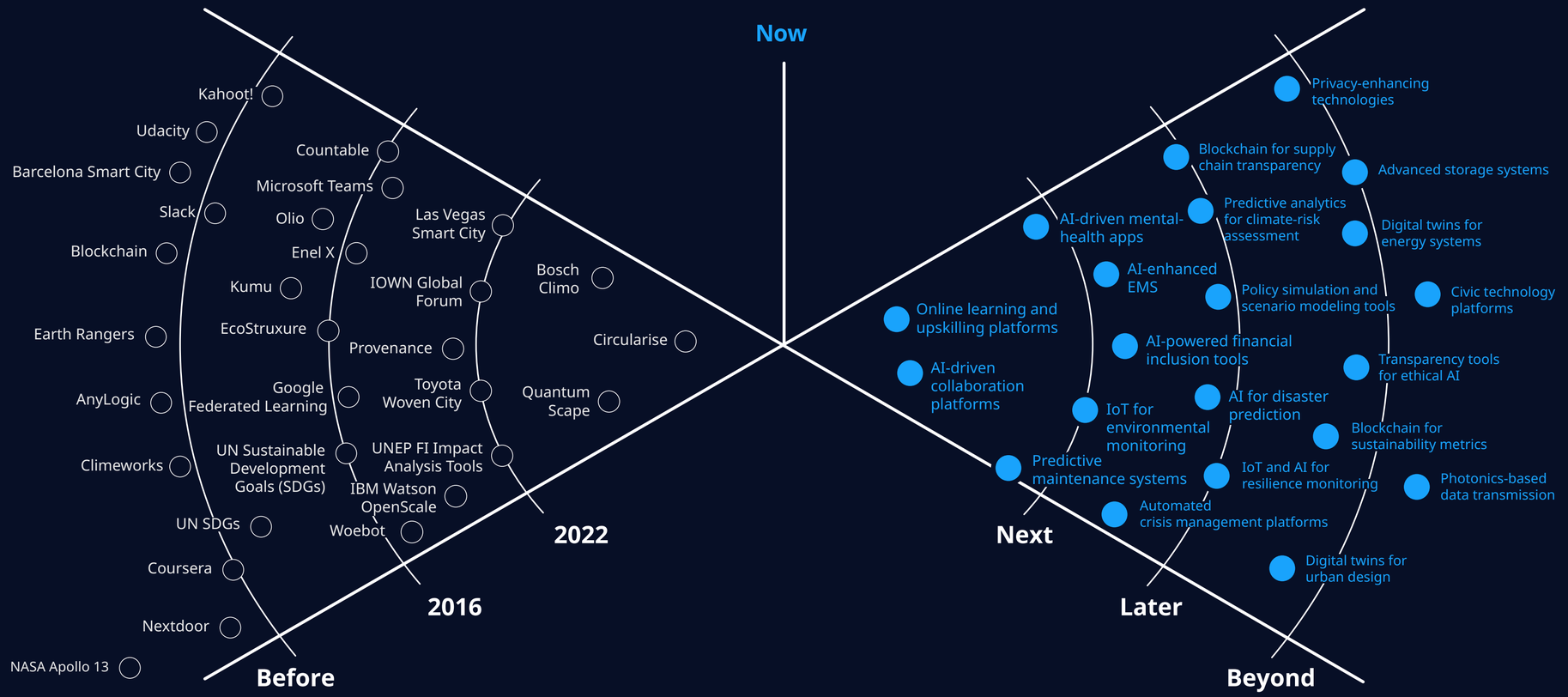


Figure 14: Tech radar — past and future technology

Future tech: now and next

A **Online learning and upskilling platforms**
Digital education platforms deliver scalable and accessible solutions to help people build the skills they need in emerging industries and evolving job markets.

B **AI-driven collaboration platforms**
Intelligent platforms enable seamless collaboration across industries and sectors, supporting projects and communication with advanced tools.

C **Predictive maintenance systems**
AI and IoT are employed to monitor equipment, predict potential failures and schedule maintenance, reducing downtime and improving operational efficiency.

D **AI-driven mental-health apps**
AI tools provide personalized mental-health support through chatbots, behavior tracking and cognitive behavioral interventions.

E **IoT sensors for environmental monitoring**
Interconnected sensors provide real-time data on environmental conditions such as air quality, water levels and weather patterns, enabling proactive management.

F **AI-enhanced energy management systems (EMS)**
AI is used to optimize energy consumption, stabilize power grids and balance energy supply and demand, making renewable energy integration more efficient.

G **AI-powered financial inclusion tools**
ML algorithms analyze alternative data to provide financial services, such as microloans and banking, to underserved populations.

H **Automated crisis management platforms**
AI-driven systems coordinate emergency responses, allocate resources and manage crises in real time, enhancing preparedness and efficiency.

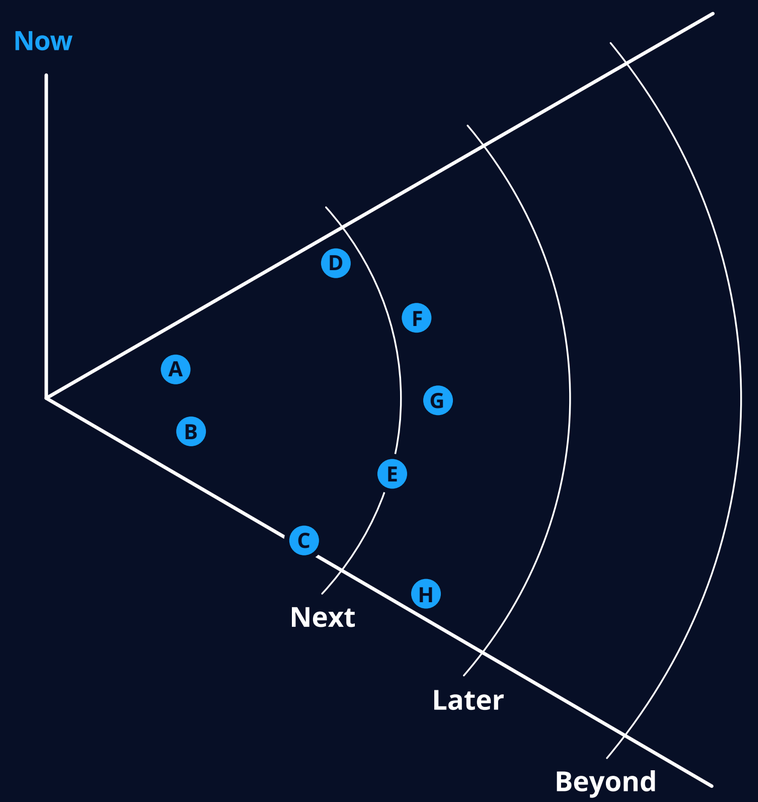


Figure 15a: Tech radar — future technology

Future tech: next, later and beyond

I **Blockchain for supply chain transparency**
Distributed ledger systems enable the secure and transparent tracking of goods and resources throughout supply chains, ensuring accountability and resilience.

J **AI for disaster prediction and management**
ML models analyze data to predict natural disasters and support efficient preventive strategies, minimizing human and economic losses.

K **Predictive analytics for climate-risk assessment**
Data-driven tools analyze environmental and economic information to predict climate risks, supporting informed decision-making for investments and policies.

L **Policy simulation and scenario modeling tools**
AI and data analysis tools model the potential impacts of policies, helping policymakers create adaptive and effective solutions.

M **IoT and AI-integrated resilience monitoring systems**
IoT sensors and AI are integrated to monitor critical infrastructure and systems, enhancing their ability to withstand and recover from disruptions.

N **Privacy-enhancing technologies (for example, federated learning)**
Advanced data privacy techniques ensure sensitive information is processed locally, preserving individual privacy while enabling secure data analysis.

O **Blockchain for sustainability metrics**
Blockchain technology tracks environmental and social impact metrics securely, ensuring transparency and accountability in sustainability initiatives.

P **Digital twins for urban design**
Virtual models of cities simulate infrastructure development, population growth and environmental impacts, aiding in the design of more sustainable urban environments.

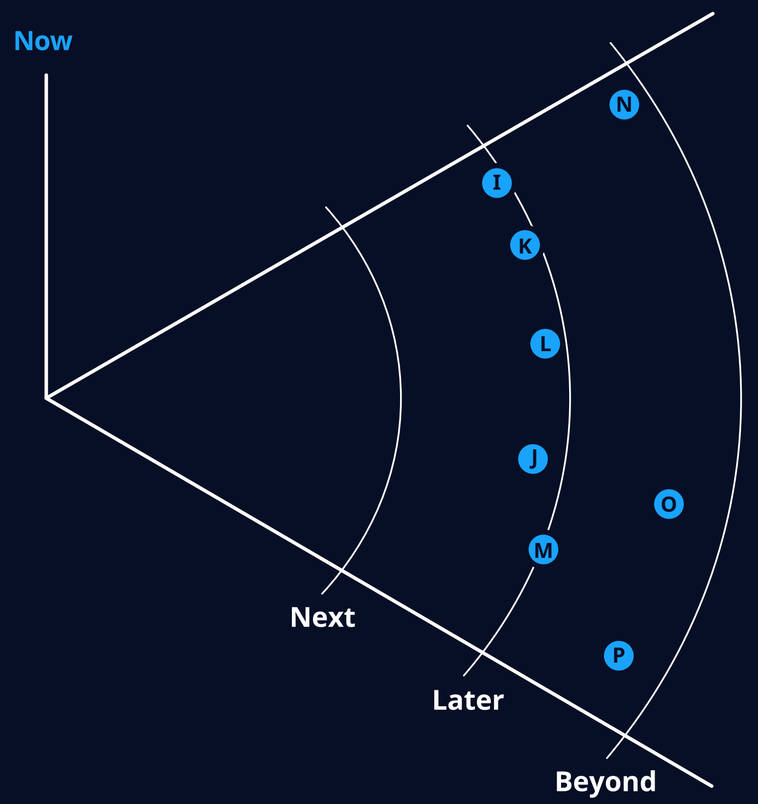


Figure 15b: Tech radar — future technology

Future tech: later and beyond

Q **Transparency tools for ethical AI**
Frameworks and tools ensure AI systems are explainable, fair and accountable in their decision-making processes.

R **Digital twins for energy systems**
Virtual representations of energy systems monitor performance, predict failures and simulate improvements for greater efficiency and sustainability.

S **Advanced storage systems**
Energy-storage technologies, such as solid-state batteries, enable safer, longer-lasting solutions for renewable-energy systems and electric vehicles.

T **Civic tech platforms for digital democracys**
Technology platforms empower citizens to engage in public decision-making, enhancing government transparency and promoting inclusive governance.

U **Photonics-based data transmission and processing**
The use of light instead of electricity to transfer and process data reduces energy consumption and improves processing speeds, making it ideal for energy-intensive operations in data centers and communication networks.

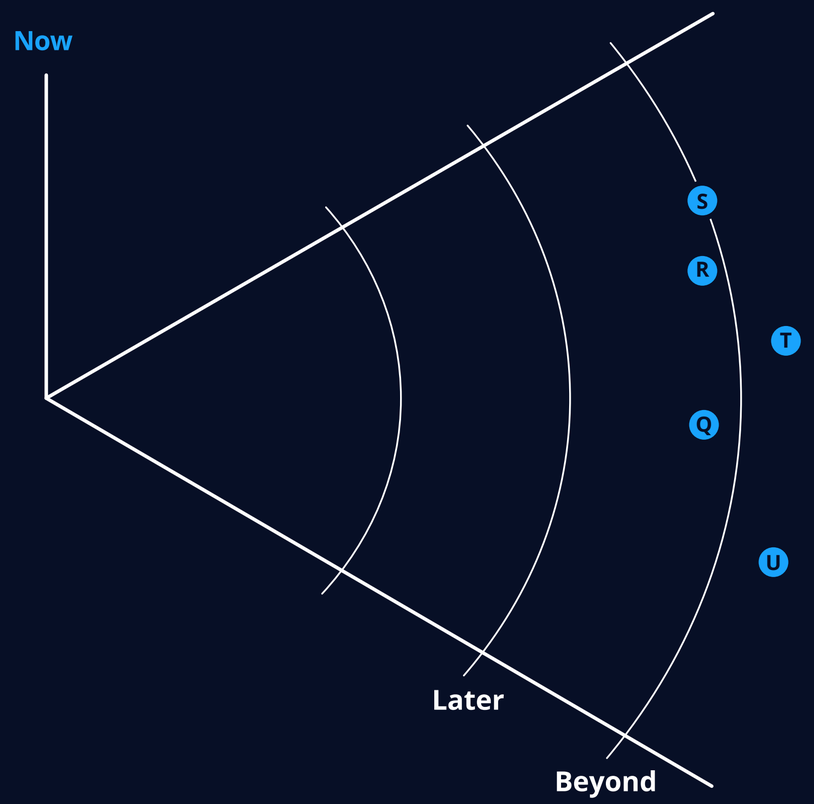
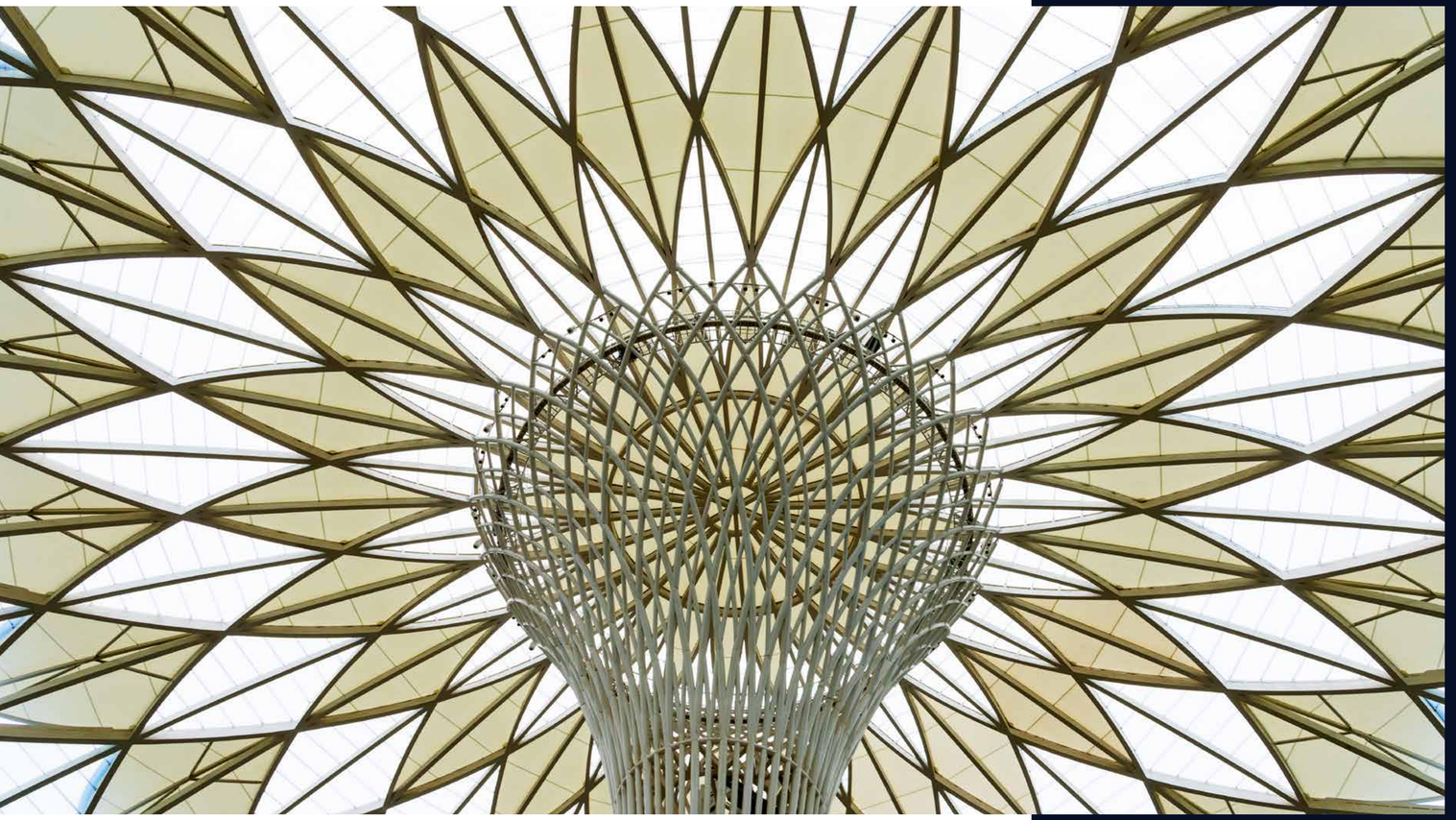


Figure 15c: Tech radar — future technology

R&D highlight



R&D highlight

Digital twins for a sustainable future

NTT is committed to driving sustainability for people and the planet through cutting-edge technology and strategic partnerships. Central to its efforts is the Innovative Optical and Wireless Network (IOWN), a groundbreaking communication infrastructure leveraging photonics for ultralow power consumption, exceptional capacity and near-zero latency.

By integrating IOWN with advanced simulation technologies, like digital twins, NTT delivers real-time insights that enable smarter, more efficient resource management.

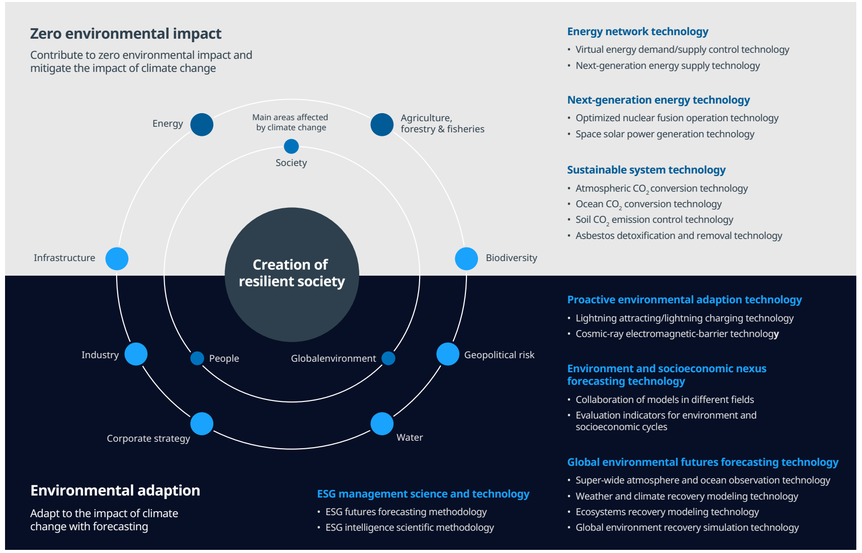
NTT's Space Environment and Energy Laboratories have developed a comprehensive Earth modeling system that serves as a global-scale digital twin. This technology combines extensive simulation and observational data to forecast environmental changes, such as extreme weather and climate trends, supporting proactive adaptation strategies and building resilience to environmental risks.

In collaboration with Waseda University, NTT spearheads initiatives fostering a "Love of the Earth," aiming to develop a sustainable society. These efforts include:

1 **Protective sustainability**
Conserving energy and ecosystems to mitigate environmental impacts

2 **Proactive sustainability**
Innovative energy solutions and sustainable food systems that address global challenges

Digital-twin technologies underpin these initiatives, offering data-driven, real-time solutions that improve energy efficiency, optimize resources and reduce ecological footprints. Through its holistic vision and multidisciplinary expertise, NTT empowers communities to address environmental, energy and societal challenges, creating a resilient, inclusive and thriving future.



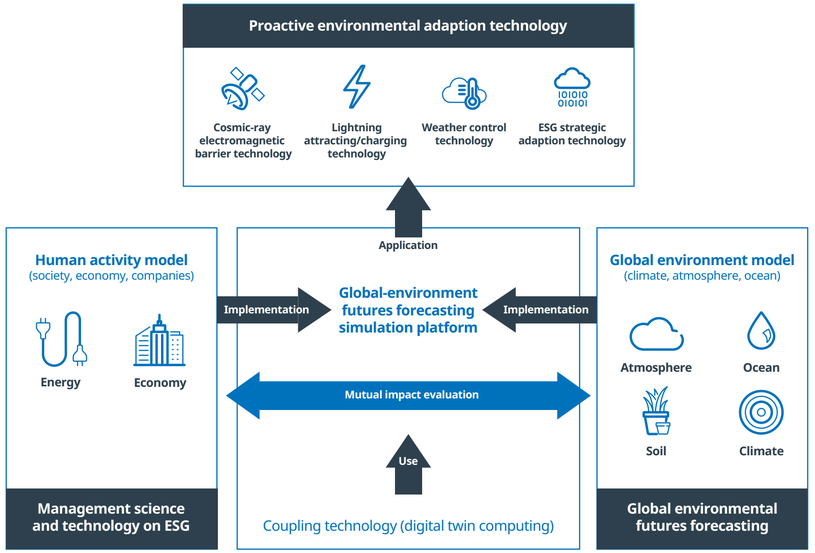
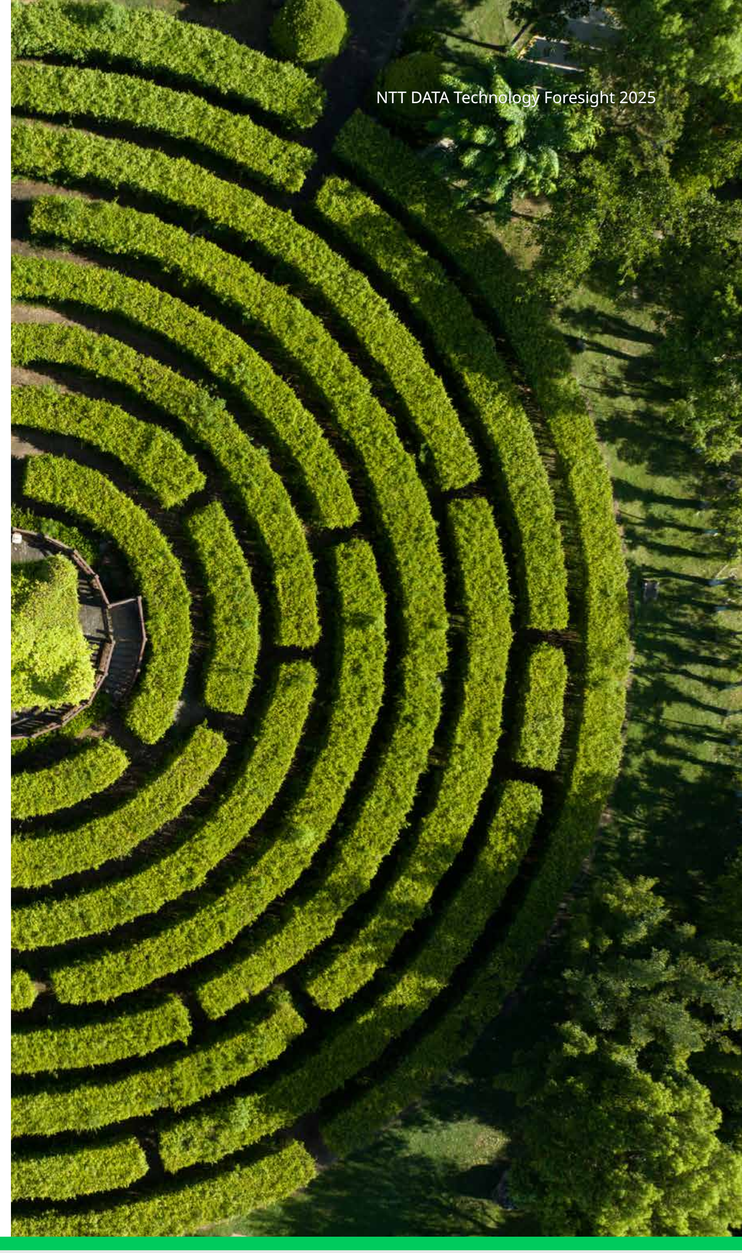
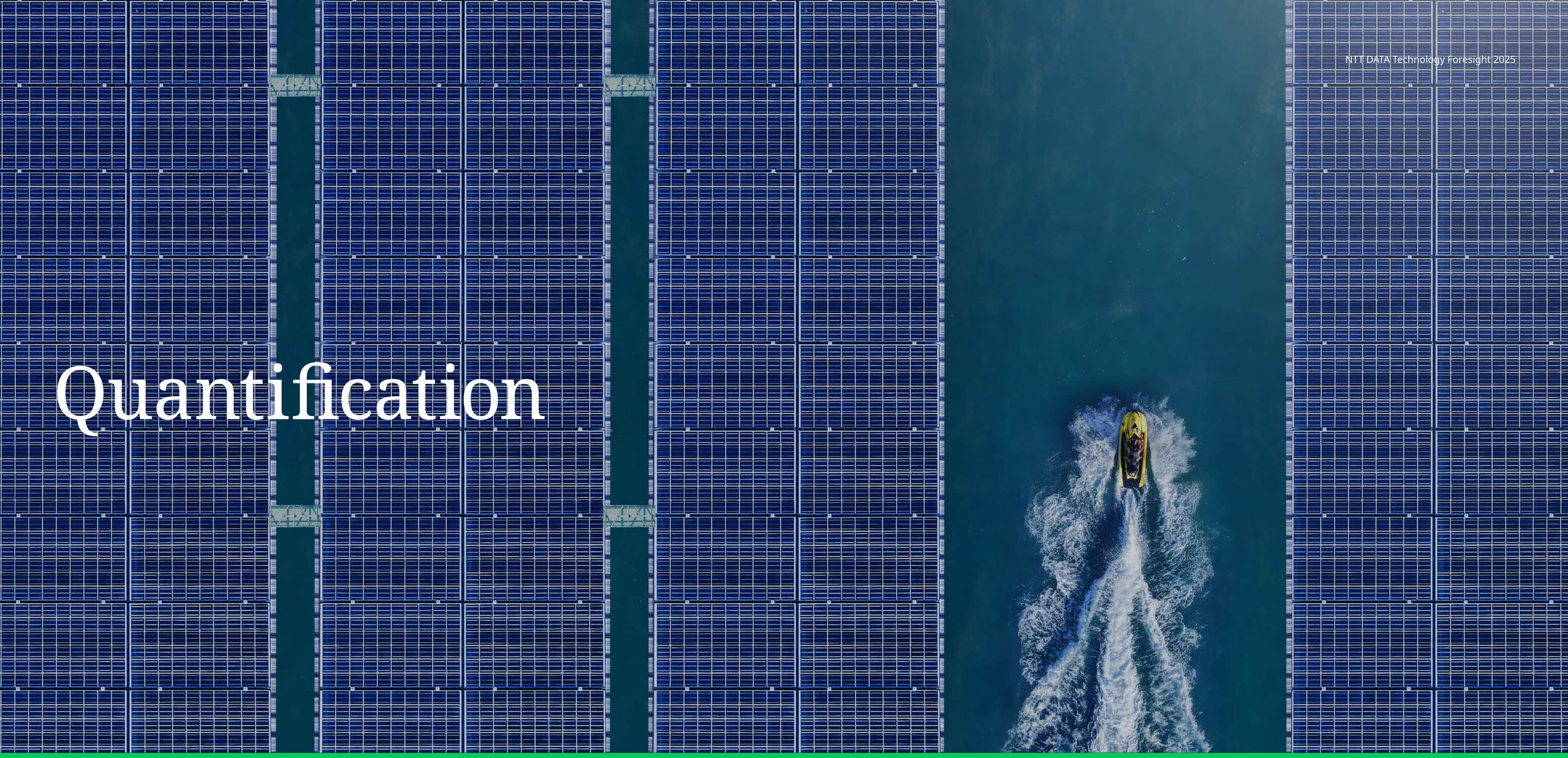


Figure 16: Digital twins for a sustainable future

(Left) Adapted from: *NTT Technical Review* Vol. 22 No. 3 Mar. 2024 | (Right) Adapted from: *NTT Technical Review* Vol. 21 No. 2 Feb. 2023



Quantification



Relevant financials

The energy-management software market is expected to grow from

$48.68 billion in 2024 to $241.56 billion by 2037, with a CAGR of

13.7%

The market for AI in disaster risk management was valued at

$479.5 billion in 2023 and is predicted to reach $2,150.1 billion by 2031, with a CAGR of

21.3%

during the forecast period of 2024–2031.

The blockchain supply chain market, which includes resource tracking applications, is valued at

$2.08 billion in 2024 and is expected to grow at a

29.14%

CAGR, reaching $9.77 billion by 2030.

The environmental monitoring market was valued at

$14.4 billion in 2024, with a CAGR of

5.7%

expected between 2025 and 2030.

The value of the global market for AI in mental health was estimated to be

$1.13 billion in 2023, with a CAGR of

24.1%

expected between 2024 and 2030.

The global federated learning market, a key component of PETs, was valued at

$133.1 million in 2023 and is projected to grow to $311.4 million by 2032, with a CAGR of

10.2%

The global market for advanced energy-storage systems was valued at

$12.80 billion in 2023 and it is expected to surpass $31.72 billion by 2033, with a CAGR of

9.5%

between 2024 and 2033.

Use cases

AI-powered microgrid coordination

Industry: **Public sector; energy and utilities**

AI-driven systems manage localized energy-generation sources, autonomously balancing supply and demand to enhance resilience and promote renewable-energy integration. This supports energy independence, crucial for sustainable development.

Business value

1. Enhances energy independence
2. Supports the transition to renewable sources
3. Improves local energy security

> “AI-powered microgrid coordination systems balance supply and demand locally, enhancing energy independence and renewable integration.

Digital twins for urban planning

Industry: **Telecommunications, media and technology**

Using virtual models of urban environments to simulate changes enables planners to optimize infrastructure and enhance city resilience against climate challenges, allowing for proactive adaptation to environmental issues.

This technique engages stakeholders through interactive models, enabling community feedback

Business value

1. Facilitates informed decision-making through simulation
2. Improves resource allocation and climate preparedness
3. Reduces costs related to infrastructure failures

Blockchain-enabled renewable-energy trading

Industry: **Manufacturing**

Implementing blockchain technology facilitates peer-to-peer energy trading between consumers and producers of renewable energy. This decentralized approach promotes efficient energy distribution, reduces transmission losses and incentivizes the adoption of renewable sources.

Business value

1. Increased efficiency by minimizing losses through decentralized energy trading
2. Peer-to-peer trading boosts investment in renewable energy

> “Blockchain-enabled energy trading incentivizes renewable adoption, minimizes losses and promotes efficiency.

City environmental monitoring

Industry: **Public sector; energy and utilities**

Smart-city solutions utilize IoT-based environmental monitoring to track air quality and predict potential environmental risks in urban areas. This technology helps local governments take proactive measures to ensure healthier and safer living conditions for residents.

Business value

1. Attracts businesses and residents to healthier urban environments
2. Supports regulatory compliance and sustainability goals

Circular manufacturing with digital twins

Industry: **Industry and services**

Creating digital replicas of manufacturing processes optimizes product lifecycles, enabling the design of longer-lasting, recyclable products with minimal environmental impact. This approach fosters longevity, integrates secondhand marketplaces, reduces waste and encourages innovation while enhancing sustainability efforts and meeting regulatory requirements.

Business value

1. Ethical sourcing builds consumer confidence
2. Meeting sustainability demands boosts market competitiveness

> “Digital twins for circular manufacturing enable recyclable designs, reduce waste and meet sustainability goals while boosting competitiveness.

IoT-based precision agriculture

Industry: **Agriculture**

Deploying IoT devices to monitor soil conditions, weather patterns and crop health in real time enables farmers to optimize resource usage, reduce waste and enhance crop yields, leading to increased profitability by ensuring more reliable and abundant harvests.

Business value

1. Efficiently allocates water and nutrients, reducing costs and environmental impact
2. Provides real-time data to anticipate issues, minimize crop loss and ensure reliable harvests

Intelligent water and waste management

Industry: **Industry and services**

IoT sensors optimize resource use in waste and water management by identifying maintenance needs and improving collection routes. AI-powered waste-sorting systems automate recyclables separation, boosting recycling rates and reducing contamination. Together, they conserve resources, lower costs and enhance waste-management efficiency.

Business value

1. Optimized resources and automation lower operational costs
2. Improved recycling rates promote environmental responsibility

> “AI and IoT revolutionize waste and water management by optimizing resources, cutting costs, and boosting recycling efficiency.

Use cases

Success case

United States | Public sector

City of Las Vegas: shaping the future of urban living

Business need

Las Vegas is a bustling metropolis known for its vibrant tourism and rapid growth, but this success brings challenges such as soaring energy demands, increasing traffic congestion and complex sustainability goals.

City leaders recognized that without a strategic approach to resource management, Las Vegas would face escalating carbon emissions, compromised air quality and a diminished quality of life for residents.

To transform Las Vegas into a model of urban resilience, the city sought a digital solution capable of balancing growth with sustainability, optimizing energy use and enhancing public safety — all while setting an example for cities worldwide.

This ambitious vision required an intelligent network to integrate and manage urban resources in real time, paving the way for a greener, safer and smarter Las Vegas.

Solution

NTT DATA partnered with the City of Las Vegas to create a sophisticated smart-city infrastructure powered by IoT, edge computing and AI-driven analytics.

The solution integrates data from city assets — traffic systems, lighting and parking — to create a connected urban ecosystem that anticipates, responds to and optimizes resource use. With IoT sensors embedded across the city, edge devices analyze data locally to reduce latency, ensuring real-time insights for critical functions like energy and traffic management.

