METAVERSE · NEW REALITIES

FUTURE TODAY INSTITUTE'S 2024 TECH TREND REPORT

Our 2024 edition includes nearly 700 trends, which are published individually in 16 volumes and as one comprehensive report with all trends included.

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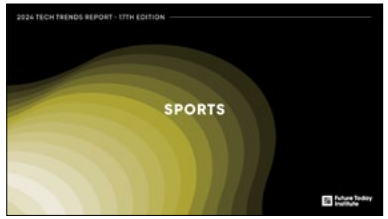

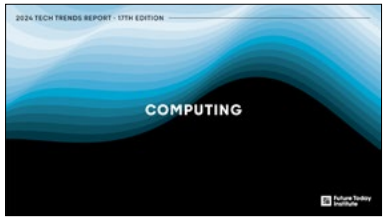

THE YEAR AHEAD: TECH SUPERCYCLE

The theme for our 2024 report is Supercycle. In economics, a "supercycle" refers to an extended period of booming demand, elevating the prices of commodities and assets to unprecedented heights. It stretches across years, even decades, and is driven by substantial and sustained structural changes in the economy.

We believe we have entered a technology supercycle. This wave of innovation is so potent and pervasive that it promises to reshape the very fabric of our existence, from the intricacies of global supply chains to the minutiae of daily habits, from the corridors of power in global politics to the unspoken norms that govern our social interactions.

Driving this seismic shift are the titans of technology and three of their inventions: artificial intelligence, biotechnology, and a burgeoning ecosystem of interconnected wearable devices for people, pets, and objects. As they converge, these three macro tech segments will redefine our relationship with everything, from our pharmacists to our animals, from banks to our own bodies. Future Today Institute's analysis shows that every technology—AR/ VR/ XR, autonomous vehicles, low Earth orbit satellites, to name a few—connects to the supercycle in some way.

The ramifications are stark and undeniable. As this tech supercycle unfurls, there will be victors and vanquished, those who seize the reins of this epochal change, and those who are swallowed whole. For business leaders, investors, and policymakers, understanding this tech supercycle is paramount.

In this 17th edition of FTI's annual Tech Trends report, we've connected the supercycle to the nearly 700 trends we've developed. Our research is presented across 16 technology and industry-specific reports that reveal the current state of play and lists of influencers to watch, along with detailed examples and recommendations designed to help executives and their teams develop their strategic positioning. The trends span evolutionary advancements in well-established technologies to groundbreaking developments at the forefront of technological and scientific exploration. You'll see emerging epicenters of innovation and risk, along with a preview into their transformative effects across various industries.

We've visually represented the tech supercycle on the report's cover, which is an undulating image reminiscent of a storm radar. Vertical and horizontal lines mark the edges of each section's cover. When all 16 section covers converge, the trends reveal a compounding effect as reverberating aftershocks influence every other area of technology and science, as well as all industries.

It's the convergence that matters. In isolation, trends offer limited foresight into the future. Instead, the interplay of these trends is what reveals long-term change. For that reason, organizations must not only remain vigilant in monitoring these evolving trends but also in cultivating strategic foresight—the ability to anticipate future changes and plan for various scenarios.

Our world is changing at an unprecedented rate, and this supercycle has only just begun.

Amy Webb
Chief Executive Officer
Future Today Institute

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TOP HEADLINES

The metaverse sees a cooldown from its initial hype, marking a phase of recalibration and more realistic expectations.

01 Meta and Apple Impress with New VR Hand Tracking and Gesture Recognition

The tech giants' latest headsets showcase hand tracking and gesture recognition capabilities offering users a more intuitive way to interact with virtual environments.

02 Events in the Metaverse Flop

Metaverse Fashion Week saw major brands invest but drew few visitors, who found it lonely and dull. Substantial investment and creativity are needed to boost engagement.

03 Metaverse Layoffs: Meta and Disney Scale Back Amid Cooling Hype

As the initial excitement around the metaverse wanes, Meta reduced its workforce, and Disney shut down its division dedicated to exploring metaverse opportunities, signaling a reset in the industry's approach.

04 Deepfakes Emerge as a Concern Ahead of Election Cycle

While some are entertainment, the technology's potential for fabricating hyperrealistic news and political footage to deceive voters is alarming ahead of upcoming elections. Experts worry viral deepfakes could spread misinformation across social media.

05 Early Adopters Explore Digital Twins for the Enterprise

Innovative early adopters in sectors like autonomous vehicles and smart cities are looking into the potential of digital twins.

STATE OF PLAY

Overshadowed by the rise of artificial intelligence, the metaverse is searching for new potential through AI integration, evolving from initial hype to a measured and mature future.

When Facebook rebranded as Meta in 2021, it bet big on leading the next computing platform—the metaverse. However, early criticisms emerged, given the rudimentary state of virtual and augmented reality (AR) technology at the time, with many clunky headsets and cartoonish avatars. The spotlight soon shifted when OpenAI unveiled ChatGPT in 2022, captivating public interest in AI. Unlike past AI systems, ChatGPT's accessibility enabled mainstream user interaction for the first time, representing a key inflection point. This overshadowed enthusiasm for the metaverse, which was having adoption challenges. Disney retreated on its own metaverse goals amid disillusionment, and Meta's Reality Labs posted a staggering $13.7 billion loss in 2022.

Yet in 2023, major tech players recognized the potential in fusing AI and metaverse technologies to take immersive simulations to the next level. Meta CEO Mark Zuckerberg unveiled strikingly realistic virtual avatars, enabled by AI—a major leap in simulation quality. Microsoft shared plans to blend its AI Copilot with HoloLens 2, delivering an AR experience for workers. And Apple introduced Vision Pro, a spatial computing headset employing machine learning for more natural user interactions. Rather than competing trends, AI and the metaverse now appear poised to complement each other. The future points to AI-enabled metaverse experiences that feel increasingly personalized by learning user preferences.

Meta also unveiled more subtle technologies like smart glasses, signaling a shift in consumer preferences for extended reality (XR) technologies that integrate digital experiences with physical reality. In doing so, these technologies could enhance human connection, as the technical interface fades into the background, replacing screen-centric interactions with more natural, human-centered ones. Spaces and the nature of work could be transformed, reducing our reliance on traditional screens and keyboards, and potentially revolutionizing the built environment and our interactions with computers. The form factor of XR technology could evolve to where our natural actions and environments become the primary means of interaction, ushering in a new era of computing that is more integrated with daily life. This evolution mirrors AI advancements in natural language, enabling more intuitive metaverse interactions.

In many ways, the trajectories of AI and the metaverse have come full circle. What began as separate trends with muted enthusiasm has given way to recognition of their interdependence in creating more immersive digital interactions. Their futures are now fundamentally linked, with advances in one enabling progress in the other.

KEY EVENTS

FEBRUARY 1, 2023

A Long-Term Vision is Challenged
Meta's Reality Labs division, specializing in AR and VR technologies, reports significant operating losses of $13.7 billion for 2022.

SEPTEMBER 28, 2023

Meta Town Hall Highlights AR
Mark Zuckerberg showcases Ray-Ban smart glasses as key to Meta's subtle, stylish AR shift. Shortly after, Meta Quest 3 debuts, offering advanced mixed reality experiences but garners mixed reviews and slow adoption.

OCTOBER 23, 2023

Saudi Cities Embrace Digital Twins
South Korea's Naver wins a $100 million deal to create digital twins for five Saudi cities, enhancing urban planning and flood management.

NOVEMBER 15, 2023

Metaverse Medical Market
Ocutrx's OcuLenz AR headset, designed for macular degeneration, highlights medical applications as a key path for AR technology adoption beyond entertainment.

FEBRUARY 2, 2024

Apple Vision Pro is Released
Apple released its newest mixed reality headset with over 600 apps, video passthrough, and spatial audio.

LIKELY NEAR TERM DEVELOPMENTS

THE FOUNDATIONS OF THE METAVERSE

As virtual experiences become more embedded into daily life, we can expect growing pains. Regulators must balance guidelines that ensure integrity without restricting an nascent industry. Tapid advances precipitate more seamless, intuitive user experiences. Hands-free environments feel within reach as innovations like gesture control tech remove friction. Past the hype, enterprise use cases will gain traction, and efficiency gains will drive adoption beyond novelty appeal. Generative AI will further accelerate proliferation by enabling amateur creators to construct fully realized 3D worlds without coding skills. With increased adoption, interoperability will rise as a priority. Metaverse technology has perpetually searched for a wide audience—if it fails to reach the mainstream consumer, industrial use cases may take over. Medical, industrial, or civic metaverses may be the first to find product-market fit. Their focused nature could lend itself more readily to creating utility and value.

Completely Hands-Free Experience

As delivery routes and last-mile deliveries continue to increase in speed and complexity, automation will let logistics companies create an intricate web of delivery offerings that can be unique to each customer.

Metaverse-Tailored Offerings

As climate change continues to be a disruption, logistics providers will explore how they can insure against extreme weather events. These costs could be passed along to consumers who choose goods from more volatile regions.

Metaverse World Building for All

Increased automation and use of virtual agents raise the need for workers to know how to manage new tech-enabled work and tasks. This upskilling could be done through remote learning and working opportunities.

Extended Reality Gets Serious

With workers continuing to grow in scarcity, virtual agents will take over back-of-house work in the warehouse. These virtual agents will soon be able to oversee themselves and their cobot workers, reducing the need for human intervention.

Regulators Target Virtual Trading

With manufacturing locations moving closer to the consumer and e-commerce increasing, manufacturers need to consider how to create products in the exact spot as their consumers.

Consumer Push for Interoperability

Global conflicts, combined with consumers and businesses wary of supporting governments with values antithetical to their own will increase demand for verification of supply chains. Granular data collection and transmission will enable this shift in transparency.

11 MACRO SOURCES OF DISRUPTION

WHY METAVERSE & NEW REALITIES TRENDS MATTER TO YOUR ORGANIZATION

Avatars Enable Personalization But Fragment Identity

Hyperrealistic avatars will enable more personalized brand experiences, but consumer identity may fragment across multiple avatars tailored to different contexts. This complicates marketing analysis, as brands must derive insights from fragmented consumer journeys and understand core motivations persisting across digital identities.

Digital Twins Save Time, Money, and Reduce Risk

Digital twins will revolutionize enterprise operations by enabling virtual prototyping, testing, and optimizing. Companies can digitally iterate designs and stress test ideas for better quality, gaining a competitive edge in market speed while minimizing downtime and disruption. By saving money and managing risk, this shift to virtual environments will drive innovation.

The Dual Edge of Hyperrealistic Avatars

Hyperrealistic avatars offer brands detailed customer insights but risk misuse. They enable lifelike interactions and richer data while supporting a deeper understanding of target demographics. However, the potential for deepfakes makes identity validation a challenge and puts brand reputations at risk. The ability to trust the accuracy of avatar identities will be critical for ensuring messaging reaches intended audiences.

