2025 TECH TRENDS REPORT • 18TH EDITION

METAVERSE & NEW REALITIES

FTSG

Future Today Strategy Group's 2025 Tech Trend Report

Our 2025 edition includes 1000 pages, with hundreds of trends published individually in 15 volumes and as one comprehensive report. Download all sections of Future Today Strategy Group's 2025 Tech Trends report at **www.ftsg.com/trends.**

Melanie Subin
Managing Director

You're already living in the metaverse; you just don't know it.

The metaverse isn't what you think it is. For the past five years, we've been sold a vision of the future that's more science fiction than reality. Tech titans, inspired by dystopian novels, poured billions into creating virtual worlds that promised to revolutionize how we live, work, and play. They built it, but we didn't come. Why? Because the metaverse, as it's been defined, is a mirage—an unaffordable, inaccessible, and unrealistic fantasy that ignores the fundamental ways humans want to experience life.

The truth is, the real metaverse is already here, but it's not what you've been told to expect. It's not a virtual playground requiring expensive headsets and impossible bandwidth. Instead, it's the invisible, interconnected digital layer that surrounds us every day. It's in the sensors in our phones, the smart devices in our homes, and the digital footprints we leave behind with every interaction. The metaverse isn't a place we go to escape reality; it's the technology that's seamlessly becoming our reality.

We're at a turning point. The decisions we make now will shape our digital future for years to come. The next decade will determine which companies and industries thrive in this hyper-connected world and which become obsolete. The winners will be those who understand that the metaverse isn't about creating new virtual worlds but enhancing our existing ones through data, connectivity, and intelligence.

This book is your guide to navigating the real metaverse—a world where digital and physical realities converge in ways both subtle and profound. We'll explore how this shift is already reshaping industries, altering human behavior, and creating unprecedented opportunities and challenges. The future is here, and it's time to see it clearly.

Welcome to the true metaverse. It's not what you expected, but it's far more exciting—and it's already transforming the world around us.

AI and invisible technologies are redefining the metaverse, sparking privacy debates, transforming industries and revolutionizing social interactions.

1

AI integration redefines the metaverse landscape

Generative AI technologies are enhancing user experiences and creating more realistic digital environments. This integration transforms how we interact with digital layers in our everyday lives, from recommendations to smart home controls.

2

The rise of 'invisible' metaverse technologies

The development and adoption of technologies that seamlessly blend into our physical reality—including advanced IoT devices, spatial computing, and edge computing—is helping fuel the development of the metaverse as an interconnected digital layer.

3

Privacy concerns spark debate over metaverse data collection

The increasing prevalence of sensors and data collection has ignited a debate about data ownership. This has led to new regulations and innovative approaches to data protection, as society grapples with the balance between personalization and privacy.

4

Companies embrace industrial metaverse applications

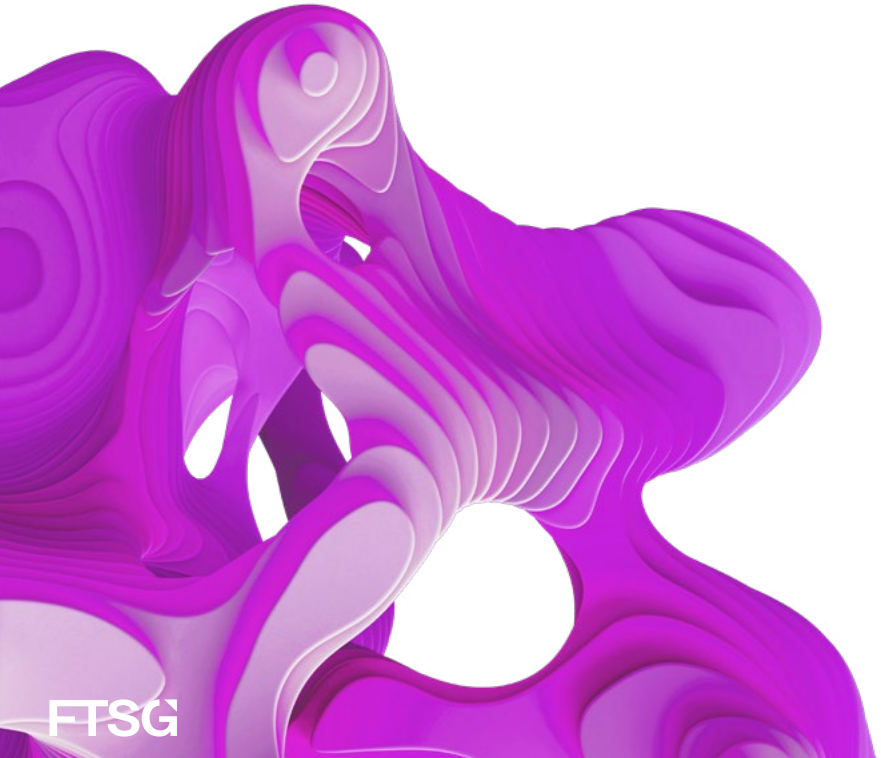
Industries are rapidly adapting to our new understanding of the metaverse. Now, they're focusing on "industrial metaverse" applications, leading to real productivity gains and growth in sectors like urban planning and manufacturing.

5

Data interoperability is critical for metaverse evolution

For the metaverse to develop, it needs a unified digital infrastructure that enables safe real-to-virtual interactions. Such data interoperability must focus on seamlessly integrating capabilities like digital identities and payment systems.

The metaverse is shifting from a hyped-up sci-fi future to a practical reality.



The metaverse is undergoing a significant recalibration after the initial hype of the early 2020s, with investment and resource allocation slowing considerably. However, this deceleration is a natural and expected part of the technology adoption curve, mirroring the trajectory of other transformative innovations. The concept of the metaverse is evolving from an overhyped, VR-centric vision to a more nuanced and practical integration into daily life. Much like the internet's gradual adoption in the 1990s, the metaverse is poised to become a subtle yet powerful augmentation of reality rather than a separate, immersive world accessible only through specialized hardware.

This shift in perspective is crucial for understanding the metaverse's true potential. Instead of viewing it as a niche technology for enthusiasts, it's more accurate to consider it as an extension of our digital interactions, seamlessly blending physical and virtual experiences. This integration is already manifesting in various sectors, from education and health care to business and entertainment, enhancing rather than replacing traditional modes of interaction. The industrial metaverse, for instance, is gaining traction with digital twins and augmented reality solutions enhancing design, monitoring, and employee training processes. In e-commerce, the integration of virtual products with physical world tie-ins is driving innovation and creating new market opportunities.

As the technology matures and becomes more accessible, the metaverse's impact on daily life will likely be profound yet subtle, reshaping how we work, learn, and interact without the need for constant immersion in virtual reality. This recalibration period is crucial for addressing challenges such as privacy concerns, regulatory frameworks, and technological limitations. It allows for a more thoughtful and sustainable development of the metaverse, ensuring its integration into society is both beneficial and responsible.

As we move beyond the initial hype, the true potential of the metaverse as a transformative force in our daily lives is beginning to take shape, promising a future where digital and physical realities coexist seamlessly.

Artificial intelligence prompts new product rollouts and several regulatory changes.

JANUARY 2024

EU Moves to Regulate Virtual Worlds

The European Parliament calls for guidelines clarifying the legal obligations of different stakeholders in virtual spaces.

FEBRUARY 2024

Apple Launches the Vision Pro Headset

The headset blends digital content with the physical world, and marks Apple's entry into mixed reality hardware.

SEPTEMBER 2024

Meta Unveils New Metaverse Hardware and Features

Meta releases a new headset and a refreshed strategy for its metaverse platform, and teases more lifelike avatars and AI-driven NPCs.

« PAST

JANUARY 2024

Davos Hosts a Metaverse Collaboration Village

More than 200 people participated in immersive dialogues via the World Economic Forum's virtual Global Collaboration Village.

FEBRUARY 2024

South Korea Enacts Metaverse Industry Law

The new law both supports and regulates the metaverse, prioritizing permissionless development with oversight after implementation.

Integrated displays and headset advancements will mark much of the progress in 2025.

MARCH–APRIL 2025

Global Conference on Metaverse Governance

The EU's conference will discuss metaverse regulation, including interoperability, ethics, and global policy coordination.

MID-2025

Samsung & Google's XR Headset Launch

The standalone mixed-reality headset features state-of-the-art displays, eye/hand tracking, and an external battery.

AUGUST 2025

MetaCom 2025

Researchers, industry professionals, and academics will discuss emerging technologies and innovations shaping the metaverse landscape.

FUTURE »

APRIL 2025

Osaka Expo Virtual World Opening

The virtual "Yumeshima Islands in the Sky" will allow visitors to join as avatars, explore, and enjoy exclusive events.

MID-2025

Meta Adds Integrated Displays to Ray-Ban Smart Glasses

Meta's updated glasses will feature integrated displays capable of showing notifications and responses from a virtual assistant.

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Businesses that prepare now for the metaverse will gain an early advantage.

Business Model Reinvention

In the metaverse era, companies will reinvent their business models to blend physical and digital offerings, integrating virtual goods, services, and immersive experiences. This transformation unlocks new revenue streams and reimagines value propositions, allowing early movers to shape the standards.

Optimized Operations

Metaverse technologies like augmented reality and data-driven digital twins are enabling unprecedented efficiencies. By simulating factory floors, supply chains, and complex systems in 3D, companies can predict issues and optimize processes in advance, leading to leaner operations and lower costs.

Immersive Customer Engagement

Metaverse platforms are redefining how companies interact with customers. Businesses will build virtual showrooms, interactive events, and branded worlds where customers play an active role, forging deeper loyalty and emotional connections that will shape the future of customer experience.

Workforce Evolution

Organizations are leveraging metaverse tools to transform their workforce, using virtual reality for everything from employee training and onboarding to seamless collaboration. This shift will fundamentally reshape how companies attract, develop, and retain talent in a borderless work environment.

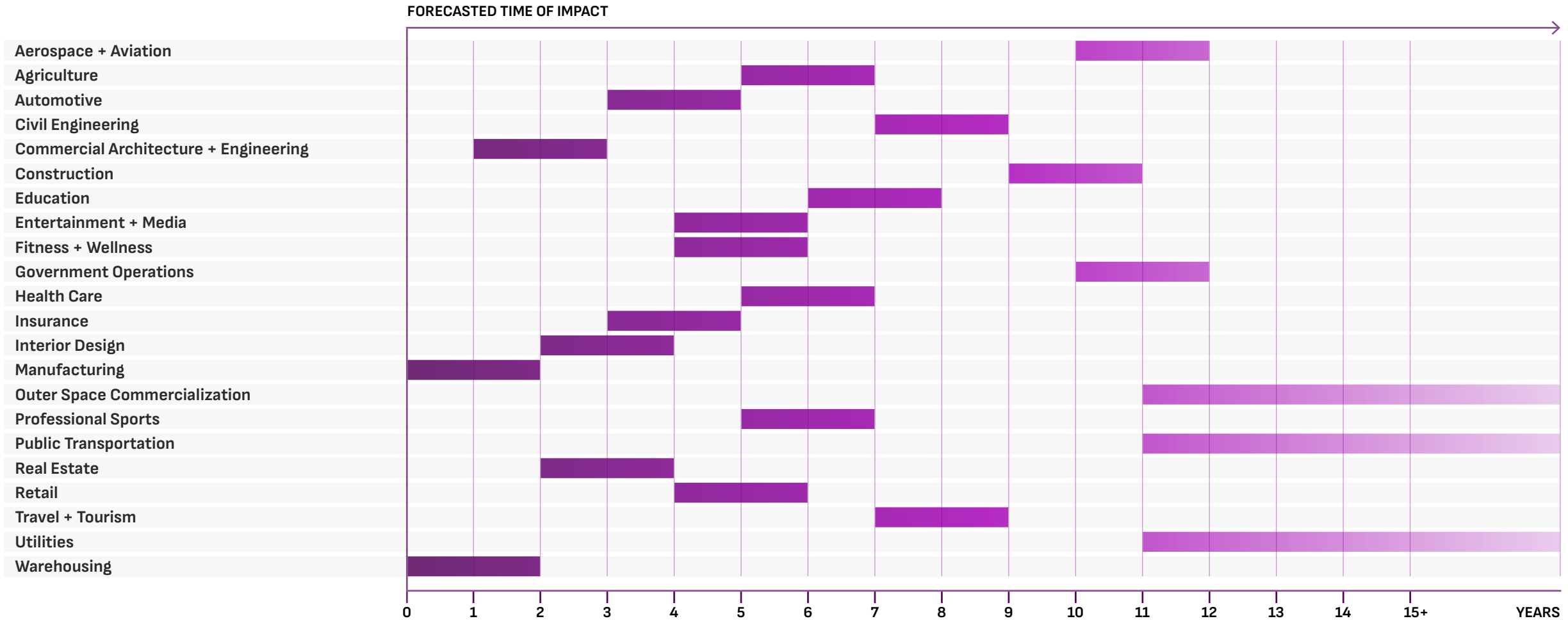
Decentralized Governance and Trust

The metaverse will accelerate the adoption of decentralized governance models, where smart contracts and blockchain-based decision-making replace traditional hierarchical structures. This will compel businesses to rethink corporate governance, compliance, and stakeholder engagement strategies.

Data Sovereignty and Privacy

Data ownership, security, and privacy concerns will become critical as businesses enter the metaverse. Ethical data stewardship will evolve from a compliance requirement into a key competitive advantage, distinguishing brands in an increasingly surveilled digital landscape.

Many industry operations are already being directly impacted.



Willingness to invest in infrastructure will determine firms' ability to benefit from the early mover advantage.

SCALING
Industries with established digital ecosystems, such as gaming and entertainment, are already experimenting with metaverse applications, while sectors requiring complex integrations face longer timelines. Cloud computing, edge processing, and AI-driven simulations will be crucial in enabling scale.

CONSTRAINTS ON ADOPTION
Workforce readiness, interoperability between platforms, and need for standardization are significant barriers to adoption. Industries with existing digital twin applications can quickly integrate metaverse solutions while fields requiring compliance or physical infrastructure will take longer to adapt.

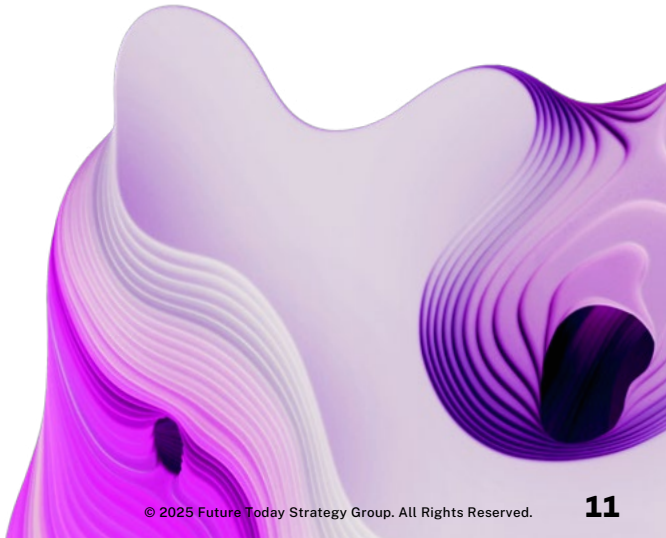
MEDIA MENTIONS
Public discussions around the metaverse impact organizational urgency to invest. Industries with high consumer engagement will feel pressure to adopt metaverse solutions sooner. Frequent coverage can accelerate experimentation and investment, while limited or negative media narratives can slow enthusiasm.

