#TechVision

Technology Vision 2022

Meet Me in the Metaverse

The continuum of technology and experience, reshaping business

Voices of **Change**

From insights to action, the path to extraordinary value starts here.

accenture

Foreword

Businesses are racing toward a future very different from the one they were designed to operate in.

Are you ready for the metaverse? This question is at the heart of our 2022 Technology Vision. Like many emerging technologies, experts differ in how to define it, and there is a great deal of hype being generated. Most of the focus is on the consumer applications of the metaverse, and many dismiss it as a consideration for the future. We have a different view. The metaverse is actionable today, and leaders must be ready. In this year's Technology Vision, we present a distinctive and broader perspective that goes well beyond the current prevailing wisdom: the Metaverse Continuum.

We see the metaverse as a continuum that spans the spectrum of digitally enhanced worlds, realities and business models. It applies across all aspects of business, from consumer to worker and across the entire enterprise; from reality to virtual and back; from 2D to 3D; and from cloud and artificial intelligence to extended reality,

blockchain, digital twins, edge technologies and beyond. As the next evolution of the internet, the metaverse will be a continuum of rapidly emerging capabilities, use cases, technologies and experiences. And as we evolve the Metaverse Continuum, we must seize the opportunity to ensure that it is developed with responsibility at the core. From ownership of data, to inclusion and diversity, to sustainability and through to security and personal safety, this work must begin now.

We are on the threshold of a new decade of digital transformation, and at a defining moment for all leaders. The Metaverse Continuum will transform how businesses interact with customers, how work is done, what products and services companies offer, how they make and distribute them, and fundamentally how they operate their organizations. Leaders need to step back and fundamentally

reimagine how you will approach your business for the next decade – which worlds you will define and design, starting now. While we are at the early days of the metaverse, it will advance very quickly. If companies don't act now, they'll find themselves operating in worlds designed by, and for, someone else.

We look forward to exploring the Metaverse Continuum and our four trends with you as we build the future together, today.

Julie Sweet
Chief Executive Officer

Paul Daugherty
Group Chief Executive - Technology & Chief Technology Officer

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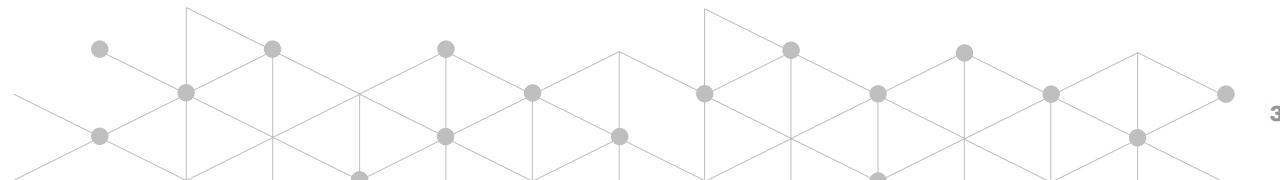
On an ordinary day in 2030, a construction foreman is operating a road roller at a worksite in California.

He and his coworker talk as they direct a construction robot to lay down asphalt on a section of Highway 1. Suddenly, his assistant appears as a hologram on the edge of the site, waving him over to confirm the work summary of the day and to remind him that it's time to meet with the city inspector for another project. He walks over to the construction site's mobile office, puts on his VR headset, and finds himself in the lobby of the virtual City Planning Department.

His AI assistant reappears to direct him towards the virtual conference room where his meeting will be held. Upon his entry, the room transforms to look like the inspection site (an overpass they recently completed) using a real-time feed from a drone onsite. Architectural drawings from the State of California Contractor Cloud are laid over the live footage, and the foreman and inspector begin to assess the work. Upon approval by the inspector, he sends his assistant to submit the applications for the next round of construction permits. Then he pops off his headset, and heads back out to the worksite.

Welcome to the "**Metaverse Continuum**" – a spectrum of digitally enhanced worlds, realities, and business models poised to revolutionize life and enterprise in the next decade.

This continuum is bringing the next major wave of digital change to enterprises, and leaders need to start making big leaps forward in how they think about their business – today. Soon, they will be at the intersection of many new worlds, from building new physical and virtual realities to providing services in environments created by others. Like in the scenario above, people will actively live in and jump between these worlds on a daily basis. Our foreman starts his day physically building a road in a digitally and robotically enhanced construction site, and ends it in an office in the metaverse, a virtual environment created by the City Planning Department, which lets him travel between geographies in seconds for government inspections. And this is just the beginning.
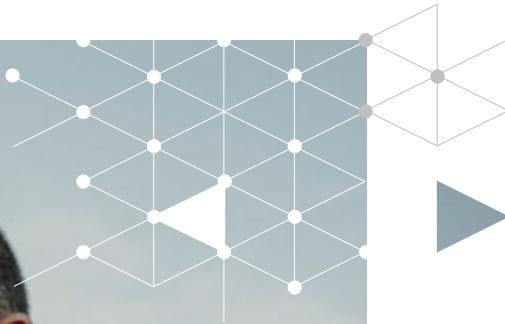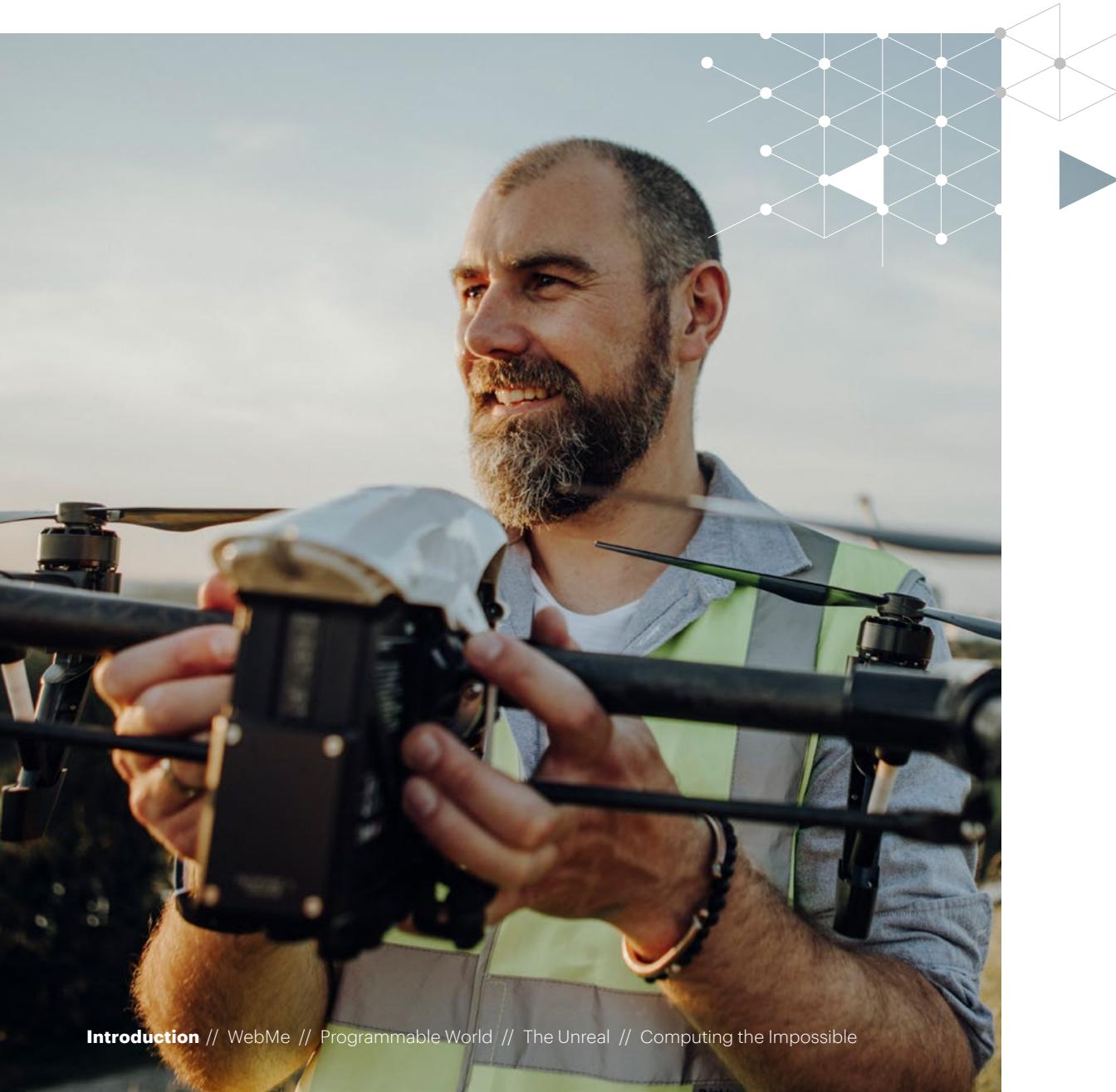
> Soon, they will be at the intersection of many new worlds, from building new physical and virtual realities to providing services in environments created by others.

The physical world is coming alive environment by environment, each with its own capabilities and rules. Today we already have small-scale intelligent physical worlds like smart factories, intelligent cruise ships, and automated ports – tomorrow we will see these grow into entire smart neighborhoods, cities, and countries, where massive digital twins mirror physical reality. And the digital world is expanding too. Soon, new consumer spaces in the metaverse will transport us to almost any type of world we can imagine, letting us relax, entertain ourselves, or socialize over long distance. And major companies will shift part of their operations

to the metaverse as well, maintaining their own internal virtual environments so employees can work from anywhere and collaborate in exciting new ways. With opportunity proliferating across all these new worlds, to best serve customers and partners alike enterprises will need a strategy to operate across the full spectrum.

This way of life seems futuristic for now, but it's already on its way here.[1]

Seeing signals of profound change, the Accenture Technology Vision found it apt to set its sights farther forward than ever before. The building blocks of the Metaverse Continuum are taking shape today, but will coalesce over the next decade to create an entirely new enterprise landscape. The 20s will see ambitious enterprises bringing shape to these new physical and digital realities, as well as worlds co-populated by people and AI, industries made possible by new computers, and more.

The building blocks of the Metaverse Continuum are taking shape today, but will coalesce over the next decade to create an entirely new enterprise landscape.
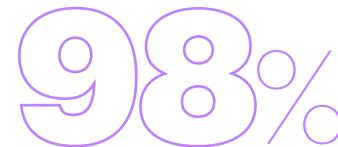
Why Metaverse Continuum?

You've probably heard the word "metaverse" over the last year, evoking a science fiction future of a persistent and shared virtual reality space. The truth is, right now a lot of early metaverses are being built with many different initial focuses and ideas for how to get it right. Some are for enterprises, some for consumers. Each has different platforms, partners, and technologies at its core.

Eventually this spectrum of ideas will coalesce into a more broadly unified experience, but the range of business areas that it will impact will only grow. Just as the internet evolved beyond simple websites to underpin the majority of today's businesses, it would be wrong to think the experience of the metaverse will be constrained to digital space.

That is why we've introduced the "Metaverse Continuum." Accenture looks at the metaverse as an evolving and expanding continuum on multiple dimensions:

- Comprises multiple technologies including extended reality, blockchain, artificial intelligence, digital twins, and smart objects – including cars and factories, and edge computing.

- Encompasses the "virt-real" – the range of experiences, from purely virtual to a blend of virtual and physical.

- Describes the spectrum of emerging consumer experiences and the business applications and models across the enterprise that will be reimagined and transformed.

98%

of executives believe continuous advances in technology are becoming more reliable than economic, political, or social trends in informing their organization's long-term strategy.