Metaverse Unlocks Immersive Marketing Avenues

Immersive virtual worlds offer a new frontier for brand marketing. In the metaverse, brands can engage customers through lifelike, personalized interactions, blending products and messages into the virtual cultural fabric. This narrative-based approach boosts virality and peer sharing, while rich data informs strategy and product development. Substantial investment in creative talent and technology is essential for establishing top-tier experiences.

Safely Mastering High-Risk Skills

XR in enterprise training rapidly upskills employees' safely, even in high-risk areas. Realistic simulations for tasks like operating machinery or handling emergencies build skills and confidence without real-world risks. This leads to a workforce adept at complex jobs, reducing mistakes. XR training offers quicker proficiency, lower risk, and no need for physical practice, optimizing talent development and shortening onboarding.

Early XR Adoption Boosts Workforce Dynamics

Augmented reality could reduce reliance on screens, minimizing screen fatigue and enabling more natural human-computer collaboration. Spatial overlays could also optimize workflows by aligning virtual models with physical spaces. As XR advances, traditional seated desk work may transition to immersive environments centered on voice and gestures rather than mouse clicks. Built spaces could be reimagined, reducing fixed real estate costs and promising more ergonomic, satisfying, and dynamic work routines with less dependence on screens.

WHEN WILL THE METAVERSE & NEW REALITIES DISRUPT YOUR ORGANIZATION?

Forecasted Time of Impact

0-4 YEARS	5-9 YEARS	10-14 YEARS	15+ YEARS
Digital twins in manufacturing	Holograms	Decentralized identity	Full interoperability
Hands-free virtual	Enterprise XR collaboration	Spatial mapping	
Photo-realistic avatars	Spatial computing	6G-enabled metaverse	
Multifactor biometric sensing	Digital twins in health		
	Normalized use of avatars in collaboration platforms		

OPPORTUNITIES & THREATS

Threats

The lack of asset and avatar portability across platforms like Meta Horizon or Microsoft Mesh limits the metaverse's potential and user experience. The inability to transfer digital assets across different metaverse platforms creates a fragmented and restrictive environment.

There is significant risk in prioritizing proprietary control, and those seeking walled-garden dominance risk stunted growth. If standardized protocols are not developed as they were for the internet, the metaverse's vision may not be actualized and it will be a flop.

The advancement of synthetic media has given rise to substantial ethical challenges, particularly around the issue of consent. Both public figures and private individuals face the prospect of their likenesses being replicated without permission, prompting serious concerns about autonomy and control over digital identities.

The creation of digital replicas raises philosophical questions about the authenticity of human expression and the ethical implications of creating and interacting with digital beings that mimic real individuals.

The metaverse could exacerbate isolation and detachment from reality. The lack of physical human interaction could diminish the quality of real-world relationships, leading to feelings of loneliness and disconnection.

Opportunities

Digital twins can serve as powerful tools for testing, optimizing, and making more informed decisions in a controlled setting. They help with proactive maintenance, predicting failures before they occur, and reducing downtime.

Metaverse marketing could bring brands closer to consumers and influencers closer to their followers. It enables interactive spaces for community building so users can interact not only with the brand but also with each other, enhancing loyalty and engagement.

Virtual training offers efficient skill development in low-risk environments, improving employee competencies and safety. Trainees can experience realistic scenarios without the dangers associated with real-life training, and it reduces the need for physical resources, travel, and on-site training facilities.

With companies integrating metaverse capabilities into platforms like Teams, remote collaboration is becoming more effective. Enhanced AI translations and the metaverse's elimination of geographical constraints means global teams can overcome language and distance barriers to access talent.

The companies that contribute most meaningfully to open standards and standardized protocols will emerge as long-term winners. By building compatibility across platforms, these companies can expand their reach, enabling their products to seamlessly integrate with a range of metaverse environments and tools.

INVESTMENTS AND ACTIONS TO CONSIDER

1

Pursue novel brand interactions. Rather than mirroring real-world marketing in virtual spaces, explore novel modalities unique to these mediums. Provide value via exclusive metaverse experiences that offer intimacy at scale. Stay atop innovations in synthetic media and immersive technologies to remain cutting-edge.

2

Get ahead of unintended consequences. Monitor early metaverse adopters across functions for potential psycho-social impacts, and implement support systems proactively, like VR-based counseling or hybrid work policies. Navigate this responsibility wisely.

3

Spearhead industry interoperability standards. Get ahead of fragmentation by convening an industry consortium to align on metaverse interoperability standards early. Prioritize user portability and platform connectivity. Lead here before ecosystems splinter and momentum makes alignment difficult.

4

Use immersive training for risk mitigation. Leverage XR for disaster preparedness, hazardous environment rehearsals, and other high-risk training needs. Repeatable virtual drills identify gaps efficiently at lower risk and cost than live exercises.

5

Differentiate with digital previews. Build 3D virtual models of spaces to allow remote previews and walkthroughs. For real estate, this enables global property tours. Hotels and venues can offer virtual site visits to event planners. Unique visibility and accessibility become a competitive edge.

6

Accelerate development cycles. Construct digital prototypes of products early in the design process for rapid iteration and user testing in VR. Refine designs, materials, and interactions before physical production. Democratize innovation by extending tools to customers.

CENTRAL THEMES

The Quest for Connection

There is a nuanced interplay between digital immersion and the desire to maintain a connection with the physical world. Consumers increasingly show a preference for augmented reality over virtual reality, indicating a broader inclination toward digital experiences that complement, rather than replace, the physical environment. The social dimension of the metaverse is equally critical. For the metaverse to be genuinely transformative, it needs to enhance social connections rather than create isolation. Its success will largely depend on its ability to foster genuine human interaction and community building. However, this new digital frontier is also reshaping social dynamics in profound ways. For instance, the increasing use of devices like smart glasses, which can record interactions, introduces a new dynamic in social behavior. People may modify their behavior, knowing they could be recorded at any time, affecting the authenticity of social exchanges. In essence, the metaverse is not just a technological space but a social one, heavily influenced by human behavior and societal norms.

The Technological Symphony of the Metaverse

The metaverse stands as a technological apex, relying on the culmination and integration of various advanced technologies still in development. Its realization hinges on the progress of numerous fields, including powerful battery technology, enhanced connectivity and the widespread deployment of 5G, as well as the evolution of wearable devices. This convergence suggests that the idealize vision of the metaverse is not just an isolated development but rather the endpoint of numerous technological trajectories. These include significant advancements in computing power, sophisticated AI algorithms, and innovations in the entertainment sector, all of which are crucial in shaping an immersive, seamless, and interactive metaverse experience. As such, the journey toward the fully realized metaverse is as much about the progression of these individual technologies as it is about their harmonious integration.

AI: Not Parallel But Key to Actualizing the Metaverse

AI is not just an accompanying technology in the development of the metaverse; it is a critical driver making the metaverse's existence and functionality possible. For instance, a key contribution of AI in the metaverse is the enhancement of user interactions through advanced natural language processing. This technology allows for more natural and intuitive communication within virtual environments, making interactions with AI-driven avatars and interfaces more fluid and lifelike. Moreover, AI facilitates the creation of expansive, complex virtual worlds. It enables the rendering of highly detailed and dynamic environments, which can adapt and respond to user interactions in real time. Additionally, AI contributes to the personalization of experiences within the metaverse. By analyzing user data and behavior, AI can tailor experiences to individual preferences. This customization capability will be necessary for making the metaverse less like a generic virtual space and one that feels uniquely relevant to each user.

CENTRAL THEMES

The Invisible Interface

An overarching drive toward more natural interactions underscores a key vision emerging for the metaverse. For input, companies like Meta, Apple, and Snap are developing innovations in voice control, hand gestures, and even neural signals that interpret eye and facial muscle movements. These updates remove the need for traditional physical controls, aligning with a frontier of silent, seamless interaction powered by AI. Gesture technology is advancing rapidly, pointing to hands-free experiences. Neural signals take this even further by tapping directly into biological cues to enable control through cognition alone. For output, advances in haptics and multisensory technologies point to a future beyond visuals and audio, where virtual experiences feel increasingly tactile and lifelike. The emergence of these subtle, intuitive technologies reveals we are slowly starting to actualize one vision of the metaverse: for the interface between humans and technology to fade into the background, becoming almost invisible.

Fragmented Realities

While individual companies are making strides developing their own metaverse platforms and capabilities, true interoperability across these disparate ecosystems remains elusive. Challenges persist around asset portability and avatar interoperability across different virtual platforms. A custom-built avatar remains confined to a single walled metaverse garden like Meta Horizon or Microsoft Mesh. Purchasing a virtual Gucci bag in one world doesn't automatically transfer digitally to other environments. This fragmentation severely limits the scope and potential of the metaverse. Users wish to move fluidly between experiences, carrying their digital possessions and personas with them. Creators want to build once and deploy everywhere, not redo work for each platform. For the metaverse to mirror the connected nature of the physical world, technical infrastructure enabling this cross-platform continuity is critical. While metaverse pioneers are acknowledging this necessity, competitive pressures and commercial interests of tech giants currently take precedence over open collaboration.

The Serious Business of the Metaverse

While consumer applications have driven much of the initial enthusiasm for metaverse technologies, substantial enterprise use cases are emerging across domains like training, digital twins, and remote collaboration. These practical business applications have the potential to push adoption further into the mainstream. Immersive training simulations are already being deployed by companies like Walmart, BMW, and Lufthansa to develop employee skills and knowledge in low-risk virtual environments. Industries from aviation to medicine are utilizing digital twins of complex systems to enable virtual testing and optimization. For remote work, Microsoft is integrating metaverse capabilities directly into Teams, which has over 270 million users. This allows colleagues to collaborate via lifelike avatars and spatial layouts in virtual meeting environments. While startups are innovating, Microsoft's massive reach gives it potential to make VR meetings a workplace norm. As these use cases demonstrate concrete ROI in areas from employee productivity and safety to time and cost savings, enterprise adoption can help further validate and destigmatize metaverse technologies.

ONES TO WATCH

Andrew "Boz" Bosworth, CFO and head of Meta's Reality Labs, for being Mark Zuckerberg's right-hand man and overseeing more than 20,400 people in realizing Meta's vision for the metaverse.

Tamir Berliner and **Tomer Kahan,** co-founders of Sightful Spacetop, for innovation in spatial computing interfaces.

Tara Boroushaki, Laura Dodds, Aline Eid, and **Maisy Lam,** researchers at MIT, for contributions to augmented reality with non-line-of-sight perception.