R&D DEVELOPMENTS
The pace of technological advancements will impact adoption timelines. Fields like spatial computing and blockchain integration are making rapid progress, accelerating adoption in industries such as automotive and aerospace. Industries with long R&D cycles will take longer to see implementation.

COSTS
The metaverse demands substantial investment in infrastructure, computing power, and hardware. Early adopters with large budgets, such as manufacturing and automotive industries, will leverage metaverse applications in the near term, while industries constrained by cost sensitivity will see slower adoption.

REGULATIONS
Metaverse adoption will be shaped by emerging policies on digital identity, data privacy, intellectual property rights, and cybersecurity. Highly regulated industries, such as health care and financial services, will experience delays while industries like retail and media, will see faster integration.

PUBLIC PERCEPTIONS
Consumer trust in digital environments will shape adoption rates. Industries where immersive experiences enhance customer interactions, such as real estate and interior design, will see earlier integration while sectors requiring trust, like insurance and health care, must address skepticism before scaling.



These individuals are defining and building the original metaverse.

- **Jeremy Bailenson, Professor of Communication at Stanford University and Founding Director of the Virtual Human Interaction Lab,** for examining how humans learn and behave in virtual environments.
- **Matthew Ball, CEO of Epyllion and Author of "The Metaverse: And How It Will Revolutionize Everything,"** for his thought leadership framing the metaverse's evolution.
- **Alvin Wang Graylin, Global VP at HTC,** for leading VR/AR adoption in China through HTC, focusing on the convergence of AI and XR, and advocating for an inclusive, AI-driven metaverse.
- **John Hanke, Founder & CEO of Niantic,** for championing the "real-world metaverse" via AR to make the world more interactive and magical.
- **Mic Mann, CEO of Africarare,** for launching "Africarare" to showcase African art and innovation in a virtual world, aiming to connect Africa to the global digital economy.
- **Dr. Morgan McGuire, Chief Scientist at Roblox,** for his work as the driving force behind one of the world's largest user-created metaverse platforms.
- **Herman Narula, Co-founder & CEO of Improbable,** for building the backbone of large-scale virtual worlds through platforms like SpatialOS that enable massive simulations.
- **Tony Parisi, Chief Product Officer at Lamina1,** for his work as a veteran VR pioneer and co-creator of several international 3D graphics standards, including VRML, X3D, and glTF.
- **Nonny de la Peña, Founder & CEO of Emblematic Group; Program Director,** ASU Narrative and Emerging Media, for pioneering immersive journalism and innovating new ways to tell stories in VR.
- **Mike Rockwell, Vice President of Apple's Vision Products Group,** for leading the driving force behind Apple's Vision Pro, redefining AR/VR interfaces and accelerating metaverse development.
- **Yat Siu, Co-founder & Executive Chairman of Animoca Brands,** for being a leading advocate for digital property rights and an open metaverse.
- **Neil Trevett, VP of Developer Ecosystems at Nvidia; President of the Khronos Group and the Metaverse Standards Forum,** for his work as a key architect of metaverse interoperability.

The metaverse brings the potential of new revenue and increased efficiencies...

OPPORTUNITIES

New Revenue Streams and Digital-First Economies

Businesses can generate revenue through digital products, immersive advertising, and blockchain assets, such as selling NFTs, leasing virtual real estate, or offering digital services.

Cost Reduction Through Immersive Technologies

VR/AR and digital twins can reduce operational expenses, such as by cutting travel and onboarding costs, lowering product development expenses, and reducing the need for physical office spaces.

Novel Channels for Customer Engagement

Companies can connect in new ways with consumers, from virtual storefronts and interactive brand experiences to immersive events and gamified marketing campaigns, creating refreshed engagement.

Data-Driven Personalization and Market Insights

Metaverse interactions generate valuable data, enabling businesses to use customer behavior data and insights to refine product offerings, personalize marketing efforts, and optimize experiences.

...but implementation will need to mind existing regulatory and legal limitations.

THREATS

Regulatory and Legal Uncertainty

The metaverse lacks clear regulatory frameworks. Companies must navigate complex legal landscapes and risks related to digital ownership, taxation, intellectual property, and jurisdictional disputes.

Changing Communication Models

Traditional digital marketing methods, such as social media ads and search engine optimization, may lose effectiveness in immersive environments, requiring businesses to adapt to new advertising models.

Data Privacy and Security Concerns

The metaverse collects vast amounts of personal and biometric data, making it a target for cyber threats. Companies must secure digital environments to maintain trust and avoid reputational damage.

Ethical and Reputational Risks

Issues like harassment, misinformation, and addictive experiences can lead to public backlash or legal consequences if not properly managed, necessitating governance policies and ethical safeguards.

The time to begin preparing is now, before the metaverse is fully scaled.

Invest in robust cloud infrastructure, cybersecurity frameworks, and blockchain systems to ensure safe, efficient, and scalable metaverse operations while protecting digital assets and transactions.

Develop specialized training programs to equip employees with VR/AR, blockchain, and digital commerce expertise, ensuring teams can effectively operate and innovate in metaverse environments.

Redefine revenue strategies by integrating digital assets, immersive experiences, and metaverse-driven commerce, positioning businesses to thrive in evolving virtual marketplaces.

Engage with policymakers and industry groups to advocate for balanced regulations on digital ownership, virtual asset taxation, and data privacy, ensuring business-friendly policies that promote innovation.

Begin transitioning from traditional ad formats to immersive brand experiences, influencer-driven interactions, and in-world sponsorships to align with evolving marketing dynamics in virtual spaces.

Allocate resources to develop metaverse environments, enhance VR/AR capabilities, and support long-term innovation in virtual commerce, ensuring sustained growth in immersive digital ecosystems.

 Technology Deployment

 Capital Expenditure

 Talent Development

 Regulatory Influence

Important terms to know before reading.

AUGMENTED REALITY (AR)

A technology that overlays digital information, images, and objects onto the real-world environment. Users see virtual elements mixed into their actual surroundings through a device screen or AR glasses/headset.

AVATAR

A digital representation of a user, often in the form of a 3D model or illustration. Avatars serve as a user's persona in online/virtual environments.

CYBERSICKNESS

Nausea or motion sickness experienced by some VR users due to proprioception disorientation. It arises from the mismatch between perceived and actual spatial positions in VR, with research suggesting that factors like vertical orientation, perception, and inclusion of music can influence its severity.

DATA PORTABILITY

The ability for users to transfer their digital identities, including avatars, and associated data between platforms and services.

DECENTRALIZATION

A core principle shared by the metaverse and blockchain technology, emphasizing an open network of interconnected virtual worlds, as opposed to closed, proprietary platforms.

DEEPFAKES

Manipulated video/audio that uses AI to realistically substitute someone's likeness and voice in existing content without their consent, raising ethical concerns.

DIGITAL TWINS

Virtual replications of physical systems used for simulation and optimization.

EXPERIENTIAL ARTIFACTS

Lingering sensory and cognitive effects in VR users, blurring the lines between virtual and real-world experiences. These artifacts result from the dissonance between virtual and physical realities, leading to feelings of disembodiment or altered physical world perceptions.

EXTENDED REALITY (XR)

An umbrella term that encompasses virtual reality, augmented reality, and mixed reality. XR provides immersive digital experiences that blend the physical and virtual worlds across a spectrum of realities. It enhances interactions with the environment and digital elements.

HAPTICS

Technology related to tactile sensations and feedback. Can include vibration, motion, pressure, and temperature changes.

HOLOGRAPHY

A technique for creating three-dimensional projections; it's becoming key in populating the metaverse with realistic avatars and environments, and merging with technologies like deepfake for various applications.

HUMAN-MACHINE INTERFACES

The components and methods through which humans interact with and control machines, like keyboards, mice, touchscreens, and voice commands.

HYPERREALISTIC AVATARS

Highly detailed avatars that closely mimic a person's real facial features, expressions, and movements through advanced 3D modeling and scanning.

INTEROPERABILITY

Blockchain's capability allowing assets and information to seamlessly transfer between different worlds and platforms within the metaverse.

MIXED REALITY (MR)

A hybrid form of reality that merges the real and virtual worlds to produce new environments and visualizations where physical and digital objects coexist and interact in real time.

NEURAL INTERFACES

Technologies that connect directly to the user's neural activity, like brain waves or facial muscle signals, to enable hands-free and silent control.

NON-FUNGIBLE TOKENS (NFTS)

Unique digital assets representing ownership of virtual items like land and avatars in the metaverse, made credible and secure through blockchain technology.

OLFACTORY FEEDBACK

Technology that generates smells and aromas digitally, allowing smells to be simulated in a virtual environment.

PANOPTICON

A system of control where individuals are aware they might be watched at any time, leading to self-regulation of behavior. In the context of smart glasses, it refers to the heightened sense of being observed and changing behavior because of it.

PASSTHROUGH

A feature in some headsets that uses outward-facing cameras to display the physical environment to the user while wearing the headset. Provides awareness of surroundings.

PLAY-TO-EARN GAMES

Virtual environments in the metaverse where players can earn real-world value through gameplay, with blockchain technology enabling the collection, breeding, and trading of digital assets as NFTs.

SITUATED VIRTUAL REALITY (SITUATED VR)

A concept proposed to align the physical and virtual worlds, minimizing experiential artifacts. It focuses on syncing physical actions with virtual feedback to create a congruent reality, including mirroring body language and emotional expressions in virtual and real worlds.

SYNTHETIC PERSONALITIES

Fully artificial digital influencers and identities generated through AI training, not tied to any specific human individual.

SYNTHETIC SPEECH

AI-generated simulated speech that clones a person's vocal characteristics to create natural sounding vocalizations. Enables voice banking, which benefits people who may lose their ability to speak later in life.

VIRTUAL REALITY (VR)

An artificial digital environment that is fully immersive and isolates users from the physical world. Users typically wear a headset with stereoscopic displays and head tracking to look around the virtual world.

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VR Headsets

The VR headset market is transforming, with key players refining their strategies to balance high-performance capabilities with mass-market accessibility. Apple's Vision Pro, launched in February 2024, set a new benchmark for mixed reality (MR) devices, integrating spatial computing with a $3,499 price tag—positioning itself as a premium, productivity-focused headset. Meanwhile, Meta responded with the Quest 3S in October 2024, emphasizing affordability at $299.99 and signaling a commitment to bringing XR to a broader consumer base. Sony also entered the XR race, announcing a 4K OLED microdisplay-equipped headset optimized for immersive content creation, further expanding VR's professional and creative use cases.

HTC's VIVE Focus Vision, released in September 2024, targeted enterprise and high-end gaming markets with its 5K resolution and 120Hz refresh rate, underscoring a push toward high-fidelity standalone VR experiences. At the same time, Samsung and Google revealed a strategic partnership to create an Android-based XR ecosystem, with Samsung leading headset development. This move could introduce a new platform challenger to Apple's visionOS and Meta's Quest ecosystem. The competition may also extend beyond traditional tech heavyweights—Immersed's upcoming XR visors, expected in summer 2025, indicate a shift toward lightweight, screen-mirroring headsets optimized for productivity. Additionally, rumors of the Pico 5 headset suggest ByteDance may be preparing to strengthen its presence in non-US markets, competing with Meta's Quest lineup in Europe and East Asia.

These developments illustrate the VR industry's divergence: on one hand, ultra-premium headsets aimed at professional and enterprise users; on the other, more accessible devices targeting mainstream adoption. As hardware capabilities improve, enabling better displays, lighter form factors, and expanded ecosystems, the next phase of VR will likely be shaped by competition between closed ecosystems (Apple) and open-platform approaches (Meta, Samsung, and Google). The battle for consumer and enterprise adoption will define the future of immersive computing.

Contact Lens Displays

The race to develop smart contact lenses as next-generation augmented reality (AR) interfaces accelerated in 2024, with key advancements in display technology, eye tracking, and human-machine interaction. XPANCEO has showcased multiple AR-enabled contact lens prototypes, including a model designed to enhance color perception and another for immersive 3D imaging. Meanwhile, RaayonNova filed a patent for a waveguide electro-optical display embedded directly into a contact lens substrate, enabling a wide field of view and the ability to refocus within a projected 3D frame of reference.

Scientific breakthroughs further pushed the field forward. In April, researchers from Nanjing University published a paper in Nature Communications on a frequency-encoded eye-tracking smart contact lens, which operates wirelessly without batteries or chips. This technology introduces a highly flexible, non-toxic interface for human-machine interaction, with applications in health care and AR. In August, scientists from KAIST in South Korea unveiled a method for integrating metasurfaces onto contact lenses, enabling holographic light projection through compact, biocompatible near-eye displays.

These innovations mark a fundamental shift from bulky headsets to ultra-thin, nearly invisible wearable displays. Smart contact lenses could revolutionize AR by offering a seamless, always-on interface that integrates directly into daily life. Potential applications range from health care and accessibility enhancements to immersive, hands-free computing. With a fully functional prototype expected by 2026, the next stage of AR adoption may no longer depend on glasses or headsets but on discreet, high-tech optics worn directly on the eye.

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Smart Glasses

Companies across the tech landscape are moving significantly toward lightweight, AI-powered, and mixed-reality eyewear. Meta finally unveiled Orion in September—its most advanced AR glasses yet—delivering immersive visuals in a sleek form factor. Meanwhile, Google and Magic Leap joined forces to co-develop AR experiences. Qualcomm signaled its intent to challenge Meta's dominance by partnering with Samsung and Google on AI-powered smart glasses that integrate with smartphones.

While quiet on product launches, Apple had a busy year at the US Patent Office. In December, it granted the company multiple patents, including an "audio privacy mode" and a smart frame system designed to align AR visuals—even during physical activity. Google's own patent filings (including one published in China) revealed a concept for advanced smart glasses featuring built-in displays, eye-tracking sensors, and voice/gesture input.

Beyond Silicon Valley, China's AR sector saw significant growth. Baidu launched AI-driven smart glasses powered by its ERNIE AI, while Xreal (formerly Nreal) secured $60M in funding and debuted its Xreal Air 2 Ultra AR glasses at CES. Rokid, another Chinese AR startup, introduced a new line of smart glasses with the eyewear brand Bolon, featuring prescription lens support.

The smart glasses market is also seeing increasing collaboration between tech and eyewear companies. Ray-Ban parent EssilorLuxottica and Meta extended their partnership into the next decade. Meanwhile, Snap Inc. launched its fifth-gen Spectacles, which are now running the new Snap OS. Industrial AR also saw momentum, with RealWear acquiring Almer Technologies and Vuzix partnering with Avegant to enhance waveguide optics.

With AI integration, advanced optics, and expanded partnerships, 2024 positioned smart glasses as the next significant wave in consumer and enterprise AR. The race to deliver lightweight, fashionable, and functional AR eyewear is intensifying.