For some, it's already starting. A Chinese news agency, Xinhua, has unveiled a virtual newsroom with an AI news anchor who can deliver breaking news to audiences 24 hours a day.[2]

Amazon Sidewalk was activated, instantly creating smart neighborhoods, and extending the reach of existing smart devices far beyond their original range.[3] And Vail Ski Resort in Colorado has built a digital twin of its resort, an intelligent virtual world mirroring their physical mountain, including details like real-time snowfall, years of weather data, and critical mountain infrastructure. They're also automating the physical mountain, investing in remote monitoring and automatic snow guns which can activate based on the weather. With this tech-focused strategy that crosses the digital and physical worlds, Vail is able to increase the predictability of ski conditions and expects these efforts to eventually let them extend their typical season by 25%.[4]

As developments like these challenge our basic assumptions about technology and business, we are entering a new landscape where there are not yet rules or expectations – creating a rich opportunity to build and shape the worlds of tomorrow.

Consider this: Enterprises that deploy human-like AI aren't just reaping the benefits of automation, they are pioneering new forms of collaboration between humans and machines. Smart materials and edge capabilities are transforming what people expect from their physical environments. Enterprises selling goods in a metaverse environment are delivering fundamentally different products, and what's more, they are piloting new modes of commerce and creating best practices for the future of the internet. All the companies building – and building in – these new worlds are bringing ideas and precedents to them, shaping how people will soon live, where businesses will find opportunity, and what it will mean to be a responsible business in these environments.

For now, it may seem that the future we're rocketing toward holds more questions than answers. How will companies conduct business and sell products, and how will consumers buy them in these new worlds? How will human interaction unfold in the metaverse, and how

will that reshape what we look for outside of it? What does the world of work look like when organizations become more distributed or autonomous? How do we manage a supply chain that cuts through different physical worlds where some cities are smart and some are not? In many ways, the new worlds companies are starting to build have no history or legacy – no right way to do anything. This means immense opportunity, but also that companies pushing these boundaries will be operating far ahead of policy and regulation.

Enterprises will find themselves on the front lines of establishing trust and safety and defining the human experience in these new places. Trust will be paramount to adoption of the new experiences leaders are beginning to build. Considerations (and concerns) already held today around privacy, bias, fairness, and human impact are becoming far more acute as the line between people's physical and digital lives further blurs. Enterprises that wish to lead in this space will shoulder the mantle of building

a "Responsible Metaverse," and the actions and choices they make today will set the standards for all that follow.

It leaves companies at a critical moment to decide their path forward. These new frontiers of technology will redefine the entire context of every business, shaping how they will operate and create value for decades to come. Those who shy away from the uncertainty ahead will soon find themselves operating in worlds others have defined – playing by someone else's rules. But bold companies will embrace the uncertainty and wield it as opportunity.

The simple truth is, there's never enough time to think about the future, but that won't stop it from happening. As the foundations of the Metaverse Continuum are constructed, early entrants are staking out key positions and partnerships while investing in the technology backbone that will secure leadership in this new landscape. Inevitably, every executive will need to ask: What will my role be in this new continuum?

Answering this – and acting on it – won't be easy; it's a journey riddled with uncertainty well outside the norms of what most companies are comfortable with. But the chance to shape the next decade of business, to build new worlds, and to explore the brand-new markets that these worlds create doesn't come often.

Your future is starting today, are you ready for it?

Architecting Tomorrow's Continuum, Today

In 2021, Gucci created The Gucci Garden Experience to sell virtual products and sold a virtual-only digital twin of a Gucci purse for a higher price than its real-world counterpart.[5,6]

A Travis Scott Fortnite concert had 27.7 million unique attendees – far more than a typical concert venue can accommodate.[7] And in the last 12 months Decentraland – a user-owned Ethereum-based virtual world – saw 21,000 real estate transactions worth $110 million.[8]

These are early signals of the Metaverse Continuum, and a clear sign that enterprises need to think about tomorrow's business differently; it's imperative they heed the call of change and start taking action today. Recall that 20 years ago many enterprises were wondering *if* they needed a presence on the web – a question that seems quaint now that every public company has augmented its sales, operations, or products with digital technology in some form. With the future on the horizon, we are hearing echoes of that question again: Is remote work here to stay? Do physical environments really need to be smart? Do I need to care about the metaverse?

Is remote work here to stay?
Do physical environments really
need to be smart? Do I need to
care about the metaverse?

The answer to these questions and others is a resounding "yes."

Just like in the early years of the web, businesses are racing toward a future utterly different from the one they were designed for. Over the next decade we will witness a complete transformation of nearly every environment that enterprises currently do business across. The way the internet operates and how we experience the digital world; the technology that propagates across the physical world and the command it gives us over our environment; how human-like, collaborative, and productive our interactions with machines can be; and even the very outer limit of computers' capabilities, are all being upended.

The ground is transforming beneath us and many of the competitive moats and advantages businesses have worked hard to erect are beginning to recede. This doesn't mean your current business is going away – just as an online web presence didn't remove the need for physical locations. But like enterprises back then needed to create new revenue streams, rethink how they augment their operations, and contend with a host of new and disruptive competitors, businesses today will also need to reimagine every dimension of their enterprise from operating models to their core value proposition. And forward-thinking leaders are already getting started.
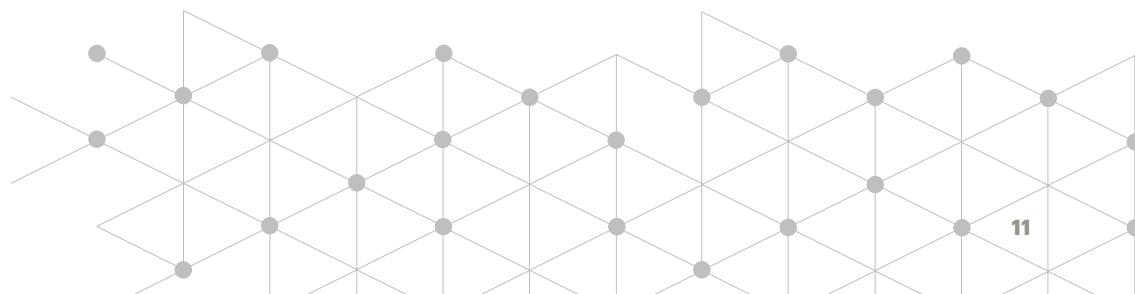
Consider how in late 2021, Square founder Jack Dorsey renamed the company to "Block," signaling its focus on the future.[9] Shortly after, the company announced plans to build an open bitcoin mining system, aiming to make bitcoin mining more distributed and efficient, and to address challenges commonly faced by the bitcoin mining community like mining rig availability, high prices, and power consumption.[10] While the company is one of the largest digital payments solutions on the market today, it's clear they believe the future of payments may soon start to change – or at least get bigger.

Or think about Tesla. First the company succeeded in proving the viability of selling electric vehicles in today's automotive market. But now their technology investments and projects are all steps to build pieces of a future that no one is selling against yet: a world of smart cities filled with electric and autonomous vehicles. Their vision of the future drives and informs the machines they build and sell today, and the resulting successes in today's market are beta tests for their leadership in tomorrow's world of autonomous vehicles.
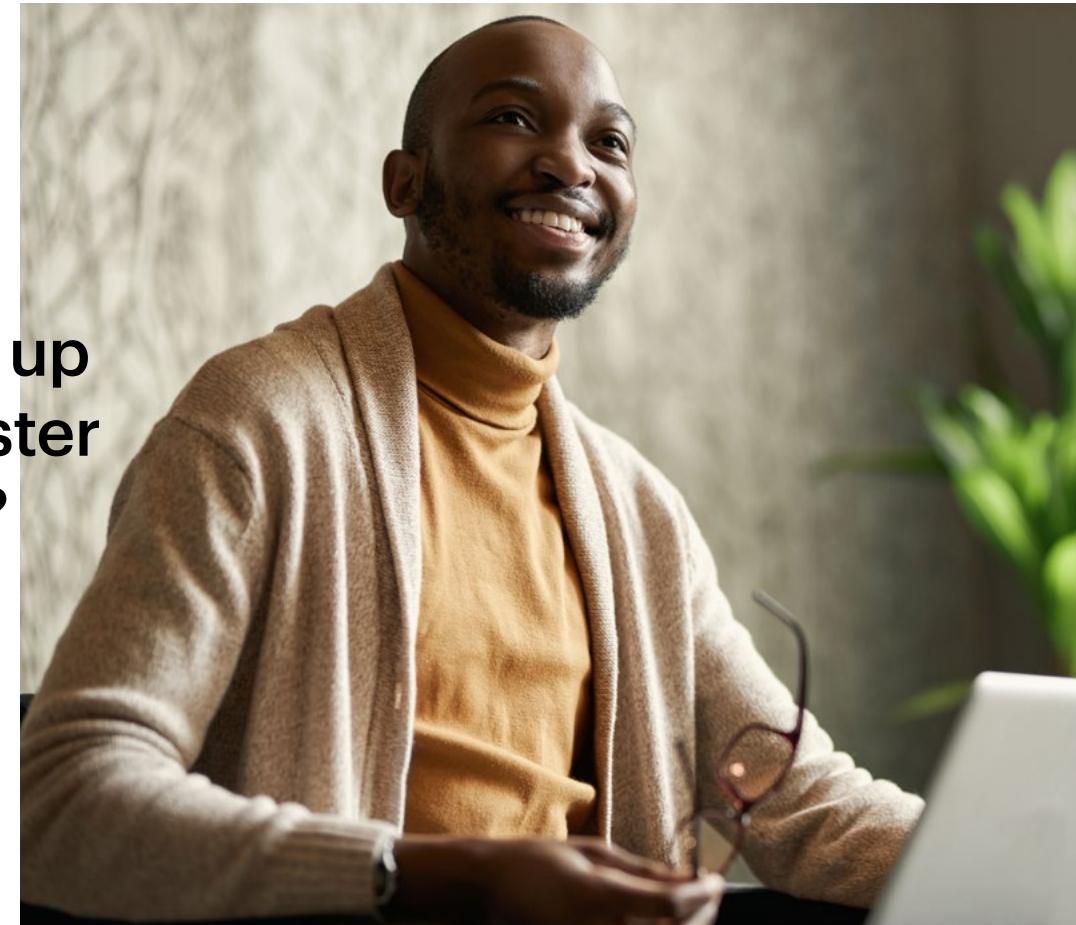
Similar to the beginning of the digital era, the companies that accelerate through the next wave of technology disruption will be those who readily embrace the changes the future holds. The good news? This time enterprises have greater warning of what's to come and there's still time to get ahead – but they need to start making decisive technology investments today. The goal is to ignite the digital foundation enterprises have been steadily putting in place: finally picking partners to build a digital twin, going beyond data and analytics to use AI in more visible and collaborative ways, or launching the "moonshot" project that increasingly feels mission critical. Only with a mature and well-oiled digital engine will enterprises be prepared to participate in, or even build, the new business environments and worlds everyone will soon need to be part of.

This past year Honeywell launched the largest quantum computing company in the world – a new venture with Cambridge Quantum called Quantinuum.[11] This journey started years ago when Honeywell's leaders looked at the technology and hardware capabilities they had, eyed the far-off field of quantum computing, and had the brazenness to say *we can build that world*.[12] Now the incubation effort is being spun out into an independent enterprise that Honeywell maintains a controlling interest in. The hope is the endeavor will become the launchpad for future generations of industry from financial services to material sciences – a new world where intractable problems become solvable through the capabilities of quantum computing.[13] Honeywell still maintains and operates their core business today, but they are also an investor, customer, and supplier of Quantinuum – effectively planting the seeds of their future.