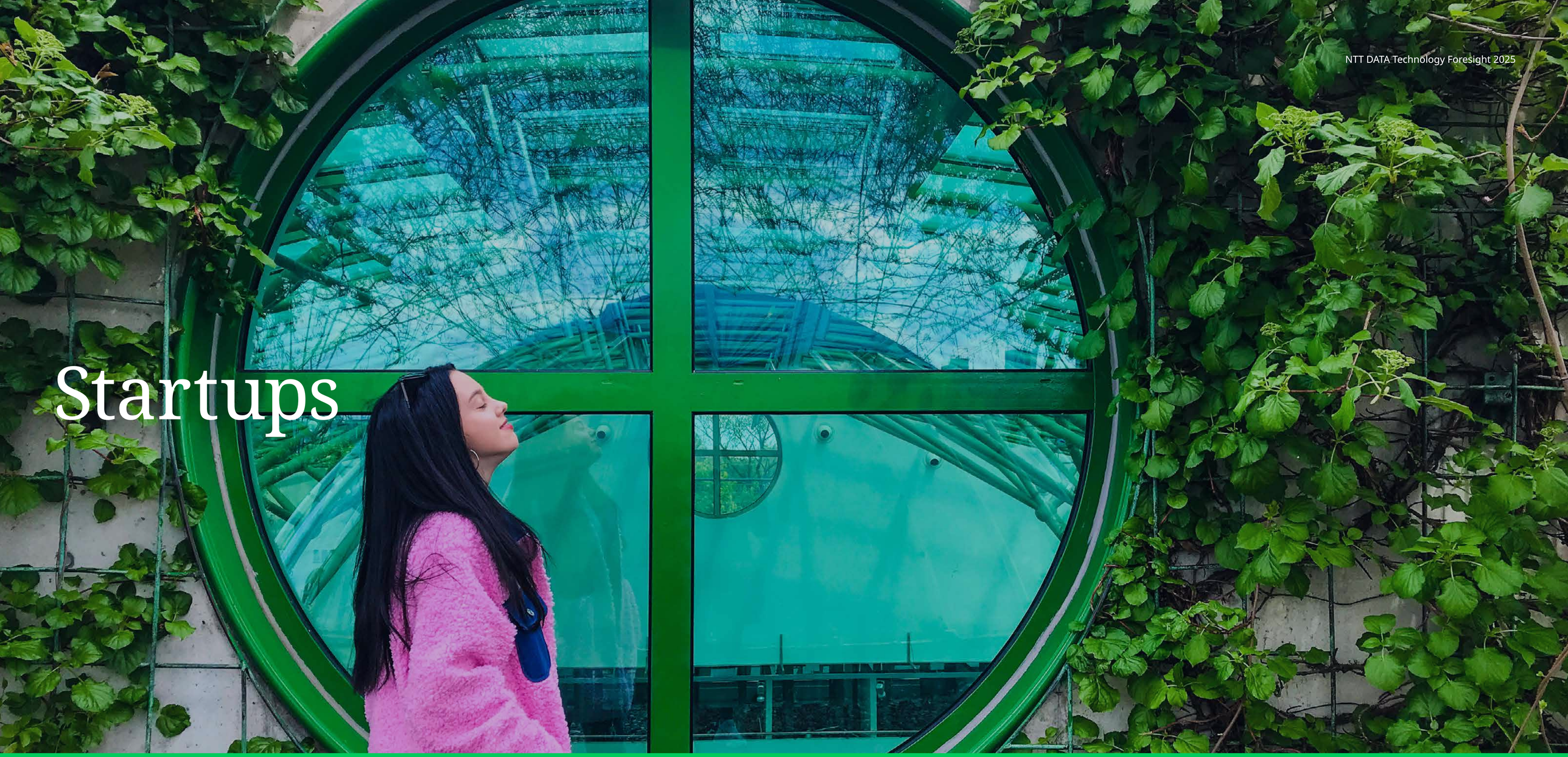
This enables adaptive lighting that dims when streets are empty, traffic-flow optimization to reduce emissions and predictive maintenance for infrastructure longevity.

The platform empowers city officials to monitor and adjust resources instantly, offering a transformative, scalable model for sustainable urban management.

Outcomes

The City of Las Vegas has established itself as a leader in smart, sustainable urban development. Through enhanced energy efficiency, reduced emissions and improved traffic flow, the initiative has not only cut costs but also enriched the quality of life for residents and visitors alike, setting a new standard for cities seeking a sustainable future.

Startups



Startup radar

In this section, we review a selection of startups relevant to digital sustainability for economic resilience, based on our observations, partnerships and investments.

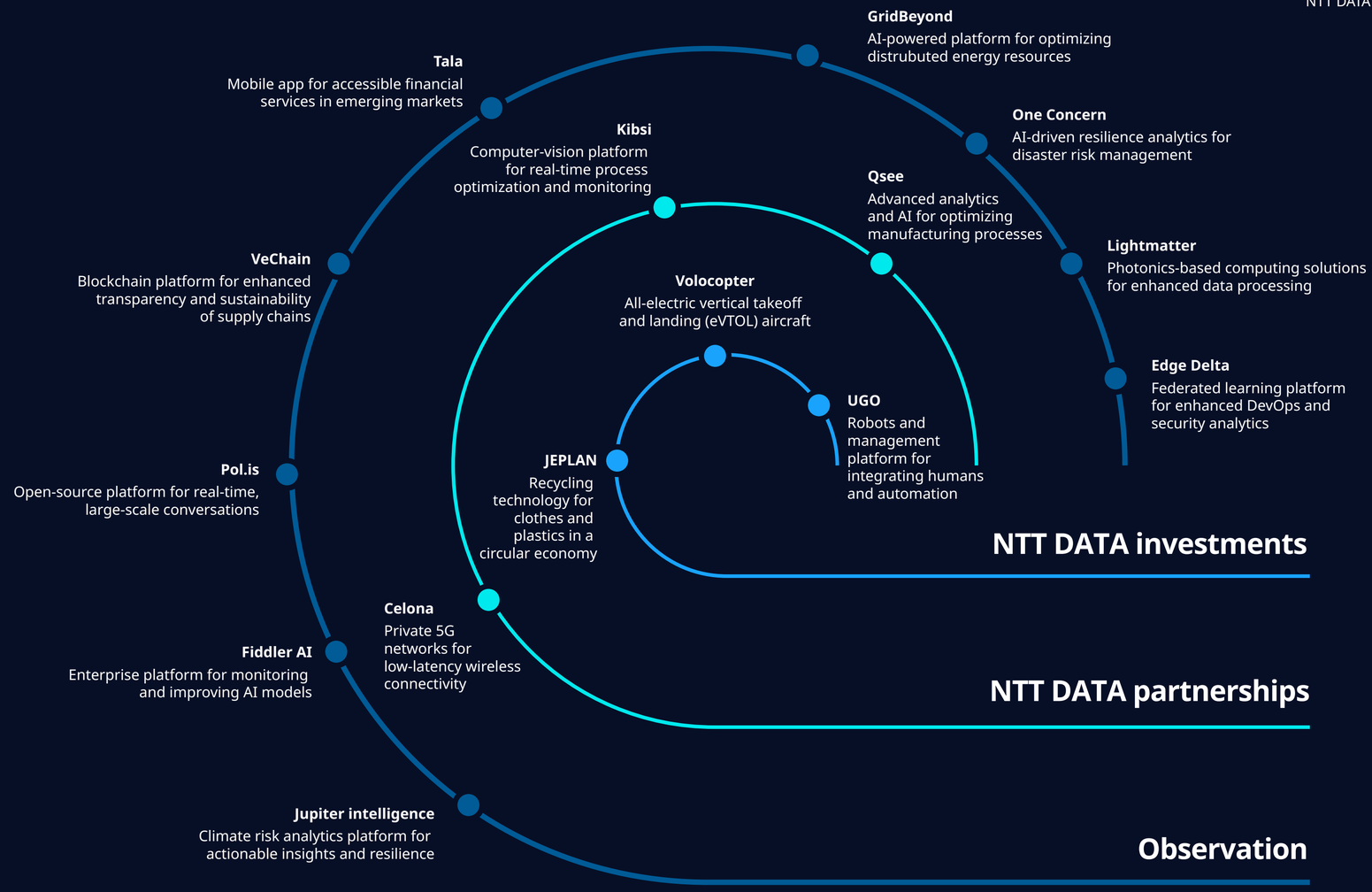


Figure 17: Investment in digital sustainability for economic resilience startups

Startups

Observation

Lightmatter

Founded in 2017, this photonic computing company develops hardware that uses light for data processing and transmission. This approach addresses the limitations of traditional electronic chips, offering significant improvements in speed and energy efficiency. Lightmatter's product lineup includes a photonic computing platform designed for neural networks and a photonic interconnect that facilitates high-bandwidth, low-latency data movement between processors.

Stage
Series D

Funding
$822 million

Valuation
$4.4 billion

Industry
Cross-industry

One Concern

Founded in 2015, One Concern is a resilience analytics company that leverages AI and ML to assess and mitigate risks associated with natural disasters and climate change. By integrating hazard science with advanced AI models, it provides organizations with actionable insights to uncover vulnerabilities and enhance decision-making processes. Its platform offers tools for risk selection, mitigation, pricing, scenario analysis and risk management, enabling clients to build resilience against environmental threats.

Stage
Series B

Funding
$119.2 million

Valuation
Not disclosed

Industry
Public sector; energy and utilities

GridBeyond

Founded in 2010, GridBeyond specializes in optimizing distributed energy resources through its AI-powered platform, enabling businesses to enhance energy efficiency, reduce costs and support grid stability. It facilitates the seamless participation of various assets — such as industrial loads, generation units and storage systems — in energy markets. This approach generates new revenue streams for clients and contributes to the transition toward a sustainable, low-carbon energy future.

Stage
Series C

Funding
$95.6 million

Valuation
Not disclosed

Industry
Public sector; energy; manufacturing

Tala

Founded in 2011, Tala is a global financial technology company that provides accessible financial services to underserved populations in emerging markets. Through its mobile app, Tala offers instant credit, payments, savings and transfer services, enabling users to manage their financial lives seamlessly. The company leverages advanced technologies, including AI and ML, to deliver personalized financial experiences and promote economic inclusion.

Stage
Series E

Funding
$372 million

Valuation
$800 million

Industry
Financial services

VeChain

Founded in 2017, VeChain is a blockchain platform that enhances supply chain transparency and sustainability. It enables businesses to monitor product origins and movements in real time using IoT technologies, ensuring ethical sourcing and reduced environmental impact. VeChain's solutions assist organizations to digitize eco-friendly practices and comply with environmental regulations.

Stage
Series B

Funding
$300 million

Valuation
$3.5 billion

Industry
Manufacturing; retail; logistics

Pol.is

Founded in 2014, Pol.is is an open-source platform designed to facilitate large-scale, real-time conversations among diverse groups. Utilizing advanced statistics and ML, it enables participants to share opinions and ideas, with algorithms identifying consensus and highlighting areas of disagreement. This approach aids in better decision-making and has been employed globally by governments, academics and organizations to engage citizens in policy development and public discourse.

Stage
Not applicable

Funding
Donations

Valuation
Not disclosed

Industry
Public sector

Edge Delta

Founded in 2018, Edge Delta offers a federated learning platform that allows organizations to use distributed analytics to identify and remediate potential DevOps and security incidents. This approach improves accuracy and speed and delivers higher levels of security and privacy than traditional centralized systems.

Stage
Series B

Funding
$81 million

Valuation
$500 million

Industry
Cross-industry

Jupiter Intelligence

Founded in 2017, Jupiter Intelligence offers climate-risk analytics that turn sophisticated climate science into actionable data. Their solutions, such as ClimateScore Global, deliver high-resolution, forward-looking analyses of various climate risks, enabling businesses to enhance resilience and comply with regulatory disclosures.

Stage
Series C

Funding
$87.2 million

Valuation
$1 billion

Industry
Public sector; energy; manufacturing; financial services

Fiddler AI

Founded in 2018, Fiddler AI is a pioneer in enterprise-model performance management. Data scientists, MLOps teams and lines of business use Fiddler to monitor, explain, analyze and improve their models and build trust in AI.

Stage
Series B

Funding
$65.1 million

Valuation
$150 million

Industry
Cross-industry

Startups

NTT DATA partnerships

Qsee

Founded in 2018, Qsee specializes in enhancing manufacturing processes through advanced analytics and AI. Its software solutions enable manufacturers to make data-driven decisions, improving productivity, reducing operational costs and minimizing environmental impact.

Stage
Pre-seed

Funding
$605,000

Valuation
Not disclosed

Industry
Manufacturing

Celona

Founded in 2019, Celona specializes in private 5G networks, providing reliable, low-latency wireless connectivity essential for modern automation and smart city initiatives. Its solutions enable efficient communication among devices, leading to optimized energy consumption and reduced operational costs. In manufacturing environments, Celona's technology supports the seamless operation of autonomous robots and AGVs, enhancing productivity while minimizing energy usage.

Stage
Series C

Funding
$100 million

Valuation
Not disclosed

Industry
Manufacturing; public sector; energy

Kibsi

Founded in 2021, Kibisi is a computer-vision platform that transforms video data into actionable insights, facilitating the real-time monitoring and optimization of processes. In manufacturing, Kibsi's platform oversees production lines, detects defects and ensures quality control, reducing waste and improving resource efficiency. By integrating with existing camera networks, Kibsi provides insights into energy usage patterns within facilities. This data enables organizations to identify inefficiencies and implement energy-saving measures.

Stage
Seed

Funding
$9 million

Valuation
Not disclosed

Industry
Manufacturing; public sector; energy

Startups

NTT DATA investments

JEPLAN

Founded in 2007, JEPLAN develops recycling technology for clothing and plastics. The company offers circular economy technology and projects designed for multiple industries, focusing on producing clothes and plastic bottles using recycled materials. It also establishes collection points in collaboration with retail and apparel brands to gather discarded clothing.

Stage
Not disclosed

Funding
$60 million

Valuation
Not disclosed

Industry
Cross-industry; retail

Volocopter

Founded in 2011, Volocopter specializes in urban air mobility and operates in the aerospace industry. The company develops all-electric vertical takeoff and landing (eVTOL) aircraft designed to provide quiet, sustainable and emission-free air transportation solutions. Volocopter's primary offerings include the VoloCity air taxi for urban environments and the VoloRegion for regional connectivity, alongside VoloIQ, an AI-powered digital platform that supports the operational aspects of its eVTOL fleet.

Stage
Series E

Funding
$544.4 million

Valuation
Not disclosed

Industry
Automotive; manufacturing

UGO

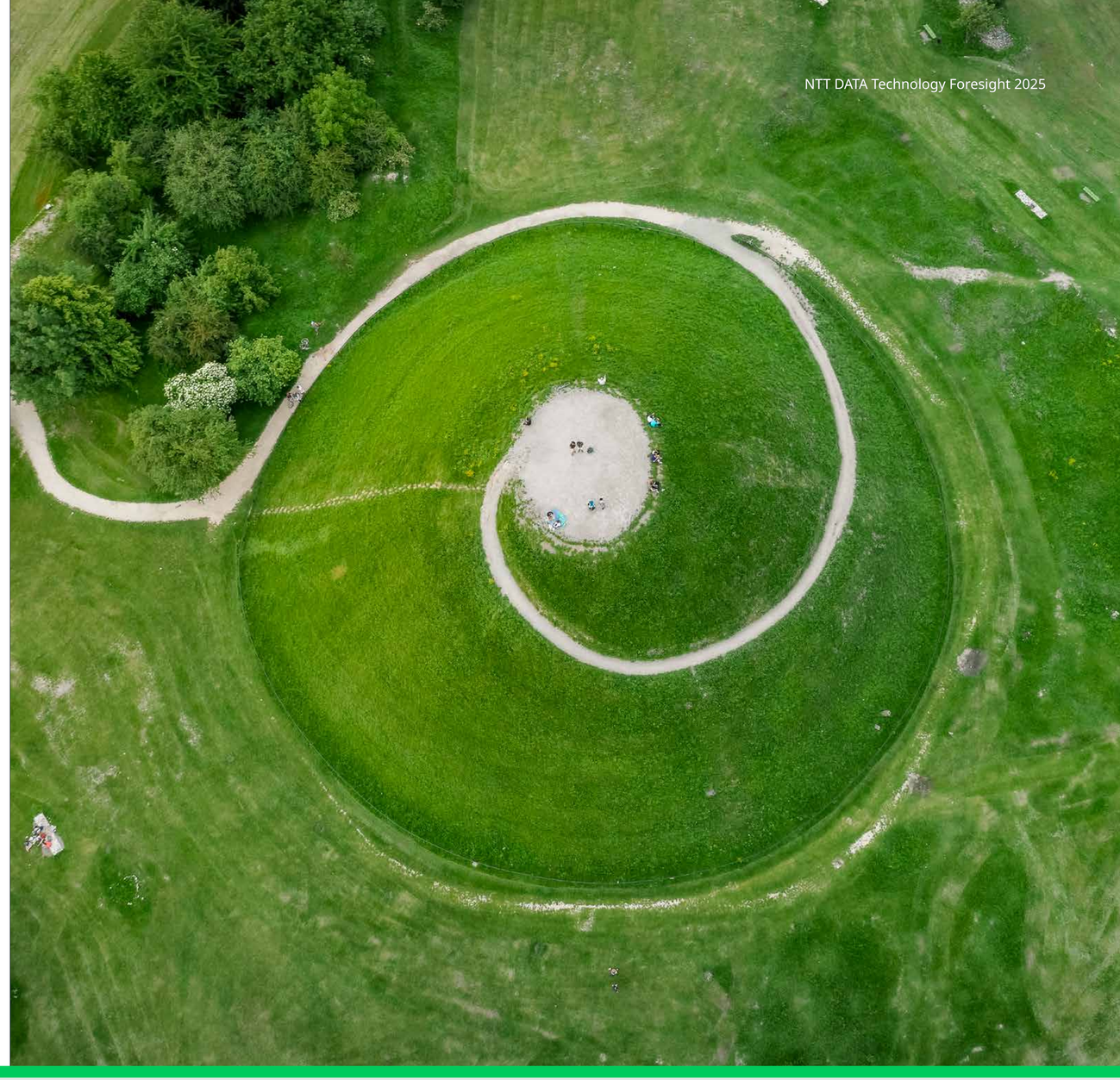
Founded in 2018, UGO focuses on integrating humans and robots to support sustainable work styles across various industries. The company offers robots capable of autonomous navigation and remote operation, which can be used in a hybrid manner for a wide range of tasks. UGO's robot management platform facilitates the use and customization of robots for different operational needs. Its solutions cater primarily to sectors facing severe labor shortages, such as security, inspection, caregiving, retail and warehouse operations.

Stage
Not disclosed

Funding
$8.89 million

Valuation
Not disclosed

Industry
Cross-industry



Future scenarios

As industries transform, new value chains emerge and technological advancements grow exponentially, companies must navigate complex, evolving landscapes.

Future scenarios and GenAI-powered personas allow organizations to explore possible futures, simulate realistic business environments and minimize risk through scenario-based planning.

Uncertainties represent what we cannot know, but identifying them can reduce the risks of blind spots down the road.

Future scenarios

Uncertainty: commitment to decarbonization

Zero-carbon sprint

What if rapid decarbonization becomes a global priority?

Breakthrough technologies and urgent policy shifts will drive swift reductions in emissions. Economies will transform through green energy and circular practices, significantly reversing environmental degradation. This scenario also sees thriving green industries, improved public health from reduced pollution and an acceleration of global innovation.

Slow burn to sustainability

What if decarbonization efforts remain slow and inconsistent?

Slow progress in decarbonization will force communities to prioritize disaster response as climate impacts intensify. Advanced prediction tools, decentralized energy systems and local collaboration will drive resilience. If global mitigation lags, adaptive measures will foster innovation and strengthen community bonds, offering a pathway to long-term sustainability.

Future scenarios

Uncertainty: global collaboration

The united front

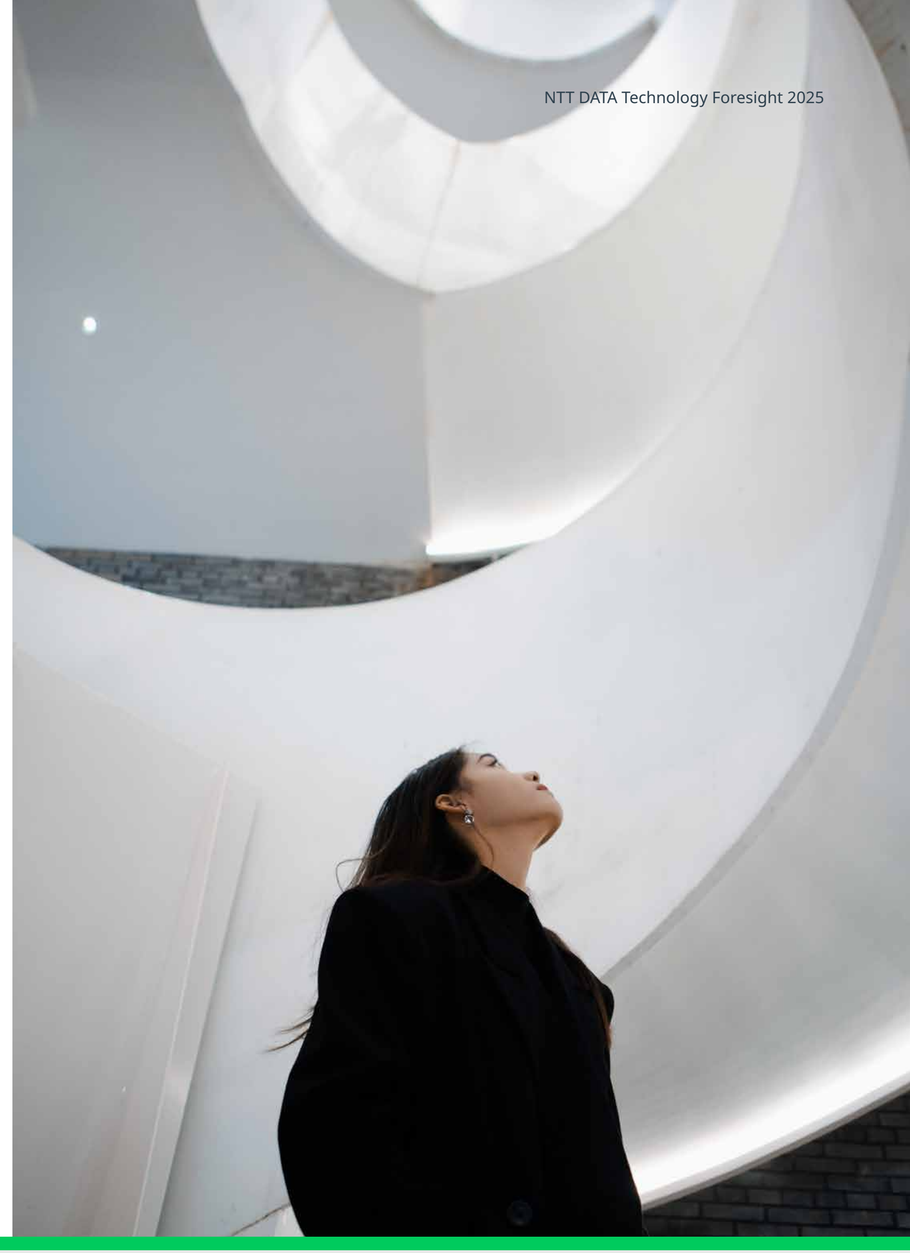
What if nations come together to solve climate challenges with unprecedented global unity?

Governments, industries and civil society could align globally to tackle climate change. Binding agreements, shared resources and collaborative technologies may lead to coordinated climate action. The positive outcomes of these actions include equitable resource distribution, widespread technological innovation and global resilience against climate risks.

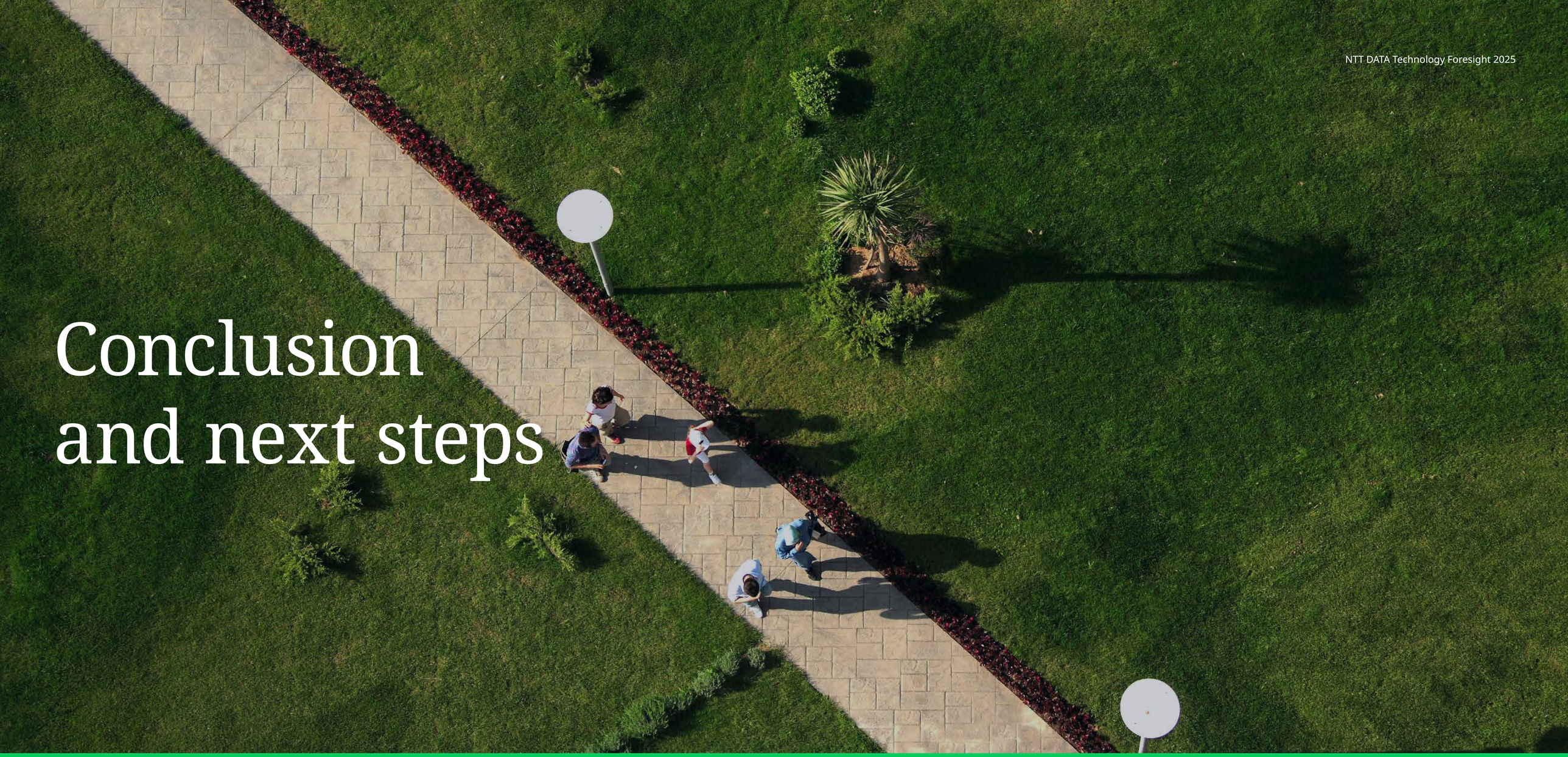
Innovators in isolation

What if fragmented geopolitics dominates the climate landscape?

If international relations fray, countries may pursue individual agendas. Progress will vary across nations, but localized solutions will emerge as some nations become innovation hubs. These nations will pioneer effective policies and technologies, providing valuable models for others despite the lack of global alignment. Competition among nations will also spark advancements in strategies for renewable energy and climate adaptation.



Conclusion and next steps



Conclusion and next steps

Think about this

Sustainability isn't just about reducing environmental harm — it now requires a **holistic approach** that integrates environmental, economic and social dimensions. Organizations must address these interconnected challenges to create lasting impact.

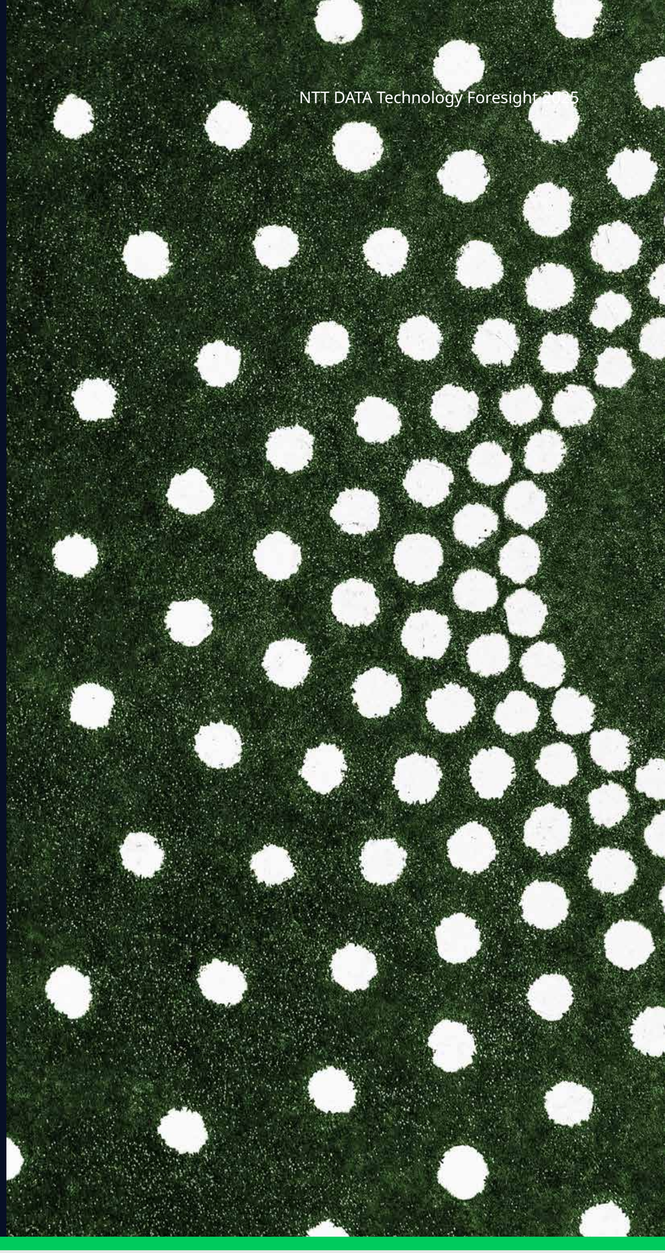
How does your organization currently support personal wellbeing, social equity and economic stability alongside environmental goals?

Actions in one area of sustainability often ripple into others, creating **interdependencies** that need to be managed effectively. Systems mapping and analysis tools help optimize these interconnected domains.

Are you leveraging such tools to identify and align these interdependencies effectively?

Advanced technologies offer immense potential to drive sustainability goals but must be **balanced with ethical considerations** to ensure social inclusiveness and address privacy concerns. Equity, accessibility and privacy must be central to digital innovations.

How are you aligning your digital sustainability efforts with these principles?



Conclusion and next steps

Do this next

5 minutes

Identify environmental priorities

Identify one high-risk environmental area or process where IoT and AI tools can provide immediate insights for real-time monitoring and disaster prediction.

5 days

Pilot upskilling platforms

Launch a pilot program using an online learning platform to train employees on how to use sustainability tools such as AI-driven energy systems and blockchain-based transparency solutions.

5 weeks

Deploy policy-simulation tools

Adopt and integrate AI-powered policy-simulation tools to model the long-term impacts of your sustainability initiatives and ensure informed decision-making across departments.