Company	In-house Development	Partnership	Notable Features
Apple	✔	✖	Patents: Audio privacy, deformation sensors
Google	✔ Patents	✔ Magic Leap, Qualcomm	Eye tracking, voice/gesture input, phone processing
Baidu	✔	✖	Built-in AI assistant, cameras, fitness tracking
Meta	✔ Orion	✔ Ray-Ban	AI overlays, AR visuals, Ray-Ban collaboration
Magic Leap	✖	✔ Google	AI optics expertise
Qualcomm/ Samsung	✖	✔ Google	AI-powered interactions, phone integration
RealWear	✔ Acquired Almer	✖	Industrial AR smart glasses
Rokid	✔	✔ Bolon	AI, lightweight, prescription support
Snap Inc.	✔	✖	Standalone AR, Snapchat Lenses
Vuzix	✖	✔ Avegant	AI-powered waveguide optics
Zreal	✔	✖	3D sensors, computer vision

Source: FTSG Proprietary Research

AI is the missing technology that AR glasses are waiting for.

Frank Furnari, Co-founder & CEO of ARuVR

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Haptic Wearables

Haptic wearables enable realistic and adaptive touch feedback across gaming, XR, assistive tech, and even prosthetics. Recent breakthroughs in multi-sensory feedback, AI-enhanced haptics, and new form factors bring touch into digital interactions.

WEART's TouchDIVER Pro gloves debuted with force, texture, and thermal feedback, while Ubisoft integrated OWO's Second Skin haptic vest into video game "The Crew Motorfest," letting players feel engine vibrations and crashes. SenseGlove's Nova 2 introduced active palm feedback, making virtual object interactions more lifelike. Meta's licensing deal with Immersion Corp signals future high-fidelity haptics in Quest hardware.

Stanford's Haptiknit sleeve replaced traditional vibration with soft pneumatic pressure for immersive VR and rehab applications. Northwestern University's flexible epidermal haptic patch delivered pressure, vibration, and twisting feedback, showing promise for accessibility and prosthetics. Max Planck's silent CUTE electrohydraulic actuators expanded tactile sensations from slow strokes to heartbeat-like pulses.

dotLumen's haptic navigation glasses helped blind users "feel" spatial information through forehead vibrations, while Shape, a smart cane from Imperial College, physically bent to direct users. MIT's adaptive haptic glove recorded and replayed touch to teach skills from playing piano to operating robots. In health care, brain-computer interface (BCI) research enabled amputees with prosthetic hands to feel touch with stable, long-term precision.

Haptic tech is moving beyond XR novelty into essential applications—from AI-assisted touch interfaces to accessibility solutions. As gaming, AR/VR, and prosthetics integrate richer haptics, the ability to "feel" digital experiences becomes more seamless and intuitive.

Voice, Gesture, and Neural Interfaces

Digital interfaces, once limited to screens and keyboards, are quickly embracing AI-powered speech, neural control, and ultra-precise gesture recognition. Apple's Vision Pro set a new standard for intuitive spatial computing with hands-free, eye-tracking-based controls. Meanwhile, Volkswagen became the first automaker to integrate ChatGPT into its infotainment systems, enabling natural language voice interactions while driving.

Gesture and neural control technologies also took significant strides. Mudra Link introduced a neural wristband that translates micro-movements into precise digital inputs, while Ultraleap Helios combined neuromorphic vision with real-time micro-gesture tracking for AR interfaces. OpenBCI's Galea headset fused biosensors with VR for real-time brain-physiology insights, opening doors for cognitive-enhanced interactions. In medical advancements, Neuralink implanted its first human BCI chip, and UC Davis's brain-to-speech system achieved unprecedented accuracy for ALS patients, restoring lost voices.

AI's role in accessibility also expanded—Whispp's real-time voice conversion app empowered those with speech impairments, and Florida Atlantic University developed an AI-driven ASL translator with 98% accuracy, bridging communication gaps.

Interfaces are shifting from physical inputs to seamless, intuitive interactions—whether through voice, gestures, or even thoughts. The coming decade will redefine how humans engage with technology, making digital experiences more natural, inclusive, and immersive.

Senses In The Metaverse

Immersive technology has expanded beyond visuals and audio, bringing scent and taste into virtual environments. Kyoto-based Aromajoin unveiled two XR-compatible scent devices at CES—the Aroma Shooter Wearable, a neck-worn "scent collar" delivering rapid, on-demand fragrances, and the Aroma Speaker 60, a system

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with 60 base scents for dynamic olfactory experiences. Meanwhile, City University of Hong Kong researchers introduced a “virtual lollipop” that simulates flavors using iontophoresis, allowing VR users to taste digital content.

The 8th Digital Olfaction Society World Congress in Tokyo highlighted the growing role of smell in extended reality, showcasing applications like “digital incense” for VR meditation and custom fragrances designed for metaverse worlds. With these advancements, XR is moving toward full-spectrum immersion, where scent and taste enhance realism in gaming, training, and wellness experiences.

True immersion requires more than sight and sound. Olfactory and gustatory feedback could redefine virtual experiences—improving presence, memory recall, and even emotional engagement. From culinary VR training to therapeutic applications, the metaverse is expanding into the senses we’ve long overlooked.

Movement in The Metaverse

From digital avatars to prosthetic limbs, 2024 saw major strides in enhancing motion realism—whether in the metaverse or real life. Meta Motivo, Meta’s new AI-driven system, refined avatar movement, improving spatial awareness and embodiment in VR. Meanwhile, Roto VR introduced the Explorer chair, a motorized seat that syncs real-world rotations with VR, reducing motion sickness and increasing immersion.

Sports simulations also advanced with Rezzil’s “Premier League Player,” which leveraged actual player-tracking data to let users recreate iconic football moments in VR. Beyond virtual environments, MIT researchers achieved a historic breakthrough in prosthetic mobility. This neural-controlled bionic leg restored near-natural gait by directly linking the prosthesis to the nervous system.

As XR technologies evolve, motion fidelity is becoming crucial for immersion, accessibility, and user experience. AI-driven avatars, VR motion synchronization, and neural prosthetics contribute to a future where digital and physical movement feel seamless, intuitive, and natural.

SCENARIO YEAR 2057

THE NEURAL TAPESTRY

The metaverse revolution didn't come from headsets or augmented reality glasses. It emerged from something far more intimate: the Neural Tapestry, a biotechnological breakthrough that transformed the human experience.

The Neural Tapestry is a quantum-organic mesh, a living network of engineered neurons that integrates with the human nervous system. Unlike its crude predecessors, this isn't just an interface—it's an extension of human consciousness.

The installation process is remarkably elegant: a precision-guided swarm of medical nanobots weaves the Tapestry through the nervous system, creating millions of synaptic connections. The procedure takes just hours but permanently bridges the gap between biological and digital reality.

Daily Life in 2050

Maya stretches as she wakes, her consciousness gradually tuning into the morning symphony of sensory streams. The Neural Tapestry automatically adjusts her circadian rhythms, gently transitioning her from sleep to wakefulness with a cascade of natural neurotransmitters.

Her apartment appears spartanly minimal to untapped eyes, but through the Tapestry, it's a rich landscape of interactive possibilities. She reaches out to adjust the temperature, and the Tapestry translates her intention into action, the environmental systems responding instantly to her neural commands.

During breakfast, Maya browses her messages—not by reading them, but by experiencing them. Each communication arrives as a carefully crafted sensory package. A note from her mother carries the familiar scent of home-baked bread and the warm sensation of a hug. A work update delivers itself as an intuitive understanding, complete with emotional context and priority weighting.

At work, Maya leads a team of architectural synthesists. Their latest project exists simultaneously in physical and digital space: a skyscraper that adapts its form and function based on the collective needs of its occupants. Through the Neural Tapestry, she can literally feel the building's stress points, intuitively understanding structural loads and energy flows as if they were extensions of her own body.

Team meetings transcend traditional communication. Ideas flow as shared experiences, with concepts materializing in the group's collective consciousness. Cultural and language barriers become irrelevant when meaning can be transmitted directly through sensory and emotional channels.

The Neural Tapestry has fundamentally reshaped human connection. People can share not just thoughts and feelings, but entire experiences. Memory becomes a collaborative space, with friends able to relive shared moments, complete with every sensation and emotion.

This unprecedented intimacy has led to new social norms. "Tapestry etiquette" emerges as people learn to respect mental boundaries. The ability to filter and control sensory input becomes as important as emotional intelligence was in the past.

But the Neural Tapestry's impact hasn't been without its shadows:

- **The "Untapped" minority—those who choose to remain disconnected—face increasing social and economic isolation. Some argue that authentic human experience is lost as more people opt for enhanced reality.**
- **"Neural drift" becomes a recognized condition where individuals lose their sense of physical embodiment, becoming too immersed in the expanded consciousness the Tapestry offers.**
- **Security concerns reach new heights. "Neural hackers" attempt to exploit the Tapestry's interconnectedness, leading to the emergence of "psychic firewalls" and "consciousness encryption."**

As humanity approaches the mid-21st century, the Neural Tapestry continues to evolve. Research focuses on expanding its capabilities while addressing its risks. Some theorists suggest it's just the first step toward a new phase of human evolution—a bridge between individual consciousness and collective intelligence.

Yet questions persist: Are we enhancing human experience or fundamentally altering what it means to be human? The answer lies in how we choose to weave this new reality into the fabric of our existence.

DIGITAL IDENTITY

DIGITAL IDENTITY

Avatars

Avatars are becoming more realistic, expressive, and accessible, transforming how users interact in virtual spaces. DeepBrain AI, in collaboration with Lenovo, unveiled a hyper-realistic AI avatar for a 24-year-old ALS patient, preserving her voice and enabling seamless communication. Meanwhile, NTT DOCOMO introduced a world-first generative AI system that automatically creates fully detailed NPCs (non-player characters) in the metaverse based on simple text descriptions, eliminating the need for manual design.

Meta further advanced AI-powered digital identity with a patent for personalized avatar generation from text prompts, mapping user profile data to create dynamic, custom 3D avatars. In contrast, Microsoft announced the discontinuation of its "Next Generation" Xbox Avatar Editor due to low engagement, offering refunds to users who made purchases in the past year.

Avatar realism also saw major improvements through the widespread adoption of facial tracking and AI-assisted motion. Apple's Vision Pro introduced "Persona" avatars, which capture facial expressions and hand movements for FaceTime calls, creating a more natural digital presence. Roblox launched Roblox Connect, allowing users to animate their avatars' faces in real-time using phone cameras. At the same time, VRChat introduced a "Selfie Expression" feature for head, eye, and face tracking using a smartphone.

Machine learning continues to refine avatar movement and response. Meta rolled out AI-powered inside-out body tracking on Quest headsets, using onboard cameras and inference models to create natural full-body motion, even without external trackers. In late 2023, Meta's Avatar SDK introduced virtual legs, using "Generative Legs" AI to animate lower-body movements dynamically. Alongside graphical upgrades such as lifelike eye reflections and improved hair and clothing textures, these advancements solved the long-standing issue of avatars appearing as floating half-bodies in VR.

Avatar Portability

As the metaverse expands, avatar interoperability is becoming a priority. Key players are moving toward standardization and cross-platform compatibility, enabling users to maintain persistent digital identities across virtual spaces. The VRM Consortium partnered with the Khronos Group to integrate the VRM avatar format into glTF 2.0, establishing a universal, platform-independent avatar file format. This shift promotes seamless movement between virtual worlds, supporting a more interconnected metaverse.

Ready Player Me reinforced this trend with its PlayerZero initiative, a Web3-driven system for cross-platform avatar collectibles. By October 2024, PlayerZero had recorded more than 81,000 Collection ZERO wearable mints, with integration into 15+ games. Meanwhile, Meta announced a major avatar overhaul at Connect 2024, introducing more expressive, high-fidelity avatars to unify its metaverse ecosystem.

A standardized, cross-platform avatar system is essential for a unified metaverse. The industry is moving toward persistent digital identities, allowing users to seamlessly navigate between VR, AR, and traditional platforms with a single avatar. As AI-driven realism improves, virtual personas will become an increasingly natural extension of self-representation in digital spaces.

Hyperrealistic Avatars

Advances in rendering, AI, and XR technology are bringing photorealistic avatars closer to everyday use. EON Reality unveiled Photorealistic XR Avatars, which replicate human facial features, expressions, and gestures with remarkable accuracy, making them appear "genuinely alive" in virtual spaces.

Meta's Codec Avatars also took a major step forward, gaining public attention after a high-profile podcast where Mark Zuckerberg and Lex Fridman held a conversation entirely as photorealistic avatars. The response was overwhelmingly

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positive, signaling strong demand for near-real digital presence. Meta is also developing lower-fidelity photoreal avatars, using neural networks to generate lifelike 3D faces from just a smartphone depth camera, making high-quality avatars more accessible.

Meanwhile, Roblox is pushing beyond static avatars with its 4D generative AI, an initiative to create not only detailed 3D models but also dynamic behaviors and interactions—effectively automating the creation of lifelike virtual characters. These advancements hint at a future where digital personas move, react, and express emotions as fluidly as real humans.

As photorealistic avatars become more accessible, they will transform social VR, virtual meetings, gaming, and even digital identity preservation. The ability to create and control lifelike digital doubles could redefine human interaction in the metaverse, making virtual presence nearly indistinguishable from reality.

Leasing Identity

Celebrities are embracing AI avatars to extend their influence into digital spaces, blurring the lines between real and virtual presence. Meta introduced AI-driven versions of Charli D'Amelio and Kendall Jenner, allowing fans to interact with digital replicas of these stars. Similarly, Singaporean actors Gurmit Singh, Li Nanxing, and Vivian Lai collaborated with a startup to create their own AI avatars, enhancing fan engagement.

Platforms like Genies continued to dominate the celebrity avatar space, with Paris Hilton, Migos, Justin Bieber, Shawn Mendes, Rihanna, and Cardi B using digital personas to engage with audiences in new ways. Meanwhile, the advertising industry adapted to AI-driven voices, with a new union agreement allowing actors to approve AI voice replicas for audio ads.

The legal landscape around AI likenesses also evolved. Anil Kapoor won a landmark case in India, securing control over his AI-generated image and voice. Chloe Amour sold the rights to her digital likeness, creating an AI version of herself to interact with fans. In posthumous AI usage, Alain Dorval's family authorized an AI-generated replica of his voice for Sylvester Stallone's film "Armor," preserving his legacy even after his passing.

AI-generated celebrity avatars are already transforming fan interactions, marketing, and entertainment. As legal protections emerge alongside commercial opportunities, the debate over digital ownership, authenticity, and identity rights will only intensify.

Synthetic Speech

AI-powered text-to-speech (TTS) and voice synthesis have significantly improved real-time multilingual speech, content localization, and creative applications. Japan's National Institute of Information and Communications Technology introduced a neural TTS system capable of synthesizing speech in 21 languages. Optimized for efficiency, this model generates one second of speech in just 0.1 seconds on a single CPU core, making it ideal for real-time applications on mobile devices and embedded systems.

AI voice cloning also saw rapid adoption. Amazon's Audible launched a beta program that allows select narrators to create AI replicas of their voices, enabling synthetic narration for audiobooks while maintaining the original speaker's tone and style. Meanwhile, Pheme, an advanced AI speech model, demonstrated the ability to generate high-quality, conversational speech in parallel, using compact datasets to enhance efficiency.

Multilingual AI dubbing expanded as ElevenLabs introduced support for more than 28 languages, allowing automatic translation while preserving the original speaker's voice, emotions, and intonation. This development streamlines content localization for global media, reducing the need for traditional dubbing processes. In creative industries, Respeecher, a Ukrainian speech synthesis company, continued refining its technology, allowing one person to speak

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in another's voice. Their AI-driven voice replication has been used in film and television to bring historical figures' and late actors' voices back to life, enriching storytelling and deepening audience engagement.