Companies today have the chance to become enterprise and technology leaders for decades to come. But like Block, Tesla, and Honeywell, they will need to shift from augmenting their business with technology to being technology-driven and future-forward by design. What you choose to do next is critical:

# Will you set yourself up as the next Blockbuster or the next Amazon?
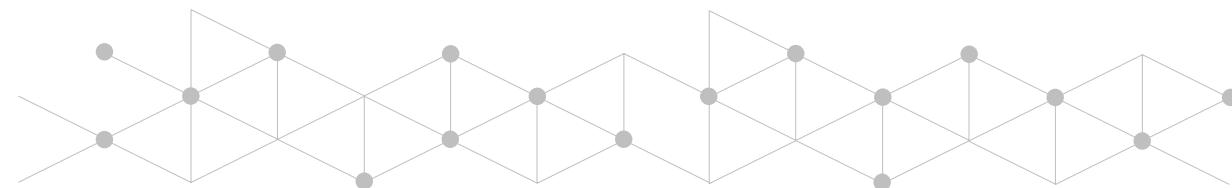
Four Building Blocks of the Metaverse Continuum

Without realizing it, some businesses have already started adopting future-forward mindsets, and in the process created the building blocks that will become the Metaverse Continuum.

A new generation of technology leaders was forged in the COVID-19 crisis. Over the last 12 months Accenture identified a special class of companies – called leapfroggers – that began rapidly implementing digital strategies to navigate the pandemic. They, along with existing digital leaders, found that the advantage provided by their technology investments led to outperforming competition by 4–5x over the last year.[14]

Far from being slowed down, when faced with new challenges and constraints many companies had a taste of what it's like to architect new revenue streams and new ways of working and living – and from their efforts, the foundation of tomorrow's market is starting to be built.

Look at Christie's Auction House, which was used to having large in-person art auctions as their primary source of revenue. In the pandemic this became an impossibility. The logical alternative was to host digital-based auctions instead, and Christie's did make this part of their new model, but they also took a risk on something new: NFTs.[15] Non-fungible tokens were a burgeoning art form, one atypical for Christie's as the NFT pieces were not physical and existed exclusively on blockchains. In 2021, Christie's hosted its first NFT auction – a piece by the artist Beeple titled *Everydays: The First 5000 Days*.[16] In that auction they accomplished two firsts: They sold the most expensive piece of digital art in history (the work went for $69.3 million) and became the first auction house to accept cryptocurrency as payment. By simultaneously validating a new form of art and digital currency to its customers, it became a leader in shaping how commerce

will be done in purely digital worlds – a future they've since doubled down on. Just one year after their first auction, Christie's has now surpassed $100 million in NFT sales.[17]

Disney also adapted to the pandemic with a bold shift to something new. The company started releasing highly anticipated films on Disney+ and in theaters at the same time, letting subscribers pay a Premier Access fee to stream the movie from their homes.[18] Disney's annual report details that Premier Access content significantly increased revenue from the company's DTC (direct-to-consumer) division, and in 2022 the company plans to increase spending on produced and licensed content by 32%, largely to support DTC expansion. And the company launched the "Mickey and Friends NFT Collection" in January, allowing fans a new way to engage with the brand.[19]

Rather than reverting to pre-pandemic ways as soon as possible, Disney is continuing to experiment with, and prepare for, worlds where they will be expected to provide omnichannel entertainment options that span physical theaters, streaming platforms, or even metaverses and beyond.

While

14%

of executives report the pandemic is continuing to disrupt their organization's business plans and operations, another

86%

report that their organization has adapted to the disruption of the pandemic and has found a new normal.

What companies are starting to realize is that in their drive to survive during the pandemic they have accelerated the future. The pivots and inventions they made are becoming the foundations for the new worlds that are starting to take shape. Though the challenges of the pandemic still weigh heavily on businesses today, we are starting to adapt to our new reality, and leaders are taking a more deliberate approach to shaping what comes next.

These companies and those that join them as leaders will evolve and shape the emerging Metaverse Continuum in ways that, for now, we can only speculate about. Each has its own idea for what the optimal future looks like, but it would be a mistake to believe these efforts are mutually exclusive. In some cases, companies' ambitions will irreconcilably conflict, but in others they will amplify one another.

In this Vision, we explore how today's technology innovations are becoming the building blocks of our collective future. The trends investigate the entire continuum, from the virtual to the physical,

across humans and machines alike, identifying where ambitious enterprises can find rich opportunity by uprooting themselves from today and planting themselves firmly in the future.

First in **WebMe** we explore how the internet is being reimagined. The last two years spurred enterprises to explore new modes of digital experience and pushed people to live virtually to an extent they never expected. Now the metaverse is emerging as a natural evolution that reconciles how the internet is designed today with what we will demand from it going forward. The advent of the metaverse, and underlying efforts to reimagine how data shapes our digital experiences, will challenge businesses to rethink their presence online and become a part of shaping the next platform revolution as they build new ways to connect to customers, partners, and their digital workforce.

But the value of new virtual worlds would be capped if not for parallel changes that anchor them in the physical one. The **Programmable World** tracks how technology is being

threaded through our physical environments in increasingly sophisticated ways. It projects how the convergence of 5G, ambient computing, augmented reality, smart materials, and more are paving the way for businesses to reshape how they interact with the physical world. As technology becomes part of the fabric of our environment, it allows us to treat our environment more like technology – unlocking an unprecedented fidelity of control, automation, and personalization.

When it comes to populating new worlds, humans are the primary residents. But we are also tracking the emergence of **The Unreal** – a trend where our environments and businesses are increasingly filled with machines that are passably human. "Unreal" qualities are becoming intrinsic to the artificial intelligence, and even the data, that enterprises aspire to integrate into mission-critical functions. At the same time, people are coming face-to-face with bad actors using this technology – from deepfakes to bots and more – igniting a growing concern that may turn into the biggest hurdle for enterprises

looking to grow their use of AI. Like it or not, enterprises have been thrust into the forefront of a world questioning what's real, what isn't, and if the line between those two really matters.

Finally, we are on the precipice of resetting the boundaries of traditional industries as we begin **Computing the Impossible**. The outer limit of what is computationally possible is being disrupted as a new class of machines emerges. Quantum, biologically-inspired, and high performance computers are each allowing companies to tackle grand challenges that once defined and shaped the very core of their industries. As problems once considered impossible become ever more solvable, business leaders will be pushed to reimagine some of the most basic assumptions about their enterprise.

We stand at a unique precipice in time. Not because there are new technologies to master, but rather that competing in this next decade will require something more than just increasing technology and innovation skills. It will require a truly competitive vision – both for what these future worlds will look like and also what your enterprise will need to become to succeed in them. Technology points us in the right direction, but the rest is up to you.

Technology points us in the right direction, but the rest is up to you.

Our Four Technology Trends for 2022

WebMe

Putting the Me in Metaverse

The internet is being reimagined as metaverse and Web3 efforts transform the underpinning and operation of the virtual world.

Programmable World

Our Planet, Personalized

Control, customization, and automation are being enmeshed into the world around us, making the physical as programmable as the digital.

The Unreal

Making Synthetic, Authentic

As AI-generated data and synthetic content convincingly mimic what is "real," authenticity is the new north star.

Computing the Impossible

New Machines, New Possibilities
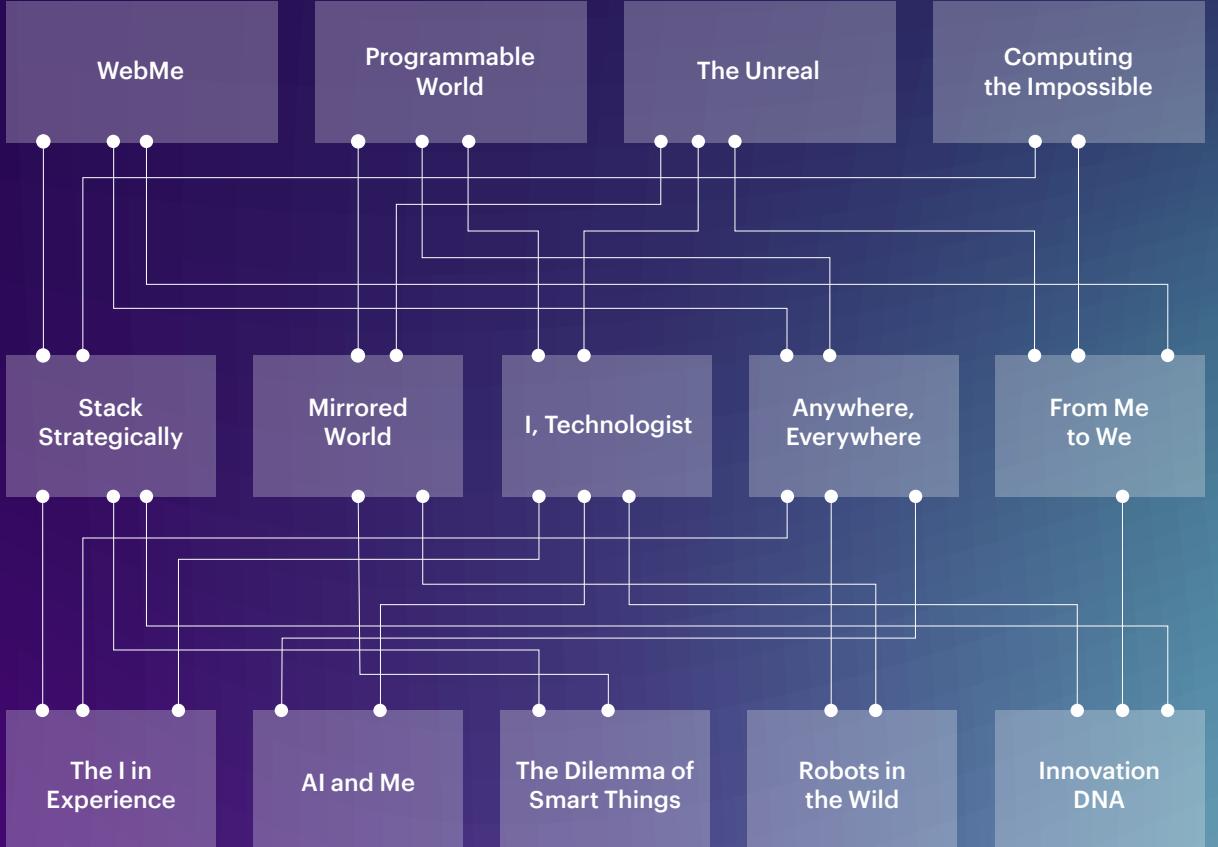
A new generation of computers are solving some of the world's most intractable problems, leading to one of the biggest technological disruptions of our time.

Completing the Picture

Accenture's Technology Vision report comprises a three-year set of technology trends, currently including trends from 2020 and 2021.

It's important to recognize that each year's trends are part of a bigger picture. Tracking how they evolve over time offers a glimpse into how they may continue to grow in the future.

2022 Trends

| WebMe | Programmable World | The Unreal | Computing the Impossible |

2021 Trends

| Stack Strategically | Mirrored World | I, Technologist | Anywhere, Everywhere | From Me to We |

2020 Trends

| The I in Experience | AI and Me | The Dilemma of Smart Things | Robots in the Wild | Innovation DNA |

2021 Trends

Stack Strategically

Architecting a Better Future

A new era of industry competition is dawning – one where companies compete on their architecture.

Mirrored World

The Power of Massive, Intelligent, Digital Twins

Growing investments in data, AI, and digital twin technologies are giving rise to a new generation of business and intelligence: the mirrored world.