Contact information

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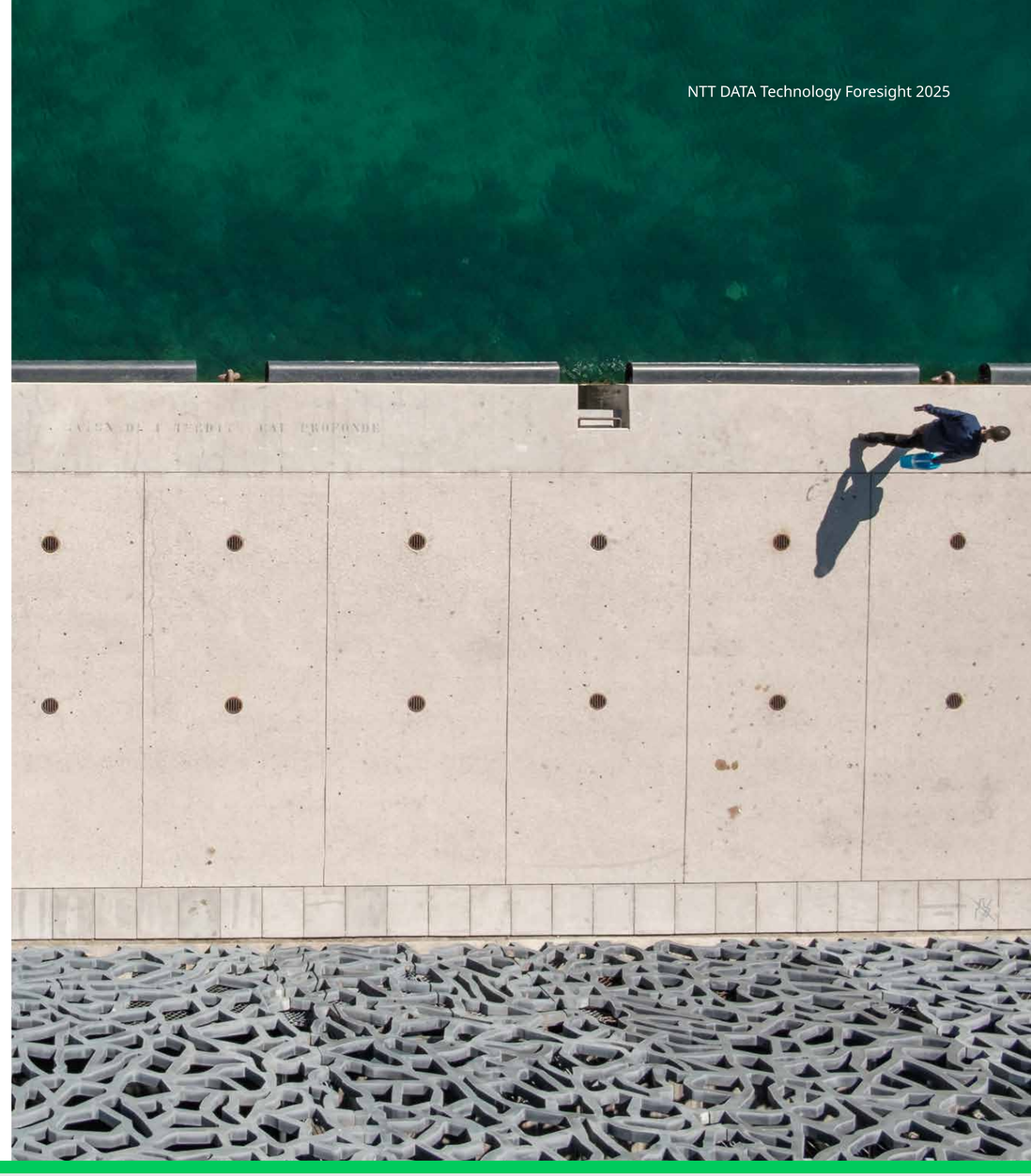


Trend 4: Cognitive cloud convergence

Picture a world where limitless possibilities await you at the intersection of technology and thought.

Introduction

Cognitive cloud convergence represents the seamless integration of advanced cloud computing technologies with AI and human cognitive abilities, empowering organizations to improve operations, enhance decision-making and derive deeper insights from their data in real time.

By using essential components such as AI-augmented software engineering, edge computing and artificial intelligence for IT operations (AIOps), organizations can streamline their operations, create personalized customer experiences and make informed decisions more effectively.

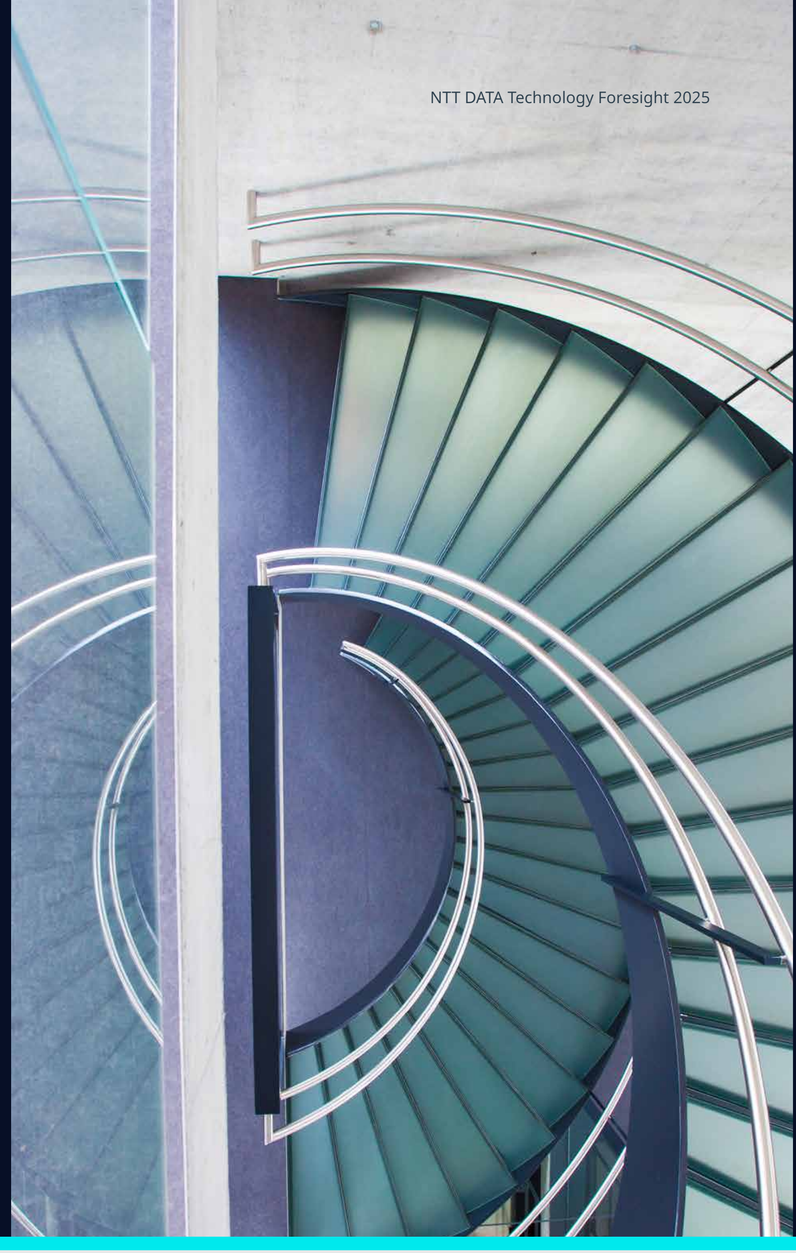
Significance and impact on business

This megatrend enables organizations to leverage data-driven insights and unlock unprecedented growth and operational efficiency. For example, they can apply predictive analytics to anticipate market trends and customer needs, which helps them prioritize strategic initiatives and gain a competitive edge.

Key drivers

A primary driver of this trend is the exponential increase in data generation. With global data volumes projected to reach 175 zettabytes by 2025, robust, intelligent cloud infrastructures are essential for effectively managing and extracting valuable insights from this vast reservoir of information.

However, cognitive cloud convergence presents several challenges that organizations must prepare to navigate. For example, data privacy and security concerns may arise due to the centralized nature of cloud systems, requiring stringent measures to protect sensitive information. Additionally, organizations may face integration complexities as they seek to unify disparate data sources and legacy systems within multiple cloud environments. Ongoing advancements in AI and cloud technology necessitate continual training and adaptation, which can strain resources and budgets. Addressing these challenges is essential for harnessing the full benefits of cognitive cloud convergence and maintaining a competitive advantage in today's dynamic market landscape.



Technical explanation

Cognitive cloud convergence describes the intersection of AI and cloud technologies to enable smarter, more adaptive digital ecosystems. This trend is fueled by progress in cloud infrastructure, edge computing, IoT and automation. Organizations that successfully align these components will create seamless, optimized experiences that scale with demand. Key components include:

1. Cloud and AI convergence

This convergence brings AI processing closer to the data source, allowing for real-time analytics and decision-making. It enhances capabilities across industries by enabling smarter data management, predictive analytics and improved user personalization.

2. Advanced cloud infrastructure

Advanced cloud architectures support the scalability required for complex AI workloads. These infrastructures use multicloud and hybrid models to ensure agility, resilience and efficient resource allocation for continuous learning and adaptation.

3. Edge technologies and IoT

Edge computing and IoT devices are integral to reducing latency and improving data processing efficiency. By processing data locally, these technologies enable real-time responses, support remote operations and improve data security and privacy.

4. Automation and optimization

Automation within this framework leverages AI to streamline processes, optimize resource allocation and boost operational efficiency. This reduces human intervention, enabling a proactive and predictive approach to managing digital ecosystems.

> “Cognitive cloud convergence is the shift toward a unified, intelligent cloud environment where AI and cloud technologies intersect to simplify complex tasks, making processes more responsive, adaptable and resilient.

Technology

Containerization is a lightweight virtualization method that allows applications to run in isolated containers with their own code libraries and dependencies, ensuring consistency across environments. Docker is a common containerization technology.

Orchestration tools like Kubernetes automate the deployment, scaling and networking of containers, improving scalability, resource efficiency and development processes.

Edge computing platforms process data closer to the source, for example IoT devices or local edge servers. This minimizes latency and reduces bandwidth consumption, enabling features like real-time analytics, secure data transfer and support for different edge devices. Azure IoT Edge and AWS IoT Greengrass are popular technologies that improve application response time, support remote operations and strengthen data security by processing sensitive data locally.

Infrastructure as code automates IT infrastructure management through code, ensuring consistent and predictable setup and configuration. This allows developers to apply version control, repeatability and collaboration to infrastructure in the same way they do to application code. Tools such as Terraform, AWS CloudFormation and Ansible improve efficiency, reduce configuration drift and enable IT teams to rapidly scale or replicate environments.

AI and machine learning (ML) services are cloud-based platforms for building, deploying and managing AI models, including data preparation, training, deployment and monitoring. For example, Amazon SageMaker and Azure Machine Learning offer prebuilt algorithms, automated machine learning (AutoML) and cloud integration. These services simplify AI implementation and streamline model lifecycle management.

Business explanation

The integration of cognitive technologies with cloud infrastructure marks a new era of digital transformation. This convergence enables organizations to leverage vast amounts of data and process it with exceptional speed and intelligence to generate actionable insights in real time. Adopting these technologies gives organizations a means to optimize their operational frameworks and accelerate the processes that support innovation.

Cognitive cloud convergence improves operational efficiency through improved data processing, automated workflows and intelligent decision-making. By using advanced analytics, organizations can streamline internal processes and resource allocation and enrich team collaboration. As a result, they are better positioned to anticipate operational needs, proactively address potential challenges and foster agility and continuous improvement, ultimately driving sustainable success.

Key advantages of this shift include:

Automated decision-making

Cognitive cloud convergence enables data-driven decision-making at scale, allowing organizations to make informed decisions across operations.

Better resource allocation

AI-driven models improve efficiency and cost-effectiveness in resource management, from inventory to human resources.

Enhanced cybersecurity

Integrating cognitive technologies with cloud infrastructure strengthens threat detection and response systems.

Accelerated innovation

Cloud-based cognitive services facilitate rapid prototyping and deployment, reducing time to market and fostering continuous innovation.

Underlying concepts

Underlying concepts

Cognitive cloud convergence represents a fundamental shift in how organizations apply technology to improve their operations. Core components include the fusion of AI and cloud computing, advanced infrastructure management, the integration of edge technologies and IoT, and process automation.

By understanding and embracing these interconnected elements, organizations can inspire innovation, optimize workflows and achieve a deeper understanding of their data in real time.

Cognitive cloud convergence

Cloud and AI convergence

- Automation and continuous improvement
- AI-managed cloud workloads
- Edge intelligence and IoT integration
- Intelligent operations and management
- Cloud and AI oversight

Advanced cloud infrastructure

- Cloud-native
- Multicloud administration
- Next-generation computing
- Serverless computing
- Software-defined infrastructure

Edge technologies and IoT

- Localized AI processing
- Hybrid computing model
- Connected-device solutions
- Smart manufacturing connectivity
- On-device intelligence

Automation and optimization

- Continuous delivery (DevSecOps)
- Network management automation
- Machine learning operations (MLOps)
- Cross-functional process integration (XOps)
- Smart infrastructure

Figure 18: Cognitive cloud convergence — underlying concepts and supporting trends

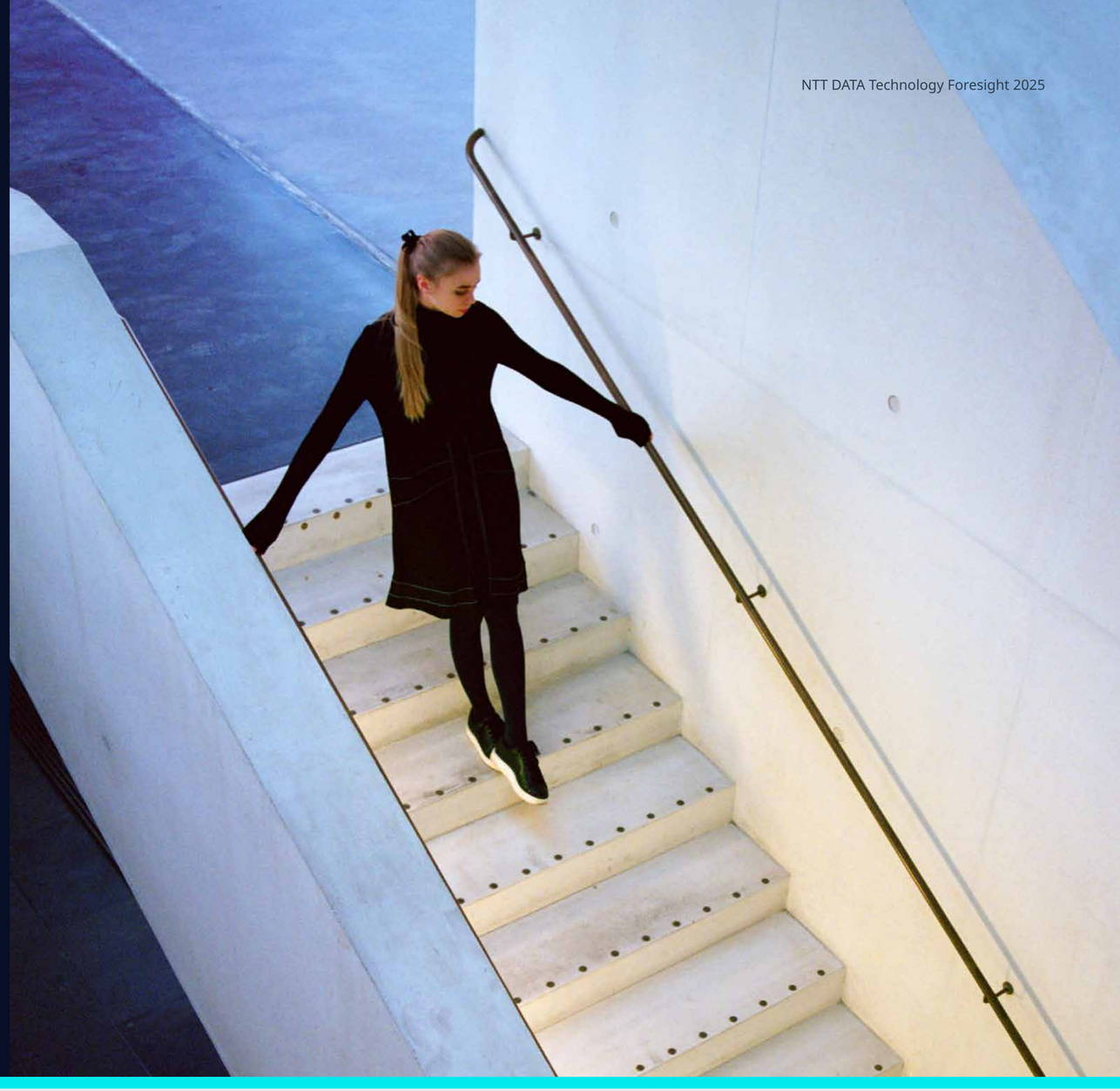
Underlying concepts

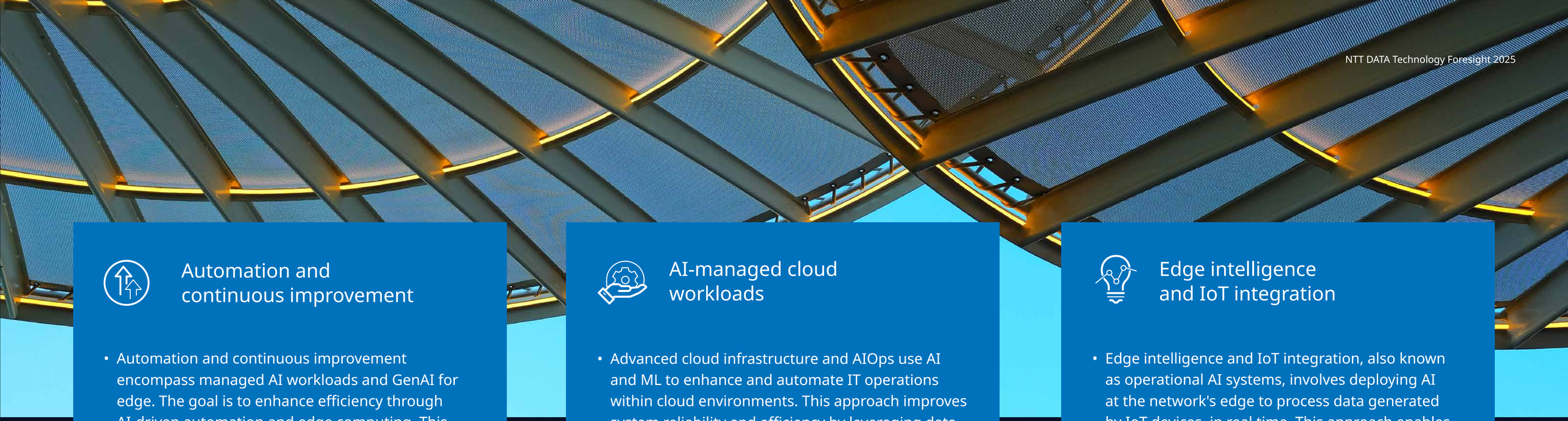
Cloud and AI convergence

Cloud and AI convergence represents a transformative shift in which cloud computing and AI integrate to create intelligent, scalable solutions. This convergence enhances decision-making, accelerates innovation and streamlines operations through advanced analytics and automation.

A key development is the integration of infrastructure for traditional transactional and AI workloads, enabling streamlined operations and improved efficiency for AI applications.

> “GenAI in cloud services, AI-augmented software engineering and operational AI systems act as transformation enablers, giving organizations a competitive edge in an evolving digital economy.





Automation and continuous improvement

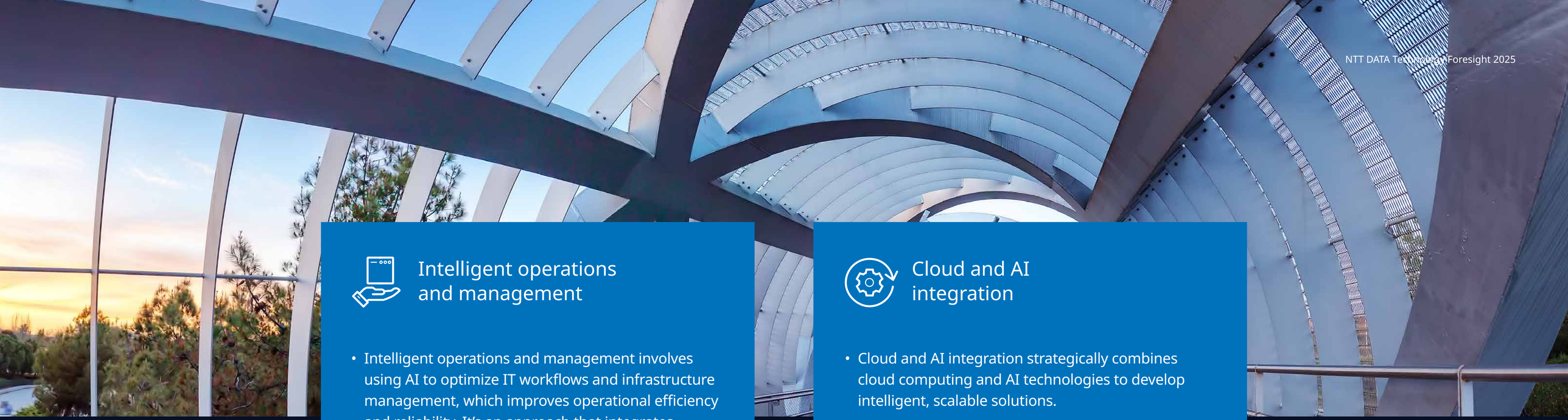
- Automation and continuous improvement encompass managed AI workloads and GenAI for edge. The goal is to enhance efficiency through AI-driven automation and edge computing. This approach streamlines operations and continuously refines AI models.
- For example, manufacturers can leverage locally managed AI workloads to predict equipment failures, while GenAI for edge enables real-time quality control. These technologies help organizations boost productivity and reduce downtime, leading to cost savings and improved competitiveness.

AI-managed cloud workloads

- Advanced cloud infrastructure and AIOps use AI and ML to enhance and automate IT operations within cloud environments. This approach improves system reliability and efficiency by leveraging data analytics for predictive insights.
- For example, cloud providers like Amazon Web Services (AWS) offer AIOps tools that automatically identify and resolve infrastructure issues, minimizing downtime. These technologies help organizations optimize resource allocation and reduce operational costs, leading to improved customer satisfaction.

Edge intelligence and IoT integration

- Edge intelligence and IoT integration, also known as operational AI systems, involves deploying AI at the network's edge to process data generated by IoT devices, in real time. This approach enables faster decision-making and reduced latency, making it ideal for applications that require immediate responses.
- For example, smart-home devices like Amazon Echo use edge AI to process voice commands locally, resulting in faster responses and greater privacy. They give customers a more responsive and secure smart-home experience while protecting the privacy of their personal data.



Intelligent operations and management

- Intelligent operations and management involves using AI to optimize IT workflows and infrastructure management, which improves operational efficiency and reliability. It's an approach that integrates advanced analytics and automation into the lifecycle of IT systems, enabling proactive monitoring, anomaly detection and predictive maintenance.
- AI-powered tools, such as intelligent assistants, streamline processes by automating repetitive tasks like system configuration, incident resolution and performance tuning. These capabilities reduce downtime, minimize human error and ensure smoother operations, allowing organizations to focus on innovation and strategic goals.

Cloud and AI integration

- Cloud and AI integration strategically combines cloud computing and AI technologies to develop intelligent, scalable solutions.
- This integration allows organizations to draw on extensive computational resources and analytical capabilities to support better data processing, decision-making and innovation, across industries.
- Streaming services like Netflix use these technologies to deliver personalized content recommendations by analyzing user data stored in the cloud. Tailored suggestions keep viewers engaged and improve customer retention.

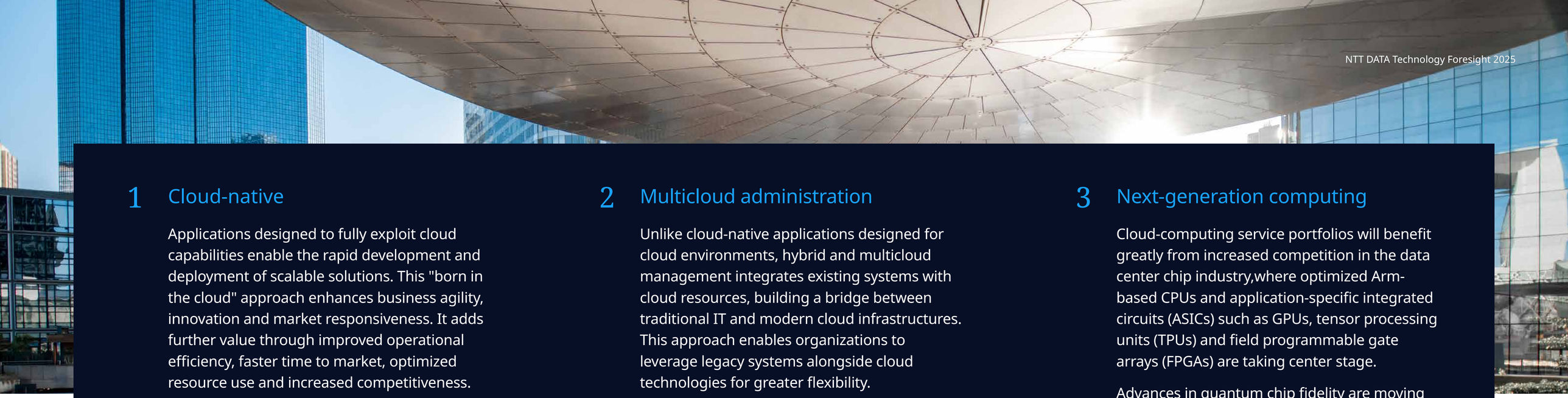
Underlying concepts

Advanced cloud infrastructure

As they explore advances in cloud infrastructure, organizations must prioritize:

- **Governance** for compliance and risk management
- **Cost optimization** for resource efficiency
- **Operational agility** for scalability
- **Business continuity** to minimize downtime
- **Skills development** for an effective workforce
- **Vendor management** for enhanced service delivery
- **Robust security measures** for data protection

> “These elements are essential for aligning the use of cloud technology with strategic goals, fueling innovation, improving service quality and delivering better user experiences.



1 Cloud-native

Applications designed to fully exploit cloud capabilities enable the rapid development and deployment of scalable solutions. This "born in the cloud" approach enhances business agility, innovation and market responsiveness. It adds further value through improved operational efficiency, faster time to market, optimized resource use and increased competitiveness.

Companies like Netflix, Uber and Airbnb exemplify successful cloud-native adoption. By embracing this approach, they've achieved digital flexibility, scaled efficiently and rapidly adapted to market demands. And they’ve built and maintained a competitive edge through improved user experiences and quick product iterations.

2 Multicloud administration

Unlike cloud-native applications designed for cloud environments, hybrid and multicloud management integrates existing systems with cloud resources, building a bridge between traditional IT and modern cloud infrastructures. This approach enables organizations to leverage legacy systems alongside cloud technologies for greater flexibility.

Unified cloud management streamlines operations by centralizing and integrating management processes across different IT environments. It simplifies complexities, enhances visibility and maximizes the scalability and efficiency of cloud technologies.

3 Next-generation computing

Cloud-computing service portfolios will benefit greatly from increased competition in the data center chip industry,where optimized Arm-based CPUs and application-specific integrated circuits (ASICs) such as GPUs, tensor processing units (TPUs) and field programmable gate arrays (FPGAs) are taking center stage.

Advances in quantum chip fidelity are moving quantum computing out of the lab and into the business mainstream. This likely won’t be the result of increased hardware investments but rather the growing sophistication of cloud services environments where quantum and quantum-inspired chips offer users more application-specific options.

Organizations should continually monitor data center chip technologies, evaluate their potential and understandt he internal transformations required to benefit from them fully.

4 Serverless computing

This approach dynamically allocates resources to execute specific tasks, abstracting away the need for infrastructure management. This approach automatically scales with demand, processes data efficiently and charges based on usage, making it highly cost-effective.

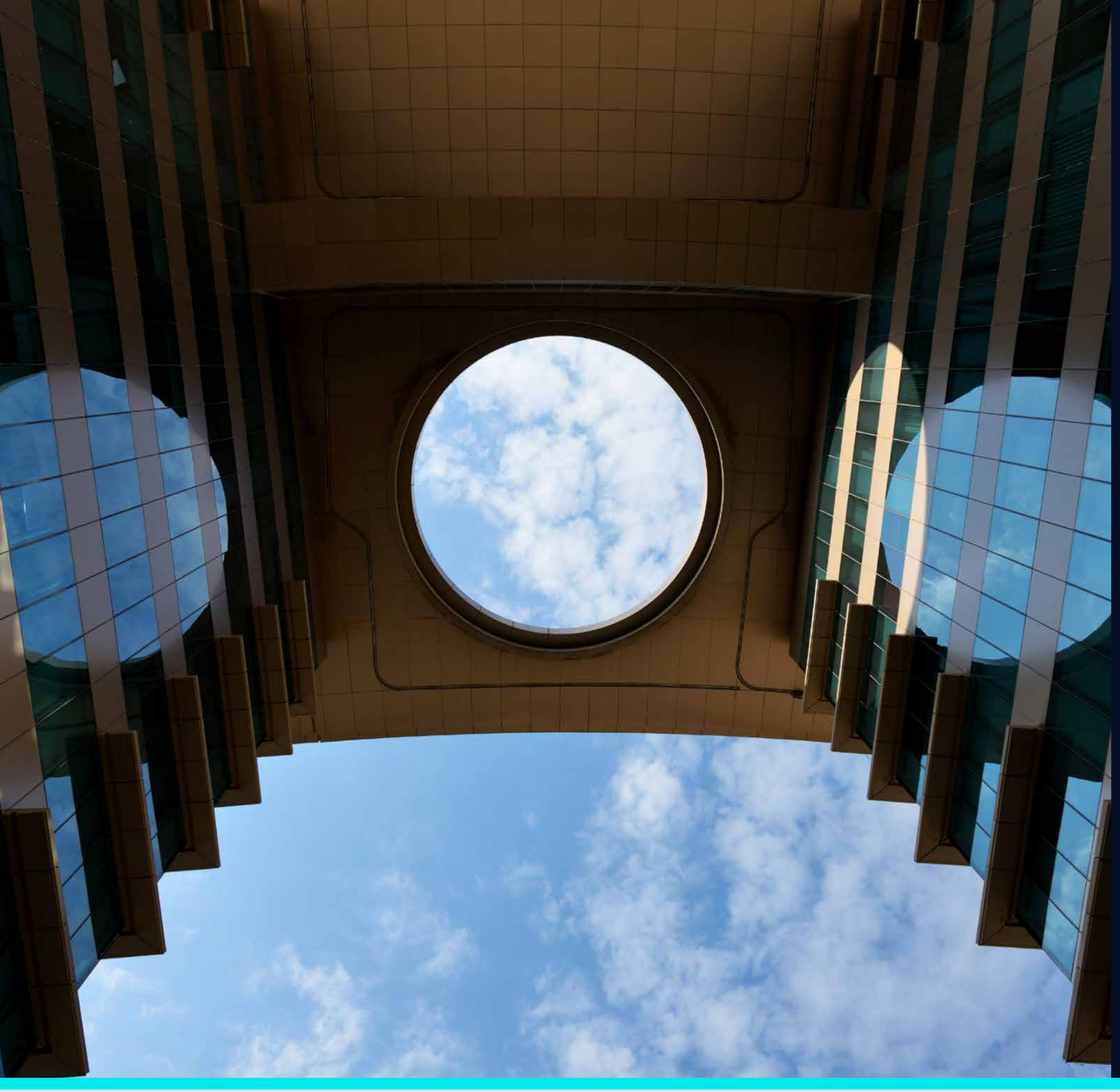
While it doesn't directly reduce latency (since processing still depends on the underlying infrastructure), its adaptability and efficiency make it ideal for applications requiring scalable and responsive systems.

For example, in healthcare, serverless computing enables the real-time processing of vital signs collected from wearable devices. Instantly analyzing and transmitting data gives healthcare providers timely updates, improves patient care, reduces emergency response times and drives better health outcomes.

5 Software-defined infrastructure

Programmable infrastructure refers to the provisioning and management of IT resources through software rather than manual configuration, allowing for greater automation and flexibility. This approach enables organizations to quickly adapt their infrastructure to changing needs and streamline operations.

Programmable infrastructure can significantly reduce deployment times, allowing organizations to implement changes in minutes instead of days, accelerating innovation and increasing responsiveness to market demands.



Underlying concepts

Edge technologies and IoT

Processing data near its source significantly reduces latency and enables real-time decision-making. For example, it enhances the performance of applications used in autonomous vehicles and smart cities, where immediate responses are crucial for functionality and user experience.

Programmable infrastructure enables dynamic resource allocation and automation, allowing organizations to adapt to changing demands and optimize performance quickly.

> “This flexibility is especially crucial in rapidly evolving environments, such as 5G networks, where traditional configurations would be inadequate.

On-device intelligence

- This trend focuses on deploying AI directly on edge devices, enabling real-time data processing and decision-making without relying on cloud connectivity. By reducing latency and bandwidth usage, on-device intelligence enhances performance across various applications, particularly healthcare and autonomous systems.
- Companies like NVIDIA enable real-time processing of data on devices like drones and cameras. Users can receive immediate insights and take action without relying on cloud connectivity.

Smart manufacturing connectivity

- Integrating IoT technologies into industrial settings enables smarter manufacturing processes through real-time monitoring and analytics. This connectivity improves operational efficiency, predictive maintenance and resource management, ultimately leading to cost savings and increased productivity.
- With IoT technology, manufacturers can monitor their equipment in real time and perform predictive maintenance. This reduces downtime and improves product quality.