The ability to synthesize, clone, and translate speech with high fidelity is transforming industries from entertainment to accessibility. AI-generated voices are enhancing audiobook production, expanding multilingual media, and even recreating voices from the past. As AI voice models improve in realism and efficiency, they will redefine how people interact with digital content, breaking language barriers and revolutionizing communication.

Synthetic Personalities

AI-powered avatars are becoming intelligent, interactive, and autonomous. ESPN unveiled FACTS, a generative AI avatar tested on its SEC Nation show, delivering real-time sports analytics and engaging fans with data-driven insights during broadcasts. Meanwhile, the University of Cincinnati in partnership with Kinetic Vision introduced Lucy, an AI-powered avatar that can assist users in navigating the university's tech transfer offerings, demonstrating AI's growing role in business and academic engagement.

Beyond user-controlled avatars, AI-driven NPCs (non-player characters) advanced in realism and autonomy. Generative animation models now allow virtual characters to move, gesture, and interact convincingly without direct human input, making digital interactions feel increasingly like face-to-face conversations. In gaming, Inworld AI—a startup partnered with Ubisoft—and other platforms introduced AI NPCs capable of responding to voice or text, engaging in unscripted conversations, and exhibiting lifelike behaviors. These advancements bring virtual worlds closer to full immersion, where AI-driven personalities adapt and respond dynamically rather than following pre-scripted interactions.

AI-powered avatars and NPCs are reshaping entertainment, education, and digital interactions. Whether enhancing live sports broadcasts, streamlining tech transfer processes, or creating lifelike NPCs in games, AI is making digital entities more engaging and intelligent. As realism continues to improve—from photorealistic rendering to nuanced body language—AI avatars will play a larger role in virtual economies, interactive media, and personalized digital experiences.

Human Digital Twins

Advancements in AI and generative technology are making digital avatars more lifelike and personalized, bringing us closer to true human digital twins. In November 2024, researchers used cutting-edge voice reconstruction to recreate the speech of King Richard III, giving the 15th-century monarch a historically accurate Yorkshire accent. This project combined expertise from speech therapy, forensic psychology, archaeology, and dentistry to digitally restore a lost voice, showcasing how AI can resurrect historical figures with unprecedented realism.

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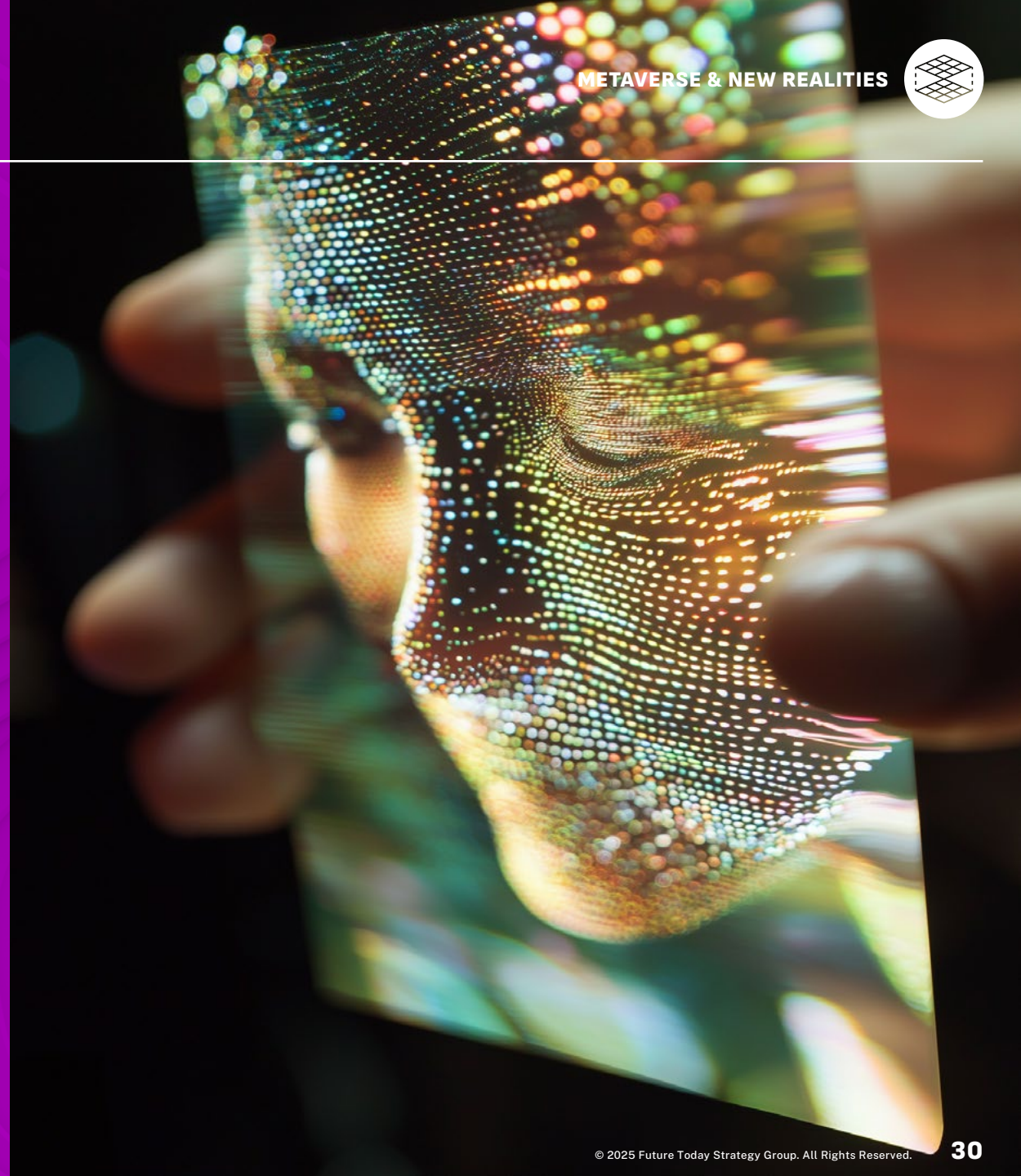
Meanwhile, Meta overhauled its metaverse avatars in September 2024, introducing advanced customization options—including adjustable eye size, nose shape, and body types—across Meta Horizon OS, Facebook, Instagram, and Messenger. This update enhances self-expression by enabling more precise digital self-representation. At GDC 2024, Roblox unveiled a generative AI-based character creator capable of designing avatar bodies and clothing from text descriptions or learned user preferences, simplifying customization and personalizing virtual identities at scale.

Ready Player Me is also pushing the boundaries of AI-powered avatars, allowing users to generate a 3D avatar from a single selfie. Its system, used across thousands of apps, automatically predicts facial features and maintains visual consistency across games, reducing the time developers spend on character creation while ensuring users retain a unified digital identity.

As digital twins become more advanced, the way we represent ourselves in virtual spaces is changing. AI-driven avatar customization, historical voice recreation, and generative character design are creating more accurate, expressive, and immersive digital identities. Whether preserving history, enhancing gaming, or personalizing social media, human digital twins are shaping the future of virtual presence.

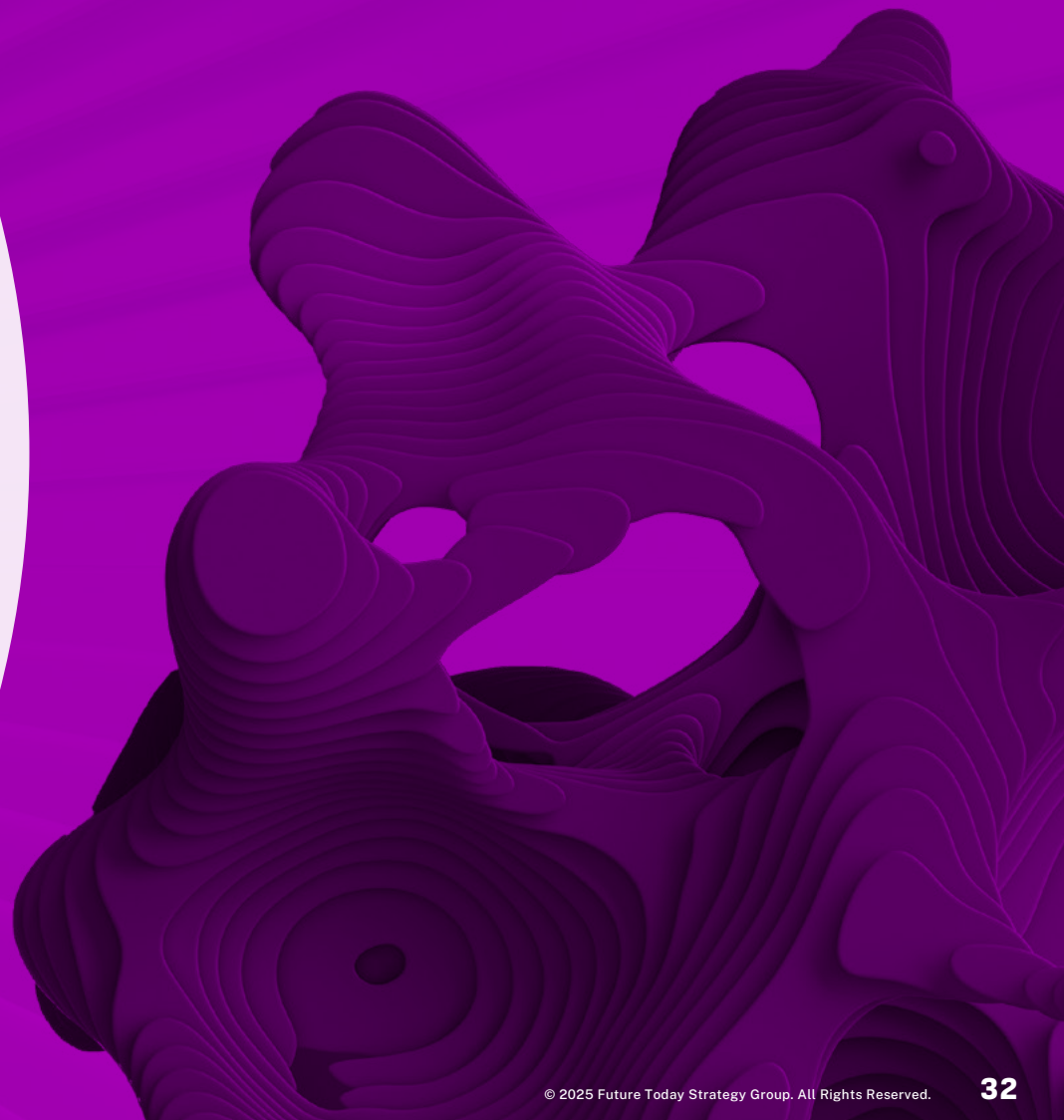


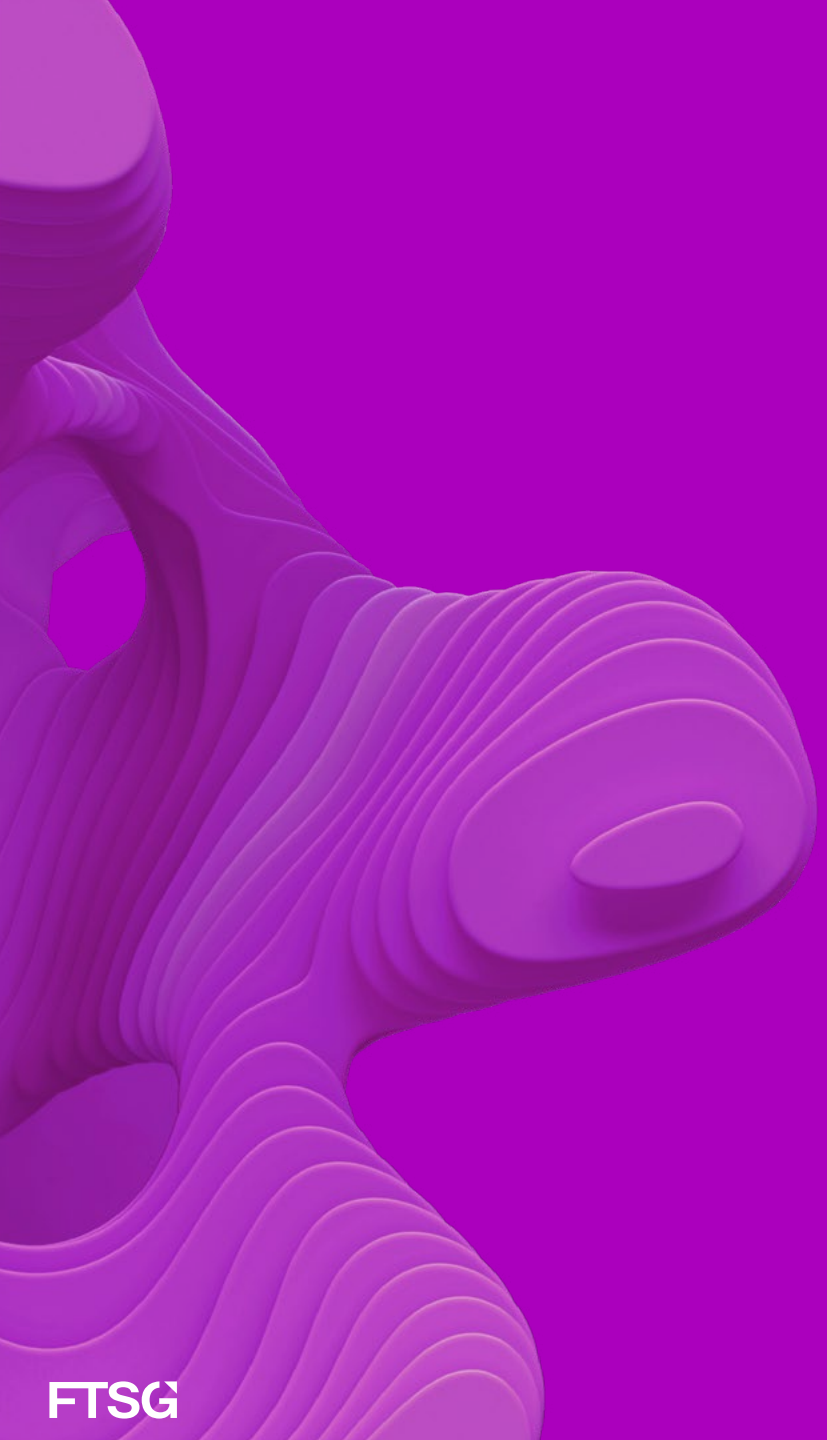
SCENARIO YEAR 2030

HYPERREAL CONNECTIONS

By 2030, businesses reliant on strong interpersonal connections are navigating a landscape radically transformed by advancements in avatar technology, synthetic speech, and AI personalities. Hyperrealistic avatars, capable of mirroring subtle emotions and personal mannerisms, are ubiquitous, offering photorealistic digital doubles for professionals and clients alike. These avatars are increasingly powered by AI, enabling personalization at scale and adapting to the nuances of individual conversations, with Meta and others developing systems for personalized avatar generation from text prompts. Synthetic speech has reached a point of near perfection, capable of replicating voices, translating languages in real-time while maintaining emotional tone, and even generating entirely new voices tailored to specific brands or individuals. The rise of autonomous NPCs (non-player characters), powered by sophisticated AI-enabled unscripted conversations and lifelike interactions, is further blurring the lines between the physical and digital realms, showcased by NTT DOCOMO's AI system and Inworld AI's work with Ubisoft. Avatar portability has become a reality as key players like the VRM Consortium and Ready Player Me moved toward standardization and cross-platform compatibility, enabling users to maintain persistent digital identities across virtual spaces. Celebrities have been embracing AI avatars to extend their influence into digital spaces for years, as demonstrated by Meta's AI-driven versions of celebrities and Genies' dominance in celebrity avatar space. AI-driven voices also impacted the advertising industry, although legal landscapes are still evolving around AI likenesses, highlighted by cases like Anil Kapoor's. These technologies have transformed how companies interact with customers, train employees, and build relationships, presenting both unprecedented opportunities and complex ethical considerations.