I, Technologist

The Democratization of Technology

Natural language processing, low-code platforms, robotic process automation, and more are democratizing technology, putting powerful capabilities into the hands of people all across the business.

Anywhere, Everywhere

Bring Your Own Environment

It's time for enterprises to transform remote work from an accommodation, to an advantage.

From Me to We

A Multiparty System's Path Through Chaos

The global disruption of COVID-19 ignited a scramble for enterprises to reimagine their partnerships – and multiparty systems gained newfound attention.

2020 Trends

The I in Experience

Helping people choose their own adventure

Redesign digital experiences with new models that amplify personal agency. Turn passive audiences into active participants by transforming one-way experiences into true collaborations.

AI and Me

Reimagine the business through human and AI collaboration

Take a new approach that uses artificial intelligence to bring out the full power of people. Move beyond deploying AI for automation alone and push into the new frontier of co-creation between people and machines.

The Dilemma of Smart Things

Overcome the "beta burden"

Address the new reality of product ownership in the era of "forever beta." Transform pain points into an opportunity to create an unprecedented level of business–customer partnership.

Robots in the Wild

Growing the enterprise's reach - and responsibility

Build new models of interaction and impact as robotics move beyond the walls of the enterprise. Companies in every industry will unlock new opportunities by introducing robots to the next frontier: the open world.

Innovation DNA

### Create an engine for continuous innovation

Tap into the unprecedented scale of disruptive technology available today. Build the capabilities and ecosystem partnerships necessary to assemble the organization's unique innovation DNA.
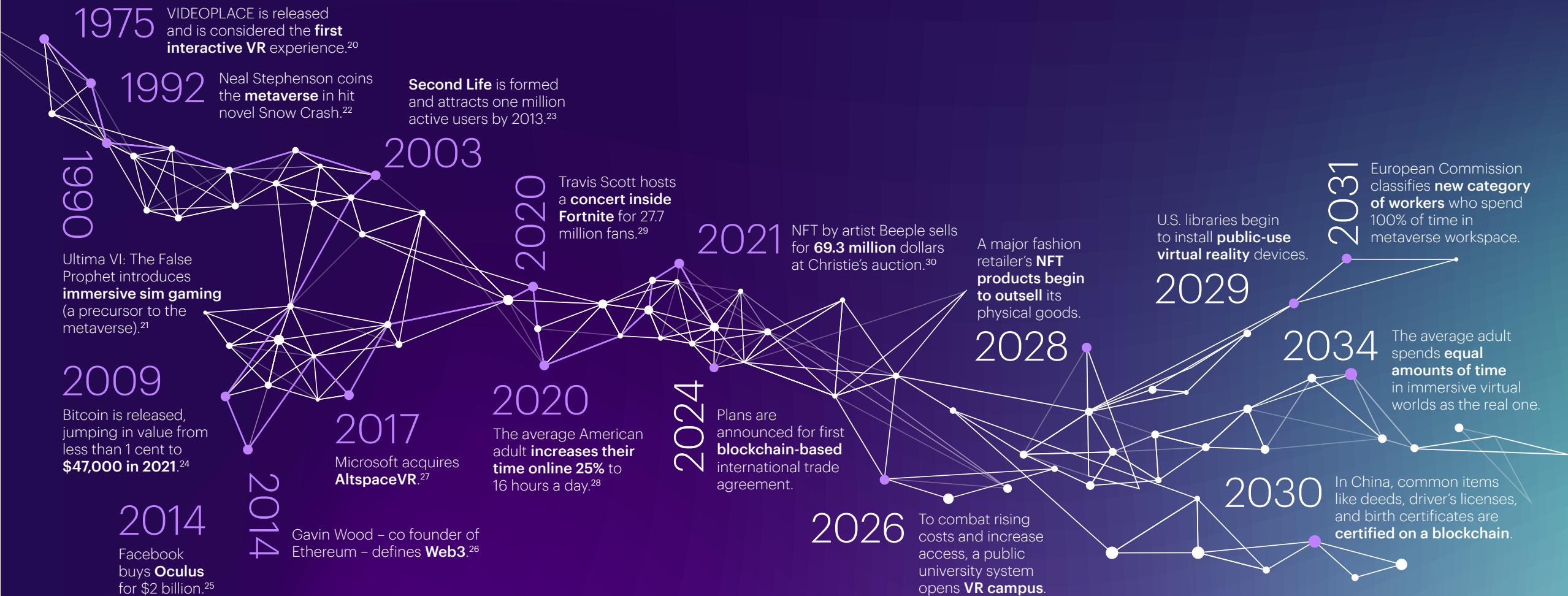
Trend 01

WebMe

Putting the Me in Metaverse

WebMe

1975 VIDEOPLACE is released and is considered the **first interactive VR** experience.[20]

1992 Neal Stephenson coins the **metaverse** in hit novel Snow Crash.[22]

Second Life is formed and attracts one million active users by 2013.[23]

2003

1990 Ultima VI: The False Prophet introduces **immersive sim gaming** (a precursor to the metaverse).[21]

2020 Travis Scott hosts a **concert inside Fortnite** for 27.7 million fans.[29]

2021 NFT by artist Beeple sells for **69.3 million** dollars at Christie's auction.[30]

A major fashion retailer's **NFT products begin to outsell** its physical goods.

U.S. libraries begin to install **public-use virtual reality** devices.

2031 European Commission classifies **new category of workers** who spend 100% of time in metaverse workspace.

2029

2028

2009 Bitcoin is released, jumping in value from less than 1 cent to **$47,000 in 2021**.[24]

2017 Microsoft acquires **AltspaceVR**.[27]

2020 The average American adult **increases their time online 25%** to 16 hours a day.[28]

2024 Plans are announced for first **blockchain-based** international trade agreement.

2034 The average adult spends **equal amounts of time** in immersive virtual worlds as the real one.

2014 Facebook buys **Oculus** for $2 billion.[25]

2014 Gavin Wood – co founder of Ethereum – defines **Web3**.[26]

2026 To combat rising costs and increase access, a public university system opens **VR campus**.

2030 In China, common items like deeds, driver's licenses, and birth certificates are **certified on a blockchain**.

THE BIG PICTURE
_____

The internet is being reimagined, and enterprises need to be ready for what comes next.

In 2021, we saw Facebook change its name to Meta and shift its focus from social media to the metaverse, which it considers "the successor to the mobile internet."[31]

Rather than viewing digital content, people will live and be present within it.[32] And Meta isn't the only company talking about this. Epic Games, whose CEO has said that people are tired of how today's internet operates, has raised $1 billion to support its own metaverse vision, which would be akin to a massive online playground where people can mingle freely with brands and each other.[33,34] Microsoft also has skin in the game: The company is bringing its suite of Azure offerings together in what it calls the

Microsoft metaverse technology stack, which will let enterprises build apps on top of digital twins, bringing the physical and digital worlds together.[35]

But when it comes to the future of the internet, we're not just watching metaverses start to form. Web3, an encompassing term for emerging efforts to build a "distributed" layer to the internet, is ripe with innovation and new applications too. Digital wallets like MetaMask, Trust Wallet, and Fortmatic

are raising new possibilities for what data people possess, how and where it's stored, and the ways it gets shared with others. Daily unique active wallets connected to decentralized apps (dapps) increased sevenfold over the past year, an estimated 300 million people own cryptocurrencies, and according to market research firm Blockdata, 81 out of the top 100 public companies are using blockchain, 65 of which are actively developing blockchain solutions.[36,37,38]

Defining Metaverse and Web3

With so much attention being paid to the future of the internet, it is critical leaders have a firm understanding of the new concepts emerging and their implications. While many technologies and efforts are encompassed by what Accenture defines as the "Metaverse Continuum," thought leaders in this space often have different definitions (some complementary, some contradictory) for the various ideas, and the fuzziness of the different terms at play can make discussions tricky.

Accenture sees the metaverse as "an evolution of the internet that enables a user to move beyond browsing to inhabiting and/ or participating in a persistent shared experience that spans the spectrum of our real world to the fully virtual and in between."

While Web3 is an evolving term, in this report we use it to refer to the emerging initiatives that are leveraging technologies like blockchain and tokenization to build a more distributed data layer into the internet.

So, what does this all mean for enterprises? For the better part of two decades, businesses have been on a journey to build out digital capabilities ranging from e-commerce offerings to analytics platforms, digital experiences, virtual workforce tools, and so much more. The global digital transformation market is set to grow to $1.25 trillion by 2026.[39] And the value unlocked by these solutions has become a mainstay of companies' bottom lines and a driver of the global economy. In fact, the World Bank estimates that today's digital economy is now responsible for 15.5% of global GDP, and is growing at a rate 2.5 times faster than global GDP.[40] But all of these solutions were built for, and value is being created from, the internet as we know it *today*: a digital world where the platforms that drive value are often separate and distinct from one another, where lack of interoperability and data portability are often assumed as design constraints, and people spend more time "offline" than in the virtual realm.

In other words, our current systems are designed to be used in the exact set of constraints that the next generation of the internet is looking to eliminate.

Metaverse and Web3 innovations are transforming the fundamental underpinning and operation of the virtual world. Instead of the internet as a disparate collection of sites and apps, metaverse efforts envision a persistent 3D environment, imbued with a sense of place, where moving from work to a social platform is as simple as walking from the office to the movie theater across the street. Web3 further shapes this evolution by introducing a data framework that generates veracity, trust, and even scarcity – things we've long had conventions for in the physical world but have in many ways evaded us in the virtual ones.

Together they are driving a shift towards a more human-centric internet and it is urgent enterprises prepare for these imminent changes.

71%
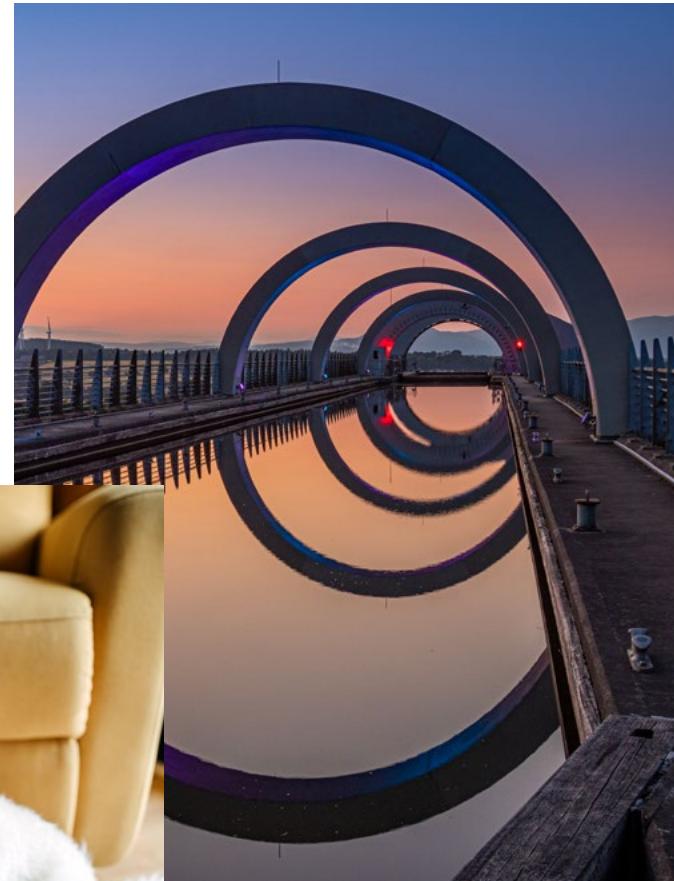
of global executives state that the metaverse will have a positive impact on their organizations, with

42%

believing it will be breakthrough or transformational.