Dr. Tim Bunnell, director at the Nemours Center for Pediatric Auditory and Speech Sciences, for work on AI-generated video clips that mimic accents and speech patterns.

Professor Garuda Fujii, researcher at Shinshu University's Institute of Engineering and ELab2, for innovative approaches to designing source-shifter structures.

Grimes, musician and artist, for pioneering new business models in AI-generated voice synthesis.

Im Doo Jung, a professor in the Department of Mechanical Engineering at UNIST, for work on smart contact lenses for AR-based navigation.

Henry Liu, professor of civil engineering and director of Mcity and the Center for Connected and Automated Transportation at the University of Michigan, for advancements in simulated driving environments.

Akash Nigam, CEO of Genies, for development of decentralized avatar systems in the metaverse.

Dr. Seung-Kwon Seol, researcher at the Smart 3D Printing Research Team at Korea Electrotechnology Research Institute, for work on smart contact lenses for AR-based navigation.

Chat Steelberg, CEO of Veritone, for advancements in synthetic Voice as a Service (VaaS) solutions.

Dr. Yu Xinge, associate professor in the Department of Biomedical Engineering at City University of Hong Kong, for co-leading a study on wireless olfactory feedback systems in VR.

Dr. Yon Visell, associate professor of biological engineering at University of California, Santa Barbara, for work on haptic holography.

Joshua Xu, CEO and co-founder of HeyGen, for innovations in translation services.

Dr. Mikael Benson, researcher at the Department of Clinical Science, Intervention, and Technology at Karolinska Institutet, for research on digital twins for treatment of inflammatory diseases.

Pouya Hamadanian, electrical engineering and computer science graduate student and lead author at MIT, for work on Ekho, which synchronizes audio and visual streams transmitting to two devices.

Elizabeth Haas, an adjunct professor at NYU School of Professional Studies, founding director at NYU SPS Emerging Technologies Collaborative, and partner at New York Consulting Partners, for writing about cities and technologies.

Dr. Sarah E. MacPherson, head of psychology and professor at the School of Philosophy, Psychology, and Language Sciences, University of Edinburgh, for her work on cybersickness in immersive digital reality.

Michael Barnett-Cowan, professor at the Department of Kinesiology and Health Sciences, University of Waterloo, for his work on motion sickness in VR games.

Jose Fuertes, founder and CEO of OWO, for developing haptic vests for virtual gaming.

Jake Rubin, founder, chairman, and CEO at HaptX, for working to bring virtual worlds to life through realistic touch.

Jensen Huang, CEO and president of Nvidia, for envisioning the Omniverse platform and developer ecosystem to build the industrial metaverse and a clear path to metaverse revenue.

Soo-yeon Choi, CEO of Naver, for instrumental work in developing the digital twin cities project between South Korea and Saudi Arabia, which will revolutionize real-time decision-making, prediction, and optimization of urban infrastructure.

Yacine Achiakh, CEO and founder of Wisear, for pioneering the development of the first earphones with a neural interface, enabling hands-free, voice-free control of XR devices.

IMPORTANT TERMS

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.

IMPORTANT TERMS

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.

METAVERSE FORM FACTOR

METAVERSE FORM FACTOR

Headsets

While early virtual reality headsets offered consumers an escapist diversion, the technology is maturing, and developers are now targeting more pragmatic industries and experiences. The Meta Quest 3, for instance, brings a 30% improvement in screen resolution, faster processing speed, and a sleeker design. Most notably, outward-facing passthrough cameras allow wearers to view both physical and virtual surroundings. This "mixed reality" mitigates the isolating feel of previous models. Apple's forthcoming Vision Pro is also set to incorporate similar passthrough technology, highlighting an industry-wide acknowledgment of the need for more interactive and less isolating VR experiences. The Vision Pro will launch with an expansive app library spanning entertainment to productivity. Major streaming services like Disney+, ESPN, and Amazon Prime Video will be available alongside work apps like Microsoft 365, Slack and Zoom.

Meta's substantial price hike compared to its predecessor indicates a strategic pivot from targeting general consumers to focusing on enterprise applications. This repositioning places the headset in direct competition with established enterprise-focused devices like Microsoft's HoloLens 2 and Magic Leap 2. Sony's version, the SonyXR Headset is primarily tailored for industrial applications, aiming to integrate various production stages, such as design and prototyping, into the metaverse. By allowing users to construct 3D design models, the headset helps spot and fix problems while plans are still digital, saving money previously spent on faulty physical prototypes.

Rather than pure escapism, developers seem concentrated on increasing VR/AR functionality across specialized fields moving forward. Allowing real environment interaction reflects acknowledgment of earlier issues in consumer adoption, while enterprise and sensory enhancement applications point to an evolving market for the technology.

Smart Glasses

Developments in smart glasses aim to make spatial computing technology subtle yet powerful in daily life. In a landmark September 2023 announcement, Meta collaborated with EssilorLuxottica to unveil Ray-Ban glasses with built-in AI capabilities. Resembling traditional Ray-Bans in design, these glasses integrate multimodal sensors to interpret the user's gaze and voice commands. Whether the wearer is curious about a building or needing a sign translated, Meta's assistant can provide answers without hand gestures. Snap plans similar AI integration for contextual recommendations and on-lens edits. Apple likewise has plans to introduce augmented reality glasses, though details are still forthcoming. Meanwhile, Microsoft recently patented swappable batteries for extended power, potentially enabling comfortable all-day wear by reducing weight. Offloading processing functions to connected accessories like backpacks presents another option for portable use.

Though slimmer smart glasses would blend into social settings better than bulky virtual reality headsets, battery limitations pose ongoing challenges to unlocking the full capabilities of the sleeker wearable technology.

METAVERSE FORM FACTOR

In early 2024, BMW introduced AR technology in their cars with the help of XrealAir 2 AR glasses. These glasses show navigation, entertainment, and electric car charging information directly to the driver. The introduction of smart glasses in vehicles and into other parts of our daily life is more than just a technological advance; it's a societal shift. Mobile phones revolutionized the way we interact with the world—pausing to record moments or look up information. Smart glasses promise the same but with an added layer of immersion: You can live stream your experiences while remaining fully present. However, this comes with questions about the implications for interpersonal interactions. Will behavior change in a world where people know they could be continually recorded or analyzed by AI? In essence, smart glasses aren't merely a new gadget; they represent a significant leap toward pervasive computing and could fundamentally alter our relationship with technology and each other.

Haptic Wearables

Virtual worlds to date have focused primarily on visual and auditory immersion, but replicating tactile sensations presents the next frontier for technologies like metaverse platforms to conquer. The ability to not just see a virtual object but reach out and feel textures, weights, and movements would provide unprecedented realism. To enable this, developers are experimenting with haptic wearables—gloves, vests, or suits equipped with actuators to simulate different sensations through vibration, electrical stimulation, or even tiny inflatable balloons. Simple vibrational alerts via eccentric rotating mass motors are already featured in smartphones and controllers, priming adaptation for games and 3D virtual environments. Companies like HaptX are leveraging more advanced pneumatic glove actuators to replicate lifelike textures and shapes. Spanish startup OWO recently unveiled a haptic vest using electrical signals to induce sensations including bullet impacts or stabbings for gaming and live entertainment applications. As these devices advance alongside motion tracking systems like Sony's full body suit loaded with sensors, the building blocks are falling into place for the creation of deeply immersive and tactile responsive spaces within virtual worlds. The end goal is ambitious yet attainable: to produce a metaverse experience that fully engages users across visual, auditory and, critically, tactile domains to enable suspension of disbelief and flow state immersion.

Voice, Gesture, and Neural Interfaces

Human-computer interaction continues progressing beyond phones and screens, leveraging modalities like voice and gesture. Virtual assistants have normalized conversational AI, powered by robust speech recognition models. Startups are unveiling experimental devices prioritizing intuitive interactions, like Humane's screenless wearable pin, which understands natural language requests. Meta's Ray-Ban Stories glasses allow hands-free voice control, while their VR headsets track hand motions to manipulate virtual objects. Apple's Vision Pro will combine subtle finger gesture rec-

Just as touchscreens became widespread in the last decade, voice and gesture control are poised to be the next major methods for interacting with computers.

METAVERSE FORM FACTOR

ognition with eye tracking, enabling users to simply look at and point to items they want to select in an augmented environment. Wisear, a French startup, is pushing the boundaries even further with experimental smart earbuds that detect facial muscle movements and bioelectrical brain signals. By interpreting these neural signals, Wisear envisions completely silent, hands-free control of devices through minute gestures like tightening the jaw. Just as touchscreens have become ubiquitous over the past decade, emerging modalities like voice, eye tracking, and brain-computer interfaces could fundamentally transform how we engage with technology in the next 10 years.

Senses in the Metaverse

Recent advancements in human-machine interfaces are ushering in a new era of multisensory experiences in VR and AR. On the haptic front, researchers at the University of California, Santa Barbara have focused ultrasound waves to induce tactile sensations from afar. This noncontact "haptic holography" allows users to perceive and manipulate virtual objects. To deepen sensory immersion without physical temperature changes, University of Tsukuba researchers simulate persistent cold sensations through gentle air blasts. This exploits the body's sensitivity to rapid cooling for virtual weather experiences. In odor transmission, Dr. Yu Xinge's team at Beihang University developed wireless olfactory feedback systems with miniaturized odor generators. Integrating facemasks and skin patches, these can simulate environmental scents ranging from flowers to smoke. Startup OVR makes headsets that diffuse cartridge fragrances for personalized aroma experiences. Advances also continue in spatialized audio for lifelike acoustics. Professor Garuda Fujii of Shinshu University engineered structures that make sounds that seem to originate from different locations. By tricking the ears' spatial perception, more convincing augmented soundscapes become achievable. As these technologies mature, they pave the way for unified multisensory environments—where users not only see and hear but feel, smell, and taste simulated worlds for unprecedented presence.

Movement in the Metaverse

Disney has developed a new flooring technology called HoloTile that allows users to walk freely in any direction without actually moving from their fixed location. Described as the "world's first multi-person, omnidirectional, modular, expandable treadmill floor," HoloTile uses advanced sensors and motors to detect a person's movement and seamlessly shift modular floor sections to keep them centered in place. Multiple people can use the floor simultaneously without the risk of colliding. In a demonstration video, inventor and imagineer Larry Smoot walks through a virtual environment using a headset while the HoloTile floor adjusts dynamically beneath him. This technology opens up new possibilities for virtual reality and augmented reality, as well as applications like interactive theater where actors could explore a scene without constraints. Disney isn't alone in its effort to enable more natural movement in the metaverse. Other companies are exploring similar technologies for natural movement in virtual spaces. Virtuix has developed a VR treadmill for individual users, featuring a concave design and special shoe covers for a realistic walking sensation. Additionally, Freedom Technologies is working on specialized shoes with AI-enabled motorized treadmills in the soles, allowing for unlimited virtual movement in a confined physical space. These innovations represent different approaches to enhancing virtual mobility, and it's still unclear which will dominate the market. The choice may depend on specific use cases and user preferences in VR and AR experiences.