The opportunities for businesses are vast. Today, companies achieve global scalability by leveraging AI to deliver personalized coaching and training programs in any language, anywhere in the world. Enhanced personalization is possible through AI-driven individual needs and preferences analysis, leading to more impactful and engaging experiences. Data-driven insights from avatar interactions help identify patterns, measure engagement, and optimize strategies. New revenue streams emerge from premium services like digital twin creation, AI-powered assistants, and immersive training simulations. However, to get to this point significant challenges had to be addressed. Maintaining authenticity is crucial in hyperreal simulations, requiring a clear distinction between human and AI interaction. The threat of deepfakes and misinformation necessitated robust security measures and education. Addressing the digital divide was essential to ensure inclusivity and accessibility for those without access to advanced VR/AR technology. Navigating the evolving legal and regulatory landscape surrounding digital ownership, AI-generated content, and data privacy was an ongoing imperative. To succeed in this transformed environment, business leaders have to invest in AI literacy, experiment with pilot programs, prioritize ethical considerations, foster human-AI collaboration, and remain informed and adaptable. Ultimately, success hinges on balancing leveraging technological advancements and preserving the core values of human connection, trust, and authenticity.





METAVERSE IN INDUSTRY

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Virtual Training For Real-World Jobs

Virtual reality (VR) and AI-driven digital humans are reshaping corporate training, allowing employees to develop skills in immersive, risk-free environments. In one recent example, Cornerstone OnDemand launched Immerse Companion, a generative AI platform featuring virtual human companions that provide interactive coaching. Employees can practice sales pitches, negotiations, and customer interactions with an AI avatar that role-plays and delivers real-time feedback.

Across industries, major enterprises are leveraging VR for workforce development. BMW trains employees in design, prototyping, and lean manufacturing principles, while Volkswagen uses VR simulations for assembling vehicle components, reducing the need for physical travel. In the financial sector, Bank of America implemented VR for onboarding and customer service training, while Walmart and Lowe's use VR to enhance customer service and management skills.

Pfizer has a 3D cube that enables scientists to walk in and virtually explore molecules. Johnson & Johnson offers VR-based surgical training, allowing surgeons to practice complex procedures before operating on real patients. UPS has integrated VR into driver training, simulating challenges like navigating busy streets and handling aggressive dogs. Similarly, Delta Air Lines uses VR to train flight attendants in emergency response procedures, ensuring preparedness for real-world crises.

The industrial sector has also embraced VR training. Siemens uses the technology to train workers in offshore wind turbine installations, Alcoa uses it to focus on equipment safety, and UPS uses it to teach package stacking and field safety. By simulating high-risk environments, these companies enhance learning while minimizing workplace hazards.

VR and AI-driven avatars are making corporate training more interactive, scalable, and effective. Employees can practice critical tasks in realistic virtual environments, reducing training costs, improving retention, and increasing workplace safety. As AI avatars become more sophisticated, virtual coaching and role-playing will further transform professional development across industries.

True-To-Reality Simulations

Virtual environments are evolving to offer highly realistic and functional simulations, bridging the gap between digital and physical interactions. In October 2024, Meta filed a patent for a virtual space configuration system that customizes artificial reality environments based on user posture. This technology dynamically adjusts virtual space settings for seated users, altering floor height, adapting application mechanics, refining virtual boundaries, and enabling passthrough workspace interactions. These advancements bring VR closer to real-world usability, allowing seamless transitions between seated and standing interactions without breaking immersion.

Beyond system-level enhancements, AI-driven avatars are redefining simulations in professional training. EY's "eVe", an AI-powered avatar introduced in November 2024, offers job candidates metaverse-based interview preparation, mimicking real-world hiring scenarios with responsive AI interactions. This marks a shift toward AI-driven, immersive job training and assessment.

The retail industry is also leveraging true-to-reality simulations to enhance customer engagement. Valentino Beauty's New York pop-up featured a smart mirror that allowed visitors to virtually try on products, blending physical retail with interactive digital experiences. Meanwhile, IKEA launched a virtual store in Roblox, hiring real employees to staff the digital space. This initiative demonstrated how virtual commerce can replicate in-person shopping experiences, offering interactive and service-driven engagement in the metaverse.

The ability to tailor virtual spaces to user posture, conduct AI-driven training in metaverse settings, and integrate digital simulations into retail signals a shift toward

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hyper-realistic virtual experiences. These advancements make virtual environments more practical, accessible, and purpose-driven, unlocking new possibilities for education, commerce, and daily interactions.

Industrial Digital Twins

Industrial digital twins are transforming operations across sectors by providing real-time, AI-driven simulations of complex systems. These virtual models enhance predictive maintenance, optimize efficiency, and reduce costs by allowing engineers to test scenarios and anticipate failures before they happen.

In the UK, Northumbrian Water launched a £20M smart sewer initiative using a real-time digital twin of its wastewater network. Integrated with hundreds of IoT sensors, the twin simulates water flow under various conditions and forecasts where overflows may occur. When heavy rain is predicted, the system "runs ahead" of the live network, suggesting how to reroute or balance flows to prevent flooding and spills. This AI-powered approach enables proactive sewer management, reducing storm overflows and protecting rivers and coasts at a fraction of the cost of traditional infrastructure upgrades. The initiative is a first-of-its-kind in the UK water industry, pioneering the use of digital twins for environmental protection.

Shell, in collaboration with Kongsberg Digital, developed an interactive 3D digital twin of its offshore platforms and plants called the Industrial Work Surface. This system integrates real-time operational data, IoT sensors, and AI analytics, allowing engineers to navigate a virtual model of the facility to monitor equipment health, analyze process data, and run "what-if" simulations. The twin predicts equipment failures, such as when a critical pump or compressor might go out, enabling proactive maintenance and preventing costly shutdowns. By improving decision-making speed and operational awareness, Shell has enhanced offshore safety, reduced unplanned downtime, and optimized workflows for greater cost-efficiency.

Airbus employs a high-fidelity digital twin of its A350 XWB aircraft, continuously ingesting flight and sensor data to track fuel consumption, engine performance, and component health. Engineers and airline operators use this virtual model to simulate different flight conditions and optimize performance. The impact has been substantial: Airbus has greatly reduced its fuel consumption and emissions, saving 1,250 tonnes of CO_2 and 3.65 GWh of energy annually. Additionally, Rolls-Royce, which supplies the A350's engines, leverages twin data for predictive maintenance, ensuring proactive repairs and preventing unexpected failures. The system also provides valuable feedback to Airbus for refining future aircraft designs, making the A350 program more efficient and sustainable.

Industrial digital twins bridge the physical and digital worlds, allowing real-time monitoring, predictive maintenance, and optimization across critical infrastructure, energy, and transportation. These AI-powered systems reduce downtime, lower costs, and improve sustainability, making industries more resilient and efficient in the face of increasing complexity.

Medical Metaverse

The integration of XR and AI into health care is accelerating, reshaping patient care, surgical precision, and medical education. The Cleveland Clinic's "Zen Quest" on Roblox exemplifies how gaming platforms are becoming tools for mental health interventions, offering guided relaxation exercises in virtual spaces. Meanwhile, Apple Vision Pro headsets are enhancing surgical outcomes at the University of California, San Diego, by overlaying critical data directly into a surgeon's field of view, minimizing distractions and improving precision.

Rehabilitation is also evolving through brain-computer interfaces (BCIs). Australian company Synchron's device enables paralyzed patients to interact with digital environments via brain signals, demonstrating the potential of minimally invasive neurotechnology. Similarly, VR is fostering empathy in health care through immersive

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storytelling. Experiences like Emperor, which simulates aphasia, are being explored for medical training and therapy.

Beyond patient care, medical training is advancing through platforms like Virti, which leverages XR and AI for interactive learning. These tools are already being implemented globally by institutions such as Cedars-Sinai and the NHS. Meanwhile, 3D-printed prosthetics and game-based rehabilitation therapies pioneered in Israeli medical centers, such as Sheba Medical Center, highlight how innovations designed for conflict-related injuries can extend to civilian health care applications. The metaverse's role in medicine is expanding, signaling a future where digital and physical health care systems are seamlessly integrated.

Education In The Metaverse

Immersive technologies are revolutionizing education, bringing AI-driven avatars, virtual field trips, and realistic simulations into classrooms and training programs. AI-powered mentors like Sofia from EON Reality now personalize learning experiences, dynamically responding to student input. Meanwhile, schools such as Cholla High in Arizona are using VR for cultural experiences, enabling students to explore Indigenous art and history in 360° environments. Greensboro Middle School's AR/VR lab, funded by the Air Force, is another example of immersive STEM education reaching underserved communities, making abstract concepts tangible.

Special education is also benefiting. Spaulding Academy utilizes VR to create personalized learning scenarios, helping students with autism practice social skills or engage with interactive science lessons at their own pace. At the university level, VR is transforming archaeology at Indiana University through Yorescape, allowing students to walk through ancient cities as they once were. Similarly, New Zealand's University of Canterbury is training early childhood educators using VR and haptic gloves to simulate infant care, ensuring teachers develop practical caregiving skills before handling real infants.

Other fields are embracing immersive training. The University of Utah's mining program leverages VR for hazard response training, reducing real-world risks. Parker University's metaversity offers a digital twin of its campus, enabling remote students to engage in virtual labs and classrooms with real-time interaction. Meanwhile, Catawba College's Dreamscape Learn turns biology into a cinematic, story-driven adventure, increasing student motivation and understanding. As these technologies scale, the metaverse is poised to redefine education, making learning more experiential, accessible, and effective.

Synthetic Media in Hollywood

Hollywood is undergoing a seismic shift as AI-driven synthetic media reshapes how films are made, edited, and even acted. Robert Zemeckis' "Here" marked a major milestone by using Metaphysic's AI deepfake technology to age and de-age Tom Hanks and Robin Wright in real-time on set. This eliminated the need for extensive prosthetics and months of VFX work, allowing Zemeckis to see final shots live as he filmed. The director noted that such a production would have been impossible just a few years ago. However, this efficiency has raised concerns about the future of VFX jobs and the role of human craftsmanship in post-production, fueling discussions in 2024's union negotiations about AI's impact on the industry.

AI isn't just altering actors' appearances—it's resurrecting them. "Furiosa" used AI face-swapping to bring back Richard Carter's Mad Max character, mapping the late actor's digitally reconstructed face onto a stand-in's performance. "Alien: Romulus" reportedly applied similar technology to bring back Ian Holm's android character from the 1979 original. These developments have sparked intense ethical and legal debates, leading California to pass legislation requiring estates' explicit consent for AI-generated performances of deceased actors. Some performers, like Robert Downey Jr., have even preemptively barred AI versions of themselves after death. Despite concerns, AI-driven recreations are opening new storytelling

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possibilities—allowing long-dead historical figures or beloved characters to return to the screen in ways previously unimaginable.

Meanwhile, AI-generated filmmaking is becoming a reality. Indie creator Hooroo Jackson's "DreadClub: Vampire's Verdict" was constructed from more than 17,000 AI-generated images, with all visuals, performances, and even music synthesized by AI. The entire film was produced for just $405—compared to the typical $1-2 million cost of an animated feature. Similarly, AiMation Studios released "Where the Robots Grow," another fully AI-animated film, showcasing how small teams (or even a single person) can use AI to create content at a fraction of the time and cost. While these films demonstrate AI's potential to democratize filmmaking, they also highlight its current limitations—early AI-generated films have been met with mixed reviews, with critics noting the lack of emotional depth and coherence in storytelling.

AI-generated audio also emerged as a powerful new tool in Hollywood. The Robbie Williams biopic "Better Man" used AI to generate Williams' voice for a surreal animated chimpanzee version of the singer. In National Geographic's "Endurance," AI resurrected the voice of Antarctic explorer Sir Ernest Shackleton, training on century-old gramophone recordings to synthesize an eerily realistic narration of his own journal entries. This technology allows actors to dub themselves in multiple languages without re-recording and lets filmmakers use historical figures' voices in new contexts. AI voice synthesis also streamlines production—allowing for dialogue replacement without requiring actors to return to set. However, this advancement raises concerns about consent and authenticity, as studios rush to establish legal guidelines for AI voice replication.

As Hollywood embraces synthetic media, the industry is navigating an uncertain future. AI promises lower costs, faster production, and expanded creative possibilities, but it also threatens traditional roles in visual effects, animation, and voice acting. While some filmmakers see AI as an augmentation tool rather than a replacement, others worry about a future where AI-generated films dominate, reducing the human touch in storytelling. As studios, unions, and lawmakers scramble to define ethical boundaries, one thing is clear: AI is no longer just a futuristic concept in Hollywood. It is already reshaping the industry in real-time.

Forensic AR/VR

Augmented and virtual reality are reshaping forensic science, law enforcement, and legal proceedings. In October 2024, the Bavarian State Criminal Police Office partnered with HTC VIVE to develop the Holodeck, a VR platform that creates photorealistic 3D reconstructions of crime scenes. Investigators, forensic analysts, and prosecutors can now simultaneously immerse themselves in crime scenes without disturbing physical evidence, testing hypotheses and analyzing details collaboratively. This innovation enhances crime scene preservation and could expand into police training applications.

VR is also changing how courts handle evidence. In December 2024, a Broward County, Florida judge used an Oculus Quest 2 headset to virtually step into a crime scene during a stand-your-ground hearing—believed to be the first time immersive VR evidence was presented in a US courtroom. The simulation, created by a forensic artist, placed the judge in the defendant's perspective, allowing for a deeper understanding of spatial relationships and incident dynamics. Legal experts predict this could set a precedent for VR-based evidence, potentially transforming how judges and juries experience complex crime scenes.

Beyond physical crimes, law enforcement is now investigating virtual offenses. In January 2024, UK police began investigating an unprecedented case—the alleged virtual rape of a 16-year-old girl's avatar in a metaverse game. Officers are treating this as a serious sexual offense, analyzing server logs, chat records, and suspect accounts much like a real-world crime. This case has sparked debate over jurisdiction,

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victim trauma, and the responsibility of tech companies to implement better safeguards. Meanwhile, in the UAE, Sharjah Police introduced Virtual Reality Radar, an AI-driven monitoring tool designed to detect cyberbullying and harassment in metaverse environments. Using machine learning, the system scans virtual interactions, flags harmful behavior, blocks malicious content, and generates real-time reports for investigators, demonstrating how law enforcement can extend their reach into digital spaces.