With metaverse and Web3 already weaving their way into board room conversations around the globe, it's necessary for executives to be able to separate hype from reality. After all, the term metaverse was coined by the author Neal Stephenson back in 1992, and today's emergence into everything from commercials to earnings calls seems sudden given the progress we've made and how much more still needs to be done. As for Web3, in the last year alone major volatility around cryptocurrencies and the multi-million-dollar sales of NFTs (non-fungible tokens) simultaneously demonstrated the disruptive potential of emerging online marketplaces and new modes of commerce – while also raising serious questions around the value and stability of these digital products.
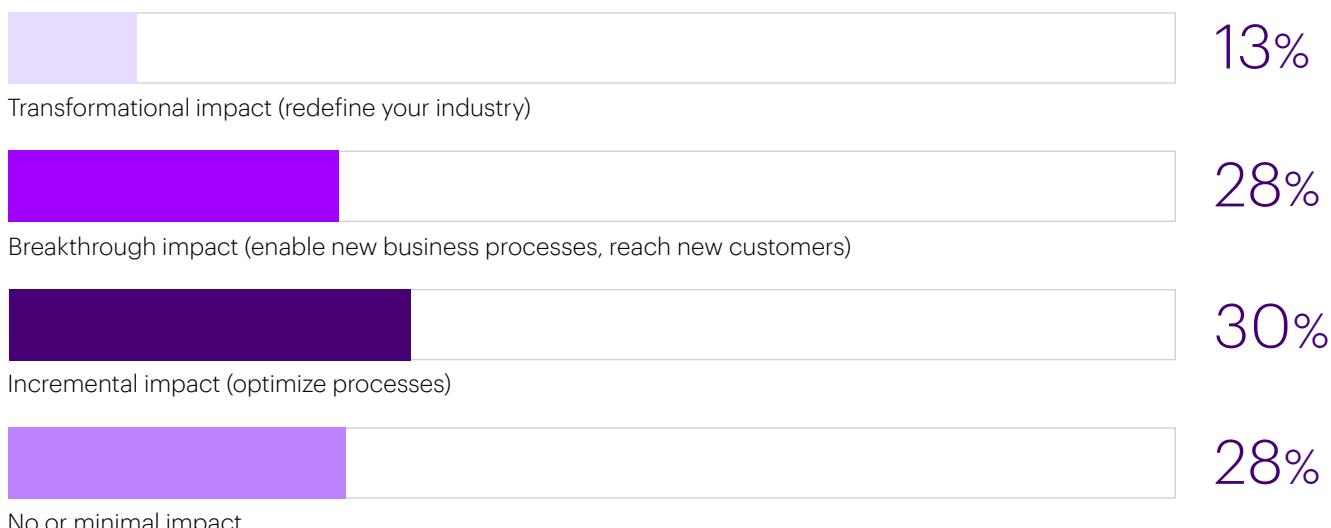
But while a critical eye is important, it's equally important not to let the debate around hype cycles dominate the bigger picture: the growing certainty that our digital world is in the early stages of significant change, and that in the coming years these technologies will become critical components of how enterprises orchestrate their digital strategies.

Either metaverse or Web3 alone would be enough to draw hype and attention – but the fact that they are unfurling *simultaneously* is what demands enterprise leaders take notice. Early efforts present a new vision of the future of the internet, with the creation of immersive digital-only worlds as well as a deeper blurring between the boundaries of the digital and physical. They are subverting many assumptions we take for granted about the function of digital offerings, and the form they take, by demonstrating exciting new ways to experience, communicate in, and transact across virtual environments.

What level of positive impact do you believe the metaverse will have on your organization in the future?

13%

Transformational impact (redefine your industry)

28%

Breakthrough impact (enable new business processes, reach new customers)

30%

Incremental impact (optimize processes)

28%

No or minimal impact

Source: Technology Vision 2022 Global Business and IT Executive Survey. N=4,650.
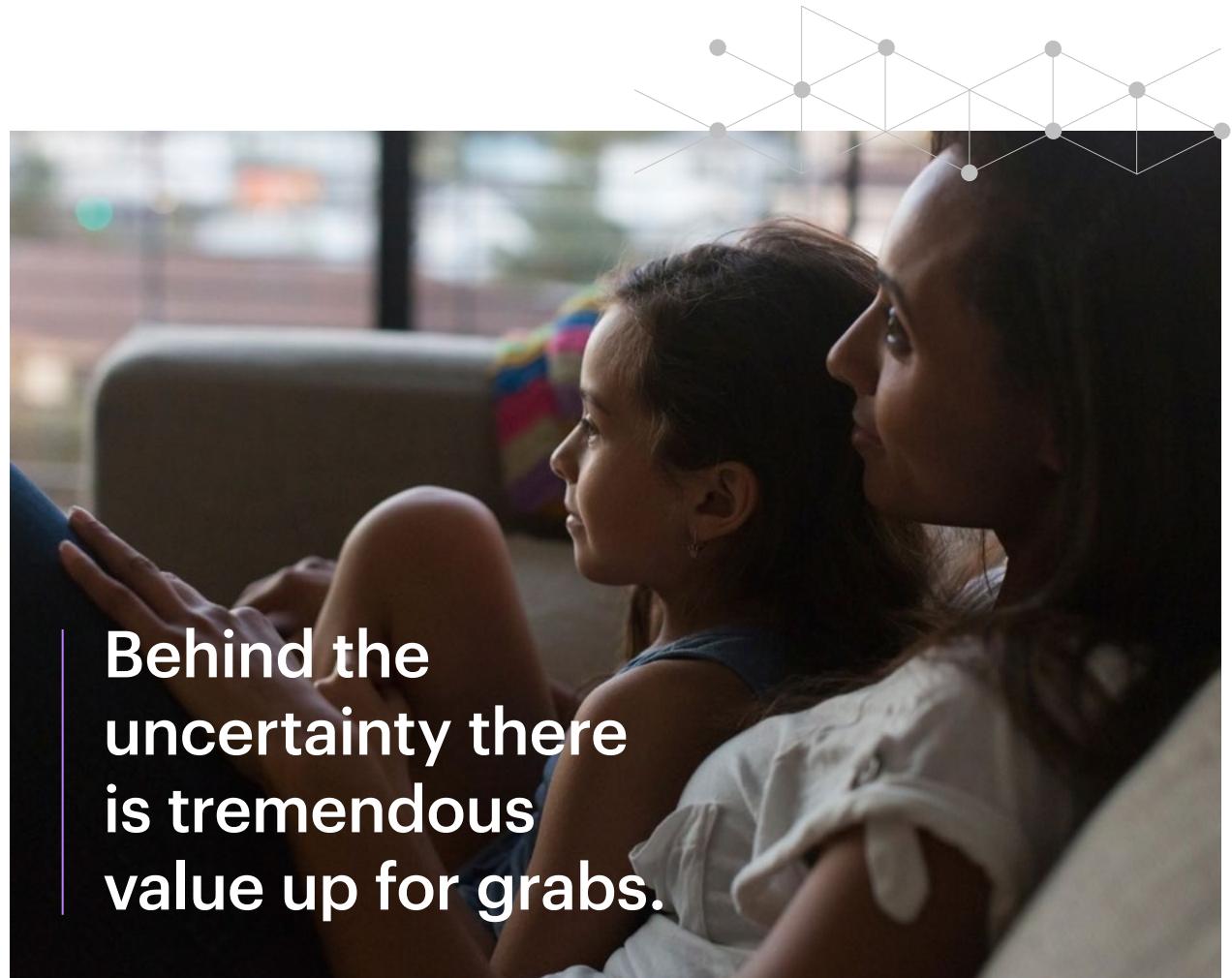
Consider Nike, which launched a virtual world called NIKELAND on Roblox in late 2021.[41] NIKELAND has buildings and fields inspired by the company's real-world headquarters, arenas where visitors can play games, and a digital showroom where they can outfit their avatars with Nike products. And the full experience crosses into the physical world too – by using the accelerometers on their phones, visitors can translate activity in the physical world into longer jumps or faster running speeds in NIKELAND games. As another example, Bayer's Crop Science group partnered with BlockApps to build TraceHarvest, an agricultural blockchain platform used to track produce from the moment it is planted as a seed, all the way through the value chain.[42] And many retailers have announced plans to seamlessly accept Bitcoin and other cryptocurrencies – which may not be the most convenient payment methods in the physical world today, but will be valuable experiments should these companies begin transacting in the metaverse.

Though today's solutions may sometimes seem too futuristic, niche, or disjointed, they are broader signals indicating the next digital revolution is beginning to appear on the horizon. Eventually, the entire online footprint that companies have been endeavoring to build over the last decade will need to be reimagined to be compatible with this new evolution: from what services are sold and what data is accessible to how advertising is conducted, and content is generated.

Now is the time for companies to decide the role that they will play – if they want to be part of the wave, or merely watch how it plays out. It's not a simple decision. There's no clearly defined end-state to this transformation. It will evolve continuously and iteratively through the visions of those leading the charge. There is tremendous work to be done building the new platforms, products and services, partnerships, and technology needed to manifest this change, as well as identifying the use cases and business models that will define how we generate value from it. But behind the uncertainty, there is tremendous opportunity up for grabs. The last time the internet went through a shift of this magnitude, companies like Amazon, Netflix, and Google went from being e-bookstores and renting DVDs by mail to becoming

nearly synonymous with the internet itself. The chance to be a driving force behind the reimagination of our digital experience, to be a leader in redefining how data shapes the lives of people and enterprises alike, or to play a part in merging those two visions together is the opportunity in front of business leaders today. The table is set for the next dominant players of every industry to emerge. Will it be you?

Behind the uncertainty there is tremendous value up for grabs.

THE ANALYSIS

Converging on our Digital Future

It's useful to think about these evolutions as taking place on two fronts: the metaverse as a re-platforming of digital experiences and Web3 as reinventing how data moves through that system.

For executives hoping to join the ranks of those that shape the next internet revolution, it starts with taking steps to understand these evolutions to the form and function of the web, why the world is so ready for these shifts, and importantly – how to apply them starting today.

Starting with metaverse, look at how BMW is taking early steps by using NVIDIA's Omniverse platform to build digital twins of 31 different factories.[43] The models use real-time data to recreate a photo-realistic 3D environment that is a living mirror for everything from the machines on the floor, the people populating stations, and even individual work-order instructions.[44]

The environment is used for wide-ranging functions including training robots to navigate the factory, bringing together designers from across the globe to experiment with new line layouts, training simulations for individual tasks, and doing ergonomic improvements. But it's not just a place for experimenting. Employees can use the environment to push software updates, monitor individual cells for disruptions, assign new "missions" to the robots on the floor, and even take over and teleoperate the machines for individual tasks.

BMW demonstrates the promise of what the next generation of the internet may hold. It's a single point of technology convergence that seamlessly moves from the digital to the physical, from simulation to real time, across the broadest macro-view of the factory down to the micro-level of individual tasks being performed. It has already reduced production planning time by 30% and promises to unlock even more value through predictive maintenance, collaboration, training, and custom manufacturing.

BMW's solution also demonstrates why a new evolution of the internet should be a welcome one. While many companies might have some, even all, of the discrete capabilities exhibited by BMW's virtual factories today, they likely exist across a dozen different systems and platforms, many of which are siloed or incapable of operating in concert with one another. And it's a problem that persists outside of enterprise technology stacks as well.