Connected-device solutions

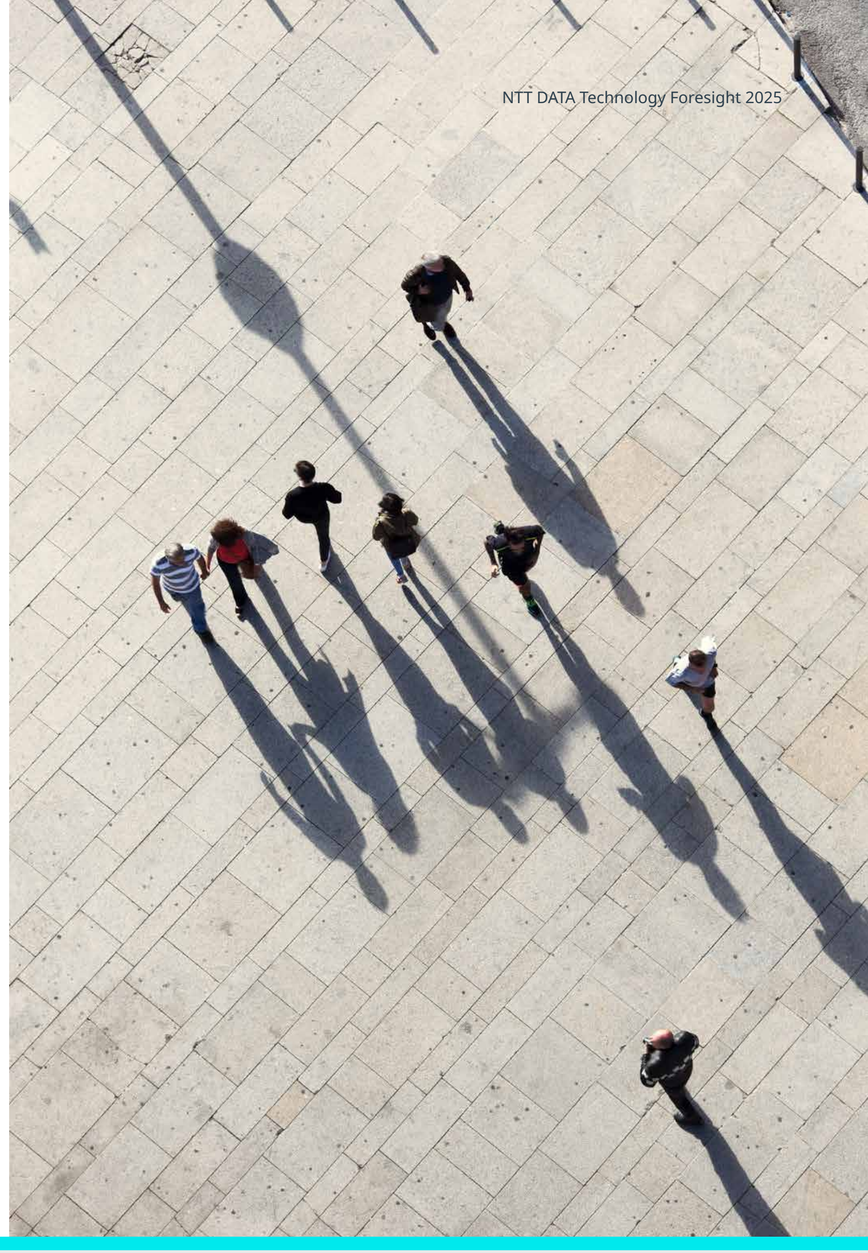
- These applications leverage IoT devices to enhance functionalities in everyday settings, such as smart homes and connected vehicles. They enable users to interact with their environments more intelligently, offering automation and improved user experiences through data-driven insights.
- Modern health devices like continuous glucose monitors (CGMs) and wearables such as the Oura Ring exemplify this integration. Both employ a three-tier architecture: a device collects real-time data, a smartphone app displays and analyzes this information, and cloud services provide advanced insights and long-term trend analysis. This seamless system empowers users to monitor their health, receive actionable recommendations and share data with healthcare providers. The results include more proactive care and healthier lifestyles.

Hybrid computing model

- Edge-to-cloud combines the benefits of edge computing with cloud capabilities, allowing for a hybrid model where data is processed locally at the edge before being sent to the cloud for further analysis or storage. It optimizes resource use, improves security and provides scalability for businesses.
- In the healthcare industry, processing sensitive patient data locally while using cloud capabilities enhances security and compliance, ensuring better protection of personal health information.

Localized AI processing

- The shift of AI workloads from centralized cloud systems to localized environments, such as micro data centers or on-device processing, enables faster response times and improved privacy. This trend supports the growing demand for efficient data handling in applications that require immediate feedback, such as autonomous vehicles and smart manufacturing systems.
- For example, Tesla uses localized AI processing in its vehicles for features like autopilot, enabling quick decision-making for safety and efficiency while driving, which improves the overall user experience.



Underlying concepts

Automation and optimization

When discussing process improvement, it’s essential to consider the impact on operational efficiency, cost reduction and employee satisfaction. Streamlining processes enhances productivity and allows teams to focus on higher-value tasks, ultimately driving innovation and improving overall business performance.

The trends and technologies we cover in this section collectively enable organizations to streamline processes, minimize human error and adapt quickly to market demands.

> “ This helps them unlock opportunities for innovation and maintain a competitive edge in an increasingly digital landscape.

Continuous delivery or development, security and operations (DevSecOps)

- This process describes the seamless integration and delivery of software updates that allow teams to release new features and fixes rapidly. By automating testing and deployment, organizations can respond to user feedback faster, which enhances customer satisfaction.
- Security is integrated throughout the development lifecycle, ensuring the appropriate measures are implemented early and continuously. This reduces vulnerabilities and builds trust in the software.
- With frequent software updates, organizations can respond to customers' feedback faster and increase their satisfaction and loyalty by continuously improving their experiences.

Network management automation

- As organizations adopt hybrid and multicloud environments, network topologies become increasingly complex, necessitating more sophisticated management strategies. Streamlining the configuration and oversight of network devices improves efficiency and reduces operational costs. This approach also minimizes human error and ensures consistent network performance.
- By automating network configurations, organizations can further decrease operational expenses and bolster service reliability, enhancing customer satisfaction and trust.

Machine learning operations (MLOps)

- Establishing a framework for managing ML models facilitates smoother collaboration between data scientists and IT operations teams. This integration allows businesses to deploy models faster and ensure they remain effective over time, ultimately improving decision-making processes.
- By establishing efficient management frameworks for ML, organizations can leverage data insights more effectively and create personalized experiences that boost customer engagement and retention.

Cross-functional operations (XOps)

- This approach fosters collaboration across various departments, breaks down silos and enhances communication. By aligning operations, development and support teams, organizations can become more agile and responsive to market changes.
- Players in the automotive industry are implementing collaborative platforms that enable design, engineering and production teams to work together seamlessly, resulting in faster product development cycles and improved vehicle quality.

Smart infrastructure

- Implementing intelligent systems improves resource utilization and operational efficiency by leveraging data analytics for proactive management. This capability lowers costs, improves service delivery and benefits users through enhanced reliability and performance.
- In the building management sector, firms that adopt intelligent infrastructure solutions can achieve significant energy savings and operational efficiencies. This helps them meet sustainability goals and improve tenant comfort and safety.

Tech radar

Tech radar

In the constantly changing tech landscape, keeping up with the latest developments is essential, not just advantageous.

Continually analyzing technology trends and tracking their evolution will help you anticipate changes and prepare yourself for upcoming shifts.

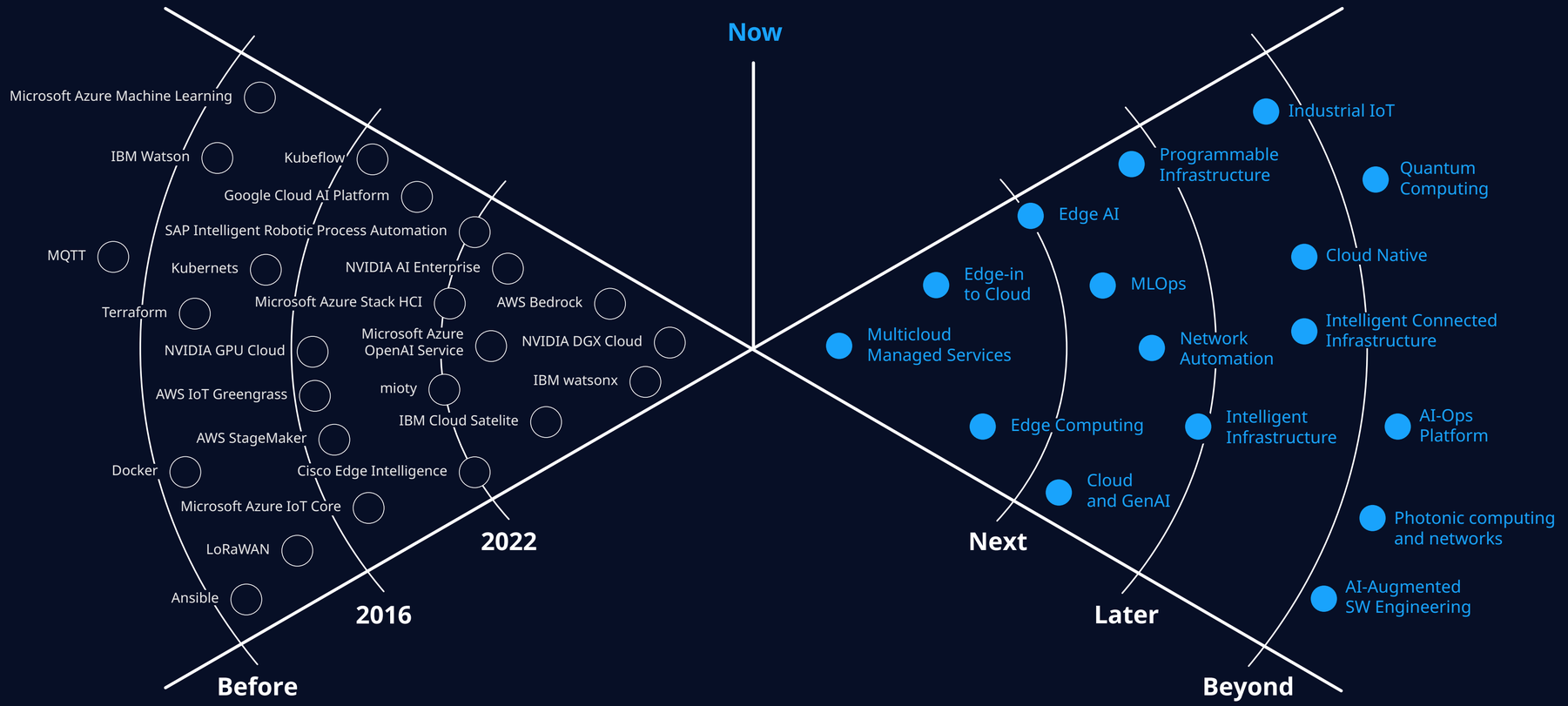


Figure 19: Tech radar — past and future technology

Future tech: now and next

A **Multicloud managed services**
A centralized platform manages resources from multiple cloud providers, integrating and governing them for better control and reduced complexity. This enables the unified management of public and private cloud resources, simplifies provisioning, orchestration and monitoring, and enhances database security across different cloud providers by managing access, tracking interactions, detecting vulnerabilities and addressing security and compliance requirements.

B **Edge-to-cloud**
This architecture is designed to enable edge systems to function independently from the cloud but still connect to it when needed. It prioritizes functionality at the edge, allowing for flexible deployment and responsiveness even if cloud connectivity is temporarily unavailable.

C **Edge computing**
Edge computing places data processing and storage closer to where data is generated, minimizing the need to send information to centralized data centers. This approach reduces latency and bandwidth usage, offering a practical solution for applications that require real-time responses, such as IoT deployments.

D **Edge AI**
Edge AI brings AI capabilities closer to the user in devices such as IoT devices and gateways. Local data-processing reduces latency and improves real-time responsiveness, making edge AI suitable for applications like autonomous vehicles and smart devices.

E **Cloud and GenAI**
GenAI in the cloud draws on the scalability and flexibility of cloud infrastructure to create new content, designs and strategies based on existing data. This supports innovation across various sectors, enhancing automation, content creation and complex problem-solving processes.

F **MLOps**
MLOps manages the lifecycle of ML models, including model deployment, monitoring and updates. Maintaining model performance and ensuring compliance makes ML applications easier to operate at scale.

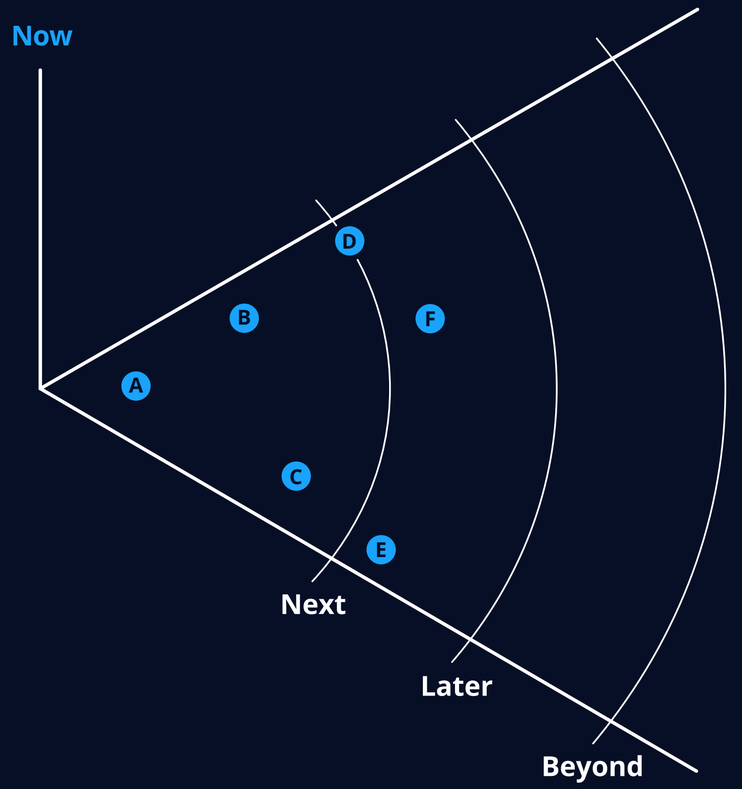


Figure 21a: Tech radar — future technology

Future tech: next and later

G **Programmable infrastructure**
Programmable infrastructure applies principles from software development to IT infrastructure, allowing for greater agility and resilience. APIs and automated processes enable the flexible and responsive management of resources and align infrastructure with modern application needs.

H **Network automation**
Network automation tools handle the setup, management and maintenance of network devices, reducing the need for manual intervention. By automating tasks like configuration, troubleshooting and reporting, these tools help improve network efficiency and reliability.

I **Intelligent infrastructure**
Intelligent infrastructure integrates AI and ML to manage resources dynamically. This approach optimizes the configuration of infrastructure components, making them adaptive and efficient. It's particularly valuable for supporting applications in complex, cloud-based environments.

J **Industrial IoT**
Industrial IoT, a specialized segment within IoT, enhances decision-making and boosts organizations' ability to monitor and control assets and infrastructure in industries like manufacturing, logistics and utilities. It integrates connected devices to improve operational visibility and efficiency in environments where managing physical assets closely is crucial.

K **Cloud-native**
Cloud-native refers to applications and services designed to capitalize on the flexibility and scalability of cloud technology. These solutions are dynamic, scalable and resilient and offer efficient, on-demand resources metered by usage and accessible through internet-based technologies.

L **Intelligent connected infrastructure**
This infrastructure setup connects various technologies to enable seamless data exchange between the systems, people and devices in an ecosystem. It's especially relevant in industries like transportation, where data flow among vehicles, equipment and technicians is essential for smooth operations.

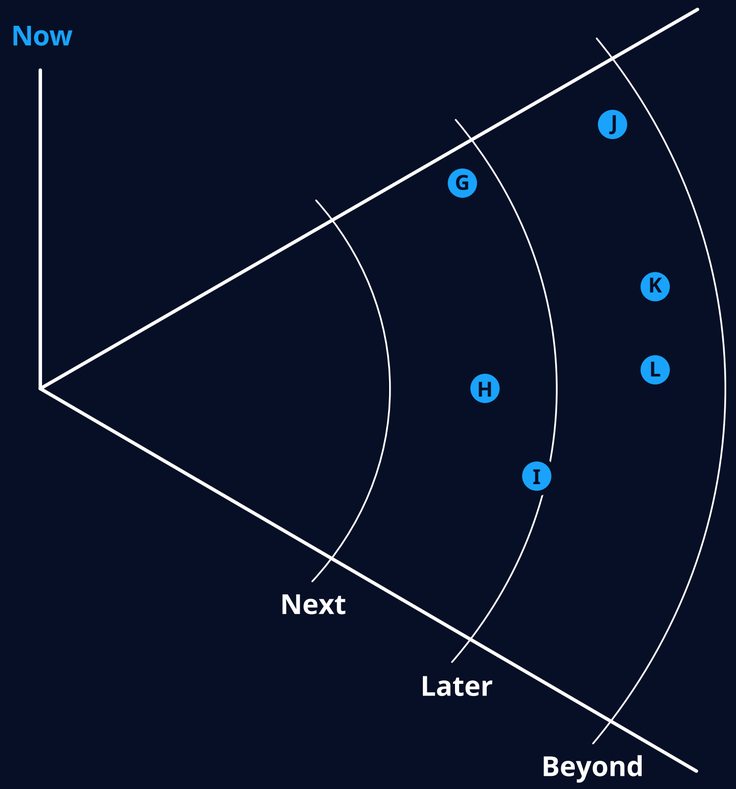


Figure 21b: Tech radar — future technology

Future tech: beyond

M **Quantum computing**

Quantum computing applies the principles of quantum mechanics to perform computations at unprecedented speeds, solving complex problems infeasible for classical computers. This revolutionary technology uses qubits, which can represent multiple states simultaneously through superposition and entanglement, allowing for massive parallelism and faster problem-solving capabilities.

N **AIOps platforms**

AIOps platforms apply AI to streamline IT operations by analyzing telemetry data across multiple sources. They identify patterns, predict issues and suggest possible fixes, ultimately enhancing automation and reducing the workload associated with incident management.

O **Photonic computing and networks**

Photonic computing uses light to process data, enabling faster speeds and lower energy consumption than traditional electronic computing. This approach leverages photons' high bandwidth and fast transmission capabilities, resulting in reduced latency and improved performance. Photonic networks enhance data transmission and routing, benefiting areas such as AI, big data analytics and high-performance computing.

P **AI-augmented software engineering (AIASE)**

AIASE uses AI technologies like ML and NLP to help software teams create applications faster, with less effort and with higher quality.

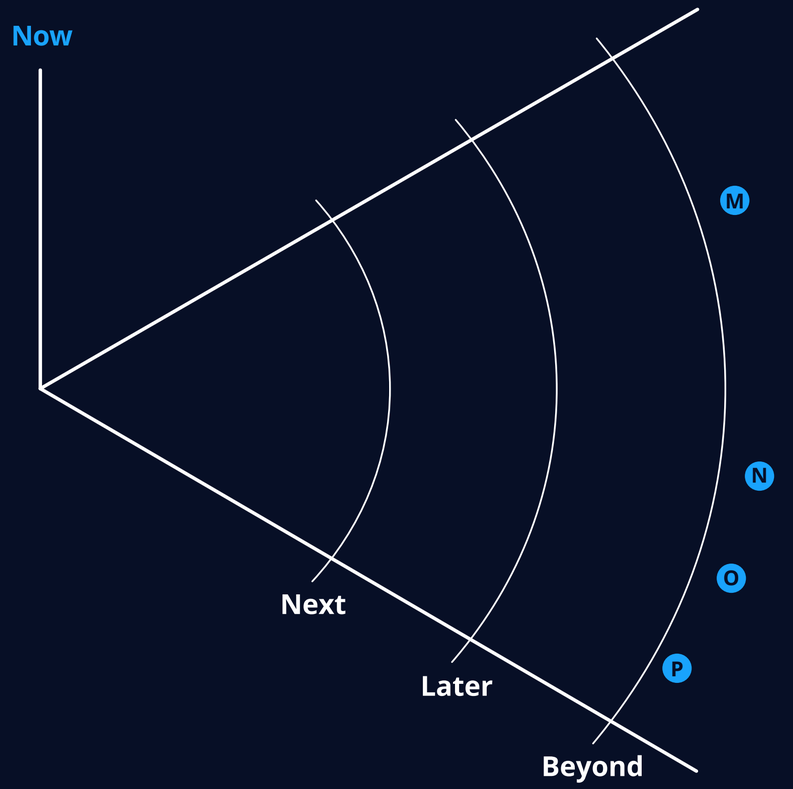
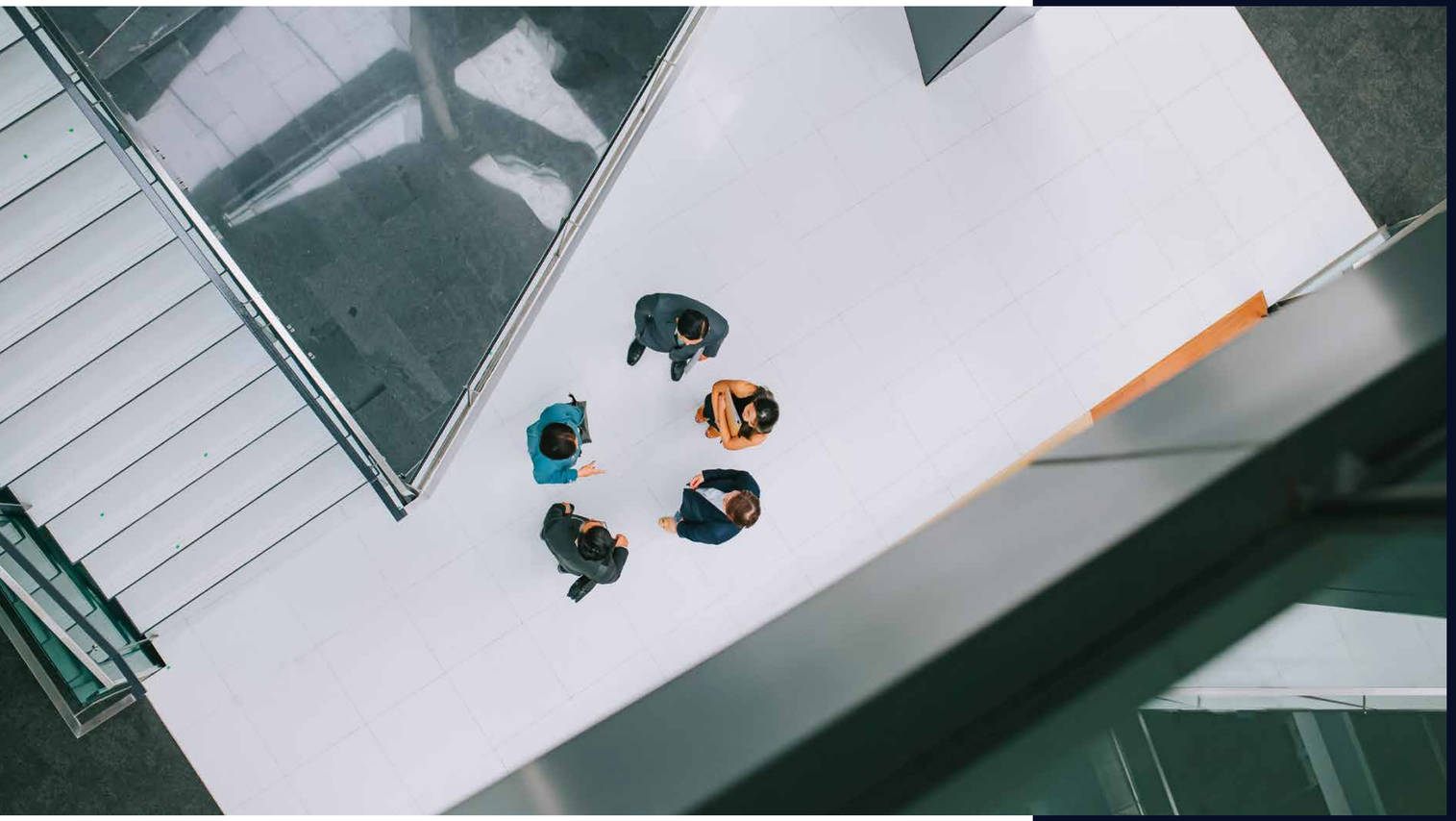


Figure 21c: Tech radar — future technology

R&D highlight



R&D highlight

Space Integrated Computing Network

NTT and SKY Perfect JSAT lead the Space Integrated Computing Network (SICN) through their joint venture, Space Compass.

This initiative aims to develop a sustainable, efficient space-based communications infrastructure to ease the strain on current terrestrial networks and mitigate risks posed by natural disasters and failures.

Using Innovative Optical and Wireless Network (IOWN) technology, the SICN plans to create high-speed optical wireless communication networks in space, supported by stratospheric cellular networks. This facility is designed to advance beyond 5G/6G mobile networks, using high-altitude platform stations and low Earth orbit satellites for real-time data collection and analysis.

The SICN will establish space-based data centers to speed the transmission and processing of imagery and environmental data. Geostationary satellites will reduce latency and improve by tracking of extreme weather events. Combining IoT sensors on Earth with optical data relays in space will enable rapid data analysis for multiple applications.

Innovations in optical technology will dramatically improve data communication speeds while significantly reducing energy consumption by using solar power for operations. The SICN aims to eliminate network interruptions and extend mobile coverage to remote areas. Initial trials began in 2023, with end-to-end implementation planned for 2025, ushering in a new era of sustainable and resilient telecommunications.

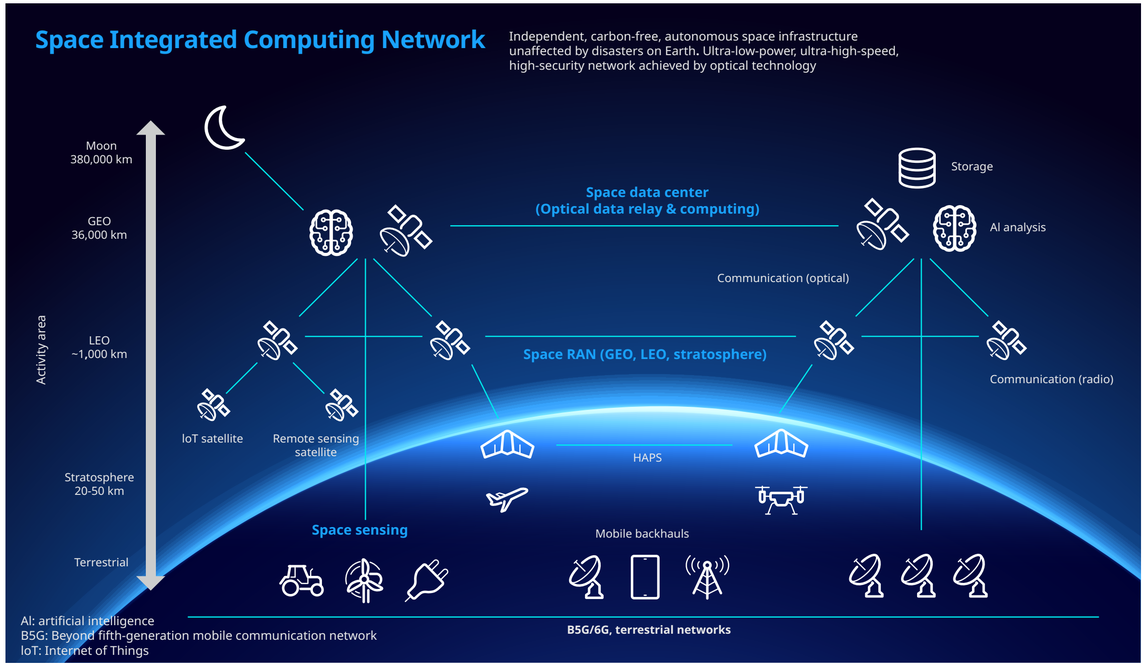
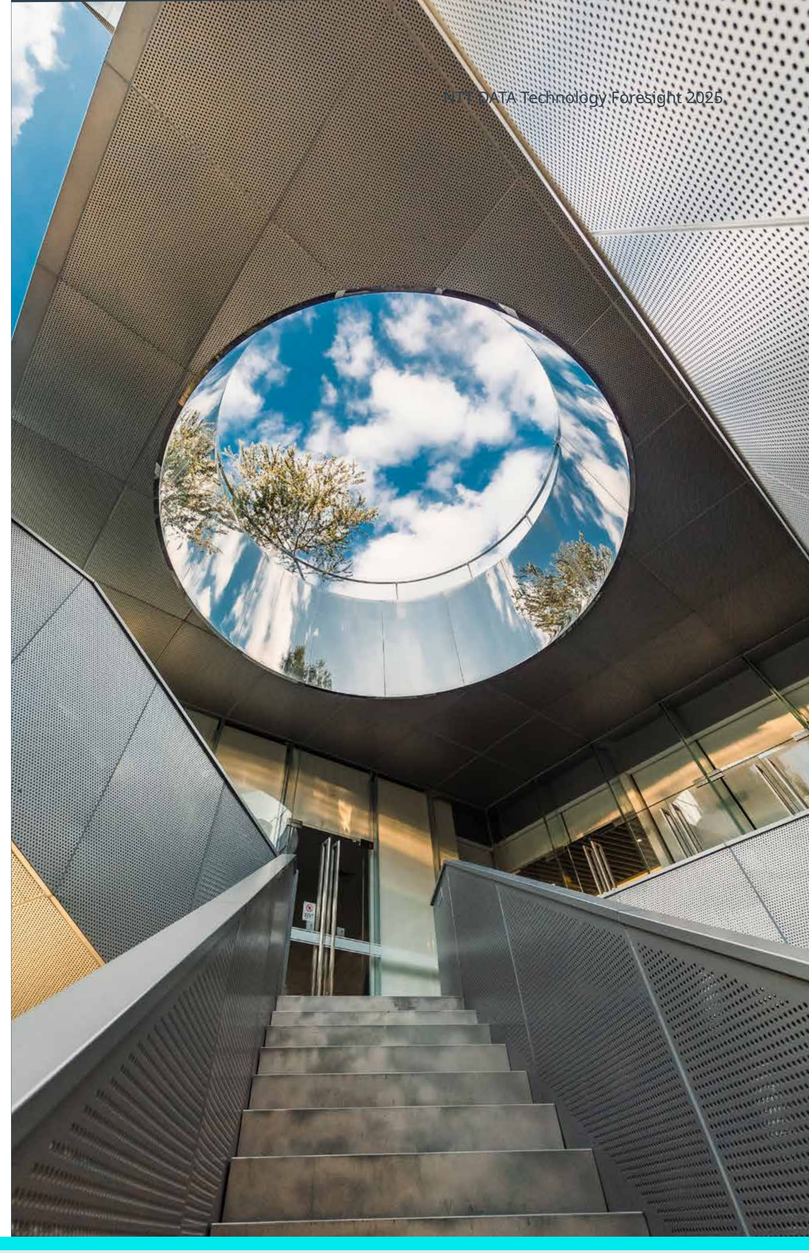


Figure 22: Space Integrated Computing Network

Adapted from: *NTT Technical Review* Vol. 20 No. 12 Dec. 2022



Quantification

Relevant financials

Cognitive cloud convergence market

Market size, 2024:

$70.5 billion

Market size growth, 2023–2024 (YoY):

+23%

Forecast CAGR, 2024–2030:

22.4%

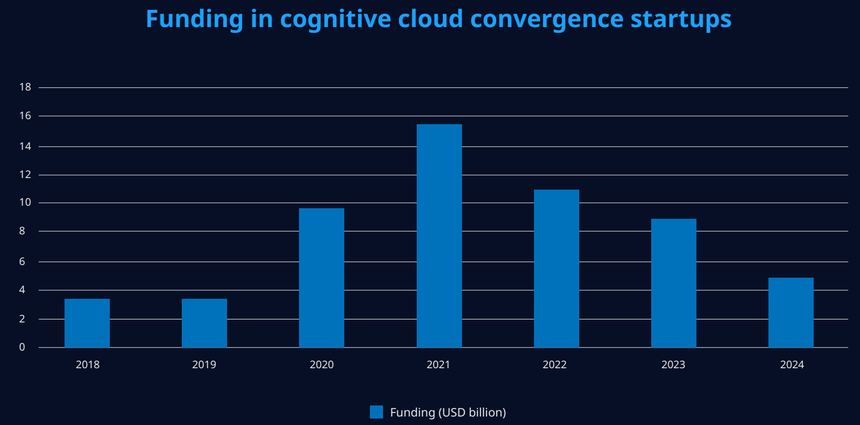


Figure 23: Funding in cognitive cloud convergence startups

> The number of large organizations with a multicloud strategy rose from 76% to 85% during 2024.

Key projections and impacts

In 2024

55%

of workloads operated within data centers, while **45% operated within clouds.**

By 2025

75%

of enterprise-generated data is expected to be created and processed outside a traditional centralized data center or cloud.

Cloud computing sales are forecast to reach **$2 trillion by 2030,** with generative AI accounting for about

10% to 15%

of this spending.

AI platforms in the platform-as-a-service (PaaS) category are projected to experience the fastest growth with a five-year CAGR of

51.1%

Over the next five years, AI lifecycle workloads are expected to grow at an

18.8%

CAGR, making them one of the fastest-growing workload categories.

Edge AI helps smart-grid energy-management agencies reduce energy losses by

25%,

according to the International Energy Agency.

Research and development

7,000*

Patents registered 2023

*Approximate figures

Use cases

Smart agriculture

Industry: **Agriculture**

Precision agriculture is a leading solution for achieving higher crop yields while reducing chemical usage. Unlike traditional, reactive methods that rely on generalized, experience-based practices, precision agriculture uses data-driven approaches to optimize each step in crop management.

Business value

1 Enhanced operations through seamless monitoring and complete lifecycle management of various crop inputs, such as fertilizers and pesticides, by fully automated, cost-effective systems

> “Cloud-enabled precision farming boosts crop yields while minimizing chemical use, delivering sustainable food production.