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A House Divided

The Komanduri family finds themselves in a dilemma: a “house divided” not by sports teams or smartphone preferences, but by their choice of AR/VR ecosystems. The eldest child, Aditya, is an avid fan of Apple’s AR/VR ecosystem, boasting the latest Apple AR headset and an array of digital accessories. Meanwhile, the younger sibling, Priya, is deeply immersed in the Meta universe, equipped with the newest Meta Quest and a collection of Meta-exclusive digital games and experiences. This division has led to more than just friendly sibling rivalry; it’s become a logistical and financial headache for the parents. Planning family activities in the virtual realm is nearly impossible, as each child is locked into their respective ecosystems, unable to interact or join the same digital spaces.

The financial strain is palpable. The family has to subscribe to two different “family plans” to accommodate both ecosystems. What’s more, the digital goods and games purchased for Aditya cannot be passed down to Priya, negating the possibility of “hand-me-downs” that would have been a cost-saving grace. This means doubling up on purchases for similar experiences or content, a redundancy that’s both frustrating and expensive.

Birthday and holiday gifts have also become a challenge. A game or digital accessory that delights Aditya is incompatible with Priya’s Meta setup, and vice versa. This has led to careful, sometimes stressful planning to ensure equity and satisfaction for both children, further adding to the family’s expenses.

DIGITAL IDENTITY

DIGITAL IDENTITY

Avatars

Avatars have matured beyond static profile images into multifaceted digital representations in virtual spaces. Initially serving as basic profile pictures, modern avatars manifest as interactive 3D entities capable of conversation, environmental navigation, and even simulated physical mannerisms. As online activities shift from websites and apps toward immersive extended reality (XR) metaverse experiences, avatars are becoming our primary digital personas—used for social connections, commerce, and professional meetings. Microsoft enables Teams users to utilize 3D avatars for calls, animated by voice cues to function sans webcams. And a 2023 podcast hosted in the metaverse demonstrated major upgrades in avatar realism, utilizing lifelike models of Mark Zuckerberg and Lex Fridman. This noticeable leap from previous cartoonish renditions drew significant public and investor interest by making broader metaverse goals appear more attainable. Companies like Genies are further expanding the scope and utility of avatars by working on open, decentralized systems that let users create not only their virtual selves but also the worlds they inhabit. This development opens up new opportunities for user engagement and potentially impacts how businesses operate in virtual environments. As avatars grow increasingly sophisticated in mimicking human appearance, motion, and interaction modalities, they reinforce their status as our digital surrogates across the internet's burgeoning virtual frontiers.

Avatar Portability

Avatar portability in the metaverse, as facilitated by companies like Ready Player Me, intersects with larger discussions about data portability and ownership. Ready Player Me and its partner, Koji, offer users the ability to create a unified digital identity that can migrate across over 200 games and virtual experiences. While this offers convenience and customization, it raises questions about who truly owns these digital identities. Your avatar, after all, is a form of data. Whether it's a visual approximation of you based on uploaded photos or a purely imaginative creation, the avatar is shaped by your preferences and actions. As such, the issue of avatar portability is inextricably linked to debates about data ownership. When an avatar can cross platforms, there's a tacit understanding that its underlying data should also be portable. But who owns that data, especially as avatars become increasingly sophisticated and personalized, is a point of contention. The issue is even more critical when considering that some metaverse companies aim to become comprehensive platforms for a wide range of activities, from reading news to socializing to shopping. In such a scenario, the platform that hosts your avatar could have significant power and control over a large swath of your personal data. So, while Ready Player Me's tools for avatar creation and portability offer users the ability to maintain a consistent digital identity across the metaverse, they also open up broader discussions about data ownership and portability in virtual spaces.

Hyperrealistic Avatars

Hyperrealistic avatars leverage 3D graphics and AI to produce nearly identical digital clones of individuals—capturing intricate facial details, expressions, and motions. Two methods exist for generating these sophisticated models. Companies like Doob utilize full body scans in studios, comprehensively recording the user's physical form. Alternatively, apps like Avatar SDK and itSeez3D enable DIY facial scanning directly through smartphone cameras. By taking a 360 degree image of their face and shoulders, users can craft impressively realistic avatar likenesses. Integrating natural language processing and vocal mimicry, these avatars graduate beyond appearances to also simulate voices, producing holistic digital surrogates. One pioneering example was during the recent taping of Lex Fridman's podcast with Mark Zuckerberg in the metaverse. Utilizing Meta's advanced "codec avatars," their uncannily realistic digital doubles exhibited nuanced mannerisms and conversations.

As solutions like HeyGen's AI-powered Avatar Clones push fidelity even further, lines blur between actual and simulated realities. While constructive applications await in gaming, en-

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terprise metaverses, and beyond, deep ethical questions emerge around authentic digital identity and behavior. Ultimately though, as avatar technology continues maturing to deliver hyperrealism, it will profoundly transform how we represent ourselves and interact in online spaces.

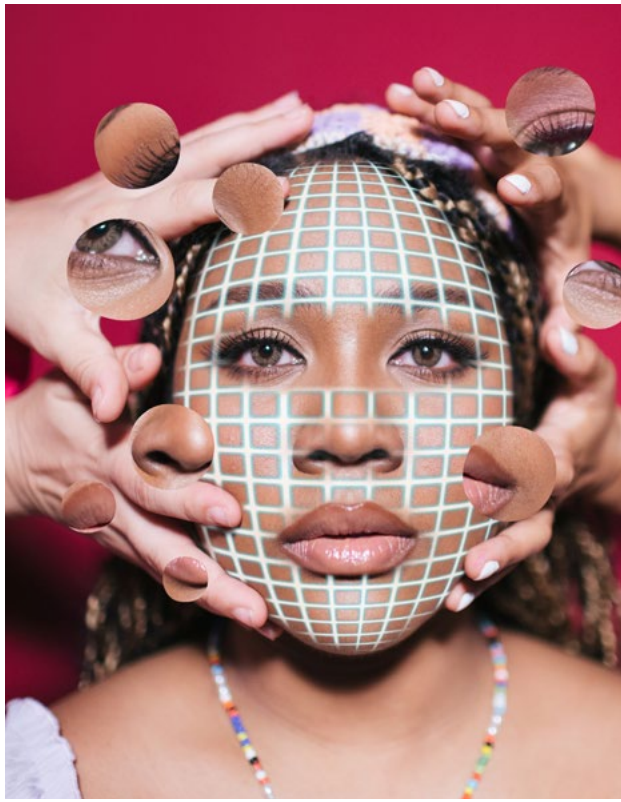
Fragmentation of Virtual Identity

Without a standardized, universal avatar system, users on various digital platforms create multiple online personas, each representing distinct facets of the self or even entirely fabricated alter-egos. This emerging paradigm signals a seismic shift in conceptualizations of identity in the digital era. We now face not just divergence between our physical and virtual selves but the fragmentation of singular legible personalities across ever-proliferating online spheres. A glimpse of this reality already manifests professionally. An individual may use one avatar, precisely modeled after their real-world appearance, for Microsoft Teams meetings. But the same person could adopt a fanciful, anonymized persona for recreational gaming universes.

For marketers reliant on data analytics, such compartmentalized self-representation poses challenges. When consumers have multiple discrete avatars, extracting useful signals becomes far more complex. Which identity should companies target for personalized advertising? How to accurately track preferences when individuals act differently across contexts? Ultimately, the fracturing of singular legible identities into specialized avatars requires businesses to fundamentally rethink behavioral analysis and personalization methodologies. As personas multiply across the metaverse, understanding users grows increasingly nuanced.

Leasing identity

AI is enabling digital replications of celebrities without their active participation or consent—an ethically murky development as likeness rights remain undefined. The 2023 Hollywood writers' strike spotlit concerns around studios exploiting synthetic acting indefinitely sans compensation. Meta recently launched celebrity chatbots like virtual Paris Hilton and Snoop Dogg alter egos, playing circumscribed roles on WhatsApp, Messenger, and Instagram. And deepfake technology already allows for CGI actor substitutions in film or ads without a physically present cast. When Bruce Willis retired for health reasons, his likeness still appeared in a Russian commercial via a deepfake generated by an AI company. To address this issue, new contract language around "simulation rights" is beginning to appear, allowing for the legal use of an actor's synthetic likeness in future productions. The music industry is also tapping into this trend; artists can now create songs using an AI-generated voiceprint of musician Grimes, splitting the royalties with her if she approves the collaboration. These early examples highlight the emerging potential to monetize synthetic celebrity beyond entertainment—anyone could perhaps license out digital persona rights for conversational AI, branding deals, or experiential metaverse content. But thorny questions around likeness consent and fair compensation remain open, especially as technology blurs lines between virtual replication and individual autonomy.



AI is enabling the creation of digital replicas of individuals' appearances and voices, opening avenues for monetizing identities.

DIGITAL IDENTITY

Synthetic Speech

Synthetic speech leverages AI to digitally mimic human voices, enabling myriad applications from accessibility tools to creative media. With enough training data, models can precisely replicate the unique vocal signature of any individual. Startups like HeyGen offer translation services that render personal video recordings into foreign languages, while retaining the original speaker's voice. Meta is also developing real-time speech translation to break language barriers using natural voice cloning. And new models need as few as 50 sentences to build vocal profiles, making synthesis more efficient and accessible. Samsung demoed a feature for its Bixby assistant to verbally respond to calls in a user's synthesized voice if they are unable to speak. Other applications of speech synthesis include "voice banking," where people at risk of losing their ability to speak due to disease can record samples that AI uses to synthesize their voice. This allows them to preserve their unique vocal identity for text-to-speech systems if they do need it later in life. Previously expensive and time-consuming, voice banking has become more efficient and affordable through AI, with some companies only needing 50 sentences to create a digital voice.

Synthetic Personalities

Beyond mimicking existing personas, large language models (LLMs) can invent completely synthetic yet persuasive media identities from scratch. After ingesting enough human data patterns, AI can reliably simulate varied personality dimensions within text or embodied conversational agents. Researchers deliberately shape these traits to craft AI virtual influencers—novel social media personas like Lil Miquela, Noonoouri, and Imma, each boasting 400,000+ Instagram followers. Instead of cloning celebrities, their personalities and backstories emerge fully formed from algorithms to fulfill commercial roles. Brands like Coinbase, Maje, and Tiffany & Co. have partnered with these AI-driven virtual influencers for endorsements and promotions. The control and presumed brand safety offered by synthetic influencers makes them an attractive alternative or supplement to human influencers. In 2023, the Federal Trade Commission indicated that virtual influencers must still disclose brand sponsorships like their human counterparts. As immersive spaces like the metaverse develop, AI-driven synthetic personas could enable personalized interactive brand experiences exceeding static posts. The technology remains nascent—but rapid improvements in AI personality exhibition point toward virtual influencers, celebrities, and beyond materializing as bona fide social presences, engineered from data to serve economic aims over authentic self-expression.