From the consumer perspective, platforms determine digital experiences – but the friction of navigating between different platforms, and the subsequent fragmentation of data across platforms, prevents us from having a *truly* seamless digital experience. Consider that, depending on where someone is located in the world, the average number of social media accounts internet users have ranges from 3.8 (Japan) to 11.5 (India).[45] So if you've ever had the experience of chatting with the same friend or coworker in multiple apps at the same time, you're not alone. People who subscribe to streaming services are also more likely to pay for two or three services rather than picking just one.[46] And it's a trend that follows us to our work lives as well: One study showed that 43% of workers feel they spend too much time switching between digital tools, yet an analysis by Gartner predicts that "by 2024, in-person meetings will drop from 60% of enterprise meetings to 25%" – necessitating the use of even more digital collaboration tools.[47,48]

95%

of global executives believe that future digital platforms need to offer unified experiences, enabling interoperability of customers' data across different platforms and spaces.

Digital platforms have become a wellspring of value but the well runs dry once the data or experience hits the proverbial garden wall.

Realizing this dichotomy is what makes the complements of Web3 and metaverse so enticing. While metaverse solutions like those from Meta, Epic, or NVIDIA, try to tackle creating a more unified experience, Web3 changes the way we treat data – creating an undercurrent of provenance, veracity, and value, that brings gravity to boundlessly creative spaces like the metaverse.

Founded by World Wide Web inventor Tim Berners-Lee, Inrupt is one of many companies working towards Web3. By associating data with the individual rather than the platform, it seeks to let people consistently carry their information with them around the digital world. In late 2020,

Inrupt released an enterprise version of Solid, a technology built on existing web standards, which lets users control their data and store it in Personal Online Data Stores, or Pods.[49,50] Now, large organizations and governments can build websites or applications that interact with the Pods and with people's permission access the data they need for certain tasks.

Inrupt exhibits just one of the many different technical approaches of Web3, but throughout all of them, the desired outcome remains consistent: to create a layer of transaction and trust across the web by making different parties the arbiters of their own data. The underlying data framework is what supports a range of capabilities from "owning" a pair of digital shoes to authenticating identity and more, while still remaining secure. In other words, activities that occur in metaverses may – and often will – be enabled by Web3. As such, Web3 is a critical, and necessary, complement that will bind our next internet together.

Importantly, Web3 also fundamentally changes the relationship between people and platforms, as well as how businesses engage with their users and business partners across digital spaces. For instance, while large platforms could still provide demographic data and channels of access to customers, businesses would also have a brand-new avenue to directly engage individual users. Companies could incentivize more personal access to create better-tailored experiences, and customers would have the comfort of knowing they were the ones in control of the information shared in that relationship. Similarly, businesses looking to share access between systems, or transact between different metaverses, will need a trusted layer to navigate across those ecosystems.
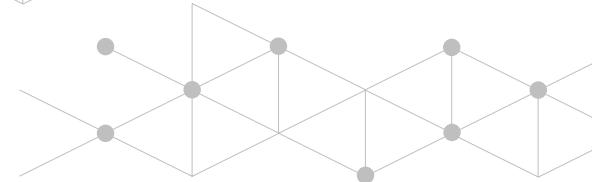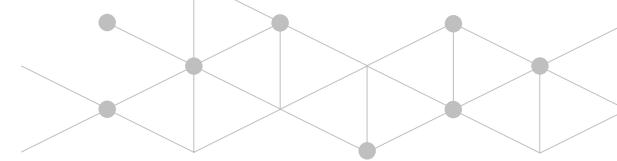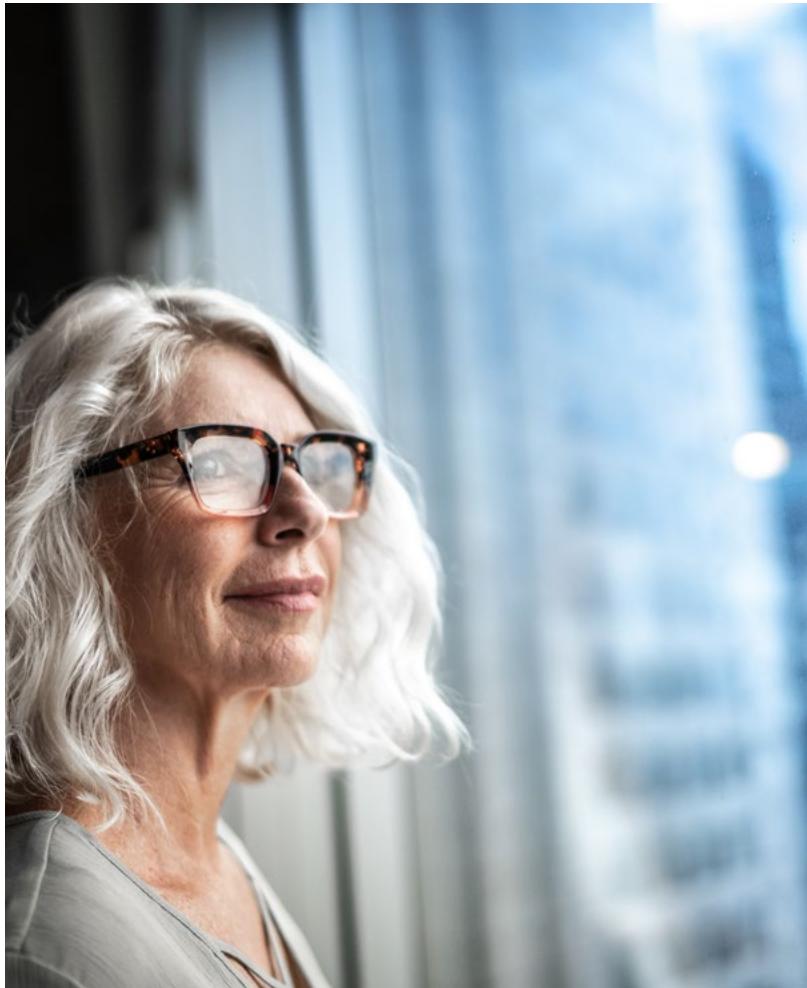
For the time being, many of the efforts to build the new metaverse and Web3 layers to the web are playing out separately, with many novel approaches towards the future. Meta's metaverse plans are wide and ambitious, and one of their early efforts – Horizon Workrooms – provides the full office experience with immersive VR environments for workplace conferencing, letting users beam in live feeds of their computer screens and use hand tracking and front-facing cameras to type on virtual keyboards.[51] The National Basketball Association spent the last year building out a platform that converted video highlights from real-world games into NFTs that fans could collect and trade – the effort generated $600 million in sales by October 2021 and provided a window into one possible future of sports content and memorabilia.[52]

Ultimately though, it seems the maximal value of both metaverse and Web3 will depend on the ways in which the two converge with one another. Efforts to reimagine the way data moves through the internet will need a simple and intuitive experience to gain widespread adoption, and efforts to make the web experience more "real" will need an underlying data foundation that guarantees trust, safety, and optionality for all involved. The two are ideal complements, and early examples to unify the two are already underway. Decentraland is a user-owned Ethereum-based virtual world where users can play, explore, and interact with games and activities.[53] Notably, almost everything in Decentraland is an NFT, from virtual real estate to art to avatar skins, meaning that there's a secure way to track ownership of these digital assets and that players can move them throughout Decentraland, even across areas developed by different companies.[54] Since the start of 2021, Decentraland's average number of daily users has grown tenfold to 18,000, and at the end of 2021, Samsung launched their first metaverse store on Decentraland.[55,56,57]

> The maximal value of both metaverse and Web3 will depend on the ways in which the two converge with one another.

THINGS TO LOOK OUT FOR

We're Finding a New Way Forward, and Not Turning Back

While much of this technology is still in the early adopter phase, there are signals that the world is steadily progressing towards this future.

Shifts in the digital world over the past 18 months have made it clear that a "wait and see" approach will before long become "look, it already happened."
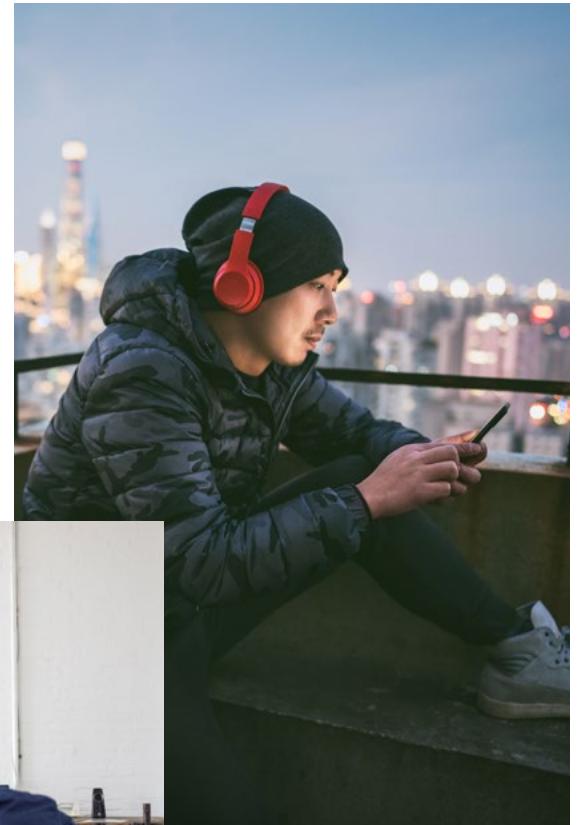
It took just 15 years to go from the launch of the first iPhone to a world with 6.6 billion smartphones.[58] Compare this to a shift we're starting to see today. In December 2021, the Oculus app rose to the top of mobile app store charts – becoming the top app in the U.S. and a top five app in 14 countries.[59] And not only is the technology that people and enterprises have access to beginning to change – their habits

are too. A study in late 2020 found that daily time spent consuming digital content in Europe and the U.S. had doubled since the start of the pandemic.[60] And in the third quarter of 2021, NFT sales surged to $10.7 billion, over eight times higher than the previous quarter.[61] The, at times astronomical, value of individual NFT sales is likely tied to hype, but the growth in attention is creating a community of web users who are comfortable spending on purely digital assets with no real-world manifestation, and perhaps more importantly – learning to think about data in a new way.

Equally significant, enterprises are starting to think about the digital world differently and are already capturing the new value that's there. When concerts couldn't take place in person, an alternative was invented. A Travis Scott Fortnite concert in April 2020, for instance, had 27.7 million unique attendees – far more than a typical concert venue can accommodate – and was viewed 45.8 million times, meaning millions of players logged on to attend multiple times over its five-day run.[62] After two years of not having work meetings happen live, virtual events platform Touchcast launched MCity, an enterprise metaverse platform where companies can register for a ".metaverse" domain name and construct a virtual hub where employees can have meetings and collaborate.[63] When people couldn't socialize face-to-face, the "realness" of their virtual lives and experiences started to matter more. Gucci created The Gucci Garden Experience to sell virtual products, and sold a virtual-only digital twin of a Gucci purse for a higher price than its real-world counterpart.[64,65]

It's easy to look at some examples of what's happening today and say they were born from necessity or from companies trying to hop onboard a hot trend. But even when these constraints are gone and the novelty wears off – can we really expect event promoters to stop selling tickets when they reach the capacity of their in-person venues, when they can be selling tickets for a virtual experience too? Do we really think the innovations that have made people's virtual lives more immersive and real will go away? The conditions of today's evolutions are certainly far from what we consider "normal life" – but people and enterprises won't unhear the bell of the future.

However, a word of warning is necessary. Just as early innovation in this space can carry outsized value, it can carry outsized risk as well. Leaders are not just pioneering a new digital future, but a new future for human and enterprise interaction, and many of the rules remain undefined. It is critical enterprises take steps to proactively shape the "Responsible Metaverse."