Digital immune systems for supply chains

Industry: **Cross-industry; manufacturing**

A consortium of manufacturers, logistics providers and retailers are implementing a digital immune system to enhance the resilience and stability of their interconnected supply chain networks, enabling real-time threat detection, automated recovery from disruptions and continuous optimization of operations across industries.

Business value

1 Operational excellence by improving product availability and delivery reliability for customers while lowering operational costs for businesses

2 Risk mitigation by reducing the impact of supply chain disruptions to ensure business continuity and customer trust

Quantum-powered drug discovery

Industry: **Pharmaceuticals**

Pharmaceutical companies and materials scientists are collaborating to use cloud-based quantum computing to simulate complex molecular interactions, accelerating drug discovery and optimizing new materials without investing in expensive quantum hardware.

Business value

1. Cost-efficiency by accessing quantum capabilities without significant upfront investment, reducing financial barriers to innovation
2. Accelerated R&D with quantum algorithms, potentially leading to faster breakthroughs in drug development and materials science

> “Cloud-based quantum simulations accelerate drug development, reducing costs and enhancing patient outcomes.

AI-powered network optimization

Industry: **Telecommunications**

A telecom provider is implementing AI to optimize network operations and enhance the user experience. The system automates management tasks, predicts outages and dynamically adjusts radio access operations based on real-time data.

Business value

1. Reduction in manual network-management tasks through AI-driven automation
2. Decrease in customer-reported issues due to improved network reliability

Smart cities

Industry: **Public sector; energy and utilities**

To enhance citizens' safety, cities are using real-time data from closed-circuit television (CCTV) and sensors (for example, noise, pollution and temperature readings) to monitor city activity, analyze demand changes, identify emergencies and generate insights (such as linking traffic with pollution). Sensors may be stationary or mobile (for example, on public transport).

Business value

1. Edge processing reduces latency and operating costs by eliminating the need to stream all video to a central cloud
2. The cognitive cloud autonomously manages the edge-to-cloud infrastructure, improving citizen services while minimizing waste in energy, processing capacity and resources

> "Cloud-integrated retail systems enhance customer satisfaction with frictionless self-checkout and 24x7 operations.

Autonomous retail

Industry: **Retail**

An advanced autonomous retail platform integrates cognitive cloud capabilities and AI, enabling frictionless self-checkout experiences in convenience stores, stadiums and universities. The solution offers modular standalone retail units for rapid deployment, and embedded systems for existing store layouts, revolutionizing retail operations.

Business value

1. Lower labor costs through automated inventory management and checkout processes
2. Ability to increase stores' hours of operation
3. Increase in customer satisfaction and transaction volumes thanks to self-checkout and AI-driven personalization

Smart grids for energy efficiency

Industry: **Public sector; energy and utilities**

AI-driven cloud and IoT technologies, coupled with drone inspections, monitor energy assets like wind turbines and solar panels. This system uses predictive analytics to optimize energy distribution and employs intelligent grid technology to regulate supply based on real-time demand, improving efficiency and informing customers of energy-saving opportunities.

Business value

1. Reduced energy waste, thanks to predictive analytics and intelligent grid management
2. Lower operational costs for providers
3. Reduced energy bills for consumers

> “Cloud-powered energy grids optimize supply and lower bills, creating a more efficient and consumer-focused energy future.

Cloud-based AI for financial security

Industry: **Financial services**

A global bank implemented a multicloud strategy, migrating 75% of its data to the cloud to support AI-driven fraud detection and risk assessment. This approach leverages public and private cloud systems, enabling the real-time analysis of transaction patterns across multiple channels. The bank deployed ML algorithms to detect and prevent fraudulent activities swiftly, improving security and operational agility.

Business value

1. Reduction in fraud losses, which has improved customer trust
2. Optimized capacity, streamlined operations and reduced risk of vendor lock-in

Use cases

Success case

Europe | Cross-industry

Machine learning systems operations (MLSysOps) for autonomic system management

Business need

Modern industries, especially in the smart cities and agriculture sectors, increasingly rely on distributed edge-to-cloud infrastructure to manage data-intensive applications that demand low latency, high resilience and high energy efficiency. As cloud infrastructure expands to integrate deep-edge resources, there's a pressing need for autonomous adaptive systems that manage resources dynamically and seamlessly across cloud and edge layers.

Businesses often face challenges in achieving efficient orchestration, securing trusted data flow, managing power consumption and ensuring resilience to network imperfections. Moreover, they need open, extensible systems to integrate new ML models as technology advances. Addressing these challenges requires a robust, AI-driven approach that improves application performance, minimizes operational costs and supports sustainable practices.

Solution

MLSysOps provides a complete AI-controlled framework for autonomic system management across the edge-to-cloud continuum.

Using a hierarchical, agent-based AI architecture, the framework enables intelligent orchestration, adaptive resource allocation and low-latency performance, improving security and energy efficiency. It dynamically learns and updates configurations with continual ML training, supported by explainable AI and an API for integrating new models.

Designed with container-based portability, MLSysOps ensures flexible deployment on heterogeneous nodes and infrastructure. Validated through testbeds in smart-city and agriculture applications, this solution offers resilient, adaptable and scalable edge-to-cloud operations that align with evolving technological and sustainability demands, bridging current infrastructure with future-ready AI advancements.

Outcomes

The MLSysOps concept has been submitted to the European Union by an industrial and academic consortium promoted by NTT DATA. The idea has been accepted and granted with with full multiyear funding by the European Union. MLSysOps will demonstrate its efficacy through two well-defined use cases in precision agriculture and smart cities, using cloud, smart and deep-edge infrastructures. The use cases correspond to dynamic, impactful applications with heterogeneous demands.

Startups

Startup radar

In this section, we review a selection of startups relevant to cognitive cloud convergence, based on our observations, partnerships and investments.

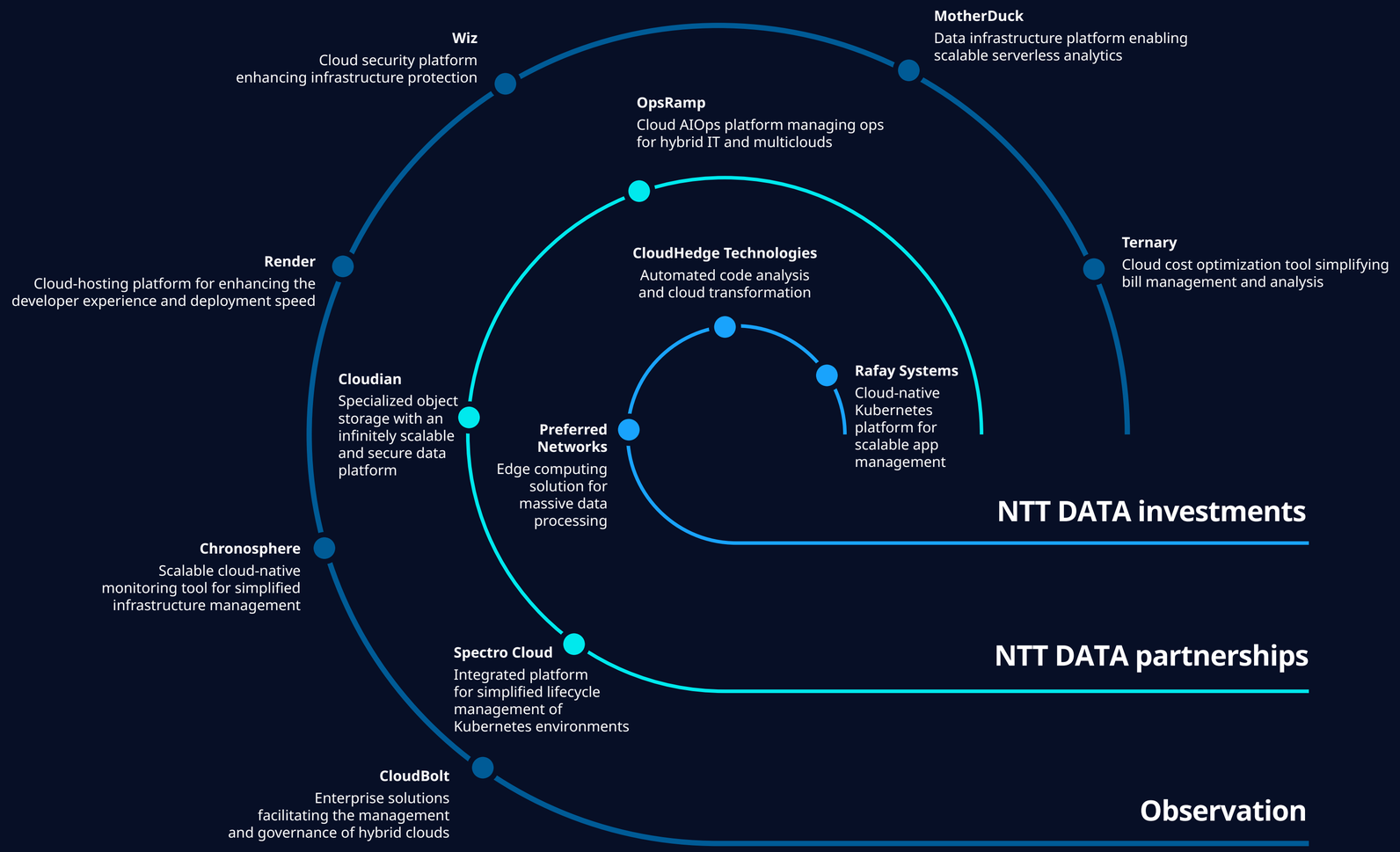


Figure 24: Investment in cognitive cloud convergence startups

Startups

Observation

CloudBolt

Founded in 2012, CloudBolt provides solutions to help organizations manage and govern their hybrid cloud environments and optimize their automation strategy. With CloudBolt, they can configure and manage private and public cloud resources — quickly, securely and cost-effectively — while empowering DevOps and end-users with self-service provisioning environments.

Stage
Series B

Funding
$61.6 million

Valuation
Not disclosed

Industry
Cross-industry

Chronosphere

Founded in 2019, Chronosphere has developed a scalable cloud-native monitoring tool designed to eliminate the cognitive load associated with monitoring infrastructure and tracking data locally. The tool analyzes the health of infrastructure, applications and businesses in a single place and solves complex issues by following them through the different layers of the stack, enabling organizations to operate reliably at scale and make precise, data-driven decisions.

Stage
Series C

Funding
$350 million

Valuation
$1.6 billion

Industry
Cross-industry

Render

Founded in 2018, Render operates a cloud-hosting platform designed to improve the developer experience. Its platform builds and runs all applications and websites with a free secure sockets layer (SSL) and a global content delivery network (CDN). Auto-deployment enables software teams to ship products quickly and at any scale by reducing complexity and cost.

Stage
Series B

Funding
$76 million

Valuation
Not disclosed

Industry
Cross-industry

Wiz

Founded in 2020, Wiz has developed a cloud-security platform to help organizations secure their infrastructure at scale. The platform provides cloud-visibility services for enterprise security, giving an overview of security risks across clouds, containers and workloads without the need for agents or sidecars. As a result, organizations can identify vulnerabilities, misconfigurations and network exposures, manage identities and privileges, and discover exposed data.

Stage
Series D

Funding
$2 billion

Valuation (approximate)
$10 billion

Industry
Cross-industry

MotherDuck

Founded in 2022, MotherDuck has developed a data infrastructure and serverless data analytics platform designed to scale systems into the cloud with hybrid execution. The platform uses an embedded database to analyze big data and build infrastructure for large and small data prototyping with local and remote data. This allows businesses to analyze their data and maximize profits in an integrated and collaborative environment.

Stage
Series B

Funding
$100 million

Valuation
$400 million

Industry
Cross-industry

Ternary

Founded in 2020, Ternary has developed a tool for cloud-cost optimization that's designed to reduce the complexity of cloud economics. The tool makes costs visible, ensures the optimal use of data, encourages collaboration and accountability, surfaces new data and optimizes expenditure in real time. As a result, clients can maximize every cloud dollar spent and easily monitor, prioritize and track their expenses.

Stage
Series A

Funding
$18 million

Valuation
Not disclosed

Industry
Cross-industry

Startups

NTT DATA partnerships

Spectro Cloud

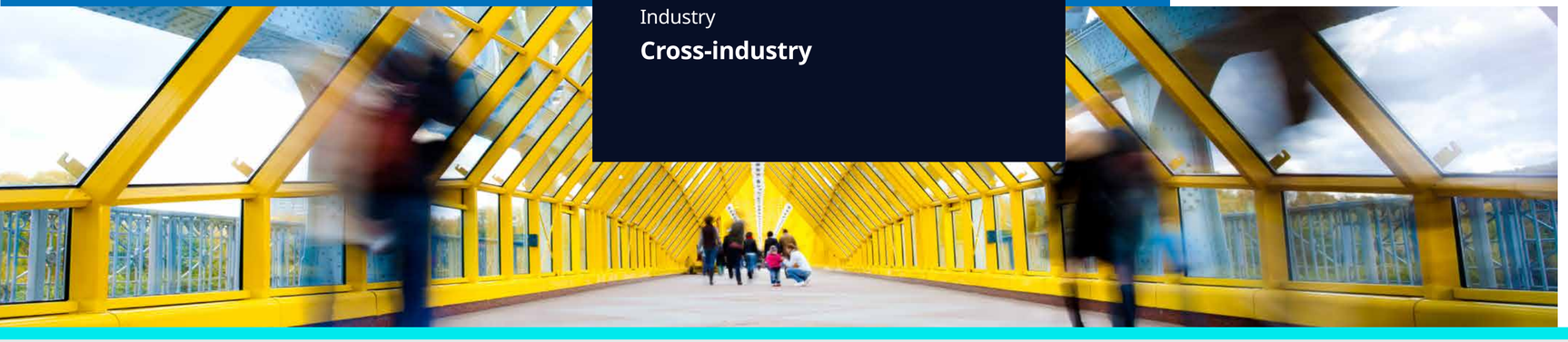
Founded in 2019, Spectro Cloud has developed an integrated platform that helps organizations easily manage the full lifecycle of any combination of new or existing, simple or complex, small or large Kubernetes environments, whether in a data center or the cloud.

Stage
Series B

Funding
$67.5 million

Valuation
Not disclosed

Industry
Cross-industry



Cloudian

Founded in 2011, Cloudian is a file and object storage company specializing in S3 object storage in the data center. It turns information into insight with an infinitely scalable platform that consolidates, manages and protects enterprise data.

Stage
Private equity

Funding
$280.1 million

Valuation
Not disclosed

Industry
Healthcare; financial services; public sector

OpsRamp

Founded in 2014, OpsRamp helps IT teams control the chaos of managing their hybrid IT operations so they can act as a service provider back to the business. Built in the cloud, the service-centric OpsRamp AIOps platform provides visibility across hybrid infrastructures. It also offers complete multicloud infrastructure monitoring and the management of business-critical services, and optimizes services through automation and integration with IT service management (ITSM) and DevOps tools.

Stage
Acquired

Funding
$57.5 million

Valuation
$300 million

Industry
Cross-industry

Startups

NTT DATA investments

CloudHedge Technologies

Founded in 2018, CloudHedge Technologies has developed a platform that analyzes code for cloud-readiness,, auto-classifies workloads and suggests the right approach for transformation. It also offers automated containerization and refactoring, application blueprinting and audit control, enabling clients to deploy, monitor, manage and share application blueprints within minutes without using custom automation scripts.

Stage
Corporate minority

Funding
Not disclosed

Valuation
Not disclosed

Industry
Cross-industry

Preferred Networks

Founded in 2014, Preferred Networks develops edge-heavy computing solutions for the distributed, collaborative processing of large data volumes generated by devices at the network edge. It aims to spark innovation in various fields, focusing on three major business areas: transportation systems, manufacturing and bio-healthcare.

Stage
Unknown

Funding
$165 million

Valuation
Not disclosed

Industry
Manufacturing; transportation; healthcare

Rafay Systems

Founded in 2017, Rafay Systems offers the industry's first cloud-based Kubernetes operations platform to help enterprises maximize the value of containerized applications. With Rafay's unified platform, teams can operate modern application infrastructure at scale across public clouds, data centers and the edge. End-to-end services help streamline the process of deploying clusters and apps across multiple environments, and deliver enterprise-grade control and governance to DevOps workflows.

Stage
Series B

Funding
$33 million

Valuation
Not disclosed

Industry
Cross-industry

Future scenarios

As industries transform, new value chains emerge and technological advancements grow exponentially, companies must navigate complex, evolving landscapes.

Future scenarios and GenAI-powered personas allow organizations to explore possible futures, simulate realistic business environments and minimize risk through scenario-based planning.

Uncertainties represent what we cannot know, but identifying them can reduce the risks of blind spots down the road.

Future scenarios

Uncertainty: data privacy and security

AI-driven trust ecosystem

What if giving users control over their data leads to new business models where users can actively participate in and even profit from data usage?

In the future, cognitive cloud providers will prioritize AI-powered, privacy-first frameworks that give users unprecedented control. This trust-driven ecosystem will enable secure, data-driven innovations in sensitive fields like healthcare and finance, fueling broad confidence and adoption.

Global data stewardship

What if regional data-privacy solutions become so effective and trusted that they inspire global standards, leading to unified regulations?

In response to diverse privacy concerns and fragmented regulations, region-specific solutions will build consumer trust locally while fostering resilience. Organizations will successfully adapt to shifting rules, strengthening connections with regional customers and setting the stage for a more unified global approach.

Future scenarios

Uncertainty: environmental impact and sustainability

A sustainable cognitive cloud revolution

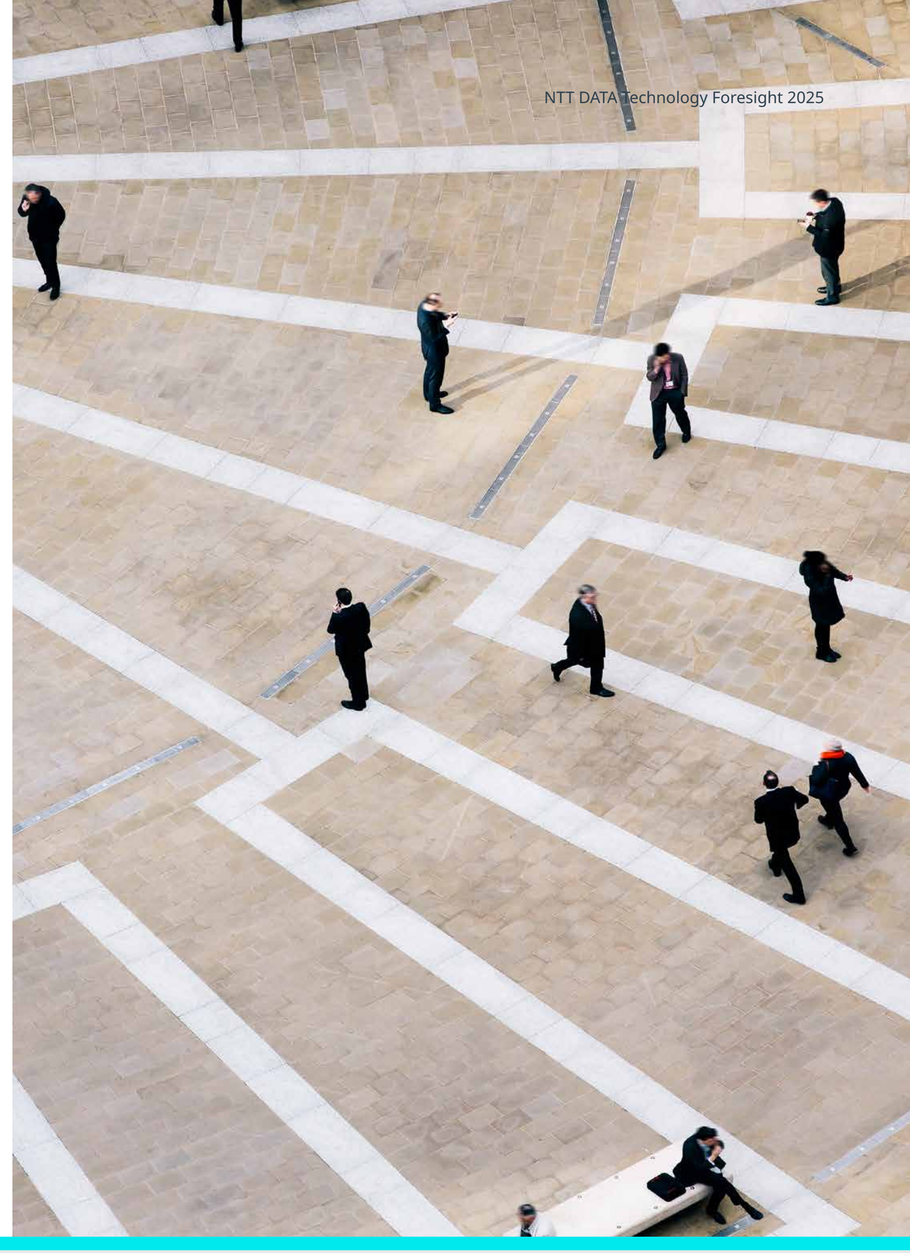
What if the cognitive cloud's commitment to eco-friendly practices sets new standards across the tech industry, giving eco-innovators a competitive edge?

Cognitive cloud providers are leading a shift toward sustainable, low-energy infrastructure powered by renewables. This commitment will attract environmentally conscious customers and investors, positioning certain organizations as leaders in responsible technology and creating momentum for a greener industry.

Regulatory pushback and eco-innovation

What if high compliance costs encourage partnerships between tech and environmental organizations, resulting in shared green technologies that benefit multiple sectors?

Rising regulatory demands will push cognitive cloud providers to develop innovative, resource-efficient solutions, such as self-regulating data centers. These eco-advances will not only enable compliance but also contribute to a more sustainable tech ecosystem, setting a positive example for other industries.



Conclusion and next steps

Conclusion and next steps

Think about this

As AI and cloud technologies merge, organizations can unlock powerful insights and adaptive services by embedding cloud–AI synergy into their core functions.

How effectively are you using this convergence to enhance data-driven decision-making?

Automation within cloud environments streamlines operations, minimizes manual tasks and optimizes resource allocation.

Which areas of your workflows could benefit most from automation to increase operational efficiency and free up resources for strategic initiatives?

Edge computing and IoT bring data processing closer to the source, reducing latency and improving security.

How prepared is your infrastructure to leverage edge capabilities for real-time responsiveness in critical processes?

Real-time analytics support proactive, agile decision-making and responsiveness to dynamic environments.

How is your organization embedding real-time data insights into its cloud strategy to drive timely and informed actions?

Conclusion and next steps

Do this next

5 minutes

Identify key business units

Identify one high-impact business unit where cloud–AI integration could enhance data-driven decision-making. Focus on areas requiring frequent, timely insights.

5 days

Assess edge and IoT infrastructure

Evaluate your current edge and IoT infrastructure to assess its readiness for rapid data processing, and identify key areas for improvement.

5 months

Launch an automation pilot

Set up a pilot project to automate repetitive cloud-based workflows. Track metrics like time savings, error reduction and resource efficiency to assess the project's impact and scalability.

Contact information

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Trend 5: Accelerated security fusion

Visualize a future where security becomes an invisible, adaptive force, always one step ahead.

Introduction

Accelerated security fusion is a pivotal approach to defending against increasingly complex and sophisticated threats.

By integrating advanced technologies such as threat intelligence, machine learning (ML) and advanced real-time analytics across multiple security domains, organizations can create a unified defense system that empowers them to identify vulnerabilities proactively, streamline response processes and strengthen their security posture across diverse operational environments.

Using capabilities like automated incident response and AI-driven threat detection, accelerated security fusion allows businesses to adapt dynamically to emerging threats, ensuring resilience in an ever-changing risk landscape.

Significance and impact on business

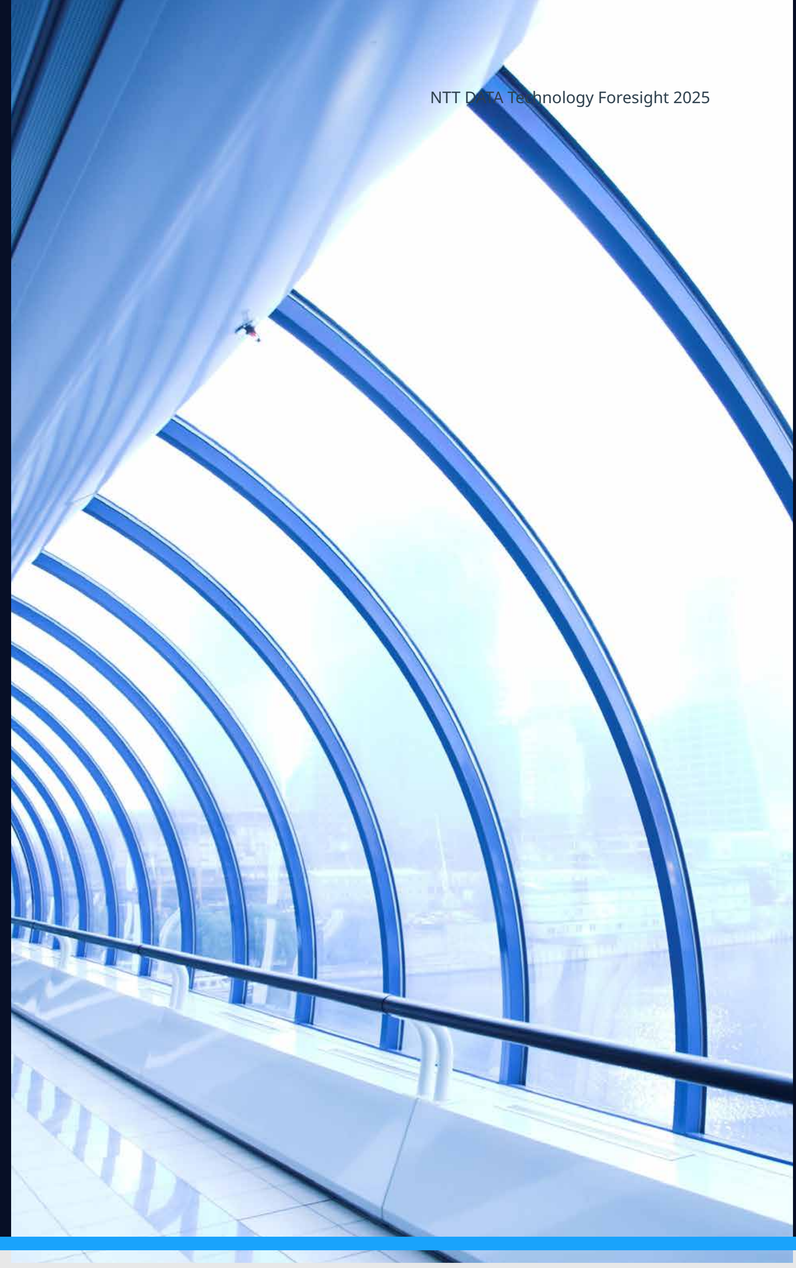
Accelerated security fusion redefines cybersecurity by transitioning it from a traditionally reactive function into a proactive and anticipatory strategy. This paradigm shift allows organizations to safeguard critical assets, ensure operational continuity and bolster resilience in the face of mounting cyber risks. With cybercrime projected to inflict over $10.5 trillion in annual damages on the global economy this year, implementing adaptive and integrated security measures has become a critical business imperative.

Organizations that embrace accelerated security fusion are better positioned to reduce financial loss, protect their reputation and cultivate stakeholder trust in an increasingly interconnected world.

Key drivers

The adoption of accelerated security fusion is driven by several critical factors. The proliferation of connected devices, the rapid expansion of hybrid and multicloud environments, and the growing complexity of regulatory compliance necessitate innovative security solutions capable of addressing modern challenges. Integrated and adaptive security approaches enable organizations to protect sensitive data, meet regulatory requirements and maintain customer trust by delivering consistent and robust defenses across all touchpoints.

In the face of significant challenges, including the escalating prevalence of data breaches, regulatory complexities, and vulnerabilities within global supply chains, accelerated security fusion offers a comprehensive framework for mitigating risks. By leveraging advanced technologies and a unified strategy, businesses can protect critical infrastructure effectively, enhance operational efficiency and establish a strong foundation for long-term growth in an unpredictable digital environment.



Technical explanation

The trend of accelerated security fusion embodies an integrated approach to cybersecurity, merging advanced technologies and methodologies to strengthen an organization's defense against evolving threats, leveraging four key concepts:

1. Proactive cyberdefense

A proactive cyberdefense approach involves anticipating and mitigating cyberthreats before they lead to significant incidents. It uses threat intelligence, ML, cryptographic agility and advanced real-time analytics to predict and prevent potential attacks, minimizing damage and downtime by neutralizing threats early.

2. Digital-identity fortification

Secures user, device and application credentials using methods like multifactor authentication (MFA) and biometric verification. It ensures that only authorized users can access critical systems and data, reducing the risk of credential-based attacks. Protecting digital identities is crucial for maintaining system integrity and security.

3. Information safegarding

Information safeguarding involves protecting sensitive data through encryption, data-loss prevention and access control policies. These measures ensure data integrity, confidentiality and regulatory compliance, and protect information against data breaches.

4. Cyber-risk governance

Cyber-risk governance includes establishing policies, roles and processes for identifying, assessing and mitigating cyber risks. It ensures that security practices align with business objectives and compliance requirements. Effective governance fosters accountability and resilience against cyberthreats.

> With these concepts, organizations can build a resilient security posture that proactively mitigates threats, ensures regulatory compliance and maintains trust, ultimately safeguarding their assets and supporting sustained business growth in an increasingly interconnected digital landscape.

Technology

Zero trust architecture implements a security model that requires strict verification for every user and device attempting to access resources, regardless of their location. It enforces the principle of least privilege and continuously validates identities to minimize unauthorized access. By assuming threats could exist both inside and outside the network, zero trust architecture effectively mitigates risks.

Behavioral analytics uses AI to establish a baseline of “normal” user behavior, enabling the detection of anomalies that may reveal insider threats or compromised accounts. It enhances security by identifying unusual activities that traditional methods might overlook. The behavioral baselines can be used to detect zero-day attacks in software supply chains and cloud-native environments, thereby providing enhanced protection for modern applications.

Cyberfusion centers are centralized hubs that integrate threat intelligence, incident response and risk management to provide a unified and proactive cybersecurity strategy. Using technologies such as advanced threat protection, automation and real-time analytics, these centers enable the rapid detection, analysis and mitigation of security incidents. By fostering collaboration among various cybersecurity functions and adopting a holistic approach, cyberfusion centers improve an organization's ability to anticipate, respond to and counteract sophisticated cyberthreats.

Encryption technologies are at the core of cybersecurity and an active research field. See the research highlight for more details.

Business explanation

Accelerated security fusion is reshaping cybersecurity by uniting advanced technologies and methodologies into an adaptable, proactive defense. By dissolving silos within organizations and fostering collaboration across security functions, this approach leverages innovations like AI-driven security to counter increasingly complex cyberthreats with precision and resilience.

Key advantages of this transformative trend include:

Holistic security ecosystem

The unified integration of detection, response, identity and data-protection technologies ensures adaptability to evolving threats, with AI augmenting real-time decision-making and automation.

Enhanced operational efficiency

AI-powered threat detection and automated workflows minimize manual efforts, boost response times and optimize resource allocation.

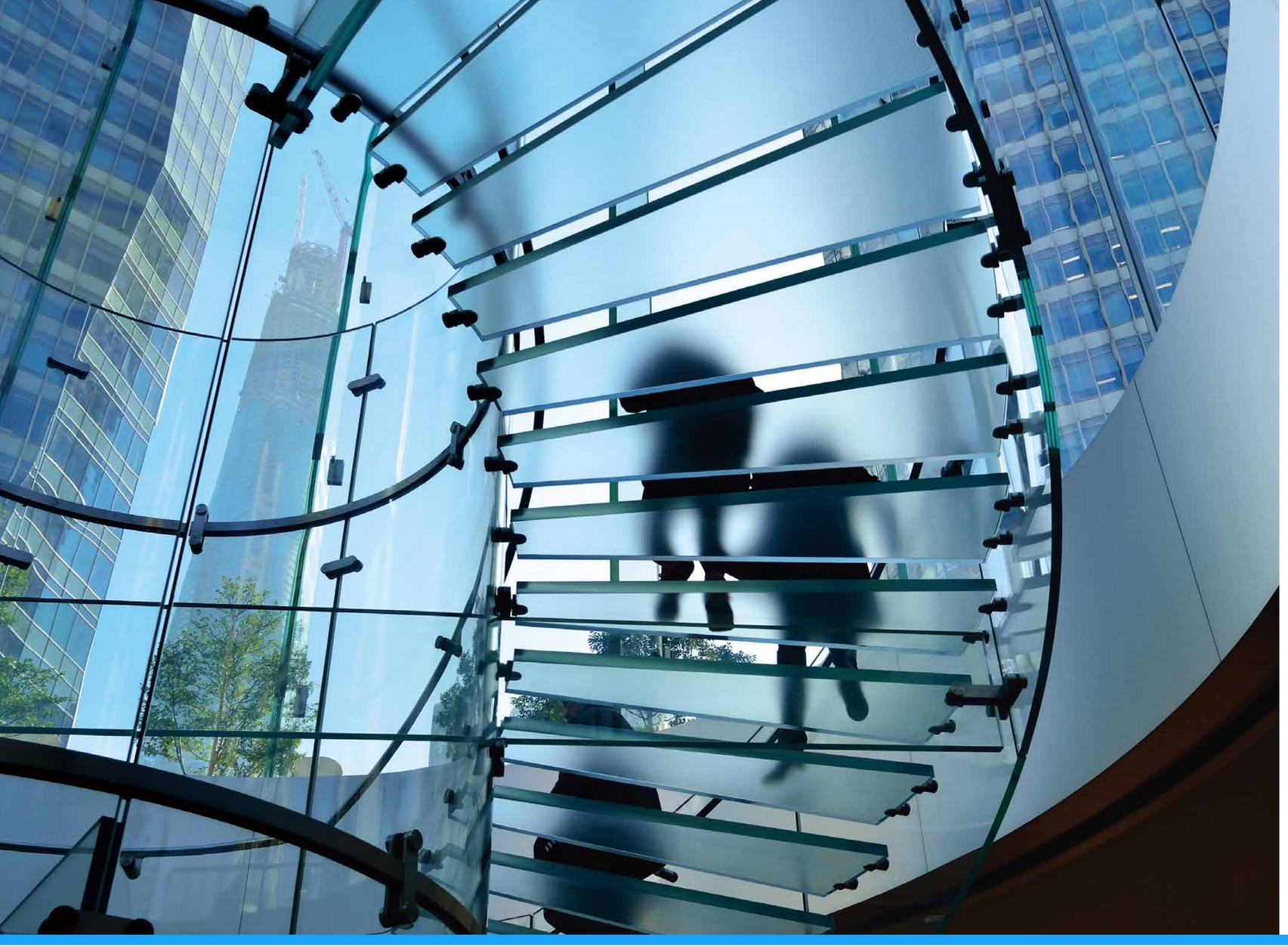
Business resilience and trust

Proactive risk management, bolstered by AI's ability to predict and neutralize threats, fosters stakeholder confidence and maintains organizational integrity.