Synthetic personalities are entirely artificial digital influencers and identities created by AI, not linked to any real human.

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Virtual Training for Real World Jobs

Virtual reality enables immersive job training simulations across industries from retail to medicine, with measurable improvements in information retention and role comprehension. Companies like Walmart have incorporated VR into training as early as 2017, reporting 5%-10% testing gains versus classical training. Simulations run the gamut from customer scenarios like Black Friday to operational skills like spill cleanups. Maryland nonprofit Vehicles for Change likewise has trainees first pick up VR goggles instead of physical tools to observe demonstrations and practice procedures before touching actual cars. Aviation leaders including Lufthansa also apply extended reality across domains from product design to flight crew certification. The technology provides a low-risk yet realistic environment to build muscle memory and mastery of complex tasks, from retail soft skills to technical maintenance procedures. Hands-on learning through lifelike simulation before real-world performance allows workers to avoid consequences as they develop confidence. With customizable training exportable across geography, VR promises scalable and measurable skill-building superior to static manuals or lectures. Trainees engage more senses in contextualized scenarios, enabling organizations to elevate talent development.

Industrial True-to-Reality Simulations and Digital Twins

True-to-reality digital twins are revolutionizing industries from autonomous vehicles to smart cities by enabling virtual testing and optimization of complex real-world systems. The University of Michigan developed a statistically accurate simulated roundabout to rigorously refine self-driving algorithms without physical risk. BMW likewise models exact factory conditions in Nvidia's Omniverse platform years before producing a new car to optimize layouts and processes. On a macroscale, digital urban twins facilitate data-driven planning and governance. South Korean company Naver partnered with Saudi Arabia to craft cloud-based digital clones of Riyadh and other municipalities. These foundations centralize infrastructure data to assist long-term development across domains from transportation to emergency response. Numerous metropoles worldwide have embarked on urban twin projects—from Shanghai to Singapore to Chattanooga. The city of Chattanooga itself collaborates with research institutions on specialized twins examining factors like energy-efficient mobility infrastructure and pedestrian-vehicle intersection patterns to inform planning. As cloud computing power scales, digital urban replicas grow increasingly high-fidelity to run simulations and extract insights unfeasible in the real world. The technology enables observers to holistically visualize, quantify, and optimize the intricate orchestration of modern cities.

Human Digital Twins

Research institutions are pioneering medical digital twins—detailed physiological simulations of individual patients for personalized care and quantitative analysis. These complex computational models incorporate genetic, molecular, and environmental factors to replicate disease mechanisms with high precision. In conditions like rheumatoid arthritis, Crohn's, and ulcerative colitis, health care teams can leverage twins to run clinical scenarios—predicting outcomes of adjusted drug regimens to tailor optimal treatments. The simulations also enable deeper study of biological drivers and responses in silico. Medical twins diverge from simplistic avatars by encapsulating dynamic physical detail beyond just identities. Researchers ultimately envision diagnostic, prognostic, and even two-way communication functions as integration with sensor data and AI intensifies.

However, as computing power expands, digital twins may mature beyond niche medical uses alone. More advanced systems could maintain dynamic multifaceted models of individuals—incorporating both medical and psychological factors to mimic personality, knowledge, and behaviors. Researchers envision such sophistication may eventually enable twins to serve as persistent, autonomous virtual agents for their human counterparts. These highly faithful digital doppelgängers could seamlessly interact with people and other twins in virtual spaces or the metaverse. They could collabo-

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rate in ways impossible for remote humans, collectively analyzing problems through continuous data sharing exceeding biological cognition limits.

Connected Well-being and VR Assisted Therapy

VR is increasingly being recognized as a powerful tool in the field of psychological therapy and mental health treatment. VR's origins in mental health date back to 1997, when it was first invested in for treating PTSD in military populations. One major application is virtual reality exposure therapy (VRET): leveraging simulated environments to gradually confront patients with anxiety disorders. VRET allows for a controlled and personalized intervention where patients can confront and become accustomed to the sources of their anxieties in a virtual setting. The treatment has proven to be as effective as traditional in-person exposure therapy for conditions like specific phobia and agoraphobia with panic disorder. Interventions for post-traumatic stress disorder likewise show VR matching traditional psychotherapy techniques for symptom relief. Beyond exposure, the immersive medium also aids in developing coping mechanisms. Recent studies, such as a pilot project by Stanford Medicine researchers, have also started using VR to address hoarding disorders. Study participants rehearsed giving up possessions in a simulation of their own homes, an exercise that helped them practice organizational and decision-making skills while also desensitizing them to the emotional distress associated with discarding items. As software and analytical dashboards improve, VR appears poised to mainstream into mental health—blending digital solutions with clinical wisdom for more agile, quantified, and personalized interventions.

Medical Metaverse

The metaverse enables transformative innovations in medical education and care delivery via immersive simulation. Medical students can now perform virtual neurosurgery to improve their technical skills before operating on actual patients. The University of Texas uses a VR "patient safety room" where students identify hazards and discuss observations with professors, allowing for more effective training than traditional methods. However, while AI tutors in VR can provide tailored feedback like a human instructor, human oversight is still needed. A McGill University study found VR trainees with additional human instruction caused less tissue damage and were more precise than those trained by AI tutoring alone. Platforms like Fundamental Surgery additionally provide sophisticated haptic feedback for practicing complex manual tasks from palpating tissue to maneuvering instruments. Its patented HapticVR technology accurately simulates the tactile sensations experienced during surgery, from bone textures to muscle and soft tissue interactions. FundamentalVR also recently launched its Fundamental Core SDK, a toolkit empowering developers to create diverse medical training scenarios, including multiuser VR experiences.

Beyond training, AR and VR are being used for patient care and surgical planning. In Cambridge, England, medical students use

AR and VR are already utilized in surgical planning and training, enabling surgeons and patients to preview expected outcomes. At least one hospital has used AR headsets during complex surgeries to overlay patient data in real-time.

SCENARIOS

SCENARIO YEAR 2037

Exploring Mars with Man's Best Friend

After strapping on the haptic suit and headset, I'm immersed in a stark reddish-orange alien landscape that can only be Mars. As I "step" forward, I feel the crunch of strange soil beneath metal feet that are not my own. This body is an extension of mine—its sensors connected directly to my nervous system via a neural link system. When I lift my foot, the robot lifts its tread. When I reach out my hand, its claw extends. My consciousness inhabits this machine shell millions of miles away, and I'm seeing Mars directly through my avatar's camera eyes. Every sensation is mapped from its tactile sensors to my own synapses, blurred with just enough latency to make the illusion complete. This robot is me, and through it I have stepped onto the surface of another world for the first time.

But what truly anchors me in this extraordinary experience is Moe, my dog. She's not just lying next to me in the physical world; she's also here with me on Mars, in a way. When I adopted Moe, she came with something special: a digital twin. This isn't a virtual pet; it's a precise digital clone, created from detailed scans and biometrics, designed to mimic every physical detail of Moe. Initially, these digital twins were meant for health monitoring, a technological advancement in pet care. But soon, people realized their comforting potential in strange, digital realms. Here on Mars, as I navigate through vast, sweeping vistas, Moe's digital twin is right beside my avatar. As I explore, I occasionally reach down to pet the real Moe, feeling her warm fur, and then I see her digital doppelgänger reacting similarly beside my avatar. It's a bizarre yet heartwarming experience to have both versions of my best friend with me as I explore this alien world.

As night falls on Olympus Mons, I gaze out transfixed with my loyal dog clone by my side at a view no earthling has witnessed firsthand. Her presence, just like the real Moe, comforts me—two versions of man's best friend, one analog, one digital, both equally enthralled by this alien world we get to explore together.

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mixed reality headsets to train on "hologram patients," while Swiss company Arbrea Labs employs AR and 3D simulation to allow both surgeons and patients to preview expected outcomes of plastic surgeries, from nose jobs to breast augmentations. Surgeons at institutions like Houston's MD Anderson Cancer Center utilize AR headsets to overlay patient data seamlessly during complex procedures—establishing a new paradigm of in-situ surgical guidance.

Education in the Metaverse

Research has indicated the efficacy of VR in enriching learning experiences. Recent findings suggest VR contributes to improved understanding, heightened attention spans, and inclusive access to digitized global curriculum exceeding geographical constraints. Real-world implementations demonstrate scalability too. Japan's N and S high schools immerse over 6,000 students in collaborative virtual classes using Meta Quest headsets. Morehouse College's VR chemistry labs yield higher average test scores than conventional modalities. Beyond supplemental content, interactive platforms like RoybiVerse and Nanome reconstruct traditional models for more intuitive handling. Learners can manipulate molecular structures with their hands or traverse inside dinosaur anatomy. By blending immersion with interactivity, VR edtech unlocks multisensory comprehension of abstract or ephemeral concepts at individual scale.

Synthetic Media in Hollywood

The rise of synthetic media in Hollywood, accelerated by advancements in AI, is bringing both opportunity and ethical dilemmas to the industry. The 2023 Screen Actors Guild strike revolved around usage of talent likenesses without clear restrictions. Ironically, during the strikes, Meta and a company called Realeyes capitalized on the abundance of out-of-work actors by hiring them for an "emotion study" aimed at making AI-generated avatars appear more human. These actors signed away extensive rights "in perpetuity," allowing their facial expressions and other characteristics to be used by Realeyes, Meta, and third parties almost without restriction. This move clearly brings into focus the ongoing debate about publicity rights, the legal concept that grants individuals the right to control the commercial use of their name and likeness.

At the same time, examples of synthetic media featuring well-known actors are growing. For instance, James Earl Jones authorized the use of his iconic Darth Vader voice so AI could generate it for future "Star Wars" films. Companies like Metaphysic AI are employing de-aging technology, allowing stars like Harrison Ford, Tom Hanks, and Robin Wright to appear as younger versions of themselves on screen. In 2022, after a 40-year hiatus, ABBA made a comeback with fresh music, accompanied by their de-aged 3D avatars, known as ABBAtars. In 2023, Kiss bid farewell to the stage at their final performance in Madison Square Garden—only to reemerge minutes later as digital avatar versions of themselves, suggesting virtual immortality for these personas powered. Platforms like Weverse give K-pop artists opportunities to directly engage followers through virtual meetups while monetizing exclusive digital content. As immersive media expands, existing regulations around reasonable compensation, consent, and protections demand modernization to address ethical dimensions related to identity replication via emerging technologies.