How does content or interaction moderation happen in the metaverse, when people now have bodies and voices not just usernames and text? How do we blend the virtual and physical in a way that ensures a metaverse-driven workplace doesn't leave employees isolated and without critical real-world human interaction? Or safely onboard people into the world of Web3, where password-recovery is a non-option for current platforms and where losing access to digital assets often means access is lost forever.

These are just a few of the questions enterprises will face, and they need to be prepared to answer or take action on them. Enthusiasm for the potential on the horizon should not come at the expense of caution and care for the human at the center of the experience. This is a once-in-a-generation chance to rethink how you do business in a new medium: what you sell, how you engage with customers or clients, how your

employees do work, and everything in between. For better or worse, the actions taken today will define the business's trajectory for a decade or more. Those who succeed will become the next digital natives, with all the advantages that come with it, and there are no guarantees that the prior successes of today's digital leaders will carry over to tomorrow.

People and enterprises won't unhear the bell of the future.

Leading Tomorrow's Internet

It's one thing to understand the urgency and opportunity of this moment, and quite another thing to be prepared to act on it.

Think back to everything it took for legacy businesses to catch up to digital natives. They had to hire new software developers, designers, and UX testers, explore cloud investments, and form new partnerships, and even then, they were only playing catch-up. For this next generation of the digital world, that isn't yet the case. Enterprises still have a chance to get ahead of the market and be part of its creation.

Business leaders should start building new strategies today, exploring the potential of new products and services and training their executives on the technologies that will soon be foundational to their business. As metaverse and Web3 technologies continue to mature, the companies

that are prepared and willing to be the first to experiment with these new platforms and data structures will be the ones who define what the next generation of digital business looks like.

But success here isn't purely strategic – it also hinges on putting your technical foundation into place. At a minimum, cloud will be essential, as will rebuilding your applications with microservices architectures and APIs to be easily usable by and shareable with others. The metaverses that emerge (whether enterprise or consumer-driven) will be defined by the services and platforms they encompass.

This means to even have a presence enterprise must have the infrastructure to share applications widely and securely. These steps can, and should, be taken today – even if the end state of the metaverse remains uncertain.

Next, businesses can start identifying – and working toward – the Web3 and metaverse skills and capabilities they will need. Enterprises looking to create metaverse experiences will require 3D artists, game designers, and experts on the platforms on which they plan to build. And companies chasing the opportunities of Web3 will need experience with multiple blockchains, to build relationships with different consortiums, and because of its distributed nature, to find partners to go to market with, as well as build new business and operating models.

This might sound like a lot of new skills to develop in a short amount of time, but in many cases, you don't have to start entirely from scratch.

The increasing sophistication and democratization of immersive design tools, for instance, is making it easier than ever to start experimenting with these technologies. Look at all the tools emerging to help people create 3D environments and experiences. Epic Games' Unreal Engine, which is a real-time 3D creation tool for photoreal immersive experiences, was updated in August 2021 to emphasize interoperability and cloud support, meaning that users can now access Unreal Engine from any normal web browser.[66,67] And NVIDIA's Omniverse, the same one used by BMW, connects existing 3D software tools – which typically haven't worked well together – making it easier for people to collaborate on 3D environments in real time and across software applications.[68]

And for many of these technologies, the best way to be an early innovator is by deploying them internally. This is what Accenture did by creating its own enterprise metaverse, the "Nth floor." Accenture is deploying 60,000 VR headsets to employees around the world and is providing immersive VR environments for onboarding, learning, and collaboration within the company – all while demonstrating best practices for VR rollouts and projects to clients.

Aside from gaining the necessary in-house skills and expertise, forming new partnerships and ensuring you can participate in future partnerships and collaborations is also a critical aspect of building your technical foundation. Companies can join consortiums like the Khronos Group, which comprises more than 150 organizations including Apple, Google, and Amazon and is working to set open industry standards for extended reality, 3D graphics, and more.[69] Or for organizations building Web3 applications, there's the InterWork Alliance which has created the Token Taxonomy Framework so that multiple parties can work together to define a "common language, behaviors, and properties" for digital tokens.[70]

The importance of consortiums and industry standards like these is twofold. They enable greater interoperability between companies, making it easier to deliver cross-platform experiences or to jointly collaborate on an experience, and they often make it possible to do so securely and without jeopardizing a company's privacy. And, by agreeing to a common framework when a technology is in its infancy, businesses can set themselves up to provide more compatible services to future shared consumers, which will help them stand the test of time as the internet continues to evolve.

Conclusion

Today's efforts around metaverse and Web3 are creating the next version of the internet. They are two momentous technology shifts, simultaneously working to eliminate the friction that exists between today's many digital platforms and to reinvent how data moves and is used across digital experiences. And in the process, they are driving new lines of business, new ways of working, and new means of interaction between businesses and people. For most, this is the first and best chance they have ever had to architect a new kind of digital world – and the race to define, build, and populate it is on.
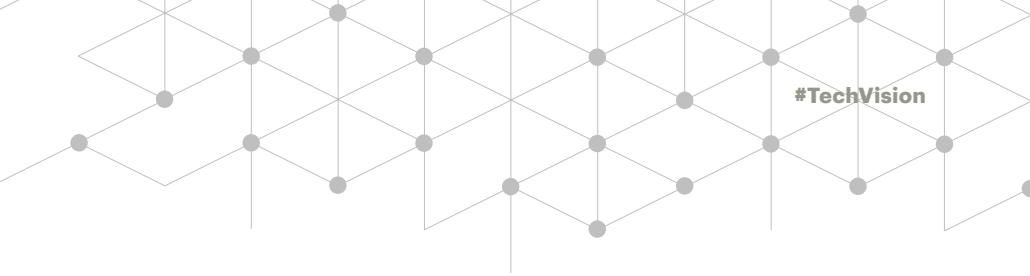
Decision Points:

Is your company ready for the next generation of the internet?

- A significant transformation is coming to our digital world, and even if the end state is not yet fully formed, many changes are already underway. Leaders should kick off a market and technology scan to understand what is evolving today and how it may impact or disrupt current digital efforts, then prioritize the opportunities and partners available.

- Use case development will be key as enterprises track the maturity of the underlying metaverse and Web3 technologies. Every company will be impacted differently, with no clear best practices. Maintaining focus on desired outcomes will mean developing a concise set of use cases for how enterprises intend to drive value from these emerging worlds.

- There are technology investments you can already make today to improve your short-term and long-term ability to adapt to the impending changes. Cloud is a must for every company. More discrete industry impacts are happening across spaces like VR, AR, digital twins, distributed ledgers, and virtual marketplaces.

How are you developing the skills needed for the next digital world?

- Just as enterprises needed to hire interaction designers, software engineers, and more to execute their digital transformations, a new set of skills will be required for a future driven by metaverses and Web3. Start by identifying where you expect to compete as an enterprise, and what skills gaps will prevent successfully executing those strategies.

- Developing the pipeline for new talent will be a longer-term effort that should nevertheless begin today. In the interim, companies should explore upskilling existing employees through vendor-based training and building familiarity and skills with the metaverse and Web3 platforms they intend to use.

- Low-code and no-code platforms are another avenue that may jumpstart an enterprise's ability to pursue metaverse and Web3 initiatives.

How are you going to start?

- Already, there are some standard metaverse use cases that companies can leverage without high levels of risk. For instance, immersive technologies for training or productivity have been tested and experimented with for years.

- To guide their pilots, businesses should investigate the ways their enterprise platforms may be holding them, their stakeholders, or their users back. They should empower development teams to design and test new kinds of experiences that eliminate or circumvent these pain points.

- To keep up with – and influence – the development of metaverse and Web3 technologies, fast track participation in consortiums.

What security (and safety) will your company need to operate and fully engage with businesses and customers in the metaverse?

- Begin planning for the metaverse architecture with new identity and data governance and frameworks and Web3. As cryptocurrency services may form the building blocks for user identity and transparent transactions, evaluate how practiced your company is in these technologies.

- Strategize on what your company wants to become in the metaverse. What is your role in creating a secure and trusted metaverse, and shaping the future of human and enterprise interaction? Could you become a leader in bringing your corporate values of trust, security, privacy and safety to the metaverse?

- Have product and services teams begin planning for the compound risk of new services and integrated experiences in a shared marketplace. Assess how this changes the risk exposure of those initiatives.
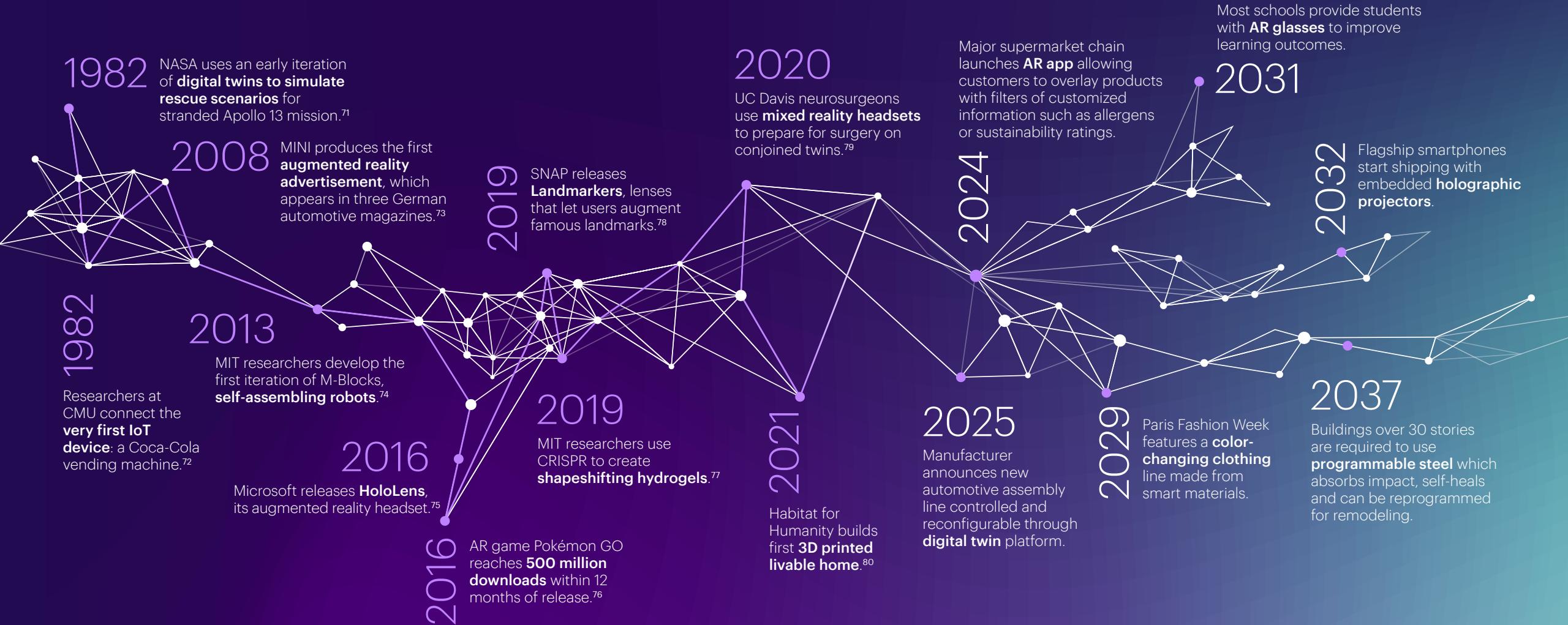
Trend 02

Programmable World

Our Planet, Personalized

Programmable World

1982
NASA uses an early iteration of **digital twins to simulate rescue scenarios** for stranded Apollo 13 mission.[71]

2008
MINI produces the first **augmented reality advertisement**, which appears in three German automotive magazines.[73]

2019
SNAP releases **Landmarkers**, lenses that let users augment famous landmarks.[78]

2020
UC Davis neurosurgeons use **mixed reality headsets** to prepare for surgery on conjoined twins.[79]

Major supermarket chain launches **AR app** allowing customers to overlay products with filters of customized information such as allergens or sustainability ratings.