AI is also accelerating traditional forensic investigations. In April 2024, the police department in Warner Robins, Georgia deployed Cybercheck, an AI-powered digital forensics tool that scours the surface web, deep web, and dark web for relevant case data. It compiles extensive suspect profiles by analyzing social media activity, online interactions, cryptocurrency transactions, and hidden connections. The system has already contributed to hundreds of breakthroughs in homicide, missing persons, and child exploitation cases. As forensic AR, VR, and AI evolve, law enforcement is gaining powerful new tools to investigate both physical and digital crimes, ushering in a new era of high-tech policing.

Metaverse–Enhanced Science

VR and AR are revolutionizing scientific research, enabling immersive exploration of brain function, cellular biology, and molecular structures. Neuroscientists are using VR simulations to study cognitive processes in real-time, recreating complex scenarios to observe neural responses under controlled conditions. This approach provides unprecedented insight into brain activity, enhancing studies on memory, decision-making, and neurological disorders. By eliminating real-world variability, VR experiments allow for precise data collection, improving the reproducibility of cognitive and behavioral research.

In cellular biology, generative AI is accelerating drug discovery and genetic research through AI-powered virtual models of human cells. These simulations replicate cellular behavior, allowing scientists to predict drug interactions, understand mutations, and test experimental treatments without physical lab work. This in silico experimentation reduces research costs and expedites breakthroughs by providing a dynamic testing ground for new therapies. Meanwhile, molecular biologists are adopting Gaussian splatting, a cutting-edge 3D capture technique, to visualize intricate molecular interactions. This technology generates highly detailed biological models, offering deeper insights into protein folding, enzyme activity, and drug-target interactions—advancing structural biology and the development of precision medicine.

The integration of immersive technologies into scientific research is bridging the gap between theoretical models and practical experimentation. By leveraging VR, AI-driven simulations, and high-fidelity 3D modeling, researchers are uncovering new dimensions of biology and neuroscience. As these tools evolve, the metaverse is poised to become a fundamental platform for scientific discovery, transforming how researchers visualize, analyze, and manipulate the building blocks of life.

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Metaversal Automotive Development

Automakers are leveraging digital twins, virtual reality, and AI-driven assistants to streamline manufacturing, enhance vehicle design, and improve customer experiences. In one leading example, BMW built a full digital twin of its new electric vehicle plant in Debrecen, Hungary, before breaking ground. Partnering with Nvidia and T-Systems, BMW created a virtual replica of the factory—including its production lines and worker operations—allowing for real-time process optimization. And BMW expects its bet to pay off: by identifying inefficiencies before construction, the company predicts a 30% boost in production planning efficiency, minimizing costly delays and accelerating the plant's launch. The factory, set to produce 150,000 electric cars annually, represents a shift toward fully virtualized manufacturing environments.

Beyond production, automakers are integrating virtual and augmented reality into customer engagement and vehicle interaction. Nissan launched the Heritage Cars & Safe Drive Studio on VRChat, where users can explore classic Nissan vehicles and participate in traffic safety education through an immersive metaverse platform. Meanwhile, Mercedes-Benz unveiled an enhanced MBUX Virtual Assistant in its new CLA model, powered by Google Cloud's Automotive AI Agent. This system offers real-time information and advanced conversational capabilities, integrating augmented reality for navigation and vehicle diagnostics.

Automotive design is also evolving through VR collaboration. Ford's Australia Design Studio has adopted immersive VR workspaces, allowing engineers, designers, and developers to interact with 3D vehicle models in real time from anywhere in the world. This virtual design approach accelerates decision-making, reduces physical prototyping costs, and fosters global collaboration. As automakers continue investing in metaverse technologies, digital twins, AI, and VR will increasingly define the future of vehicle manufacturing, design, and user experience.

SCENARIO YEAR 2035

THE INDUSTRIAL NERVOUS SYSTEM

By 2035, the metaverse has evolved from a consumer-focused novelty into the central nervous system of industrial operations. Driven by advancements in AI, digital twins, and XR technologies, it isn't just about visualization but control, optimization, and resilience. The industrial metaverse isn't a single, unified platform but a mesh of interconnected virtual environments tailored to specific needs.

Every major industrial asset, from wind farms and power plants to manufacturing facilities and logistics networks, has a fully realized, real-time digital twin residing within the metaverse. These twins are no longer static models, but living simulations constantly updated with data from IoT sensors, edge computing devices, and AI analytics. Drawing on the success of early initiatives like Northumbrian Water's smart sewer digital twin, these systems "run ahead" of the real world, predicting failures, optimizing performance, and simulating the impact of changes before they are implemented, helping to preempt environmental disasters.

The industrial workforce of 2035 operates seamlessly between the physical and virtual realms. Technicians use AR overlays on smart glasses to guide them through complex maintenance procedures, overlaying schematics, diagnostic data, and even real-time guidance from remote experts. Drawing on early successes in virtual training, manufacturing, and production, companies use sophisticated VR simulations to train new employees, allowing them to practice hazardous tasks and refine skills in a risk-free environment. These simulations also include AI-driven avatars for interactive coaching, providing personalized feedback in real-time, and increasing employee engagement and retention.

The metaverse has become the orchestration layer for global supply chains. AI-powered avatars facilitate real-time collaboration between suppliers, manufacturers, and distributors, allowing them to visualize and optimize the entire flow of materials and products. Drawing on early examples of automotive companies using VR workspaces to design and engineer vehicles collaboratively, these virtual environments enable faster decision-making, reduce waste, and enhance resilience in the face of disruptions.

Expert knowledge has become democratized through the metaverse. Senior engineers and subject matter experts create AI-driven digital twins of themselves, effectively capturing and disseminating their expertise to a broader audience. Recalling AI avatars from early education programs, these “expert bots” can answer questions, provide guidance, and even troubleshoot problems remotely, reducing the reliance on scarce human expertise and accelerating knowledge transfer within organizations.

But the growing reliance on the industrial metaverse has created new security vulnerabilities. Protecting these virtual environments from cyberattacks and data breaches is now paramount. Industrial organizations invest heavily in blockchain-based authentication systems, AI-driven threat detection, and secure communication protocols to safeguard their critical infrastructure. Forensics has extended into the virtual realm. Law enforcement agencies have virtual reality radar: AI-driven monitoring tools designed to detect cyberbullying and harassment in metaverse environments.

The pervasive integration of the metaverse into industrial operations has also raised profound ethical questions. Concerns about data privacy, algorithmic bias, and the potential displacement of human workers have to be carefully addressed. Organizations have developed ethical guidelines for AI development and deployment, ensuring transparency, accountability, and fairness in their metaverse initiatives.

A subtle but profound shift has occurred. The line between the digital twin and the real-world asset has blurred to the point where it is sometimes difficult to distinguish between them. Decisions are increasingly made within the metaverse, with the physical world simply acting as the executor of those virtual directives. This raises philosophical questions about the nature of reality, the locus of control, and the potential for unintended consequences when the virtual world assumes primacy over the physical.

The industrial metaverse of 2035 is a powerful tool but also a complex and potentially destabilizing force. Its success depends not only on technological advancements but also on a thoughtful and ethical approach to its development and deployment. The challenge is to harness its potential while mitigating its risks, ensuring that it serves humanity’s best interests.

PSYCHOSOCIAL DYNAMICS AND INCLUSIVITY IN THE METAVERSE

PSYCHOSOCIAL DYNAMICS AND INCLUSIVITY IN THE METAVERSE

The Panopticon

Surveillance technology is increasingly shaping public and private spaces, driving behavioral changes as individuals self-regulate under the assumption of being watched. During the 2024 Paris Olympics, authorities implemented AI-powered video monitoring at an unprecedented scale, sparking debates about normalizing such surveillance beyond large-scale events. Concerns grew over whether these measures would persist post-Games, reinforcing a society where constant observation influences behavior. Similarly, a Federal Trade Commission report exposed the extent of social media and video streaming surveillance, revealing platforms' extensive data collection, and that they often retain vast amounts of user and non-user information indefinitely. The knowledge of this persistent tracking leads individuals to modify their online behavior, making them aware that their activities are being monitored.

Corporate surveillance is also expanding, as highlighted by a lawsuit against Apple accusing the company of enforcing employee monitoring through internal software on personal iPhones. The case raises concerns about workplace surveillance and its impact on employees' autonomy. Meanwhile, government surveillance powers have been reinforced with the reauthorization of Section 702 of the Foreign Intelligence Surveillance Act under the Reforming Intelligence and Securing America Act. This legislative action broadened the government's ability to collect international communications, prompting some individuals to self-censor due to the risk of surveillance. At the state level, New York proposed legislation requiring surveillance cameras in various public and private spaces, including for-hire vehicles and public litter baskets, further entrenching the presence of surveillance in everyday life. As corporate, governmental, and event-based surveillance expands, privacy expectations are being redefined, and self-censorship is becoming an implicit societal norm.

PSYCHOSOCIAL DYNAMICS AND INCLUSIVITY IN THE METAVERSE

Metaverse Accessibility

Collaborative initiatives are redefining accessibility in mixed reality, ensuring that emerging technologies serve diverse user needs. In one project, Meta worked with both people with disabilities and accessibility advocates to co-design new products. This approach allowed them to prioritize real-world experiences, grounding product development in authentic user requirements. And as an additional benefit, as seen in the "curb-cut effect," features designed for specific groups—such as improved navigation tools—can enhance usability for all. By fostering trust and mutual respect through co-design, Meta is strengthening community ties and ensuring that underserved populations are considered in product development.

Beyond corporate efforts, the Metaverse Standards Forum's "Accessibility in the Metaverse" working group is setting industry-wide guidelines to make virtual environments more inclusive. The group focuses on identifying potential accessibility risks, recommending best practices, and addressing the needs of disabled content creators and developers, ensuring that accessibility extends beyond end-users to those building the metaverse. Meanwhile, CES 2024 showcased groundbreaking assistive technologies. Those included AR glasses with real-time closed captioning for the hearing impaired, as well as navigation aids for the visually impaired that provide auditory spatial guidance, increasing independence and safety.

Academic research is also shaping the conversation, emphasizing the need for disabled creatives to be actively involved in metaverse development. Scholars propose leveraging VR and AR alongside IoT to create more engaging, accessible platforms. These frameworks highlight how inclusive design not only benefits disabled users but also enhances digital spaces for all, reinforcing accessibility as a fundamental principle of the evolving metaverse.

Diminished Sensory Overload

AI and XR technologies are transforming assistive tools for individuals with autism, enhancing communication while minimizing sensory overload. A 2024 review analyzed AI's integration into assistive technologies, highlighting advancements in AI-driven robotics and wearable devices like smart glasses. These innovations provide personalized support, helping individuals with autism navigate social interactions. However, challenges remain, including concerns around bias, ethics, and cybersecurity in AI deployment.

In education, researchers are exploring AI-powered metaverse environments to create accessible learning experiences for students with disabilities, including autism spectrum disorder. These controlled virtual spaces simulate social interactions while reducing sensory overwhelm, offering tailored skill development opportunities. Ethical considerations are also at the forefront — December 2024 research stressed the need to design XR environments that are sensitive to autistic individuals' sensory needs. The study emphasized the importance of co-designing XR experiences with autistic users to ensure inclusivity and prevent unintended harm.

In June 2024, researchers, clinicians, and individuals with lived experience gathered at a virtual summit to address the complexities of sensory health. Presentations synthesized research and theory, providing insights into managing sensory overload in both physical and virtual environments. As AI and XR continue to evolve, their role in reducing sensory stress for neurodivergent individuals highlights the potential for technology to enhance inclusivity in education, health care, and everyday life.

Cybersickness

Researchers and developers are advancing solutions to mitigate cybersickness, a common barrier to XR adoption. A study from the KITE Research Institute, led by Dr. Behrang Keshavarz, demonstrated that

PSYCHOSOCIAL DYNAMICS AND INCLUSIVITY IN THE METAVERSE

integrating avatars into VR simulations can significantly reduce symptoms. In a trial with 54 participants, those who viewed an avatar reported less severe cybersickness than those without, suggesting that enhanced presence through self-representation helps users acclimate to virtual environments.

Beyond visual techniques, researchers are exploring physiological interventions. A study on vestibular stimulation found that using a bone conduction device during VR experiences helped users endure longer simulations with lower nausea levels. Similarly, technological improvements in VR headsets are reducing cybersickness—Dr. Peter L. Stallo's research compared the Meta Quest 2 and Meta Quest Pro, revealing that adjustable interpupillary distance and enhanced optics in the Quest Pro led to fewer symptoms of motion sickness.

Specialized hardware is also emerging to address cybersickness. The Roto VR Explorer chair, equipped with an integrated motor, synchronizes physical movement with virtual experiences, reducing sensory mismatch that often leads to discomfort. As XR adoption expands across industries, these innovations mark a critical step toward making virtual environments more comfortable and accessible for all users.

Dissociation From Reality

The immersive nature of the metaverse is raising concerns about problematic use, with cognitive factors like focal immersion and temporal dissociation playing key roles. Researchers Mahathi Koutha and Ronnie Jia from the University of North Texas explored these effects, drawing parallels between excessive metaverse engagement and social media addiction. As users lose track of time in highly immersive environments, the risk of overuse grows, prompting discussions on digital well-being and regulatory interventions.

On the therapeutic front, metaverse applications are showing promise in mental health treatment. A review of pilot studies found that avatar-based sexual therapy programs outperformed traditional methods in treating female orgasm disorders, while a metaverse-based social skills training program significantly improved interactions among children with autism. These findings highlight the potential of virtual environments for specialized therapeutic applications, though ethical considerations around privacy and efficacy remain.

Efforts to better understand metaverse engagement have led to the development of the Metaverse Experience Scale, which identifies six dimensions influencing user perception: sensory/affective, intellectual, behavioral, relational, interoperability, and safety. Research suggests that sensory/emotional experiences, interoperability, and safety concerns significantly shape user attitudes, providing insights for mitigating dissociative effects. Meanwhile, metaverse-related patent activity has surged, with companies like Apple, Microsoft, and Meta filing patents aimed at improving user safety. The World Intellectual Property Organization reports more than 390,000 pending patents for VR, AR, and XR technologies, reflecting a global push to refine and regulate the metaverse experience.

SCENARIO YEAR 2040

A HOLLOW WORLD

The metaverse, once envisioned as a realm of boundless opportunity, is now a gilded cage for a significant portion of humanity. Companies and officials ignored early warnings about its addictive potential, fueled by focal immersion and temporal dissociation, and safeguards to protect mental health are either absent or ineffectual.

Outside the shimmering walls of the hyper-realistic metaverses, a stark reality exists. Physical infrastructure crumbles, public services are underfunded, and a chasm divides the “Logged In,” who can afford high-bandwidth connections and cutting-edge XR gear, and the “Logged Out,” who are increasingly marginalized and forgotten. The “Curb-Cut Effect,” once celebrated for its inclusive potential, is inverted; accessibility initiatives are focused solely on the metaverse, leaving the physical world to decay.