Forensic AR / VR

AR and VR show great potential in advancing forensics. Sophisticated AR/VR crime scene simulations facilitate analysis even when the physical location remains inaccessible after the fact. Some systems use machine learning and medical imaging to enhance AR-assisted autopsies, leading to more accurate victim identification and determinations of cause of death. A major advantage of AR/VR is the ability to visualize complex forensic data in new ways. AR overlays digital information directly onto physical crime scenes, allowing for dynamic interaction like real-time tagging of evidence and voice-recorded annotations. In the legal system, AR and VR are modernizing evidence presentation in courtrooms through 3D modeling and mapping to provide an

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immersive crime scene experience for judges and jurors. This boosts understanding of complex evidence sequences. These technologies also facilitate remote testimony for improved accessibility. On the training side, companies like CBF Forensics use realistic VR simulations to deliver cost-effective forensic skills training for law enforcement. While still emerging, AR and VR integration in forensics promises to enhance remote capabilities, evidence presentation, and training.

Metaverse-Enhanced Science

The metaverse could significantly enhance the effectiveness and reach of science. Its interactive, three-dimensional spaces provide opportunities for unprecedented levels of collaboration and accessibility in research. For example, digital replicas of physical labs can enable scientists around the globe to get together and discuss and advance projects, bypassing geographic and logistical constraints. Experiments conducted in virtual environments have the added benefit of being precisely replicated, improving the reproducibility of research findings. Agencies like the Centers for Disease Control and Prevention are already leveraging the metaverse to train scientists in various locations, allowing them to engage in experiential learning without the real-world risks. Moreover, the metaverse allows for the creation of entirely new kinds of experimental spaces. For instance, scientists could utilize existing data and images to develop virtual models of far-off places, such as Mars, and remotely engage with these environments. However, realizing the metaverse's full promise requires surmounting adoption obstacles around equipment costs and centralized tech giant control.

Digital lab replicas could allow scientists to collaborate and perform virtual experiments mirroring real-world conditions, reducing costs and increasing accessibility to experimentation.

SCENARIOS

SCENARIO YEAR 2027

Experiential Equations

Daniel slips on a headset, eager to explore the immersive calculus simulator his teacher introduced in class. As the virtual world loads, Daniel finds himself standing on an abstract grid landscape, with colorful curves undulating in all directions. He reaches for a squiggly purple function in front of him, knowing that in this virtual world he can physically interact with the fundamental building blocks of mathematics.

“Today I want you to explore the concept of curvature,” the instructor’s voice emanates from the air. “Take this controller and manipulate the curve in front of you. Get an intuition for how bending changes along the arc.” Daniel reaches out and takes hold of the squiggly purple function. As he moves his hands, the curve reshapes itself like virtual taffy. Daniel instantly understands the curve better than equations on paper could convey—he feels how tapered regions have lower curvature than tight curls.

“Now, let’s step into a derivative’s shoes,” the instructor says. The world blinks, and Daniel’s perspective shrinks. He has become the orange derivative denoting the curve’s slope! As he glides along the ripples of the function, Daniel physically experiences each peak and valley in its slope and their full spatial relationship clicks intuitively. The immersive manipulations unlocked conceptual knowledge allowing math to finally make sense. He had felt what those cryptic formulas tried explaining: that curvature captures the rate of direction change. VR let Daniel enter into mathematics, instead of just staring formulaically. Equations had become experience.

PSYCHOSOCIAL DYNAMICS & INCLUSIVITY IN THE METAVERSE

PSYCHOSOCIAL DYNAMICS AND INCLUSIVITY IN THE METAVERSE

Situated VR

In the metaverse, the dissonance between virtual and real-world experiences often leads to "experiential artifacts," a phenomenon where VR users experience lingering sensory and cognitive effects that blur the lines between these two realities. This issue arises from the noncongruent realities that users encounter when transitioning between digital and physical spaces. Users may feel a surreal detachment from their bodies or environment, reporting feelings of disembodiment or altered perceptions of the physical world after VR sessions. These experiential artifacts are a result of the complex interplay between our sensory inputs and past interactions with the world, evolving as we are exposed to various contexts, including virtual environments. Recognizing the psychological impacts of these artifacts, which can range from mild curiosity to disorientations affecting daily life. Researchers at MIT have proposed "situated virtual reality" as a solution. This concept, currently under review for publication in IEEE, aims to align the physical and virtual worlds, minimizing experiential artifacts. Situated VR focuses on syncing physical actions with virtual feedback, such as matching natural movement or object interactions, to create a more congruent reality. The approach also extends to social interactions, ensuring that the body language and emotional expressions in virtual environments mirror those in the real world. The goal is to establish a hybrid reality that is free from experiential artifacts, prioritizing not just technological innovation but also the psychosocial well-being of users in the metaverse.

The Panopticon

The psychological effects of being constantly filmed, particularly when interacting with individuals wearing smart glasses, can be significant and multifaceted. Smart glasses, which may be always recording or perceived as such, introduce a dynamic similar to the concept of a panopticon in social interactions. The panopticon refers to a system of control where individuals are aware that they might be watched at any time, leading to self-regulation of behavior due to the perception of constant surveillance. When interacting with someone wearing smart glasses, people may act differently when they experience a heightened sense of being observed. This phenomenon is similar to the observer effect in psychology, where individuals modify their behavior in response to their awareness of being watched. In social contexts, this can lead to increased self-consciousness, anxiety, and potentially altered social dynamics.

The introduction of "trust lights" on some smart glasses, designed to indicate when recording is taking place, attempts to mitigate this effect by providing a visual cue to others about their privacy status. On the Ray-Ban Meta smart glasses for instance, the camera will not record if the LED light is covered. However, the effectiveness of these trust lights in alleviating concerns about privacy and constant surveillance is not clear-cut. While they might offer some reassurance, the underlying tension and psychological impact of potential constant recording remain.

XR Accessibility

Accessibility XR is a growing area of focus, aiming to ensure these immersive technologies are inclusive for all users, including those with disabilities. Key areas of accessibility in XR include sensory, physical, cognitive, and universal design aspects. For example, Google's ARCore improves environmental understanding, crucial for users with visual impairments. The design of XR interfaces is evolving to cater to diverse physical abilities, incorporating features like voice commands and eye tracking. Microsoft's inclusive design approach in VR and AR, featuring voice recognition and adaptable controller settings, exemplifies this advancement. Similarly, many companies now offer voiceover support in AR experiences, aiding visually impaired users with audio descriptions. Cognitive accessibility is also a priority, particularly for users with conditions like autism, necessitating simplified interfaces and controlled sensory inputs. Meta Quest demonstrates this by providing customizable controls and head tracking options for users with limited mobility.

PSYCHOSOCIAL DYNAMICS AND INCLUSIVITY IN THE METAVERSE

Many efforts in the XR accessibility space are underpinned by the principles of universal design, aiming to create XR experiences that are inclusive and enjoyable for everyone, regardless of their abilities. Leading this charge are initiatives like the XR Association's Accessibility Working Group and the XR Access Initiative, which bring together industry, academia, and advocacy groups to research, develop, and educate about accessible XR technologies, ensuring that the immersive digital world is open and welcoming to all.

Diminished Sensory Overload

People with autism spectrum disorder (ASD) often struggle to process sensory information, finding stimuli like bright lights or loud noises particularly overwhelming. This sensory sensitivity can turn routine activities into significant challenges. Augmented reality presents a promising tool to mitigate these sensory integration issues. AR's ability to create controlled and customized environments can gently introduce sensory inputs to those with ASD, allowing them to adapt at a comfortable pace. Among the innovations in this field are "Unfear" and "Floreo," which use technology to create supportive spaces for individuals with ASD. Samsung's Unfear is an app that uses real-time selective noise filtering to reduce auditory stress. It targets specific sounds that are distressing to the user, offering a more relaxing and fear-free auditory experience. Unfear also extends its functionality to digital content, like mobile games, filtering out loud sounds to make such media more accessible for those sensitive to audio intensity. Though not an AR application per se, Unfear embodies principles that could be integrated into AR platforms. Floreo, on the other hand, directly utilizes AR to replicate real-life situations in a controlled, less overwhelming manner. It's particularly beneficial for teaching social, communicative, and practical life skills in a secure environment. Floreo's simulated interactions offer a practice platform for users with autism, helping them develop skills transferable to everyday life. Both Unfear and Floreo exemplify how adjusting sensory inputs and offering flexible learning environments can be revolutionary for those with ASD.

Cybersickness

Motion sickness and nausea remain significant challenges in the mass adoption of virtual reality, both for consumer and industrial applications. One key issue is proprioception disorientation, which arises when there's a mismatch between where you perceive your limbs to be and their actual spatial position in the virtual environment. Recent research led by the University of Waterloo sheds light on why some individuals are more susceptible to VR-induced "cybersickness" than others. The study found that the perception of vertical orientation could shift after engaging in high-intensity VR experiences. This sensory adjustment significantly influences the severity of cybersickness. The findings could help VR developers create more comfortable and adaptable experiences by understanding the relationship between sensory reweighting and cybersickness susceptibility. In another study, researchers found that incorporating music into VR experiences can mitigate symptoms of cybersickness. Both joyful and calming music were shown to reduce the intensity of nausea-related symptoms, with joyful music having a particularly significant impact on reducing the overall intensity of cybersickness. These research developments offer promising avenues for reducing barriers to VR adoption, potentially leading to more personalized and enjoyable virtual experiences for users.

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“Visiting” Pregnancy

Due to her age, Lauren was unable to safely carry her pregnancy herself. Instead, her daughter was growing in an artificial womb at a specialized facility. The high-tech womb was calibrated to Lauren’s own heartbeat and voice via a monitor that she wore at all times, surrounding the growing baby with the familiar, comforting sounds of its mother. The artificial amniotic fluid was even infused with Lauren’s natural scent through a filtering process.

Today, Lauren is preparing to “visit” her pregnancy. She dons a state-of-the-art haptic suit, designed to simulate the physical sensations of pregnancy. The suit gently expands around her abdomen, mimicking the gentle pressure and movements of a growing baby. As the virtual nursery flickers into view, Lauren gasps. It was a line-for-line re-creation of the room her husband Eli was assembling at home, down to the plush rainbow rug and decaled quotes from her favorite children’s books.

As Lauren settles into the metaverse experience, the suit adjusts snugly around her midsection, gently applying pressure to simulate the swell of pregnancy. She runs her hands along the warm, taut skin, marveling at how real it feels. Lauren feels a sudden thump and lays her hand on her belly. Her daughter is kicking up a storm today.