Future-ready adaptability

Advanced encryption, zero trust, and risk frameworks, enhanced by AI empower organizations to confront next-generation challenges like quantum computing and hyperconnected systems.

Underlying concepts



Underlying concepts

Organizations that neglect cybersecurity pillars face increased vulnerability to cyberattacks, data breaches, compliance violations and operational disruptions. This negligence can result in significant financial losses, reputational damage and competitive disadvantages in increasingly security-conscious business environments and societies.

Several interconnected elements form the backbone of a robust security strategy, enabling organizations to tackle complex cyberthreats. The accelerated security fusion megatrend represents a holistic approach to cybersecurity that integrates four pillars, explained below.

Accelerated security fusion

Advanced threat detection and response

- Scalable and flexible security solutions
- Enhanced security validation and strategy optimization
- Cost efficiency through automation
- Operational resilience in industrial environments
- Proactive risk management

Digital-identity fortification

- Mitigation of security risks
- Improved customer trust and satisfaction
- Operational efficiency and productivity
- Regulatory compliance and risk management
- Resilience against emerging threats

Information safeguarding

- Holistic security strategy
- Operational efficiency
- Regulatory compliance
- Mitigation of financial risks
- Enhanced data protection

Cyber-risk management

- Enhanced risk assessment
- Effective vendor management
- Integrated risk management
- Automated compliance assurance
- Dynamic response capabilities

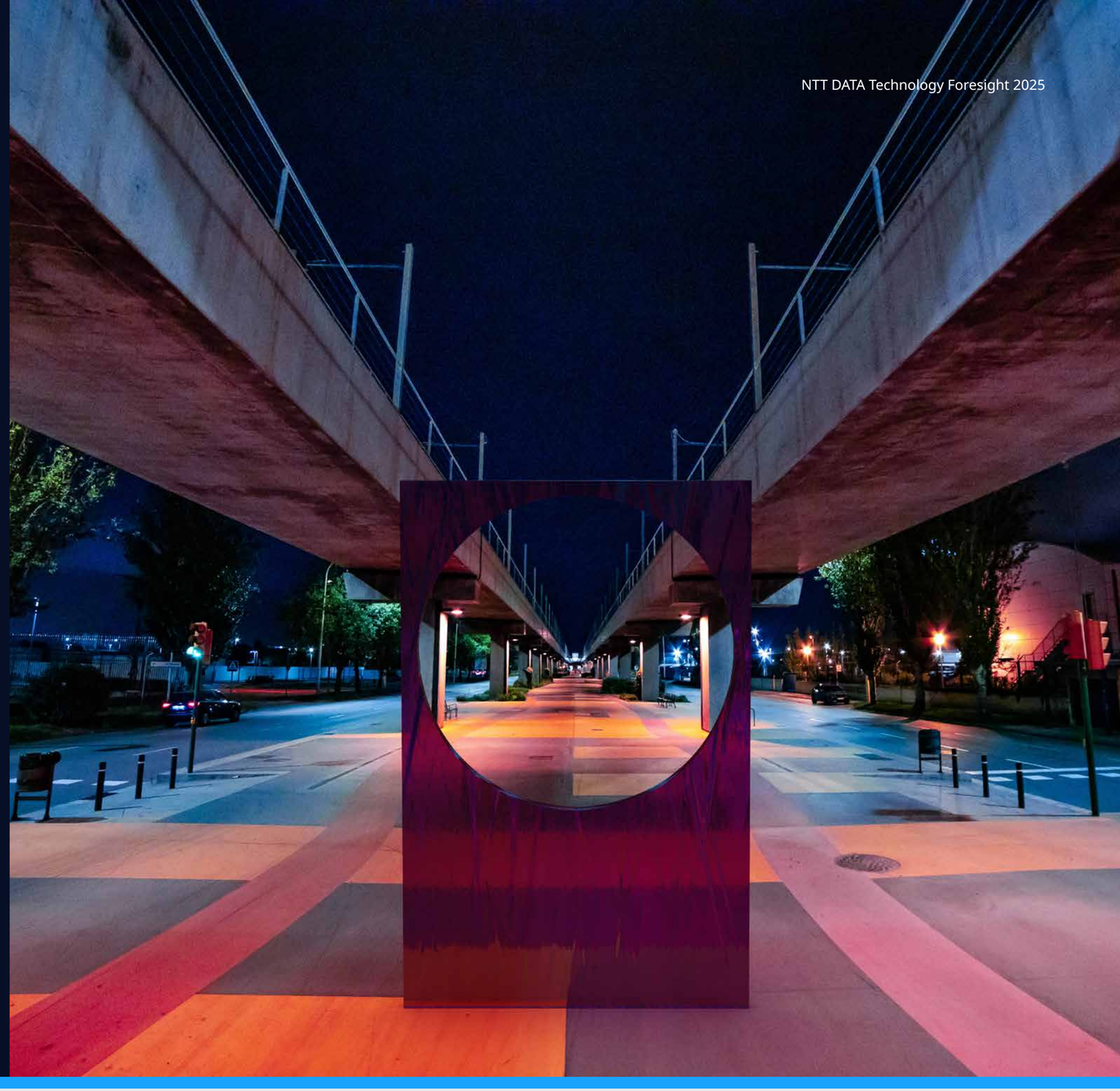
Figure 25: Accelerated security fusion — underlying concepts and supporting trends

Underlying concepts

Advanced threat detection and response

Advanced threat detection and response integrates organizational strategies, new technologies and user engagement to address cyber risks proactively. By fostering a culture of preparedness and continuous monitoring, organizations enhance their ability to swiftly detect, respond to and mitigate threats.

> AI-powered tools elevate these defenses, enabling businesses to tackle both known and emerging challenges in a rapidly evolving digital landscape.



Scalable and flexible security solutions

- Organizations require adaptable defenses to address the complexities of modern cybersecurity.
- Scalable solutions like MDR services and real-time analytics help businesses remain secure while aligning with growth strategies. Flexible approaches ensure continued protection in the face of ever-changing threats.
- Cloud security services like AWS Shield provide scalable solutions that protect against distributed denial-of-service (DDoS) attacks and adapt to business growth. These services include automated monitoring and real-time threat detection, ensuring robust security as businesses expand.

Enhanced security validation and strategy optimization

- Regularly testing and refining cybersecurity measures keeps defenses strong against evolving threats. AI-powered analytics provide actionable insights, enabling organizations to continuously optimize their security strategies and meet compliance requirements.
- Solutions like Darktrace use ML algorithms to detect anomalous behavior and provide insights that allow organizations to strengthen their security strategies.

Cost efficiency through automation

- Automation reduces manual intervention, enabling faster incident responses and lower operational costs. AI-driven tools, such as breach and attack simulations, detect threats and optimize resource allocation, ensuring the effective management of cybersecurity budgets.
- Cortex XSOAR (formerly Demisto) helps organizations automate incident response workflows, significantly reducing the time needed to contain and remediate security incidents. This automation enhances efficiency and allows security teams to focus on more strategic tasks.

Operational resilience in industrial environments

- In sectors reliant on operational technology (OT), safeguarding infrastructure is critical. Advanced detection systems identify vulnerabilities across IT and OT environments, preventing disruptions and enabling seamless integration while ensuring compliance with industry regulations.
- Companies like Honeywell offer integrated security solutions that protect these systems from cyberthreats, helping to prevent unauthorized access and ensure operational continuity in critical environments.

Proactive risk management (PRM)

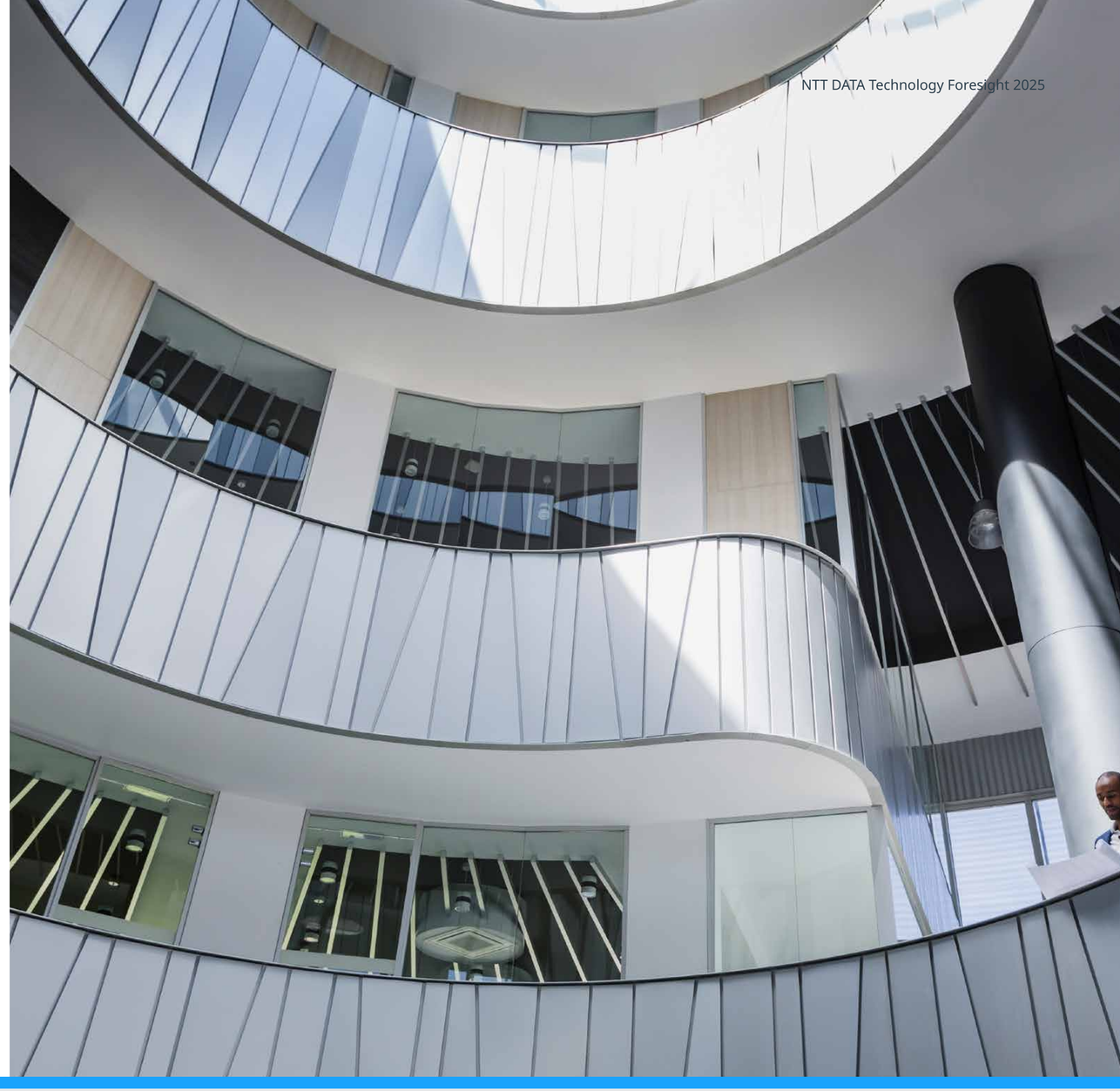
- Integrating cybersecurity into organizational strategies builds resilience against potential threats. Proactive measures, such as managed detection and response (MDR) and threat intelligence, enable businesses to identify risks early, minimize disruptions and protect assets. This commitment to data security fosters customer trust.
- To further strengthen these measures, adversarial ML defense techniques are employed, enhancing AI-powered tools to counter manipulative attacks designed to exploit weaknesses in AI models.
- This proactive integration not only maintains system integrity but also fosters customer trust by ensuring that emerging and advanced threats are effectively managed.

Underlying concepts

Digital-identity fortification

Digital-identity fortification is critical to safeguarding sensitive information and ensuring secure access to digital platforms. By enhancing identity and access management (IAM), organizations not only protect against breaches but also create seamless user experiences that drive customer loyalty.

> “AI tools play a central role in this transformation, enabling the real-time detection of anomalies and delivering frictionless authentication.



1 Mitigation of security risks

Passwordless authentication and MFA reduce risks associated with traditional passwords, lowering the chances of credential theft and phishing.

These security measures enhance customer trust, essential for maintaining a competitive edge, and help prevent financial losses due to data breaches.

Integrating AI tools allows for real-time threat detection and swift responses, further improving security resilience.

By focusing on these strategies, organizations not only mitigate security risks but also strengthen their market position and foster customer loyalty.

2 Improved customer trust and satisfaction

Customers increasingly demand security and privacy for their personal information due to rising concerns about data breaches and identity theft. To meet these expectations, businesses must create secure systems that prioritize user trust. Implementing user-friendly identity verification methods boosts customer confidence. When customers feel their data is protected, they're more likely to engage with and remain loyal to a brand. A seamless authentication process enhances satisfaction, leading to increased loyalty and revenue growth.

AI technologies can further enhance customer trust by offering personalized verification processes. By analyzing user behavior for anomalies, AI ensures security measures are effective yet frictionless, helping organizations proactively address potential concerns.

3 Operational efficiency and productivity

Enhancing operational efficiency is crucial for organizations to remain competitive in today's fast-paced business environment. Employees need quick, secure access to resources, supported by robust security measures that protect against evolving cyberthreats.

Implementing zero trust management ensures continuous verification of users and devices while reducing repetitive security checks that slow operations.

Streamlining access controls and eliminating traditional password management allows employees to focus on their tasks, boosting productivity and satisfaction.

Additionally, integrating AI technologies automates identity verification and access management, analyzing user behavior to provide seamless access and reduce friction in the authentication process.

4 Regulatory compliance and risk management

As data protection and privacy regulations tighten, organizations must prioritize compliance to protect customer information and avoid penalties. Customers expect transparency, making adherence to regulatory standards essential for building trust.

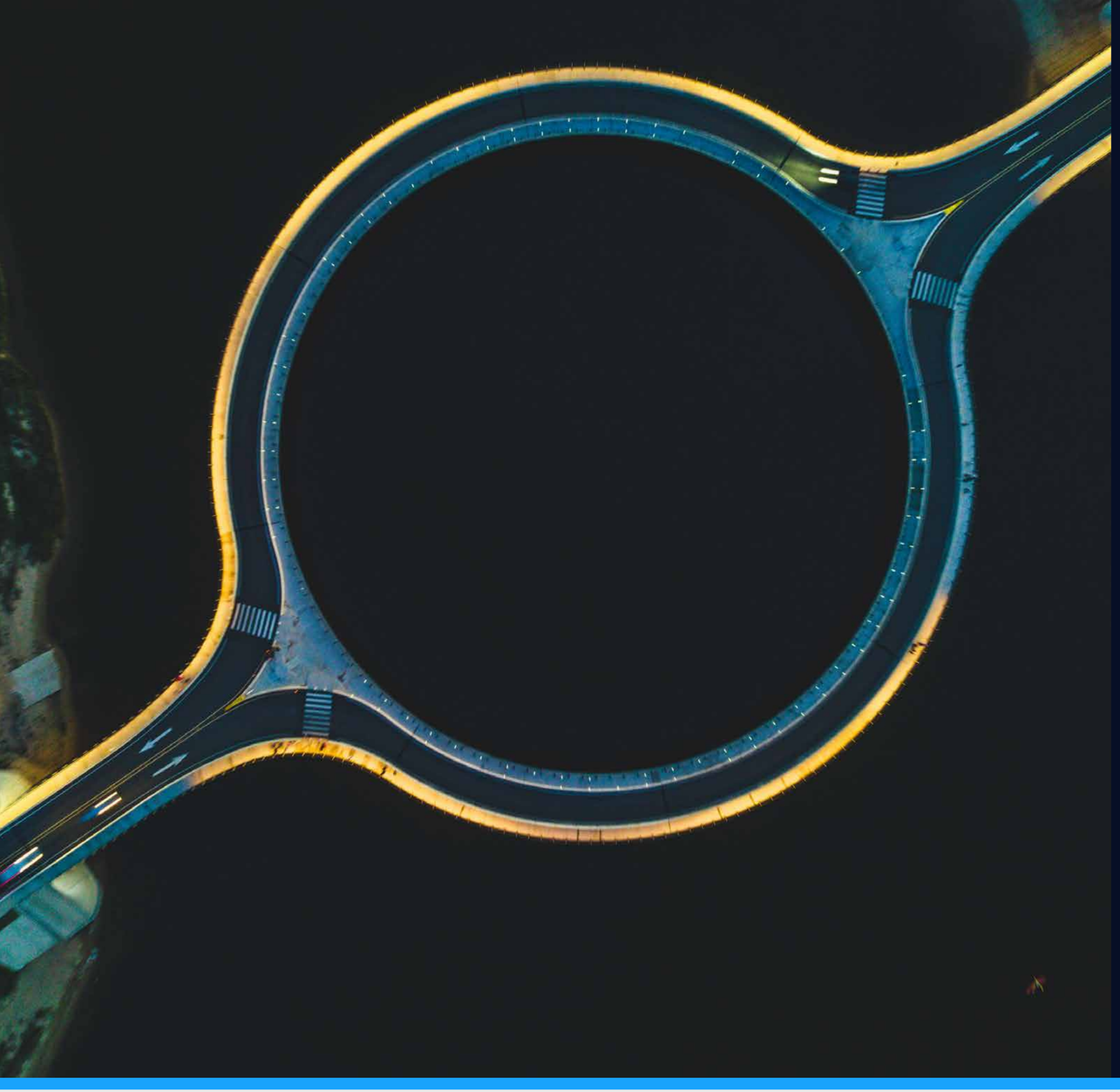
Implementing advanced identity verification technologies allows organizations to meet regulatory requirements efficiently, ensuring accurate record-keeping and streamlined reporting for easier audits. A proactive compliance approach reduces costly fines and enhances reputation.

Integrating AI further strengthens compliance by automating monitoring and reporting. AI can quickly identify compliance risks and detect anomalies in user behavior, ensuring real-time adherence to regulations and improving operational efficiency.

5 Resilience against emerging threats

Cyberthreats are becoming increasingly sophisticated, requiring organizations to enhance defenses to protect sensitive data and ensure continuity. Robust security measures are essential to foster resilience and maintain customer trust.

Adopting identity management strategies like passwordless systems and MFA enables businesses to effectively counter emerging threats. A zero trust model enhances security by promoting the continuous monitoring of user behavior for early detection of suspicious activities.



Underlying concepts

Information safeguarding

Information safeguarding involves measures designed to protect sensitive data from unauthorized access and breaches, ensuring the security of personal and organizational information.

Companies that prioritize data security can attract customers by demonstrating their commitment to privacy, fostering trust and loyalty in a data-conscious marketplace.

> “Additionally, employing advanced security practices enhances the framework by enabling continuous monitoring and management, which provides a robust defense against evolving cyberthreats.

Enhanced data protection

- As organizations increasingly depend on digital data, protecting sensitive information has become essential for building customer trust and loyalty.
- Advanced encryption techniques safeguard data at rest and in transit, effectively preventing unauthorized access and significantly reducing the risk of data breaches.
- Integrating AI into data-protection strategies strengthens security by identifying patterns and detecting anomalies, allowing for swift responses to potential breaches.
- The threat of “harvest now, decrypt later” attacks, where encrypted data is stolen with the hope of future decryption by more advanced technologies like quantum computers, necessitates the use of safeguards such as tokenization and post-quantum cryptography to secure data against future threats.

Mitigation of financial risks

- In light of increasing data breaches, organizations encounter significant financial risks that threaten their stability and reputation.
- Using network tokenization reduces those risks by replacing sensitive data with nonsensitive tokens, making stolen data less valuable.
- Adopting AI enhances risk mitigation by analyzing patterns for early detection of vulnerabilities, enabling quick responses to threats.
- Ultimately, the mitigation of financial risks is vital for safeguarding organizational stability and customer trust through solutions like tokenization and AI.

Regulatory compliance

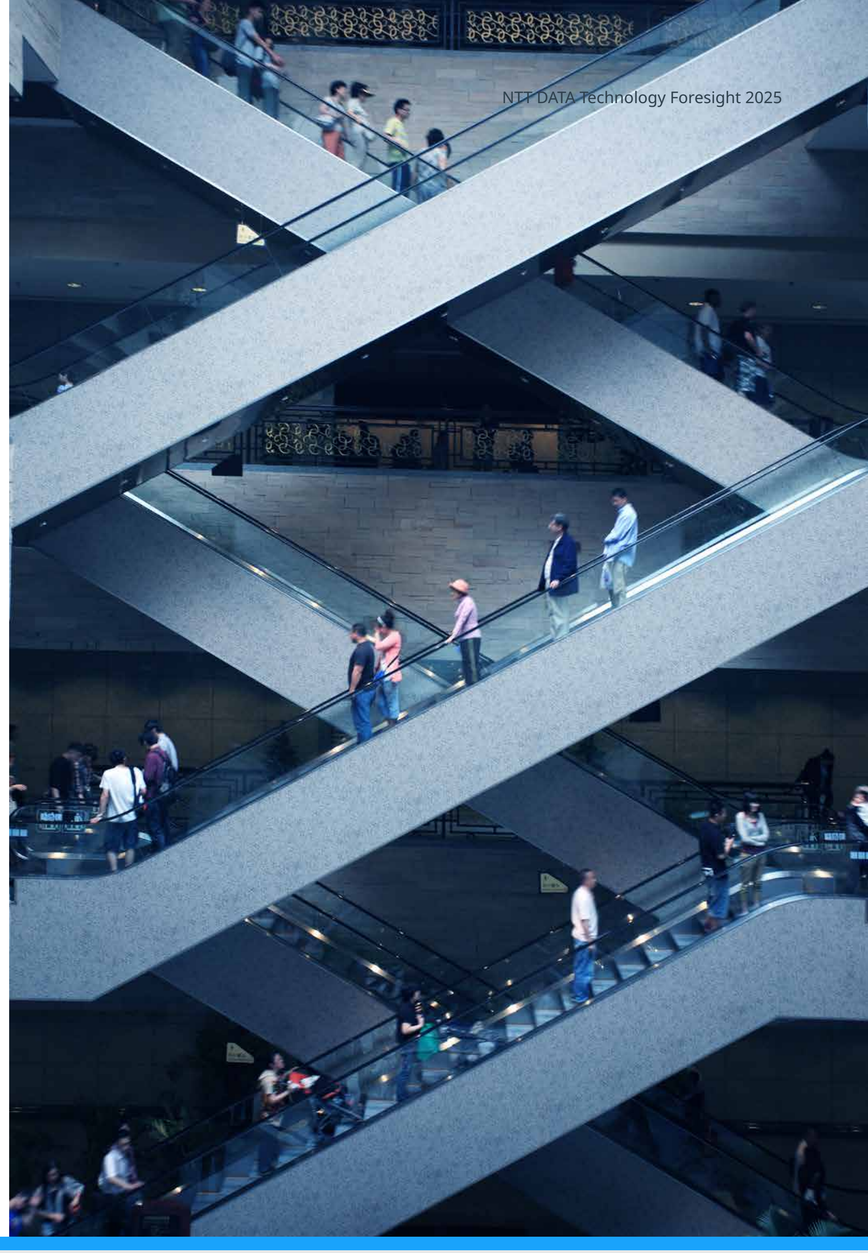
- As data privacy regulations like GDPR, HIPAA and CCPA evolve, organizations must prioritize compliance to protect consumer information.
- Implementing data security platforms and cloud security posture management (CSPM) enables the effective monitoring and management of data security configurations, ensuring adherence to legal requirements.
- Automation monitoring through AI analyzes data to identify compliance risks and ensures that security configurations align with legal standards.
- Achieving regulatory compliance is essential for protecting consumer data and maintaining public trust, while advanced security solutions and AI enhance organizational effectiveness.

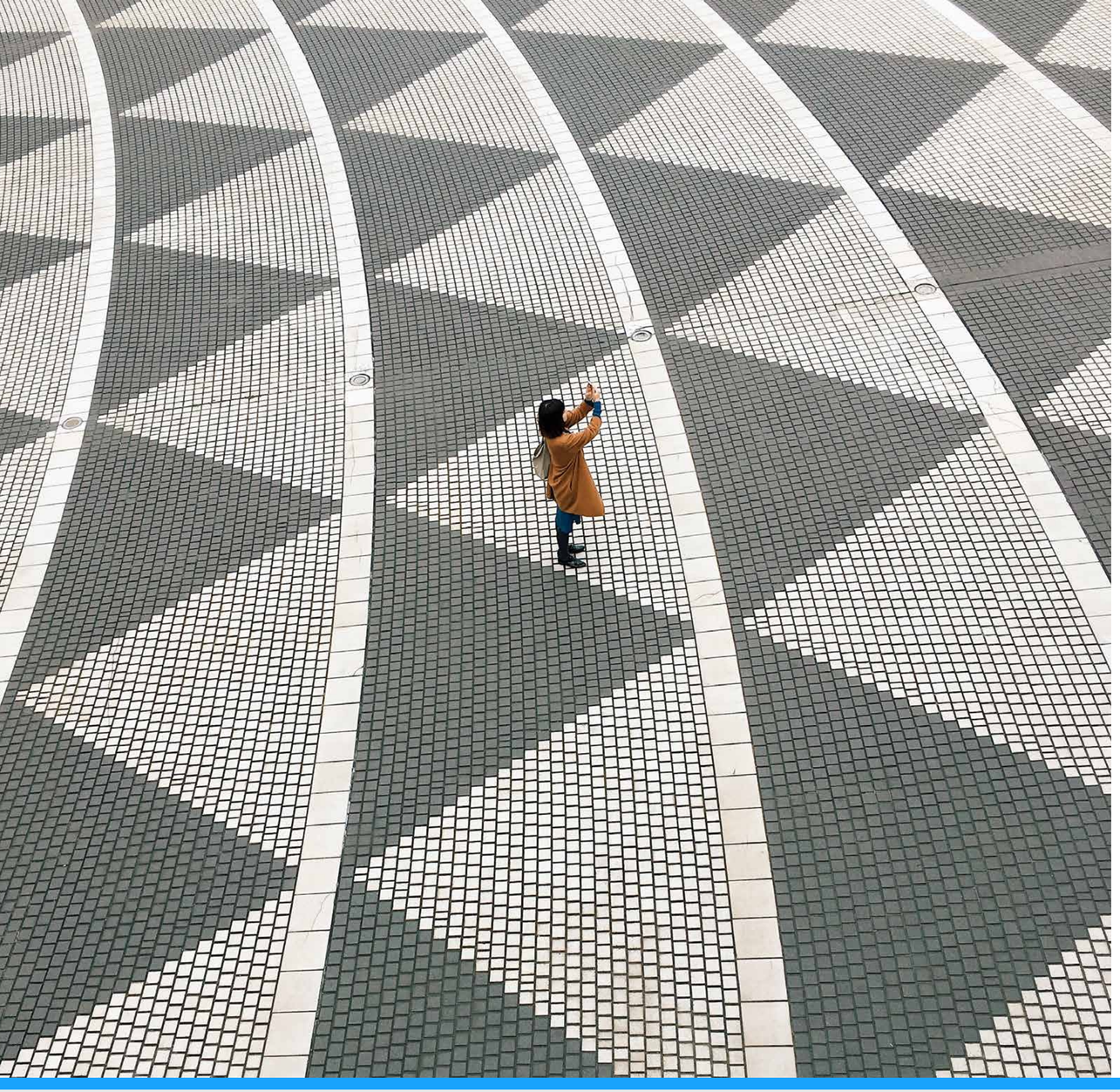
Operational efficiency

- Organizations face increasing security threats while striving to maintain operational efficiency in a rapidly changing digital landscape.
- Cloud-native application protection platforms (CNAPPs) and CSPM provide centralized security management that streamlines operations and automates monitoring, enhancing incident response times.
- Incorporating AI into security strategies improves operational efficiency by automating repetitive tasks and providing real-time analytics for faster threat detection.

Holistic security strategy

- In today's environment, organizations must adopt a comprehensive approach to security to protect critical assets from complex cyberthreats.
- By integrating advanced encryption techniques, network tokenization and robust data security platforms, organizations create a multilayered defense against cyberthreats.
- Incorporating AI into this strategy significantly improves threat detection and response times, offering real-time insights into potential vulnerabilities.





Underlying concepts

Cyber-risk management

Cyber-risk management provides organizations with a structured approach to identifying, assessing and mitigating risks in an increasingly complex threat environment.

> AI integration enhances these processes, enabling businesses to stay ahead of emerging vulnerabilities and maintain stakeholder confidence.

Enhanced risk assessment

- Comprehensive risk assessments inform decision-making by quantifying potential threats and prioritizing resources. AI tools analyze large datasets in real time, uncovering patterns and vulnerabilities that might otherwise go unnoticed. This enables the precise allocation of resources and strengthens overall security.
- Mastercard's Decision Intelligence uses AI and ML to analyze transactions in real time, detecting potential fraud by evaluating various data points and cardholder behaviors. This system helps identify and prevent fraudulent activities before they escalate.

Effective vendor management

- Third-party vendors often introduce significant risks to an organization’s ecosystem. A strong vendor risk management strategy ensures continuous monitoring of their security measures, aligning with regulatory requirements. AI-driven tools automate this process, enhancing oversight and trust.
- RiskRecon, a Mastercard company, uses AI to continuously monitor and assess third-party vendors' cybersecurity. Its platform automatically scans public-facing systems, analyzes security practices, and delivers real-time risk assessments.

Integrated risk management

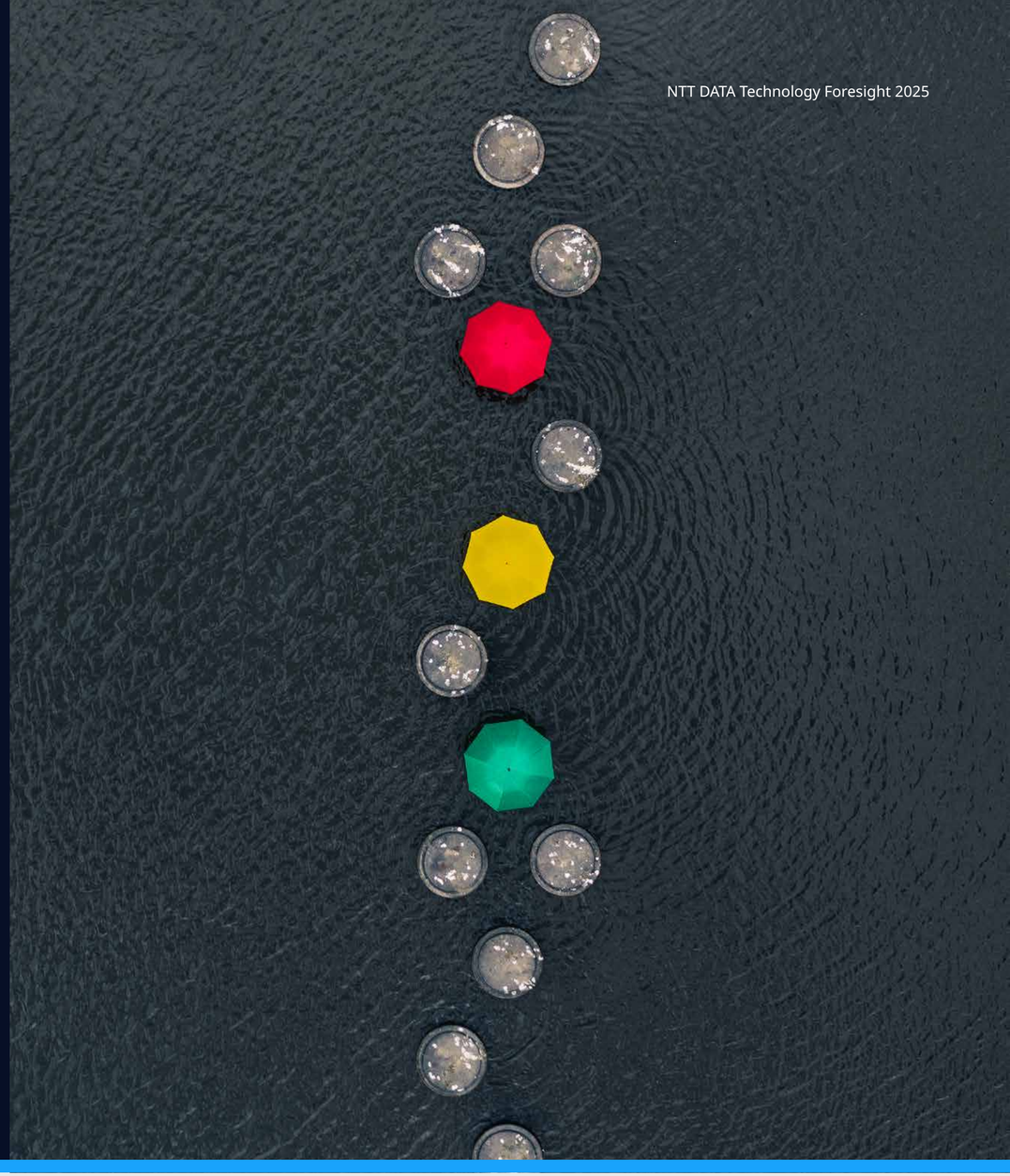
- Siloed risk management approaches can miss interconnected vulnerabilities. Integrated risk management (IRM) consolidates these efforts across functions, providing a unified view of risk exposure. AI improves IRM by automating assessments and generating actionable insights.
- ServiceNow's IRM platform uses AI and ML to consolidate risk data, prioritize risks, generate real-time insights, automate assessments and provide a unified dashboard for enhanced visibility across the organization.