The generation raised on the metaverse is profoundly affected. Real-world social skills have atrophied, replaced by carefully curated online personas. A surge in mental health issues, including anxiety, depression, and a new form of “Virtual Reality Dependence Disorder” plagues adolescents and young adults. The real-world suicide rate is significantly higher than it was in the early 2020s. Sensory overload is a constant threat, and the already struggling population of neurodivergent people are even further isolated. VR has become so deeply integrated into daily life that more

and more people suffer from cybersickness and have even begun to develop dependencies on the tools used to reduce the negative effects, just to be able to spend time in the metaverse. Attempts to address the mental health crisis are largely ineffective. Avatar-based therapy programs show some initial promise but ultimately fail to address the underlying societal issues. The metaverse offers an escape from reality, not a solution to its problems.

Mega corporations, the architects of the metaverse, wield unprecedented power. They control access, shape narratives, and harvest user data with impunity. Digital ownership is a mirage; user-generated content is routinely exploited, and virtual assets can be seized at will. The promises of a decentralized, user-owned metaverse has evaporated in the face of corporate greed. Surveillance is commonplace. The physical economy stagnates as more and more economic activity shifts to the metaverse. “Metaverse jobs”—creating content, providing virtual services, and managing digital assets—are plentiful but often precarious and exploitative. The allure of earning “crypto-credits” in the metaverse lures many away from real-world employment, further weakening the physical economy.

Crime in the metaverse is rampant, ranging from virtual theft and harassment to more disturbing offenses. However, law enforcement struggles to keep pace. Jurisdiction is murky, evidence is easily manipulated, and the sheer volume of virtual interactions overwhelms investigators. A deepfake can erase someone from existence. Here, the “Panopticon” effect is weaponized; surveillance is omnipresent but selectively applied, used to control dissent and protect corporate interests.

In 2040, the metaverse stands as a stark warning against the unchecked pursuit of technological progress. The dream of a digital utopia devolved into a dystopian nightmare, a hollow world where human connection is mediated by algorithms, reality is malleable, and mental well-being is sacrificed at the altar of corporate profit. The few who remember the pre-metaverse world look back with a mixture of nostalgia and dread, wondering if humanity has passed the point of no return. The integration of virtual and physical reality has become so seamless and intertwined that physical and mental realities are no longer distinguishable. The question remains: Can humanity reclaim its analog soul before it is lost forever?

EXPERIENCING IMMERSIVE WORLDS

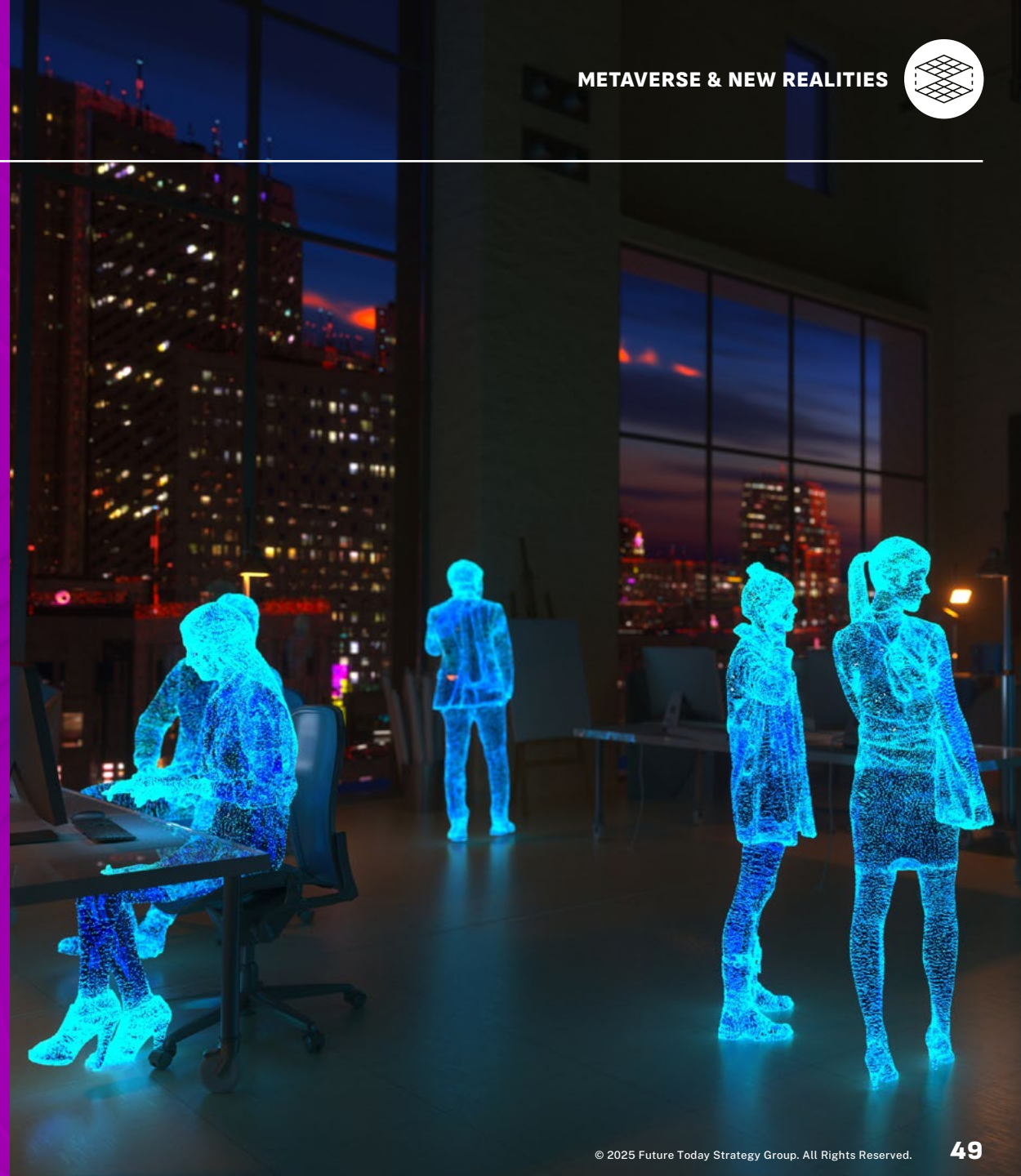
EXPERIENCING IMMERSIVE WORLDS

Events In The Metaverse

Metaverse events are becoming fully immersive platforms that blend commerce, entertainment, and community-driven experiences. In 2024, digital fashion weeks allowed designers to act as startups, raising funds through direct investments in virtual collections. Music artists like Snoop Dogg leveraged gaming platforms to transform concerts into interactive, in-game events. Even political discourse shifted into virtual spaces, with election night watch parties in VR fostering real-time engagement. These developments indicate a shift in how people experience live events—moving from passive viewership to active participation in dynamic, AI-enhanced environments.

The integration of AI and spatial computing is making virtual events more intelligent and engaging. Conferences such as the AI & Metaverse Innovate Summit explored how generative AI can personalize attendee experiences, while Meta Connect showcased how new AI-powered avatars and AR devices are shaping the next wave of digital interaction. Unlike early metaverse experiments, today's events are focused on usability, accessibility, and monetization—demonstrating that virtual gatherings are no longer just a futuristic concept but a viable alternative to traditional in-person events.

Beyond entertainment and networking, metaverse events are becoming economic engines. Platforms hosting these experiences are increasingly optimized for commerce, sponsorships, and direct-to-avatar sales, as seen in Metaverse Fashion Week and sports leagues like Improbable's Victory League. The challenge now is scalability—ensuring these virtual events can accommodate large audiences without compromising interactivity. As infrastructure advances, metaverse events could become primary touchpoints for industries seeking new ways to engage global audiences in immersive, customizable environments.



What's clear is that the speed of technical evolution is increasing and developments in digital technologies are probably the most significant to impact the future... I feel this presents a strong future with holograms continuing to be a key component.

Dr. Paul Dunn, Chair, International Hologram Manufacturers Assoc.

EXPERIENCING IMMERSIVE WORLDS

AR Lenses and Filters

AR lenses and filters are critical components for professional training, spatial computing, and next-generation optics. In medical education, AR filters powered by generative AI are being used to enhance training by simulating conditions across diverse skin tones. Research in Frontiers in Virtual Reality highlights how these filters improve diagnostic accuracy and build confidence among medical students, showcasing AR's growing role in high-stakes, real-world applications. This shift suggests that AR filters will increasingly serve as functional tools for specialized industries, moving beyond simple visual effects.

Advancements in AR optics are addressing long-standing challenges in display clarity, color accuracy, and user perception. Meta's newly patented wavelength band selective filters and Apple's dispersion compensation system both tackle image distortion, ensuring more lifelike AR experiences. Meanwhile, Tobii's patented eye-tracking calibration enhances AR headset precision by adjusting to user gaze in real time, improving usability for both everyday consumers and enterprise applications. Canon's development of lightweight AR/VR glasses further supports a trend toward more comfortable and practical devices, reducing barriers to widespread adoption.

But as AR becomes more ubiquitous, the way the technology affects human perception is under scrutiny. A study from the University of Toronto found that AR users overestimate distances in the real world, a distortion that subsides over time. This insight is crucial as AR becomes a staple in navigation, automotive displays, and remote work applications. As AR lenses and filters become more intelligent and integrated into daily life, developers must balance enhanced digital overlays with accurate real-world perception, ensuring that AR augments reality without unintentionally altering it.

Holograms

Holography is advancing from futuristic novelty to practical applications across multiple industries. Researchers at Princeton and Meta have developed ultra-thin optical devices that enhance holographic clarity, small enough to integrate into standard eyewear. This marks a step toward immersive virtual experiences without bulky headsets, signaling a shift from traditional AR/VR to seamless, everyday holographic displays. Meanwhile, Meta's Orion augmented reality glasses further blur the line between physical and digital, introducing neural interfaces for interactive holography that could eventually replace smartphones.

Beyond personal devices, businesses are leveraging holograms for visualization, advertising, and security. The oil and gas industry is adopting 3D holographic displays to improve geological analysis, allowing for better decision-making in resource exploration. Companies like HYPERVSN are transforming advertising with high-definition holographic displays, creating dynamic, attention-grabbing visuals. Meanwhile, the International Hologram Manufacturers Association is advancing anti-counterfeiting measures, integrating micro-lenses and plasmonics to enhance security features in authentication and brand protection. These developments show how holograms are not just visual enhancements but functional tools shaping commerce and industry.

In the arts and luxury markets, holography is changing the way valuable assets are displayed and sold. Christie's investment in holographic art displays allows buyers to view high-fidelity digital representations, expanding access to rare pieces without requiring physical presence. As holographic projection becomes more lifelike, its role in retail, education, and communication will continue to grow. The challenge now lies in refining hardware for mass adoption—ensuring clarity, affordability, and integration into everyday environments. With breakthroughs in optics, neural interfaces,

EXPERIENCING IMMERSIVE WORLDS

and 3D rendering, holograms are poised to become a mainstream interface for work, entertainment, and commerce.

Real Estate in the Metaverse

Metaverse real estate, once a high-profile trend in 2021 and 2022, has seen a sharp decline as speculative interest waned. However, we are keeping it in this report because the concept is evolving, and its potential may resurface as virtual environments become more advanced. Rather than focusing on purchasing digital land, the future of this space may center on ownership of metaverse-designed experiences. For example, instead of buying a generic virtual plot, individuals or brands might acquire exclusive rights to a virtual stadium that hosts high-profile concerts. As immersive digital experiences grow in sophistication and consumer adoption, this shift in perspective could redefine value in the metaverse.

Worlds for Purpose

The metaverse is evolving into a hub for global cooperation, activism, and digital governance. The World Economic Forum's Global Collaboration Village, developed with Accenture and powered by Microsoft Mesh, showcases this shift. In January 2024, the Village facilitated more than 200 participants in virtual discussions using realistic avatars and spatial audio, demonstrating how XR can bridge gaps beyond traditional video conferencing. Partners such as Aramco, Interpol, SAP, and Schneider Electric debuted virtual pavilions, signaling a growing commitment to collaborative problem-solving in immersive spaces. In June 2024, participants explored XR applications for addressing climate change, sustainable manufacturing, and other global challenges at the Village's first all-virtual event, "Creating Value through XR."

Meanwhile, activism and social justice initiatives are transforming the metaverse into a space for advocacy. The ARtivism project leverages AR to make public art accessible to blind and low-vision individuals. Users engage with AR-enhanced descriptions and interactions, ensuring that activism through art reaches a more diverse audience. Elsewhere, the Mariah AR app challenges power structures by overlaying historical and contemporary resistance narratives onto physical locations, effectively allowing users to "legally trespass" in the metaverse as a form of protest. Events like Metaverse Safety Week 2024 in December further highlighted how open-source frameworks can promote privacy, digital rights, and governance, while American University's 2024 symposium examined the metaverse's impact on human rights and advocacy. These initiatives underscore how XR-driven metaverse platforms are rapidly expanding beyond entertainment—becoming key tools for inclusion, activism, and policy-making.

Worlds for the Enterprise

Enterprises are rapidly integrating metaverse technologies to redefine collaboration, productivity, and workplace presence. Virtual office platforms such as Meetaverse enable employees to engage in immersive 3D environments, utilizing avatars, spatial audio, and interactive whiteboards for real-time teamwork. Unlike traditional video conferencing, these virtual spaces create a persistent digital workplace where spontaneous interactions and collaboration occur naturally. Businesses are leveraging metaverse offices to replicate physical environments, offering customizable meeting rooms and tools that enhance engagement among remote and hybrid teams.

Further advancing enterprise adoption, Warner Brothers filed a patent in August 2024 for a mixed reality (MR) system that dynamically integrates real-world context into virtual workspaces. The system uses headset-based imaging to analyze an environment's objects, lighting,

EXPERIENCING IMMERSIVE WORLDS

sound, and people, enabling the rendering of adaptive virtual objects within an MR session. By aligning virtual content with real-world context parameters, this innovation could allow context-aware enterprise applications, such as AR-powered brainstorming sessions or real-time data visualization in boardrooms. The intersection of mixed reality and enterprise collaboration is poised to deepen digital work experiences, transforming how teams interact and problem-solve in hybrid work settings.

Play-to-Earn and Virtual Marketplaces

In gaming, blockchain and metaverse platforms are redefining digital economies. In late 2024, Bright Star Studios released "Ember Sword," an MMORPG with tokenized in-game assets, allowing players to earn and trade NFT cosmetics. Ubisoft launched "Captain Laserhawk: The G.A.M.E.," integrating blockchain-based assets into a multiplayer experience featuring Rayman. And Roblox announced a new monetization model, enabling developers to sell entire games for real currency, transforming its user-generated content ecosystem. At HIKKY's Virtual Market 2024 Winter in December, there were 22 venues selling 3D items and avatars, supporting creators in virtual commerce. Additionally, Epic Games introduced Fab, a digital asset marketplace unifying resources from Unreal Engine, Sketchfab, Quixel, and ArtStation, streamlining the creation of interoperable metaverse experiences. With these advancements, enterprises and gaming platforms are converging on immersive, blockchain-integrated virtual economies that blur the line between work, play, and commerce.

SCENARIO YEAR 2034

A METAVERSE UNITED FOR THE AMAZON

As the relentless threat of deforestation continues to loom over the Amazon rainforest, innovative solutions are paramount. The Amazonian Reforestation Initiative (ARI) emerges as a transformative metaverse event, uniting global citizens in a shared commitment to conservation. Unlike traditional fundraising campaigns, ARI leverages the power of immersive technology to create a dynamic and engaging experience. Participants, represented by realistic, customizable avatars, journey into a stunningly rendered virtual Amazon, complete with spatial audio that captures the rich soundscape of the rainforest. Here, they encounter holographic guides—AI avatars modeled after indigenous elders and environmental experts—who share their knowledge and passion for this vital ecosystem.