The haptic suit is just one part of the experience. The headset she wears is pivotal, not just visually, but also in altering Lauren’s sense of smell to mirror the acute olfactory sensitivity typical in pregnancy. Scents are intensified, creating a vivid and authentic sensory experience. Furthermore, the headset induces psychological states akin to those of pregnancy, fostering a deep emotional bond between Lauren and her unborn child.

As Lauren walks through this virtual world, she speaks softly, knowing that her baby, though miles away in its artificial womb, can hear her. She sings lullabies, tells stories, and shares her hopes and dreams for their future together. Each word, each note of her song, is transmitted back to the womb, enveloping her baby in a warm embrace of mother’s love.

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World Building on Blockchain

Advocates of the metaverse and blockchain share a core principle: decentralization. In the metaverse, this manifests as an open network of interconnected virtual worlds as opposed to closed, proprietary platforms. Some advocates argue that when built on blockchain, the metaverse can offer true digital ownership through NFTs, by allowing users to own, trade, and monetize virtual assets like land and avatars. Blockchain's transparent and immutable record-keeping lends credibility to digital ownership claims, while its interoperability allows assets and user profiles to carry seamlessly across metaverse environments. Examples like The Sandbox demonstrate this in practice—users can build, own, and sell their game creations through a dynamic, collective ecosystem. Other platforms like Hyperfy and Voxels, both running on the Ethereum blockchain, provide tools for users to design, construct, and trade entire worlds they own. This fusion of blockchain and the metaverse not only democratizes virtual space but also enables a more trustworthy and interconnected digital reality.

While the idealized vision of the metaverse and blockchain both emphasize decentralization, it's worth noting that many platforms, like Meta's proposed metaverse, may operate as closed ecosystems.

Events in the Metaverse

The metaverse shows promise as the next frontier for virtual experiences by creating immersive 3D environments mirroring real-world settings. Gaming, an early adopter of shared digital spaces, has expanded its virtual horizons beyond gameplay into events and social interactions. Games like "Roblox" and "Fortnite" have been pioneers, transforming their platforms into concert venues for top-tier artists, creating a new paradigm for live performances. In 2023, Decentraland hosted its second Metaverse Fashion Week, featuring over 60 fashion brands, including heavyweights like Balenciaga, Adidas, and Coach. While this event showcased the allure and possibilities within the metaverse, it also cast light on its current developmental infancy, evidenced by the participant feedback that spoke to feelings of solitude, the complexity of navigation, and a deficiency in compelling content—revealing a stark contrast between the high ambitions of brands and the actual user experience. The concept of a metaverse festival has also been embraced by Coachella 2023, in partnership with "Fortnite." This collaboration introduced a new dimension to music festivals, combining iconic Coachella elements with the interactive and boundless nature of the "Fortnite" universe. Weverse has become a central hub for virtual K-pop events, where fans can engage with their favorite idols' avatars in a digital concert setting. This virtual space not only hosts concerts but also fosters fan interactions, proving that the metaverse can indeed re-create the vibrancy of live events in a digital format. As these digital spaces evolve, the focus must shift toward user experience to ensure the metaverse can fully realize its potential as a platform for communal and interactive events. Converting isolated solitary activities into bonded social occasions remains contingent on platform maturation.

AR Lenses and Filters

AR lenses overlay real-time digital information onto the physical world. Simple AR filters and lenses have long been a staple of social media, enabling users to add digital enhancements to their faces in real time. But these playful features are just the beginning; AR technology is becoming more sophisticated by leveraging generative AI. Snapchat's Cosmic Lens feature is a case in point, for using generative AI to transform the user's environment into an animated cosmic backdrop. Filters like TikTok's "Bold Glamour" echo this trend, offering hyperrealistic effects with the help of AI. Furthering the integration of AR into daily life, Snapchat is now streamlining the user experience by introducing intelligent recommendations for lenses based on environmental context—such as the weather or the time of day—using advanced visual recognition and API integration. Snap has also announced plans to introduce AR mirrors in retail stores, allowing customers to see how clothes would look on them in Nike stores and in Men's Wearhouse locations without the

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need to change outfits. This effort is part of a broader move to integrate AR technology into the physical world, including at music festivals and even in vending machines. Brands like Ikea are also leveraging filters to enhance the customer's shopping journey at home. Using smartphones' lidar sensors, Ikea's AR tools allow customers to replace their existing furniture with detailed 3D models of new items. Similarly, retail giants Walmart and Amazon have successfully adopted AR to enable customers to visualize products in their own space before making a purchase, whether it's placing furniture or trying on glasses.

Holograms

Holography is a technique that records and displays objects in three dimensions, making them either stand still or move just like real objects. It's more than just a 3D picture; it can show every detail of a person's face or body in motion. This capability is becoming increasingly important for the future of augmented reality and virtual reality, particularly as we look to populate the metaverse with realistic avatars and environments. The fusion of holograms with deepfake technology and synthetic media is paving the way for their use in everyday settings. Already, holography has enabled the creation of virtual concerts featuring past celebrities, and it holds the potential for production companies to bring popular synthetic characters and celebrities into our physical world as interactive entities. For instance, Ukrainian President Volodymyr Zelenskyy harnessed this technology for remote addresses across European cities using Canadian firm ARHT Media's state-of-the-art holographic technology, speaking from within his country amid conflict. The Hologram Zoo in Brisbane, Australia, presents a new way for people to experience wildlife. Here, holograms create lifelike depictions of animals, such as a herd of elephants charging toward and then seemingly through the spectators. This attraction makes holographic technology more accessible by significantly reducing costs, thus avoiding the ethical dilemmas of captive wildlife exhibits and offering an immersive educational experience.

ARHT Media has also introduced Capsule, a versatile holographic display designed to shine in any lighting condition, perfect for captivating audiences in cinema lobbies. This technology allows live hologram presenters to interact with people across distances, and it can showcase prerecorded content that engages viewers through interactive touchscreens. The potential applications are vast, ranging from advertising and immersive trailers to live talent meet-and-greets and product demonstrations. In the pursuit of more lifelike holographic projections, researchers have developed three-dimensional scattering-assisted dynamic holography (3D-SDH), which greatly enhances the depth resolution of 3D images. This cutting-edge method could revolutionize how we interact with virtual environments by offering a much richer, more detailed experience.

Real Estate in the Metaverse

Real estate in the metaverse is emerging as a new digital frontier where people can buy, develop, and experience virtual land and

Metaverse real estate offers long-term prospects for virtual land as spaces for community, commerce, and creativity, free from physical limitations.

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properties. Though still nascent, metaverse real estate is drawing interest from individual investors, corporations, and even real world real estate companies. In metaverses like The Sandbox and Decentraland, virtual land is sold as NFTs on blockchain. Parcels near popular virtual spaces or owned by celebrities can sell for hundreds of thousands of dollars or more. The overall metaverse real estate market is estimated to be worth over $1 billion. Corporations like Adidas and Atari, and celebrities like Snoop Dogg have purchased virtual land to host branded experiences, digital HQs, stores, and spaces. One buyer paid $450,000 to become Snoop's neighbor in the virtual world.

Some companies are taking it further by developing conceptual virtual homes and structures with architectural firms. Everyrealm, a metaverse technology and infrastructure company, has partnered with artists like Misha Kahn and Daniel Arsham to create an imaginative collection of digital homes called The Row. These futuristic virtual abodes feature melting, Salvador Dali-esque architectural angles and dreamlike floating spheres. Mirroring real world tactics, traditional home builders like KB Home have also established presences to showcase model homes. They aim to reach new demographics and drum up interest in real-life offerings. While speculative now, advocates see long-term potential for virtual real estate as immersive spaces for community building, commerce, and creativity. The metaverse provides freedom from physical constraints to create imaginative environments.

Worlds for Purpose

The metaverse is being harnessed for significant causes, transcending beyond a mere digital escape into a platform for meaningful global action. The World Economic Forum has taken a pioneering step by introducing the Global Collaboration Village in the metaverse, a collaborative effort with Accenture and Microsoft. This virtual space is dedicated to convening organizations to address, brainstorm, and act on global crises. It was revealed during the Annual Meeting 2023 in Davos, showcasing a tangible prototype that exemplifies the vision of a global community coming together in a digital realm. The village is structured to facilitate impactful interactions, with areas such as a Virtual Congress Centre akin to a digital town hall for hosting various future meetings and sessions. It also comprises immersive collaborative centers that serve as hubs for engaging storytelling and spreading the Forum's insights on critical issues, fostering a collaborative spirit aimed at real-world change. Partners of the Forum have the opportunity to carve out their virtual campuses, allowing them to rally their stakeholders and drive forward initiatives to solve worldwide problems. Simultaneously, The Sandbox's Wistaverse has emerged as a pioneering virtual protest platform, offering a secure space for worldwide activism and education. Its goal is to empower users to engage in nonviolent protest and discourse, removing the risks associated with physical gatherings.

Worlds for the Enterprise

Major tech companies are racing to make virtual collaboration a reality for enterprises. Microsoft is integrating Mesh directly into Teams to allow coworkers to join 3D meetings as avatars, sans VR headset. This aligns Mesh with Microsoft's everyday work tools after an initial failed launch as a standalone developer platform. Mesh now focuses on enabling Teams' 320 million users to have more engaging meetings using spatial audio, simulated environments like a virtual lake house, and AI features like virtual whiteboards. Microsoft is betting its massive user base will propel adoption despite strong startup competitors like Jugo and Frame also offering immersive meeting solutions. Jugo similarly provides 3D collaboration spaces for remote teams to brainstorm ideas on virtual whiteboards or conduct meetings as customizable avatars. Frame uses volumetric video to generate photorealistic avatars, targeting enterprises seeking hyperrealism. These companies aim to make remote collaboration more natural by simulating the nuances of in-person interactions. Though still early, some companies are

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piloting these technologies to enable hybrid teams to work together more intuitively. Microsoft's integration into Teams gives it a distribution advantage, but the space remains competitive as startups offer differentiated features around customization and realism.

Play-to-Earn and Virtual Marketplaces

Play-to-earn games fuse gaming and economics in metaverse environments by enabling players to generate real-world value through virtual gameplay. Leveraging blockchain technology, these games establish in-game assets like fantasy creatures or virtual land as tradable NFT commodities. This diverges from traditional in-game items, where items lack external utility or ownership portability after usage. Instead, metaverse games facilitate exchange of digital goods for cryptocurrency or fiat money. "Axie Infinity" is a pioneer in this space, where players breed, raise, and battle fantasy creatures called Axies, with in-game transactions involving Ethereum-based cryptocurrencies. "My Neighbor Alice'" also offers a blockchain twist to casual farming simulators, where players can buy virtual land and earn rewards through daily activities and can use their NFTs to decorate their virtual space. The well-known game "Minecraft" is also considered a virtual economy, allowing players to trade items, and this concept of in-game value is amplified in the metaverse.