Automated compliance assurance

- With regulatory landscapes constantly evolving, organizations must adopt proactive compliance strategies. AI technologies automate monitoring and reporting, reducing manual effort and ensuring real-time adherence to legal standards. This protects organizations from penalties and reinforces stakeholder confidence.
- OneTrust, a privacy management platform, uses AI and ML to help organizations comply with GDPR and HIPAA by scanning and classifying data, identifying compliance risks in real time, automating access requests and consent management and generating automated audit reports.

Dynamic response capabilities

- In today's fast-paced environment, organizations must adapt quickly to new threats. AI enables dynamic risk management by automating threat detection and accelerating incident response. This agility ensures operational continuity and enhances trust in the organization's ability to protect sensitive information.
- Microsoft's Copilot for Security leverages AI to analyze incidents, provide contextual insights, prioritize threats and recommend containment strategies, enabling faster and more effective decision-making in cybersecurity operations.



Tech radar

Tech radar

In the constantly changing tech landscape, keeping up with the latest developments is essential, not just advantageous.

Continually analyzing technology trends and tracking their evolution will help you anticipate changes and prepare yourself for upcoming shifts.

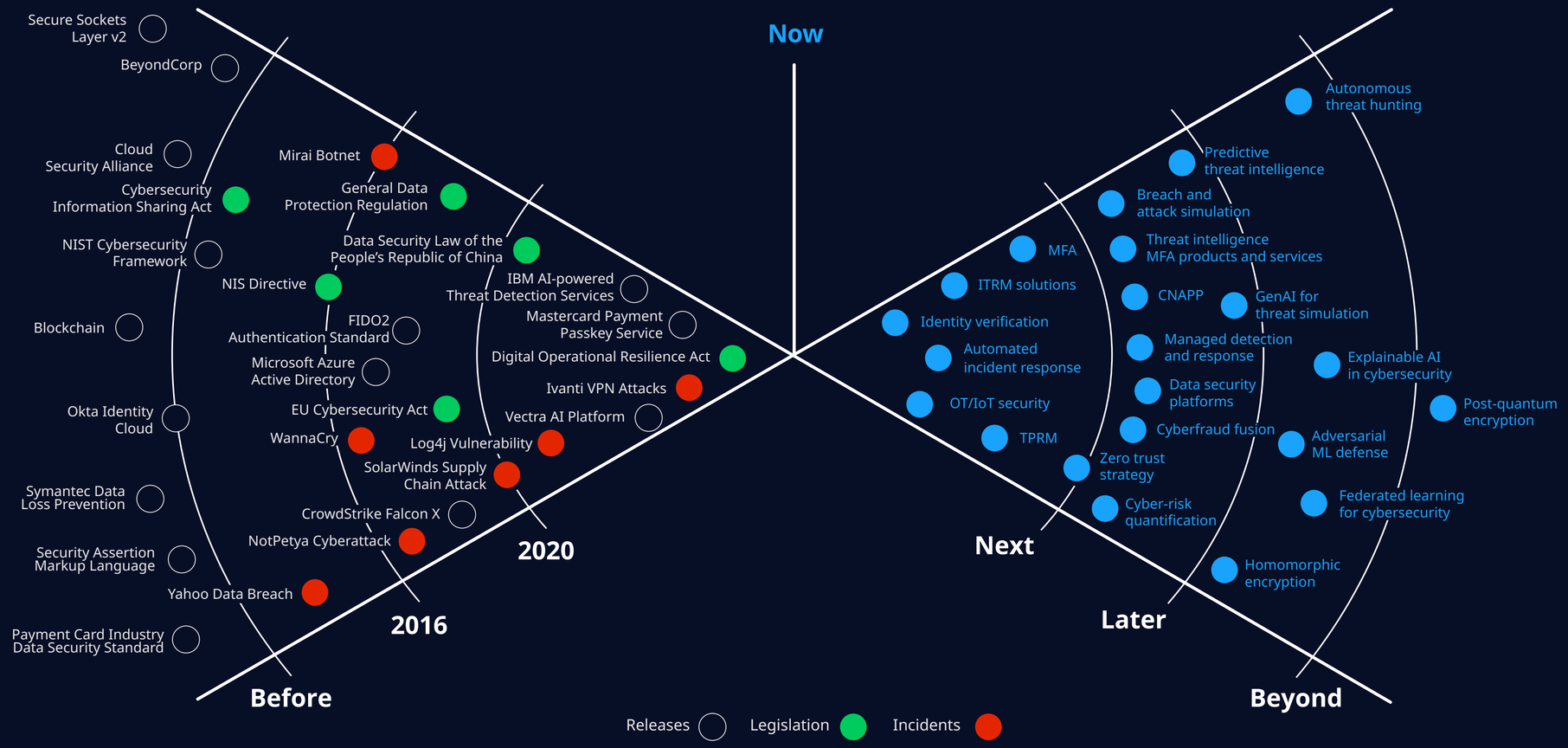


Figure 26: Tech radar — past and future technology

Future tech: now

A **Identity verification**
The process of confirming a person's identity by analyzing official documents, verifying live presence, and matching the individual to the document.

B **OT/IoT security**
Protects interconnected operational systems and IoT devices from cyberthreats and operational risks, securing hardware, software and networks.

C **Automated incident response**
Centralized systems that use automation to streamline and accelerate incident routing, resolution and collaboration.

D **IT risk management (ITRM) solutions**
Tools for managing IT risks, supporting compliance, regulatory requirements and cyber-risk assessment through governance workflows.

E **Multifactor authentication (MFA)**
Security method requiring multiple forms of verification, such as biometrics, tokens or passwords, for access control.

F **Third-party risk management (TPRM)**
Tools for identifying, assessing and managing risks associated with external vendors, suppliers and partners.

G **Zero trust strategy**
A security framework that enforces strict, adaptive access controls based on user identity, context and asset sensitivity, eliminating implicit trust.

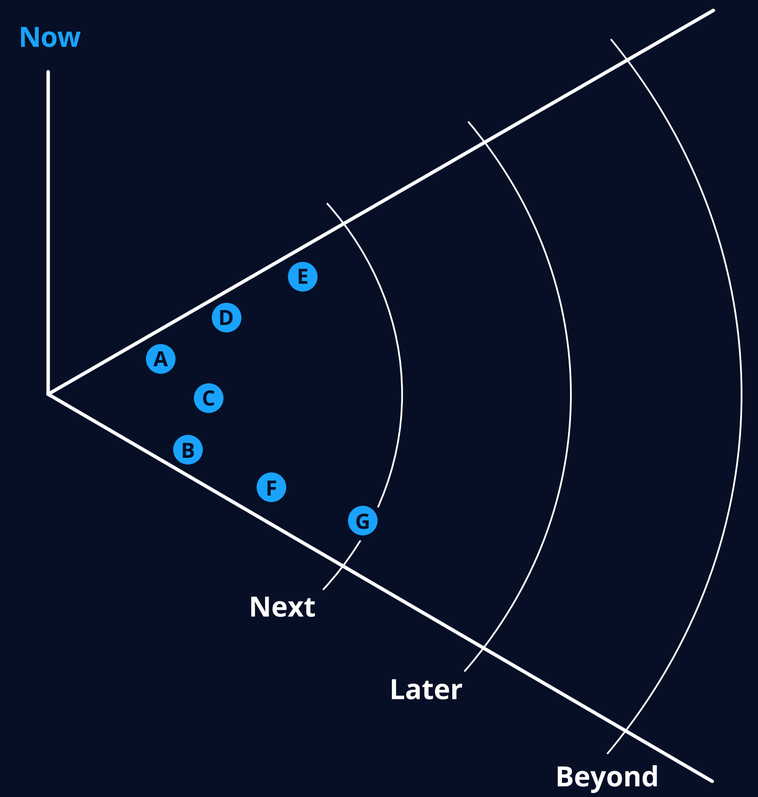


Figure 27a: Tech radar — future technology

Future tech: next and later

H **Breach and attack simulation (BAS)**
Tools that simulate cyberattacks to test organizational defenses, identify vulnerabilities and improve security posture.

I **Threat intelligence products and services**
Systems providing insights into the cyberthreat landscape by analyzing tactics, techniques and adversaries to enhance preparedness.

J **CNAPPs**
Integrated tools that secure cloud-native applications by combining workload protection, security posture management and application security.

K **MDR**
Services that proactively detect and respond to cyberthreats through advanced analytics, threat hunting and predefined workflows.

L **Data security platforms (DSPs)**
Solutions aggregating data protection requirements, including data discovery, masking, encryption and access controls across ecosystems.

M **Cyberfraud fusion**
Integrated approach combining cybersecurity and fraud prevention strategies to address evolving fraud tactics and improve response.

N **Cyber risk quantification (CRQ)**
Method of assessing risk exposure in business terms, such as financial impact or operational disruption, using mathematical models and historical data.

O **Homomorphic encryption**
Encryption method allowing computations on encrypted data without decryption, ensuring privacy during processing.

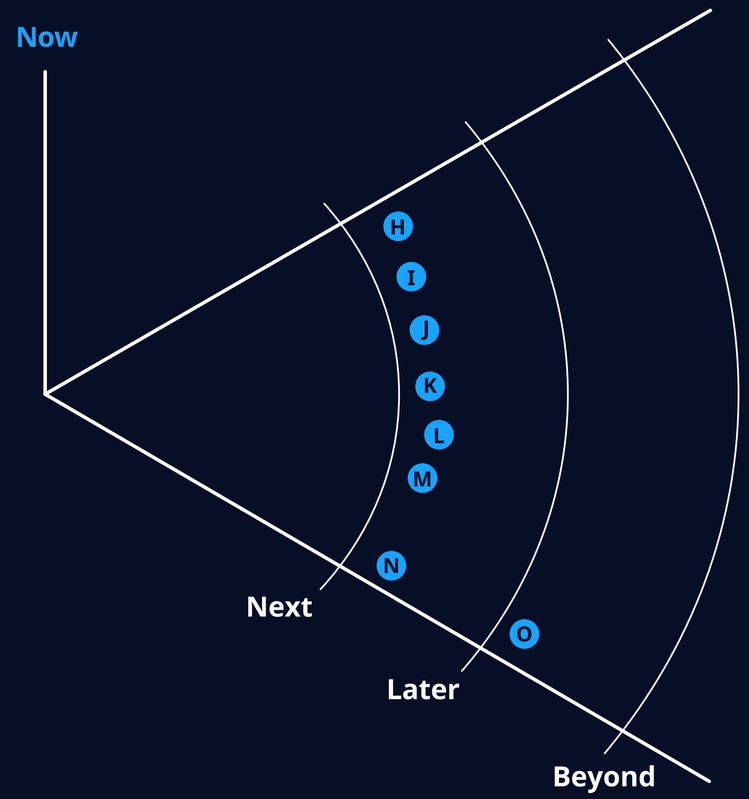


Figure 27b: Tech radar — future technology

Future tech: later and beyond

P **Post-quantum encryption (PQE)**
Cryptographic techniques designed to withstand attacks from quantum computers, ensuring long-term data security.

Q **Predictive threat intelligence**
AI-powered tools that analyze historical data and real-time feeds to forecast and prepare for future cyberthreats.

R **Generative AI for threat simulation**
AI-driven systems that create realistic attack scenarios to test and improve an organization's defenses

S **Autonomous threat hunting**
Fully AI-driven solutions that proactively search for vulnerabilities and threats without human intervention.

T **Adversarial ML defense**
Techniques to identify and mitigate manipulative attacks on AI models designed to exploit their weaknesses.

U **Federated learning for cybersecurity**
A collaborative AI training approach that protects sensitive data by sharing model updates instead of raw data.

V **Explainable AI in cybersecurity**
Tools and frameworks that make AI-driven cybersecurity decisions interpretable and transparent to users and regulators.

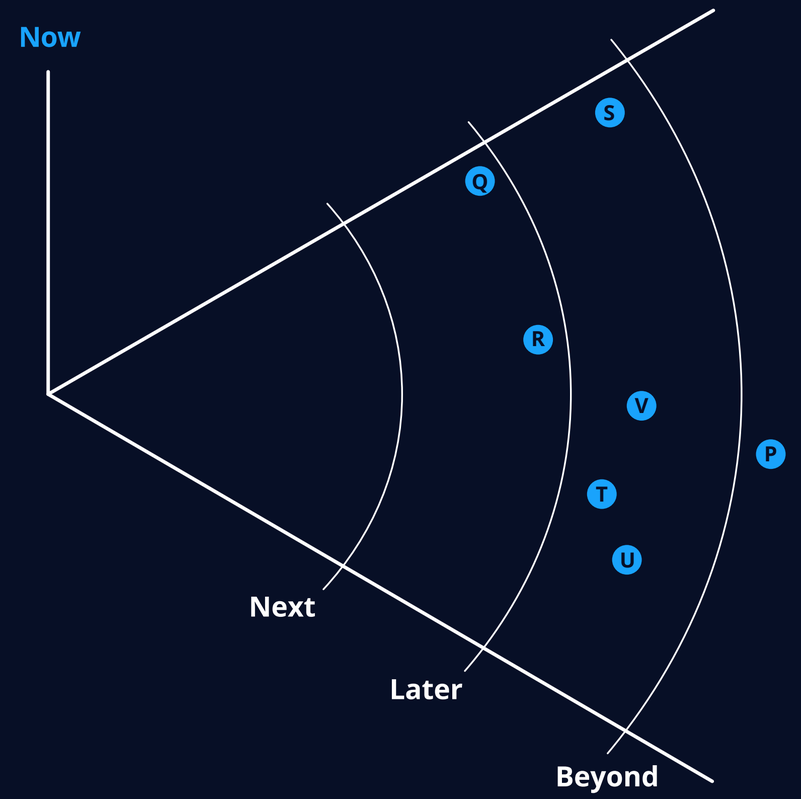
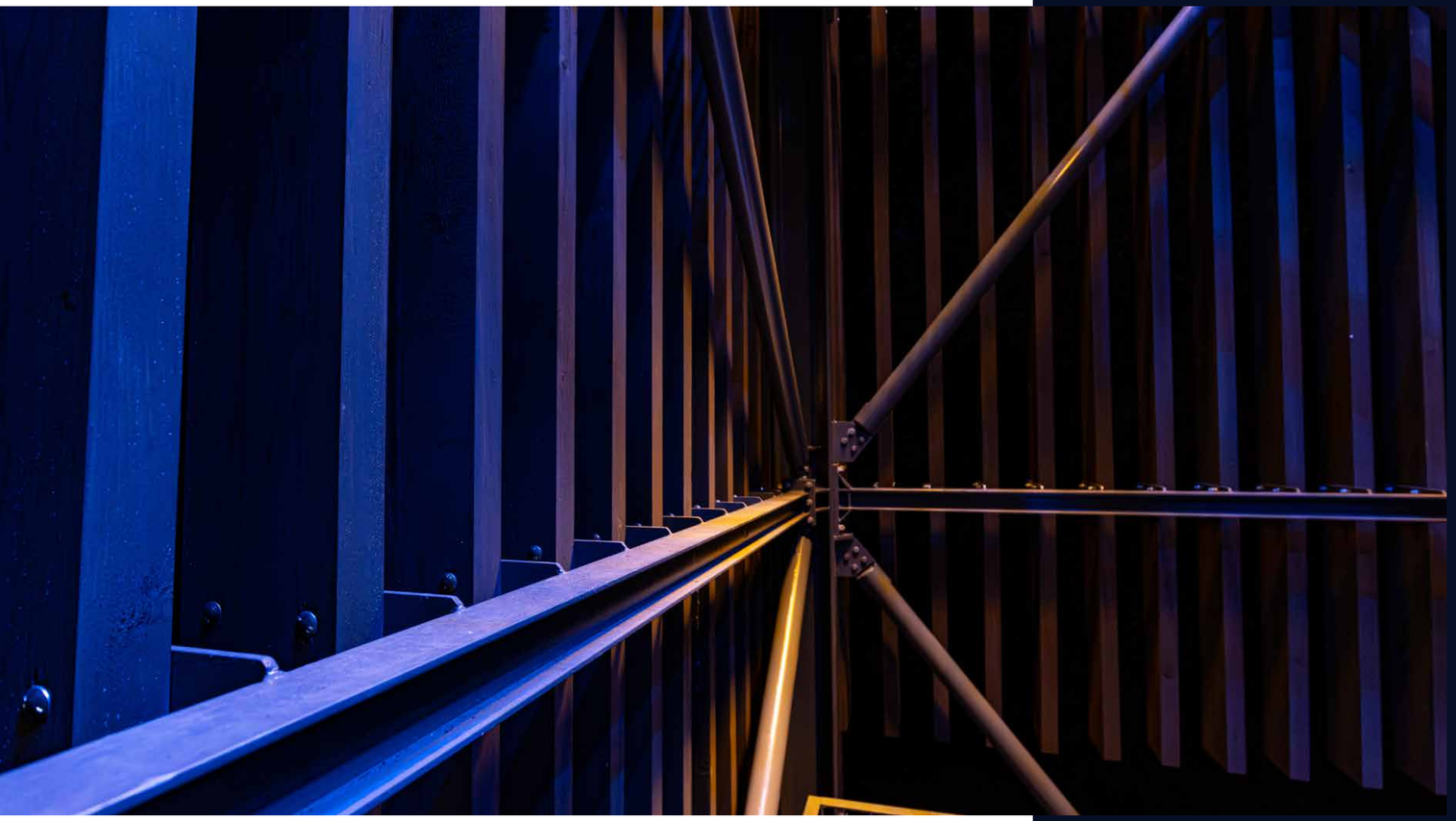


Figure 27c: Tech radar — future technology

R&D highlight



R&D highlight

Innovative encryption technologies

The ever-evolving digital landscape necessitates robust encryption technologies to safeguard against sophisticated cyberthreats.

NTT's research focuses on next-generation encryption methods designed to meet the demands of various applications.

Attribute-based encryption

This revolutionary paradigm combines encryption with attribute-based access control, allowing access to encrypted data based not just on a private key but also on a set of attributes.

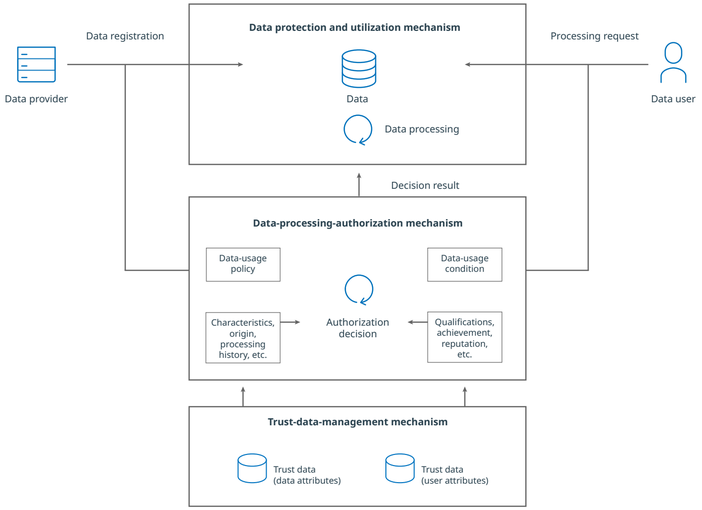
This enables the definition of flexible access policies based on a variety of attributes, such as user role, geographic location or access time, thus offering a more granular control over sensitive data in different scenarios like content distribution, secure data-sharing and privacy-preserving transactions.

Homomorphic encryption

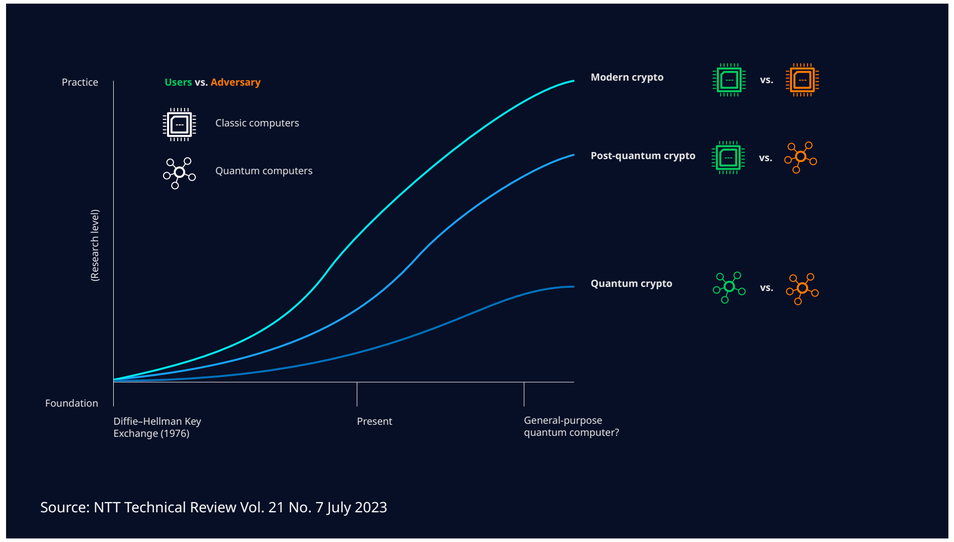
NTT is pioneering research into fully homomorphic encryption, focusing on enabling computations on encrypted data without requiring decryption. Arithmetic operations, such as addition and multiplication, can be performed directly on ciphertexts (the result of encrypting plaintext), providing a powerful mechanism for processing sensitive information securely. This is particularly beneficial for applications in cloud computing, as data can be processed by external servers without exposing the underlying information, thereby ensuring privacy and compliance with data protection regulations.

Post-quantum cryptography

In response to the growing threat posed by quantum computers, which have the potential to break current public-key encryption schemes, NTT is investing in post-quantum cryptography research. By combining advanced security techniques with quantum key distribution, NTT provides robust end-to-end security solutions. These innovative approaches are designed to protect today's encrypted data from future quantum attacks, thereby ensuring long-term security and maintaining trust in digital communications.



Source: NTT Technical Review Vol. 19 No. 6 July 2021



Source: NTT Technical Review Vol. 21 No. 7 July 2023

Figure 28: Innovative encryption technologies

Quantification

Relevant financials

Accelerated security fusion

Market size, 2024:

$26.9 billion

Market size growth, 2023–2024 (YoY):

+10.6%

Forecast CAGR, 2024–2030:

11.3%

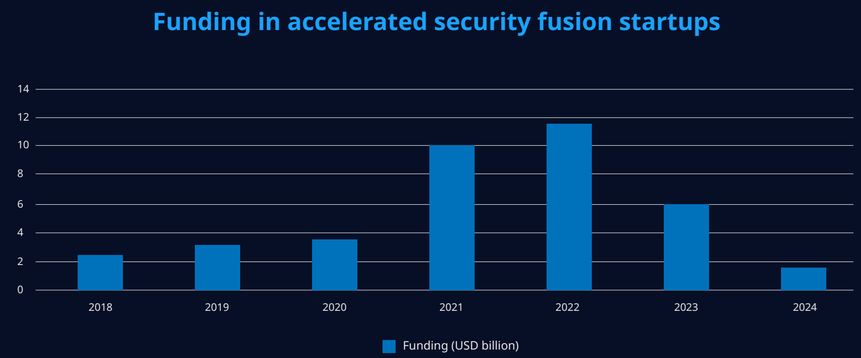


Figure 29: Funding in accelerated security fusion startups

> 69% of enterprise executives believe AI will be necessary to respond to cyberattacks.

Impact of AI on security

Organizations using AI and automation for their security efforts experienced an average data breach cost of $3.05 million, compared to $4.43 million for those without.

90%

of organizations are actively implementing or planning to explore LLM use cases, **while only 5% feel highly confident in their AI security preparedness.**

71%

of security stakeholders are confident that AI-powered security solutions are better able to block AI-powered threats than traditional tools.

77%

of companies experienced breaches in their AI systems over the past year.

62%

of organizations have deployed an AI package with at least one common vulnerability and exposure (CVE).

37%

of data leaders say they have a comprehensive strategy in place to remain compliant with recent and forthcoming AI regulations and meed data-security needs.

Research and development

16,300*

Patents registered 2023

*Approximate figures

Use cases

Automated automotive cybersecurity solution

Industry: **Automotive**

An advanced cybersecurity platform is transforming automotive security with an automated solution for OEMs and Tier 1 suppliers. It ensures compliance with global standards and enables proactive security management through risk-driven approaches and digital-twin capabilities.

Business value

1. Automates critical cybersecurity processes, reducing compliance costs
2. Ensures rapid adherence to evolving regulatory standards, enhancing product security

> “AI automates cybersecurity for vehicles, ensuring compliance and proactive protection while reducing costs.

Integrated cybersecurity platform for supply chain

Industry: **Logistics**

This solution enhances the protection of a global logistics and supply chain network by integrating data from diverse sources, including cybersecurity systems, IoT sensors and physical security systems. It enables real-time threat detection, analysis and response to minimize risks like cyberattacks and operational disruptions.

Business value

1. Integrating data from multiple sources improves threat detection and response times, safeguarding the logistics and supply chain network.
2. Enhanced protection against cyberattacks boosts operational efficiency and reduces costly interruptions.

Enhanced smart-grid security

Industry: **Public sector; energy**

Quantum-resistant encryption strengthens the security and resilience of smart grid infrastructure against cyberthreats, including those from quantum computing. This implementation protects critical data and boosts consumer confidence in the utility's commitment to robust, future-proof cybersecurity.

Business value

1. Long-term data protection by safeguarding data from quantum threats
2. Increased consumer trust through proactive security

> “Quantum-resistant encryption fortifies smart grids, safeguarding critical data and building consumer confidence.

Real-time fraud detection

Industry: **Financial services**

A real-time fraud-detection system uses ML to identify and prevent suspicious transactions, safeguarding customer accounts. By significantly reducing fraud losses and improving customer retention, the bank demonstrates a strong commitment to protecting its clients' finances.

Business value

1. Reduce fraud loss by up to 40%, protecting the bank's assets
2. 15% better customer retention through improved account security

Cloud permission management

Industry: **Cross-industry**

A cloud-security platform manages and analyzes permissions across multicloud environments. It examines configurations and behavior patterns across identities, networks, data and computing resources to prevent breaches caused by misconfigurations or excessive permissions.

Business value

1. Reduces data-breach risks by identifying and mitigating excessive or misconfigured permissions
2. Simplifies compliance management in complex multicloud environments

Secure digital content within entertainment

Industry: **Media**

A leading streaming service uses attribute-based encryption to control access to its content library based on user attributes such as age, subscription level and location. This ensures that only authorized users can access specific titles, protecting copyrighted material while offering tailored viewing experiences.

Business value

1. Enhanced content security by reducing the risk of unauthorized access and safeguarding intellectual property
2. Personalized user experience by transforming specific attributes into recommendations

> “Attribute-based encryption secures content and personalizes experiences, protecting intellectual property while tailoring viewing for users.

AI-powered penetration testing

Industry: **Cross-industry**

A startup provides an autonomous penetration testing solution that continuously evaluates an organization's security across external, identity, IoT and cloud attack surfaces. By simulating real-world attacks, it identifies vulnerabilities before they can be exploited.

Business value

1. Lowers costs and complexity of security testing through automation
2. Enables ongoing assessments to keep pace with evolving cyberthreats

> "Continuous automated penetration testing identifies vulnerabilities, staying ahead of evolving cyberthreats.

Use cases

Success case

Europe | Healthcare

SECANT: Security and privacy protection for IoT devices

Business need

A report by F5 Labs found a 280% growth in attacks on IoT devices. Similarly, Symantec reported a staggering 600% growth in IoT cyberattacks over a six-month period.

The healthcare sector relies heavily on interconnected IoT solutions. It's an industry where sensitive information is processed every moment, and the race for contact-tracing applications has promoted the need for privacy. Healthcare services relying on IoT devices need to be cyber resilient and equipped with advanced cybersecurity capabilities for ensuring quick recovery in the face of crippling modern cyberthreats.

Solution

NTT DATA leads the SECANT Consortium, which has developed an automated threat detection platform for computer emergency response teams (CERTs) and computer security incident response teams (CSIRTs), focused on threat identification and security awareness in complex ICT infrastructures, such as healthcare.

The platform enhances stakeholders' capabilities by implementing:

- Collaborative threat intelligence collection, analysis and sharing
- Advanced risk analysis for interconnected industrial ecosystems
- Trust and accountability mechanisms for data protection
- Employee security-awareness training for more informed security choices

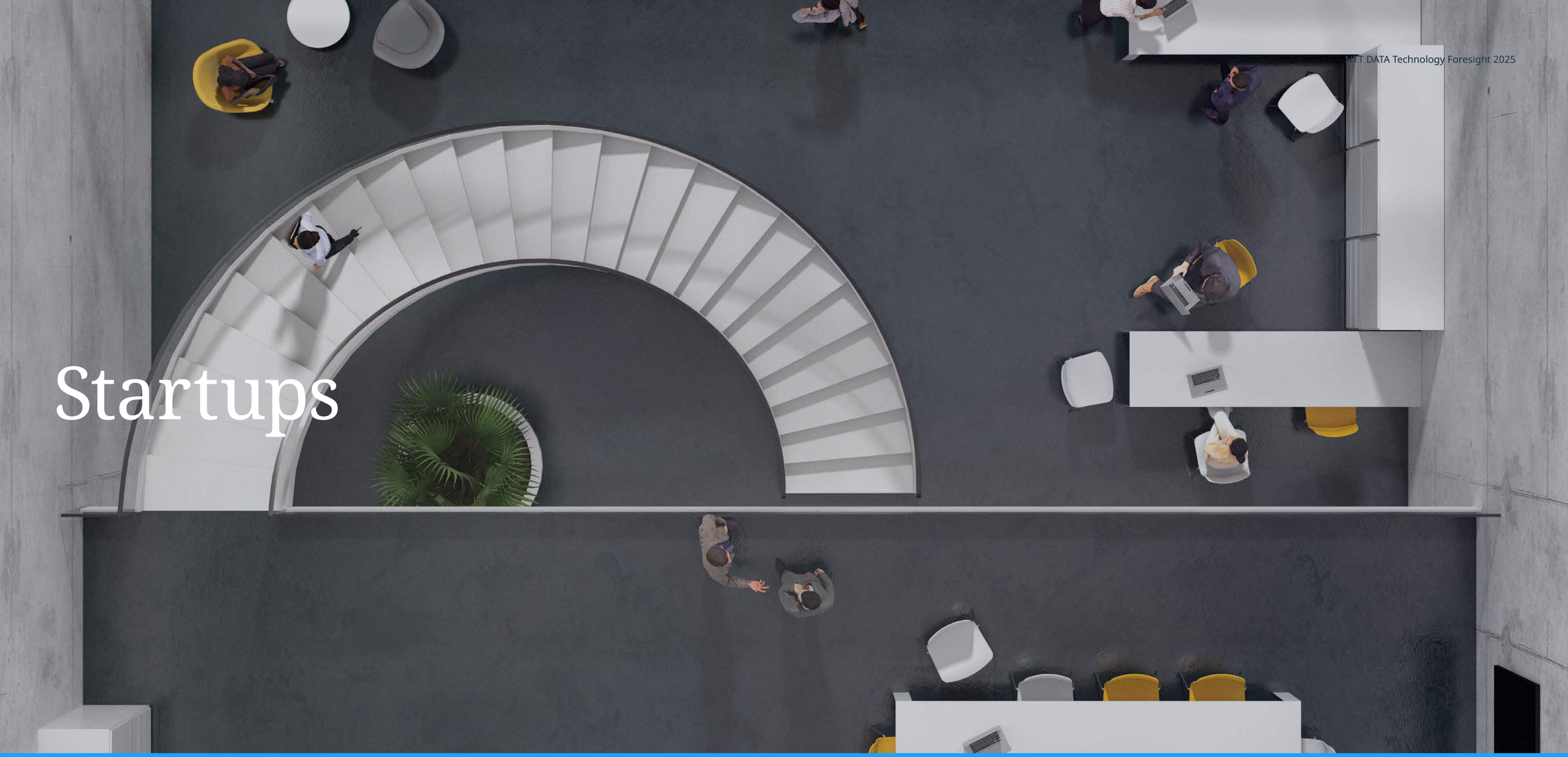
The platform was validated in four pilot use cases in the healthcare sector. It aims to:

- Improve organizational readiness and resilience against modern cyberthreats
- Increase privacy, data protection and accountability across the interconnected ICT ecosystem
- Reduce training costs

Outcomes

The SECANT platform empowers supply chain stakeholders, including CERTs and CSIRTs, with advanced cyberthreat intelligence collection, analysis and sharing capabilities. It delivers innovative risk analysis tailored for interconnected industrial ecosystems, advanced trust and accountability mechanisms for data protection, and comprehensive security awareness training to support more informed cybersecurity decisions.