Within this virtual world, attendees actively participate in interactive simulations that vividly illustrate the devastating impact of deforestation on climate change and biodiversity. They engage in simulated reforestation efforts, learning about sustainable practices and planting virtual trees that translate into real-world action. The event also showcases a digital art auction, featuring exclusive pieces inspired by the Amazon, with proceeds directly supporting reforestation projects. Highlighting the cultural richness of the region, musicians and storytellers from indigenous communities deliver captivating live performances, transcending geographical boundaries through AI-powered translation ensuring global accessibility. The use of spatial computing allows participants to gather around the digital stage, creating a sense of shared experience despite physical distance.

Further emphasizing engagement and collaboration, ARI incorporates interactive workshops led by experts and community leaders. Participants exchange ideas, learn about sustainable agriculture, and actively contribute to conservation strategies. In a groundbreaking approach, ARI also integrates play-to-earn game mechanics, rewarding players with NFTs and other digital assets for their participation in reforestation activities, gamifying environmental action. This initiative faces challenges, including ensuring accessibility for those with limited internet access, addressing concerns about cultural appropriation, and guarding against misinformation. However, by promoting education, inspiring tangible contributions, and fostering cross-cultural collaboration, ARI demonstrates the metaverse's transformative potential as a platform for environmental stewardship and global unity. It represents a shift towards ownership of metaverse-designed experiences, where the value lies not in virtual land, but in the impactful event itself.

METAVERSE INFRASTRUCTURE

METAVERSE INFRASTRUCTURE

AI Scalability

As metaverse ecosystems expand, AI scalability is becoming a critical factor in enhancing virtual experiences, moderating digital interactions, and enabling real-time adaptation. In October 2024, researchers from China's Shaanxi Institute of Technology and South Korea's Kunsan National University introduced ALMAA (Adaptive Learning Model for AI Agents)—a framework designed to improve AI contextual decision-making and scalability in metaverse environments. ALMAA integrates real-time adaptation, predictive analytics, and behavioral moderation, allowing AI to generate dynamic content and personalize user interactions. The study highlights ALMAA's theoretical applications in platforms such as Epic Games' virtual events and AltspaceVR, emphasizing its potential to create more adaptive and ethical AI agents while addressing data privacy, integration complexity, and scalability challenges through standardized APIs and cloud-based infrastructure.

Meanwhile, Nvidia is driving AI scalability through OpenUSD (Universal Scene Description) microservices. These new tools—USD Code NIM, USD Search NIM, and USD Validate NIM—allow developers to seamlessly integrate AI copilots and agents into metaverse applications, improving automation, search functionality, and content validation. By embedding generative AI directly into metaverse platforms, Nvidia's innovations enhance scalability, streamline AI deployment, and expand the capabilities of virtual environments. Together, ALMAA's theoretical framework and Nvidia's OpenUSD microservices represent a significant leap forward in scalable AI-driven metaverse experiences, paving the way for more interactive, responsive, and intelligent virtual worlds.

Interoperability

Interoperability is becoming the foundation of a scalable, user-centric metaverse. Epic Games' development of Unreal Engine 6 signals a move toward cross-platform content creation, integrating high-end tools with Unreal Editor for Fortnite to enable seamless application deployment. Epic's partnership with Disney further underscores this commitment, as they work to build a persistent, interoperable ecosystem within Fortnite. Meanwhile, Improbable's launch of MSquared introduces Metaverse Markup Language and Construct, open-source tools designed to enhance cross-platform virtual world creation. Partnerships with Google, Nvidia, and Dolby highlight efforts to break down technological silos, ensuring digital assets and experiences remain fluid across environments.

Industry-wide initiatives are reinforcing these efforts. The Metaverse Standards Forum's 2024 Annual Report stresses that a robust interoperability framework will drive adoption, market growth, and cohesive user experiences. Similarly, IEEE's recent publication advocates for an open and inclusive metaverse, defining technological interoperability standards essential for integrating virtual economies, digital assets, and communication protocols across platforms. As companies align around common standards, open APIs, and scalable toolsets, the future metaverse is shifting from isolated experiences to a fully interconnected digital ecosystem, enabling users, developers, and businesses to operate seamlessly across virtual worlds.

Government Investment

After a surge of interest in metaverse technologies between 2021 and 2023, government investment has slowed significantly. Many early initiatives struggled with technical limitations, unclear economic returns, and shifting policy priorities, leading to reduced funding and stalled projects. However, a few governments continue to explore targeted applications for digital twins, financial regulation, and industrial strategy. Shanghai and Tokyo remain committed to virtual city models, using metaverse-driven digital twins for urban planning, infrastructure management, and citizen engagement. Other nations, including the United Arab Emirates, South Korea,

METAVERSE INFRASTRUCTURE

Barbados, Finland, Japan, and China, have maintained limited investments in smart city initiatives within the metaverse, though at a reduced pace.

In policy, the European Commission's Web 4.0 strategy represents one of the few new large-scale metaverse initiatives, focusing on virtual public services, industrial applications, and global standards for interoperability. Meanwhile, the US Financial Industry Regulatory Authority explored the metaverse's role in finance, publishing an October 2024 report on potential applications such as virtual trading, investor education, and financial data visualization. While broad government-backed metaverse adoption has slowed significantly, these targeted efforts indicate that policymakers are still searching for practical, scalable applications of virtual worlds.

Developer Tools and Application Building Blocks

Major tech companies are advancing developer tools and foundational technologies to streamline metaverse content creation, AI-driven environments, and real-time 3D rendering. Apple's visionOS, launched for the Apple Vision Pro, establishes a spatial computing platform with Reality Composer Pro, enabling developers to build interactive 3D environments and spatial UIs with minimal coding. Apple's Unity integration simplifies deployment of AR/VR applications, while improvements to ARKit enhance hand-tracking, eye-tracking, and spatial awareness, making mixed reality interactions feel more intuitive and lifelike.

Epic Games continues to refine Unreal Engine 5 with MetaHuman Animator, allowing developers to generate realistic avatars from video footage in minutes. The Verse programming language introduces real-time updates and cross-platform interoperability, ensuring digital assets remain flexible across different metaverse ecosystems. Looking ahead, Unreal Engine 6 is expected to scale metaverse applications to larger, more persistent virtual worlds. Meanwhile, Meta's AI-powered Motivo model enhances avatar realism, emotional responsiveness, and NPC interactions, enabling AI-generated VR environments where users can create virtual spaces simply by describing them.

Breakthroughs in 3D capture technology are also reshaping how real-world environments integrate into the metaverse. Google and Niantic's Gaussian Splatting technology replaces traditional polygon-based rendering with photorealistic point-cloud representations, offering faster, higher-resolution 3D scans. Niantic's Scaniverse integration lets smartphones capture metaverse-ready objects, while Google's immersive maps and digital twins bring real-world locations into VR/AR navigation. Together, these advancements lower development barriers, making metaverse world-building faster, more scalable, and more immersive than ever before.

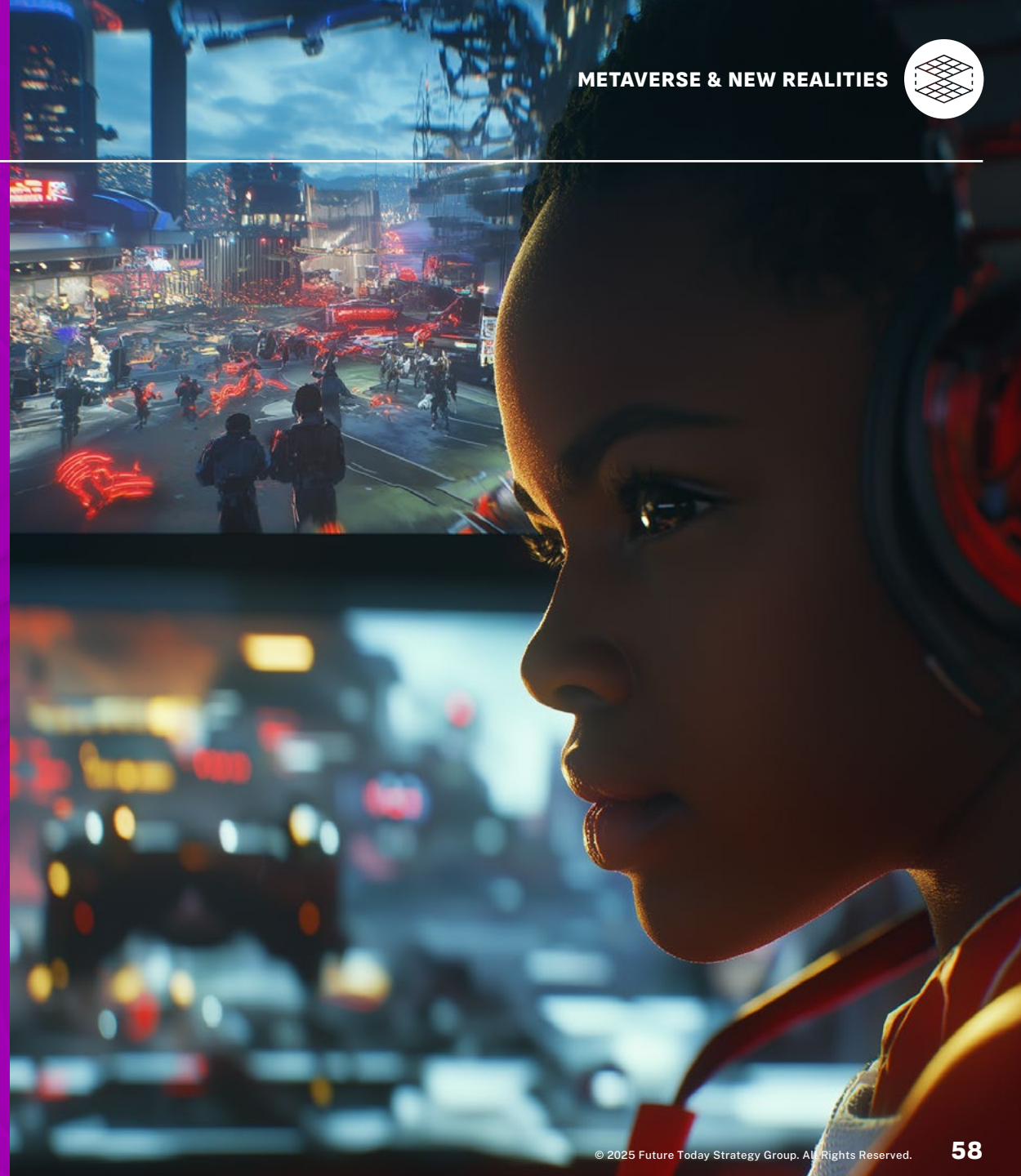
METAVERSE INFRASTRUCTURE

Interdevice Synchronization

As metaverse experiences become more immersive, interdevice synchronization is emerging as a critical feature, ensuring seamless interaction between users across different VR, AR, and traditional gaming platforms. In February 2025, Innersloth announced “Among Us 3D,” a first-person multiplayer version of the popular game, enabling real-time cross-play between PC users and VR headset players on Meta Quest, SteamVR, PlayStation VR 2, and PICO devices. This development demonstrates synchronized gameplay across different hardware ecosystems, allowing players using different input methods—motion controllers, gamepads, and keyboards—to share a single game world without performance disparities.

Social platforms like VRChat exemplify synchronized multi-device interaction by supporting simultaneous presence across standalone, PC, and high-end VR headsets. Users on Meta Quest, Valve Index, HTC Vive, PICO 4, and Android-based standalone VR devices experience synchronized spatial audio, real-time avatar movement, and shared interactive environments, ensuring that actions appear fluid and natural, regardless of hardware limitations.

On the infrastructure side, the Khronos Group’s OpenXR 1.1 update released in April 2024 enhances interdevice synchronization by standardizing hand-tracking, eye-tracking, and controller interactions across VR platforms. This allows a single metaverse application to recognize and adjust to different input systems, ensuring smooth, coordinated interactions between users, whether they are using inside-out tracking on Apple Vision Pro or external sensors on SteamVR headsets. These advancements signal a future where hardware barriers dissolve, creating frictionless, real-time synchronization between diverse metaverse participants.



SCENARIO YEAR 2040

GATED REALITIES

In 2040, the United States exists with a metaverse fractured by the ghosts of repealed net neutrality. The open and equitable digital frontier once envisioned has been supplanted by a tiered reality where access, speed, and experience are dictated by the depth of one's pockets and the preceding decades' corporate alliances. This wasn't a sudden cataclysm, but a slow, incremental erosion of digital principles, driven by regulatory inertia and the relentless march of technological advancement. The early promises of the metaverse—democratization, connection, empowerment—ring hollow for millions, replaced by a sense of digital disenfranchisement and a growing chasm between the "haves" and "have-nots" of the virtual world.

The knock-on effects are profound. Innovation has become concentrated within the walled gardens of major tech companies, which have partnered with telecom giants to ensure preferential treatment for their platforms. The cost of entry for independent developers skyrockets, as competing with the optimized bandwidth and AI-driven enhancements of the Tier 1 metaverse becomes impossible. Rural communities, already struggling with digital access, find themselves further isolated, unable to participate in the immersive educational, health care, and economic opportunities available to their urban counterparts. A digital underclass emerges, consigned to laggy simulations and stripped-down AR experiences, effectively locked out of the full potential of the metaverse.

The clear winners are the telecom conglomerates (Comcast, AT&T, Verizon), who leveraged their infrastructure control to become the gatekeepers of the metaverse. By prioritizing traffic from partner platforms like Meta, they created a self-reinforcing ecosystem, driving up subscription prices and securing dominance over the digital landscape. These companies not only collect premium fees for fast-lane access but also profit from the data generated within their walled gardens, using sophisticated AI algorithms to personalize advertising and monetize user behavior. Their stock prices soar as they become indispensable pillars of the 21st-century economy, shaping culture and commerce from behind the scenes.

Conversely, those who suffer the most are the small businesses and startups attempting to carve out a space for themselves, and the consumers on low incomes who are increasingly unable to access the essential services that are now confined to the metaverse. For lower-income communities, where basic internet access is already a struggle, the two-tiered metaverse deepens existing inequalities. Telemedicine, virtual education, and remote work opportunities are readily available to the wealthy, while the poor are forced to rely on antiquated technologies or simply miss out altogether. Indie developers and artists who can't afford the premium bandwidth or the AI enhancements offered by the major platforms are relegated to the digital margins, unable to reach a broad audience or monetize their creations effectively.

The unintended downstream consequences are equally troubling. Political polarization is amplified, as the wealthy retreat into echo chambers of tailored content and personalized experiences, while the marginalized are left to navigate the digital backwaters, susceptible to misinformation and online extremism. The sense of social cohesion erodes, as Americans increasingly inhabit separate and unequal virtual worlds, further fueling distrust and division. More and more people are starting to suffer from cyber sickness and AR and VR users are being encouraged to purchase extra equipment to mitigate the effects, thus increasing income inequality.

What started as a vision of a connected, democratized digital future has devolved into a new frontier of economic and social division, leaving many Americans locked out of the full potential of the metaverse, and the nation grappling with the consequences of a two-tiered digital society.

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