Marketplaces like OpenSea act as trading hubs for these virtual goods, allowing the digital assets from various metaverse games to be bought and sold, underpinning the economic potential of play-to-earn games. Exponential growth potential looms as financial institutions like JPMorgan strategically support metaverse transaction platforms like Tilia. Seamless fiat currency interchangeability can further expand adoption and capital inflow. Just as physical economies rely on agreeing on currency, unit of account, and other standards, maturing these fundamentals will shape the trajectory of blockchain-based virtual marketplaces. The fusion of play and profitability through ownership of digital goods represents merely the first stage.

Players can earn real-world value in virtual environments through gameplay, with blockchain allowing for the acquisition and trading of digital assets such as NFTs.

SCENARIOS

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Cosplay Category Announcement

Welcome to the 2027 Super Cosplay Con—the world's premier cosplay convention where physical reality converges with the virtual multiverse. This year's Super Cosplay Con is enabled by augmented reality glasses that project 3D avatars and effects, blurring the lines between the real and virtual worlds. The costume contest categories reflect the multifaceted experiences of Super Cosplay Con attendees.

The Digital Division honors stunning costumes crafted entirely from interoperable assets across different metaverses. Contestants proudly display their creativity in mixing and matching skins, accessories, and effects from platforms like Cryptoverse, Mara, and VRealms.

The Physical Division shines the spotlight on traditional handcrafted costumes made with real-world materials. Cosplayers spent months bringing elaborate costumes to life with fabric, foam, paint, and painstaking detail. Their devotion to practical craftsmanship is on full display.

The Mixed Reality Division highlights the best blended costumes—real-world apparel taken to the next level through digital avatars and AR enhancements viewable through attendees' smart glasses. A knight's armor appears charred from virtual dragon fire, while a wizard's cloak billows from fabricated wind.

Hope to see you at Super Cosplay Con!

METAVERSE INFRASTRUCTURE

METAVERSE INFRASTRUCTURE

Interoperability

Interoperability is fundamental for the envisioned metaverse: Akin to the universal standards of today's internet, it would allow seamless data exchange and interaction across various systems and technologies. This functionality is essential to enable asset transfer and identity management across diverse digital and physical spaces, and its importance is highlighted in the World Economic Forum's 2023 briefing paper, "Interoperability in the Metaverse." As companies advance in integrating within their platform silos, the challenge shifts to connecting these silos to meet the growing demands for cross-platform 3D assets. Facilitating this effort, the Metaverse Standards Forum, formally incorporated in April 2023, brings together a consortium of organizations to foster interoperability, not by creating standards themselves but by producing technical reports, best practices, and guidelines. This collaboration is crucial for developing the necessary standards to build a cohesive and functional metaverse. Businesses have made significant progress in integrating various elements within their individual platform silos. However, the forthcoming challenge lies in interlinking these silos themselves. This necessity will grow more pronounced as enterprise applications converge and as the demand for cross-platform 3D assets increases.

Government Investment

Government investment in the metaverse is emerging as a key strategy for fostering economic growth and innovation, with several nations recognizing the potential of this digital space. By supporting metaverse infrastructure, governments aim to create new jobs, attract businesses, and enhance the lives of their citizens. Dubai's Metaverse Strategy is a prime example, where the city plans to become a global hub for the blockchain and metaverse sectors by 2030. This strategy aims to support over 40,000 virtual jobs and increase the number of blockchain companies fivefold, as part of the UAE's broader vision to create one of the smartest cities worldwide. Similarly, China is focusing on the metaverse as part of its technology strategy. The Ministry of Industry and Information Technology (MIIT) is looking to set standards for the metaverse industry, which they see as crucial for promoting a healthy and orderly market development. China's stance is to address the challenges in the metaverse sector—such as the lack of clear definitions that can lead to market speculation—by providing standardization and guidance. South Korea has also made significant strides by investing 24 billion Korean won ($18.1 million) in a fund dedicated to metaverse initiatives, recognizing the difficulties local companies face in securing private investments due to the risks associated with emerging technologies. The government's support extends to helping with mergers and acquisitions and ensuring domestic firms can compete on a global scale. In a tangible demonstration of their commitment, Seoul launched a digital twin in the metaverse with a substantial government investment, underscoring the importance of the metaverse in urban and social development.

Developer Tools and Application Building Blocks

The creation of the metaverse is driven by a diverse array of developer tools, many of which are open source to align with the metaverse's principles of inclusivity and community-driven development. This democratic approach to building virtual spaces is crucial, as it allows for a metaverse that is crafted by its users, rather than solely by large corporations. This method of construction by a passionate user base contributes to the metaverse's unique and innovative nature. A prime example is the "Roblox" platform where a majority of creators are under 18 years old. These young developers use Roblox Studio to craft their own games, employing Luau—a version of the programming language Lua. The platform facilitates creativity and entrepreneurship, allowing these young creators to earn through game passes and microtransactions, a testament to the economic potential within the metaverse. Tools like the Ethereal Engine (XREngine) support this creative explosion, offering open-source capabilities for crafting immersive and interactive 3D experiences.

METAVERSE INFRASTRUCTURE

Platforms like Webaverse extend the creative frontier further into decentralization, allowing developers to build and interact with dApps within the metaverse. What's unique about the metaverse developer tools is how they empower builders, many of whom are young and passionate users, to take ownership of their creations. This participatory culture is fueling the metaverse's growth into a rich, vibrant digital ecosystem where innovation is constant and opportunities are vast.

Interdevice Synchronization

Interdevice synchronization is a vital component in constructing the infrastructure of the metaverse, as it guarantees a unified and real-time interaction across various devices in AR and VR settings. This has been a significant hurdle to overcome. In environments like online gaming and virtual workspaces, where multiple users engage in a shared virtual space, synchronization is key to ensuring a smooth and coherent experience for all participants. It is also crucial for accurately replicating user movements within the virtual realm, thereby enhancing the sense of immersion and averting problems such as motion sickness. To address this challenge, researchers from MIT and Microsoft developed the Ekho system, which synchronizes audio streams across different devices. The system works by embedding subtle white noise sequences into the audio stream sent from the cloud server, which are then picked up by the audio sensors in the player's controller or other devices. Ekho's core mechanism involves continuously monitoring the time lag between the sent and received audio streams through these white noise markers. When a delay is detected, Ekho promptly adjusts the timing, aligning the streams to achieve near-perfect synchronization. This advancement by MIT and Microsoft researchers marks a significant leap forward in enhancing the overall quality and realism of virtual experiences in the burgeoning field of the metaverse.

5G for the Metaverse

The advancement of 5G technology is required for the metaverse to reach its full potential, as metaverse applications demand high bandwidth and reliable networks to process and transmit extensive visual data for immersive experiences. The rollout of 5G by major US carriers like AT&T, Verizon, T-Mobile, and Dish Network is a game-changer, offering up to 10 times the bandwidth of 4G, with speeds up to 10 gigabits per second, lower latency, and greater reliability. These features are key to avoiding disruptions in the metaverse, ensuring a seamless alternate reality experience. China, as an early adopter and implementer of 5G, exemplifies the impact of this technology on the development of virtual and augmented reality applications. With a large user base in VR and AR, China is quickly becoming a leading market in this field. The symbiotic relationship between 5G and the metaverse is evident here; the metaverse benefits from 5G's widespread access, reliable connectivity, and the ability for XR devices to offload processing to the edge of the network. This mutual enhancement, evidenced in China's rapid growth in VR, is paving the way for more comprehensive and globally accessible metaverse experiences.

For a seamless metaverse with low latency, it depends on network connectivity, making 5G a crucial enabling technology.

AUTHORS & CONTRIBUTORS

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SAM JORDAN

Manager

Sam Jordan is a Manager at Future Today Institute. She leads our Advanced Computing practice area, which includes technology, artificial intelligence, virtual realities, networking, telecommunications, and space. She is a distinguished practice area lead, where she enables organizations to navigate through uncertainty with innovative strategies. With a proven track record across various sectors, Sam's visionary leadership has driven growth and resilience for Future Today Institute's global clients and partners.

Before joining FTI, Sam was the CEO and co-founder of TrovBase, a secure data discovery and analysis-sharing platform. Sam grew the company from idea to launch and executed the company's transition from scientific replication to its current focus. In parallel, Sam engaged with the open science community, advocating for better data management practices to address challenges in scientific replication. Previously, she worked for IBM, where she helped large enterprises in the retail and distribution sector modernize their IT stack. Her expertise centered around mainframes, assisting with the integration of new software and modern methodologies to legacy systems.

Sam is a coach in the strategic foresight MBA course at the NYU Stern School of Business. She holds a BS in Economics and Data Analysis from George Mason University and an MBA from New York University's Stern School of Business.

Chief Executive Officer
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Managing Director
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Creative Director
EMILY CAUFIELD

Editor
ERICA PETERSON

Copy Editor
SARAH JOHNSON

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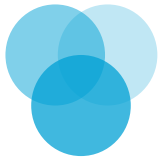

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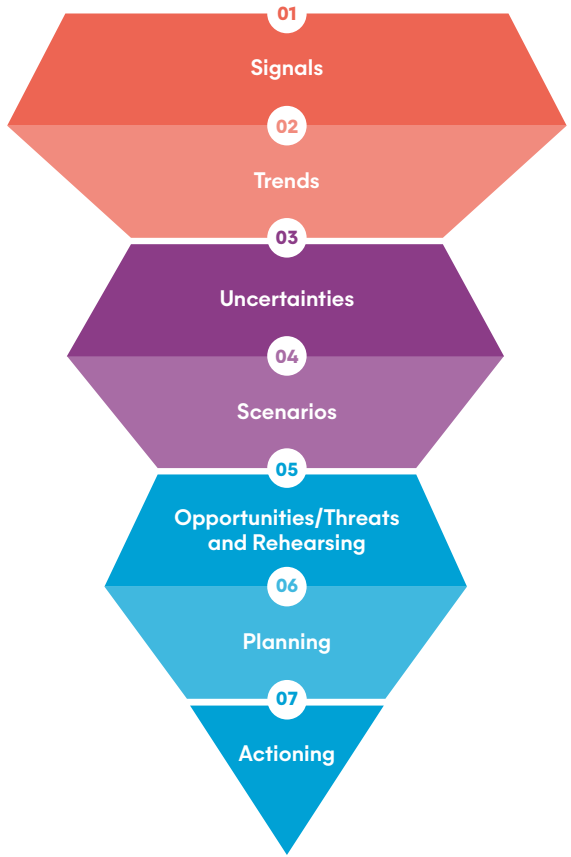

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