Startups



Startup radar

In this section, we review a selection of startups relevant to accelerated security fusion, based on our observations, partnerships and investments.

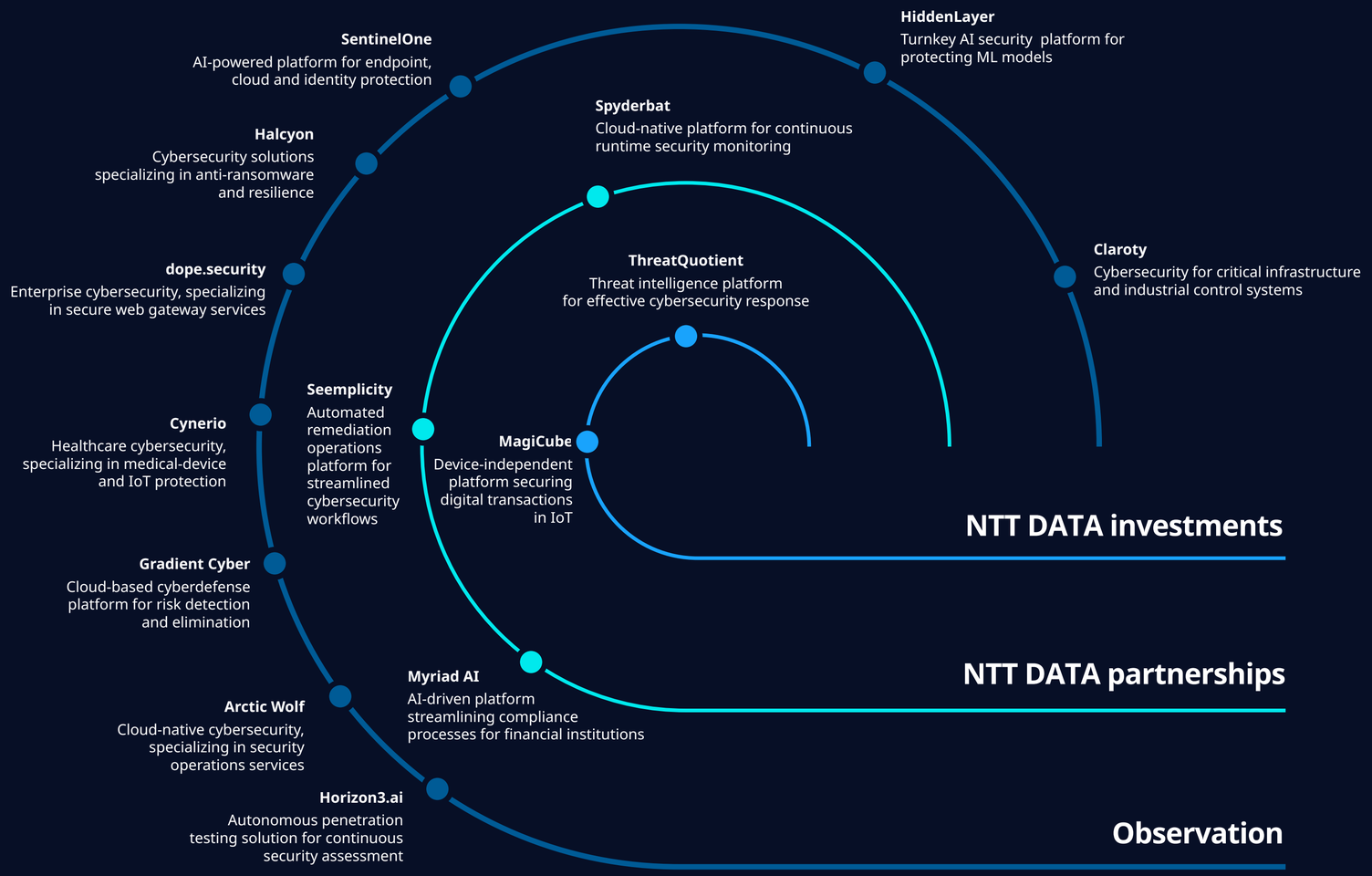


Figure 30: Investment in accelerated security fusion startups

Startups

Observation

Arctic Wolf

Founded in 2012, Arctic Wolf specializes in security operations. Its cloud-native platform offers services such as MDR, managed risk, managed security awareness and incident response. These services are delivered through a concierge delivery model, providing organizations with 24x7 monitoring, detection and response capabilities.

Stage
Series F

Funding
$899.2 million

Valuation
$4.43 billion

Industry
Cross-industry

HiddenLayer

Founded in 2022, HiddenLayer specializes in AI security, providing a turnkey platform for ML models that protects enterprises against threats such as inference attacks and model theft. Its solution offers robust protection without adding complexity or requiring access to raw data. The company aims to establish itself as a leader in the rapidly evolving AI security landscape.

Stage
Series A

Funding
$56 million

Valuation
Not disclosed

Industry
Cross-industry

Cynerio

Founded in 2017, Cynerio is a healthcare-focused cybersecurity company specializing in protecting medical devices and IoT systems in healthcare environments. It integrates generative AI into its Cynerio 360 platform, enhancing capabilities in device classification, security, rule generation and anomaly detection. Cynerio also offers a unique attack detection and response (ADR) product tailored for healthcare.

Stage
Series B

Funding
$37 million

Valuation
Not disclosed

Industry
Healthcare

Halcyon

Founded in 2021, Halcyon specializes in anti-ransomware solutions and cyber resilience for enterprise customers. Its platform provides layered protection against ransomware, including pre-execution detection, behavioral modeling and recovery features, as well as key capture and automated decryption to prevent data extortion. Halcyon primarily serves the global enterprise sector, offering tools and assessments to enhance cyberdefense capabilities.

Stage
Series B

Funding
$90 million

Valuation
Not disclosed

Industry
Cross-industry

SentinelOne

Founded in 2013, SentinelOne provides an AI-powered platform for endpoint, cloud and identity protection. SentinelOne's autonomous endpoint protection technology uses a single AI-powered agent to unify prevention, detection, response and threat hunting across all attack vectors, automatically eliminating threats in real time for both on-premises and cloud environments.

Stage
Post-IPO

Funding
Not disclosed

Valuation
Not disclosed

Industry
Cross-industry

Claroty

Founded in 2015, Claroty protects cyber–physical systems (CPS) and the extended Internet of Things (XIoT), focusing on critical infrastructure and industrial control systems. The Claroty Edge platform is a zero-infrastructure industrial cybersecurity solution that provides complete visibility of industrial networks without requiring network changes, sensors or physical footprint.

Stage
Series D

Funding
$735 million

Valuation
Not disclosed

Industry
Manufacturing; public sector; energy; telecommunications

Horizon3.ai

Founded in 2019, Horizon3.ai provides an autonomous penetration testing solution. The company offers NodeZero, which enables organizations to continuously assess the security posture of their enterprise, including external, identity, IoT and cloud attack surfaces.

Stage
Series C

Funding
$79 million

Valuation
Not disclosed

Industry
Cross-industry

Gradient Cyber

Founded in 2017, Gradient Cyber is the developer of a cloud-based cyberdefense platform designed to detect and eliminate cyber risks and maintain data privacy. The platform combines cognitive computing algorithms and measures 3D tomographic attack surfaces using AI that mimics a hacker's own skills to find network vulnerabilities. It plugs them before the hacker has a chance to exploit them. This enables clients to measure and assess their current cybersecurity posture to achieve greater cyber situational awareness.

Stage
Debt financing

Funding
$16.3 million

Valuation
Not disclosed

Industry
Cross-industry

dope.security

Founded in 2021, dope.security focuses on secure web gateway services. Its main offerings include an on-device proxy for direct internet access, with local SSL traffic inspection and an AI-powered data-loss prevention tool for cloud applications. The company primarily serves sectors that require robust cybersecurity solutions for endpoint and cloud applications.

Stage
Series A

Funding
$20 million

Valuation
Not disclosed

Industry
Cross-industry

Startups

NTT DATA partnerships

Myriad AI

Founded in 2023, Myriad AI is developing an AI-driven platform designed to streamline compliance processes for banks and fintech companies. The platform leverages advanced AI to enhance access to regulatory information, aiming to simplify and automate compliance tasks. This approach seeks to reduce the complexity and time associated with traditional compliance methods, offering a more efficient solution for financial institutions.

Stage
Pre-seed

Funding
$2 million

Valuation
Not disclosed

Industry
Financial services

Seemplicity

Founded in 2020, Seemplicity offers a remediation operations (RemOps) platform designed to automate and streamline risk-reduction workflows. Its platform consolidates security findings from various tools, enabling security teams to prioritize and manage vulnerabilities efficiently. By automating remediation processes, Seemplicity aims to accelerate vulnerability reduction and enhance overall security posture.

Stage
Series A

Funding
$32 million

Valuation
Not disclosed

Industry
Cross-industry

Spyderbat

Founded in 2019, Spyderbat provides a cloud-native runtime security platform that delivers continuous security monitoring, improved observability and timely alerting. Their platform uses eBPF-based* agents to capture comprehensive runtime events, enabling organizations to detect, identify and block threats in real time across hybrid and multicloud environments.

*eBPF: extended Berkeley Packet Filter

Stage
Series A

Funding
$14.2 million

Valuation
Not disclosed

Industry
Cross-industry

Startups

NTT DATA investments

MagicCube

Founded in 2014, MagicCube provides security solutions for digital transactions in the IoT sector. The company offers a device-independent platform that secures digital transactions on any device, in transit and in the cloud, providing a level of security comparable to hardware solutions but without the associated complexity and cost.

Stage
Series C

Funding
$25.95 million

Valuation
$100–$500 million

Industry
Cross-industry; financial services

ThreatQuotient

Founded in 2013, ThreatQuotient offers a threat intelligence platform designed to help organizations understand and respond to cyberthreats effectively. Its solutions integrate threat data, prioritize security operations and facilitate collaboration among security teams to enhance overall defense strategies.

Stage
Series C

Funding
$87.6 million

Valuation
Not disclosed

Industry
Cross-industry

Future scenarios

As industries transform, new value chains emerge and technological advancements grow exponentially, companies must navigate complex, evolving landscapes.

Future scenarios and GenAI powered personas allow organizations to explore possible futures, simulating realistic business environments and minimizing risk through scenario-based planning.

Uncertainties represent what we cannot know but identifying them can reduce the risks of blind spots down the road.

Future scenarios

Uncertainty: effectiveness of GenAI for threat simulation

AI's dual edge

What if GenAI becomes a double-edged sword in cybersecurity?

As GenAI evolves into a powerful tool for simulating and preempting cyberthreats, it makes defenses more adaptive than ever. However, the same technology may empower malicious actors to design more sophisticated attacks, creating a constant race between innovation in defense and exploitation.

Guardians of tomorrow

What if AI-driven defenses redefine cybersecurity, transforming it into a predictive science?

GenAI is increasingly becoming a proactive agent, predicting and countering cyberthreats before they occur, significantly reducing attacks. Beyond protection, the efficiency gains from AI will allow organizations to redirect resources to innovation, boosting overall productivity and technological development.

Future scenarios

Uncertainty: post-quantum cryptography readiness

Quantum race, digital chaos

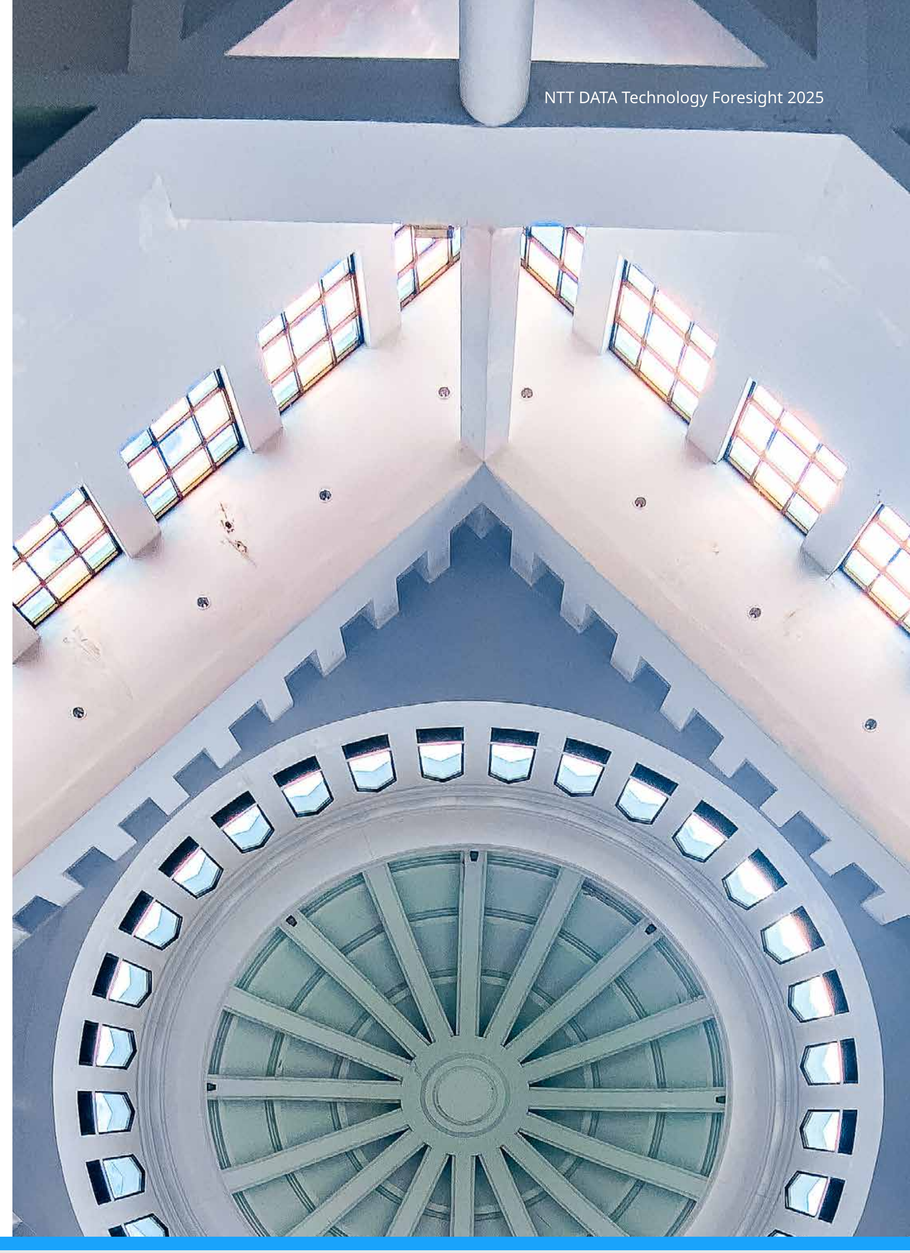
What if a fragmented digital ecosystem accelerates innovation while exposing vulnerabilities to quantum-powered attacks?

As early adopters of post-quantum cryptography secure critical systems, laggards face heightened risks, creating a global digital divide. This competition may drive rapid advancements in encryption and decentralization technologies, enabling niche industries and robust local solutions to thrive.

Quantum strongholds

What if quantum readiness becomes the new determinant of power and resilience in the digital age?

Nations and corporations investing in post-quantum cryptography will create secure, future-proof infrastructures that can withstand quantum-powered breaches. The race for quantum resilience may fuel a renaissance in science, engineering, technology and math (STEM) education and workforce development, creating a generation of quantum-savvy professionals.



Conclusion and next steps

Conclusion and next steps

Think about this

As businesses face increasing security complexity, identifying and prioritizing weaknesses across detection, response, identity management and data privacy becomes essential.

How robust is your organization's approach to systematically analyzing vulnerabilities, including cryptographic standards, to safeguard against emerging risks?

AI-driven threat intelligence programs unlock value by fostering cross-departmental alignment, streamlining information-sharing and enhancing decision-making capabilities.

How does your organization ensure integration between teams and technologies to establish a cohesive and proactive defense strategy?

With automation reshaping security paradigms, optimizing incident response workflows can significantly reduce operational bottlenecks and improve agility in addressing critical threats.

Are your security systems leveraging automation to enhance speed, accuracy and scalability in cyberincident management?

Conclusion and next steps

Do this next

5 minutes

Identify and address security weaknesses

Assess the current state of your organization's security infrastructure. Identify gaps in threat detection, response or identity management that could benefit from AI-driven solutions.

5 days

Select and prepare simulation tools

Evaluate and shortlist breach and attack simulation tools. Prepare an implementation plan and secure approvals to launch a proof-of-concept project.

5 months

Build a security deployment roadmap

Develop a roadmap for deploying key accelerated security fusion technologies, such as MDR services, CNAPPs and zero trust frameworks.

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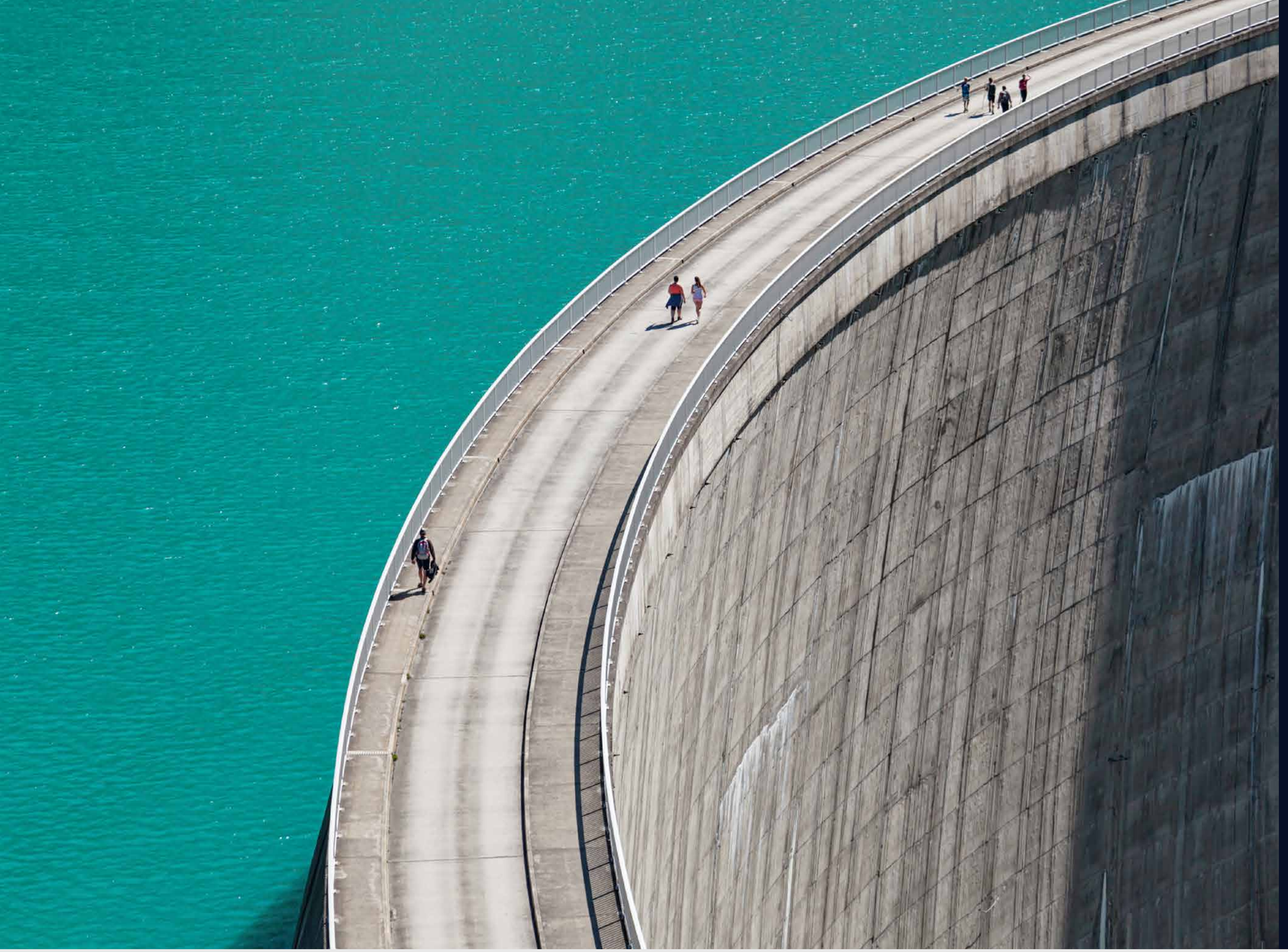

Conclusion

While the possibilities and potential of the technology trends we've explored in this report are exciting, we must remain alert to their potential risks. As organizations continue to experiment and iterate, we expect them to draw on the support of GenAI-powered personas who will simulate realistic business environments and apply scenario-based planning to mitigate risks.

Uncertainties will always persist, but striving to comprehend future scenarios can decrease the likelihood of organizations facing unexpected challenges and blind spots.

NTT DATA stands ready to help. Our services include business and technology consulting, data and artificial intelligence, industry solutions, as well as the development, implementation and management of applications, infrastructure and connectivity.

We are also one of the leading providers of digital and AI infrastructure in the world.

NTT DATA is part of NTT Group, which invests over $3.6 billion each year in R&D to help organizations and society move confidently and sustainably into the digital future.

Visit us at nttdata.com

About the research

About the research

Research methodology

The methodology behind NTT DATA's Technology Foresight 2025 combines rigorous research practices with unique internal resources to explore and refine emerging technology trends. Drawing from NTT Group's extensive investments in basic and applied research, our team benefits from direct access to cutting-edge developments in a wide array of fields, enabling a deep understanding of technological advancements and their potential applications.

A key component of the process is the use of an internal market intelligence platform which aggregates and analyzes data from diverse sources, including market forecasts, analyst insights, and public information on investments and partnerships. This automated, data-driven approach ensures that trend selection is grounded in objective evidence.

The methodology is further enhanced by consultation with a global network of technology and business experts in NTT Group. These specialists contribute localized and domain-specific insights, refining trends through a collaborative, multidisciplinary lens. Finally, techniques from strategic foresight are employed to map these trends and use cases to future scenarios, examining their implications for individuals, businesses and society. This structured, iterative process ensures that the identified trends are not only technologically robust but also contextually relevant and future-ready.

Research at scale

Future signals

Basic research
Future signals are taken from NTT Group's basic and applied research.

Market intelligence

Data-driven preselection
Automated, data-driven intelligence on technology players and markets.

Expert refinement

SME-based consolidation
Technology and business experts are consulted to refine trends.

Envisioning

Use cases and scenarios
Relevant use cases are cross-referenced with future scenarios.

Insights

Recommendations
Information is turned into insights, a compass to decode the future.

Contact information

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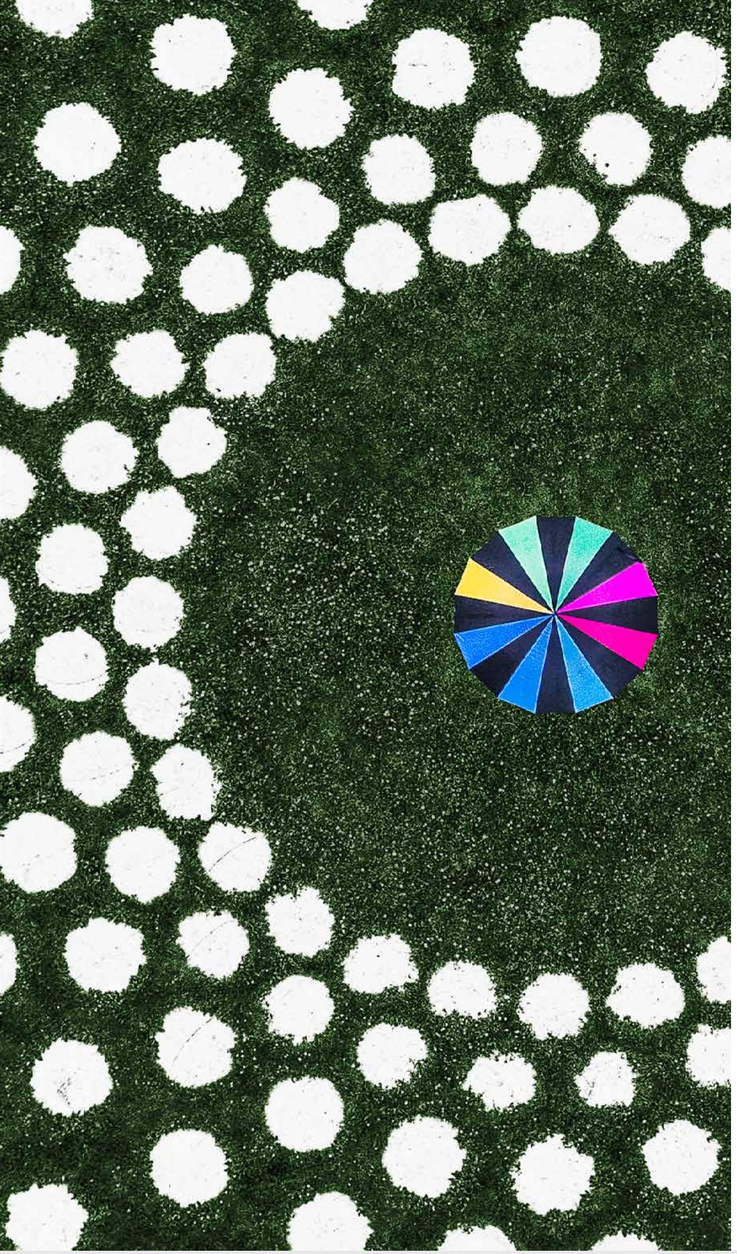

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Glossary of key terms

Enhanced humans
People and machines are collaborating to shape a future where human potential isn't limited by time, task or knowledge.

Ambient intelligent experiences
Technologies like AI, spatial computing and automation are fundamentally changing how organizations connect with their audiences across different touchpoints.

Digital sustainability for economic resilience
A new business strategy is emerging where organizations integrate environmental stewardship with economic growth and assign individual and collective responsibility.

Cognitive cloud convergence
By integrating advanced cloud computing technologies with AI and human cognitive abilities, organizations can improve operations, enhance decision-making and understand their data in real time.

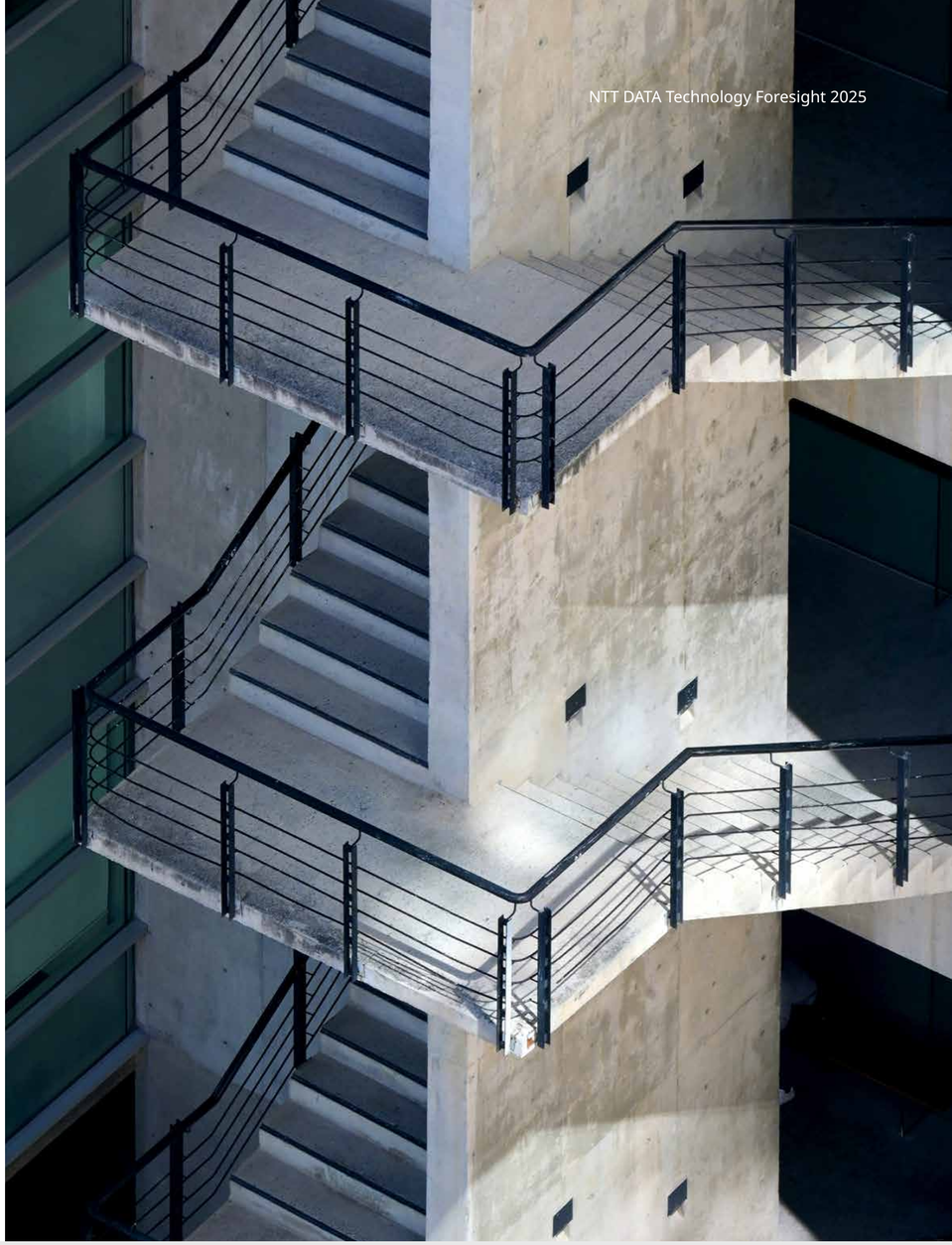
Accelerated security fusion
A new business strategy is emerging where organizations integrate automated incident response and AI-driven threat detection to adapt dynamically to emerging threats and build cyber resilience.

List of abbreviations

ADR	attack detection and response
AGV	automated guided vehicles
AI	artificial intelligence
AIASE	AI-augmented software engineering
AIOps	AI for IT operations
AMR	autonomous mobile robots
API	application programming interface
AR	augmented reality
ASIC	application-specific integrated circuit
AutoML	automated machine learning
AWS	Amazon Web Services
BAS	breach and attack simulation
CDN	content delivery network
CERT	computed emergency response team
CGI	computer-generated imagery
CGM	continuous glucose monitor
CI/CD	continuous integration and continuous delivery or deployment
CNAPP	cloud-native application protection platform
CPS	cyber-physical systems
CPU	central processing unit
CRQ	cyber risk quantification
CSIRT	computer security response team
CSPM	cloud security posture management
CX	customer experience
CVE	common vulnerabilities and exposure
DevSecOps	development, security and operations
DDoS	distributed-denial-of-service
DoT	deep learning of things
DSP	data security platform
EMS	energy management systems
ESG	environmental, social and governance
eVTOL	electric vertical takeoff and landing
FPGA	field programmable gate array
GenAI	generative AI
GPU	graphics processing units
GPT	generative pretrained transformer
IAM	identity and access management
IDE	integrated development environment
IOWN	Innovative Optical and Wireless Network
IPA	intelligent personal assistant
IRM	integrated risk management

List of abbreviations

ITRM	IT risk management
ITSM	IT service management
IoT	Internet of Things
LIME	Local Interpretable Model-Agnostic Explanations
LLM	large language model
MAG	multiagent generative system
MDR	managed detection and response
MFA	multifactor authentication
MLOps	machine learning operations
ML	machine learning
MR	mixed reality
NLP	natural language processing
OEM	original equipment manufacturer
OT	operational technology
PaaS	platform-as-a-service
PET	privacy-enhancing technology
PDE	provider data extractor
PQE	post-quantum encryption
PRM	proactive risk management
RAG	retrieval-augmented generation
RemOps	remediation operations
RPA	robotic process automation
RFID	radio frequency identification
SaaS	software-as-a-service
SHAP	Shapley Additive exPlanations
SSL	secure sockets layer
STEM	science, technology, engineering and math
TPU	tensor processing unit
UAV	unmanned aerial vehicle
VA	virtual assistant
MLOps	machine learning operations
VoC	voice of the customer
VR	virtual reality
XIoT	extended IoT
XOps	cross-functional operations



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