Most schools provide students with **AR glasses** to improve learning outcomes.

2031

2032
Flagship smartphones start shipping with embedded **holographic projectors**.

1982
Researchers at CMU connect the **very first IoT device**: a Coca-Cola vending machine.[72]

2013
MIT researchers develop the first iteration of M-Blocks, **self-assembling robots**.[74]

2019
MIT researchers use CRISPR to create **shapeshifting hydrogels**.[77]

2016
Microsoft releases **HoloLens**, its augmented reality headset.[75]

2016
AR game Pokémon GO reaches **500 million downloads** within 12 months of release.[76]

2021
Habitat for Humanity builds first **3D printed livable home**.[80]

2025
Manufacturer announces new automotive assembly line controlled and reconfigurable through **digital twin** platform.

2024

2029
Paris Fashion Week features a **color-changing clothing** line made from smart materials.

2037
Buildings over 30 stories are required to use **programmable steel** which absorbs impact, self-heals and can be reprogrammed for remodeling.

THE BIG PICTURE

We're building the next version of the physical world.

Twelve thousand years ago, new farming techniques and technologies started the Agricultural Revolution. People left hunter-gatherer societies to maintain crops and raise livestock on farms, and they began to command their physical environments to a degree that had never been done before.

Deforestation, permanent settlements, and eventually systems for irrigation all started to change the face of the world.

Millennia later in the 1700s, mass-production machinery, the construction of factories, and inventions like the steam engine sparked the first Industrial Revolution. These new technologies further transformed our relationship to the physical world. They led to the buildup of cities, long-distance transportation networks, and tunnels and bridges, turning impassable geological features into main thoroughfares.

This pattern has happened time and again across human history. Major revolutions occur when technology fills the world and transforms our relationship with it, giving us more command and control over our environment. And just as our physical world changes, so does what we do in it. We go from gatherers to farmers; from stable hands to machinists; from country-dwellers to urbanites.

Now, as the real-world impact of the current digital revolution begins to hit critical mass, we are embarking on the next major transformation: the programmable world.

In this world control, customization, and automation – things taken for granted in software – will be enmeshed into the environment around us. People will have unprecedented ability to command the world to meet their own individual needs, deciding what they see, interact with, and experience with greater ease and fidelity than ever before. And enterprises will build and deliver these experiences, as well as reinvent their own operations for a new kind of world. Simply put, the world is becoming a place that can be shaped as broadly, as personally, and as often as our experiences on the internet – fundamentally changing the way we live.

Imagine, for instance, that someone on vacation wants to go to a restaurant for dinner. Instead of looking at his phone for restaurants nearby, he simply asks his AI assistant what his options are, and through an earpiece, it points him to several nearby restaurants, highlighting their cuisine and reviews based on his past preferences. Upon confirming his reservation, his augmented reality (AR) glasses render a highlighted route on the sidewalk to direct him toward his destination. As he steers his wheelchair to the entrance, the small staircase to the door autonomously flattens into a ramp, and the restaurant receives his Yelp profile so the server knows just what to highlight on the menu, translated into his native language.

Or imagine that a worker is entering her company's manufacturing plant. She puts on her smart jumpsuit and AR glasses and quickly monitors the site. A blinking notification over one machine alerts her that it's due for maintenance and the OEM has already been contacted; a drone is scheduled to arrive with the necessary parts in eight minutes, but she will need to help install them. As she makes her way to the machine, ambient cameras in the room track her movement, autonomously shutting down and

92%

of global executives agree that leading organizations will push the boundaries of the virtual world to make it more real, increasing the need for persistence and seamless navigation between the digital and physical worlds.

reactivating machinery in accordance with safe operating procedures. The parts arrive, and as she removes them from the box, the packaging neatly disassembles for return to the shipping company. Her glasses have highlighted the specific machine panel the parts are intended for, but she verbally dismisses the training tutorial being offered and gets to work.

In these scenarios, digital capabilities are woven into the very fabric of the world, making the physical world as smart, customizable, and *programmable* as we expect the digital one to be. People have more information about their real-world surroundings, along with greater context, and they can frictionlessly interact with their environment in novel and more efficient ways.

We've been building toward the programmable world for years: Digital technologies have proliferated across the physical world for over a decade. We've put cameras everywhere and filled our homes with smart devices and microphones. Now, advances in natural language processing, computer vision, and edge computing are amplifying the capabilities of those devices, freeing digital interactions from being trapped and turning them into an ambient and persistent layer across our environment. The global 5G rollout adds more fuel to the fire, setting the stage for the further proliferation of low-power, low-latency connected devices. And researchers across enterprise and academia alike are working on even more transformative technologies, like AR glasses, new methods of manufacturing, new kinds of smart materials, and programmable matter.

Though many enterprises still view these technology elements as distinct and separate – as new ways to connect to a customer, create efficiencies in a warehouse, or deliver faster network connectivity – they are part of a much broader mosaic, a confluence of technologies that is pushing the full force of the digital revolution into our physical reality.

74%

of global executives report the number of IoT/edge devices deployed in their organizations significantly or exponentially increased over the past three years.

An early signal of what's to come happened in June 2021, when Amazon activated Sidewalk. Amazon had been deploying hundreds of millions of Echo, Ring, and Tile products into the world for years, and Sidewalk became the mesh network connecting them together.[81] It uses low-power Bluetooth and 900MHz radio signals to share data between devices and across greater distances than before, creating bridges that can extend connectivity up to half a mile beyond Wi-Fi range and let anyone with compatible devices connect. Now, if your dog escapes and gets lost, a Tile tracker on his collar could stay connected thanks to Sidewalk bridges from your neighbors' homes. And though Sidewalk is limited to Amazon devices and largely centered around increasing connectivity range for now, the way that it came together, connecting existing IoT devices to create instant smart neighborhoods, hints at the power that connecting other, even more sophisticated technologies will soon unleash.

Enterprises can be at the forefront of bringing the programmable world to life, from launching the next generation of customizable products and services to architecting the hyper-personalized and hyper-automated experiences that will let us shape and control our world down to the individual level. Those who ignore this trend, fatigued from the promise of IoT, will overlook the signals as the world automates around them. They will delay building the infrastructure and technology necessary to tap into this rich opportunity, and they will find themselves playing catch-up in a world that has already taken the next step.
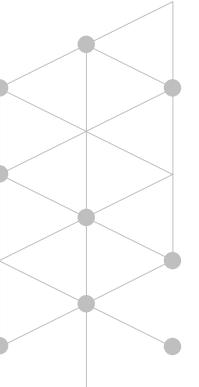
The physical world is the last, and perhaps greatest, frontier for the digital revolution. The world we once thought of as static is becoming infinitely programmable. From augmented reality to robotics, ambient computing, or programmable matter, the options to shape our world are vast – leaving enterprise leaders to ask one question:

When we have this level of control, what will we be able to create?

THE ANALYSIS

The Three Layers of the Programmable World
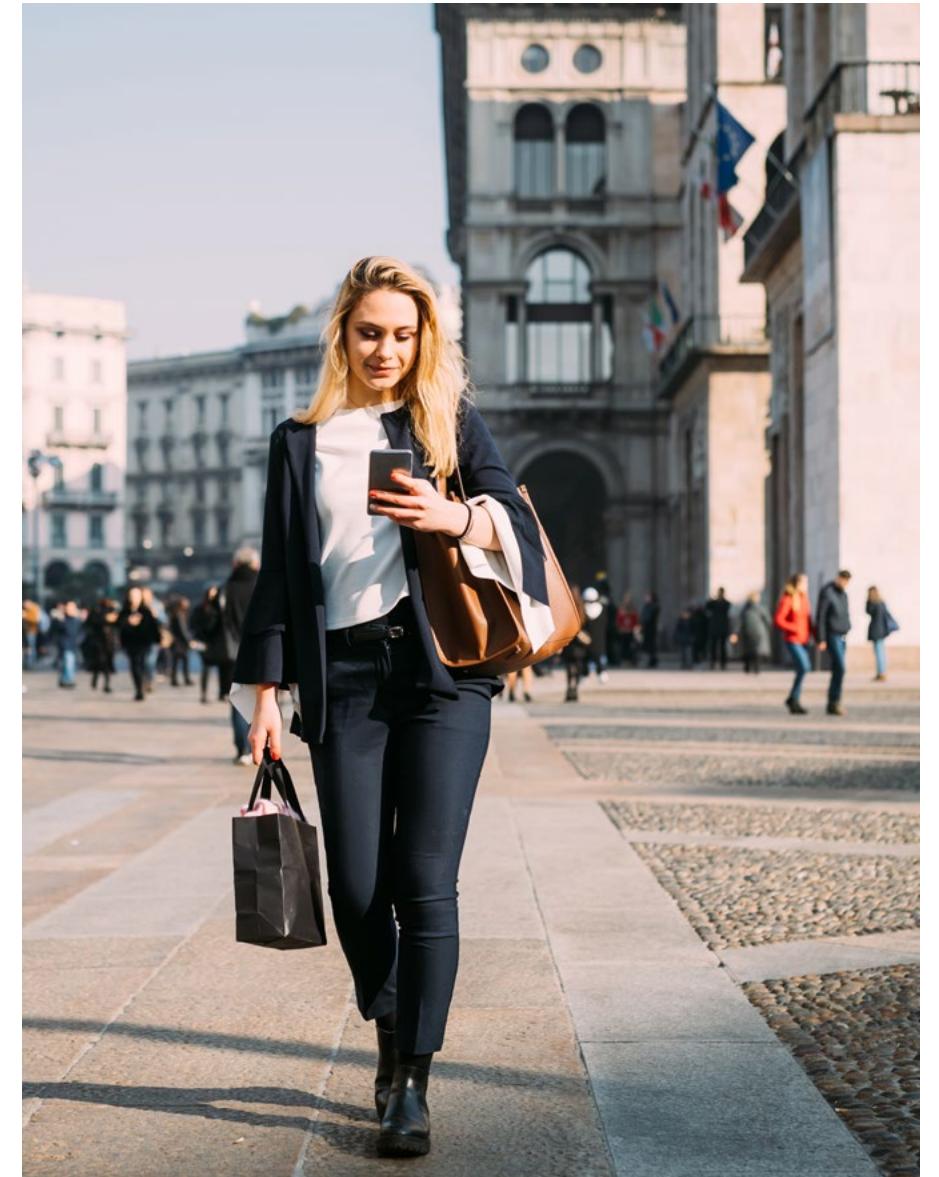
Innovation in the physical world should be high on enterprises' agendas.

Since the beginning of the COVID-19 pandemic, we've witnessed a surge of new inventions to help people live more fully and easily in the virtual world, and many have gotten used to a virtual lifestyle. They like the ease and personalization of online shopping, virtual interactive learning at their own pace, and always seeing (so never forgetting) their colleagues' names during a Zoom meeting. Now that the world is reopening, many people are eager to return to in-person activities and many businesses are eager to reopen offices and return to full physical world operations – but they don't want to leave these digital boons behind.

Though our attention for the past years has been fixed on companies making digital work and life possible, the advancement of real-world tech hasn't slowed down. In fact, we're already starting to see aspects of the programmable world emerge: Digital experiences and capabilities are coming out of screens and into the world itself; ambient computing is turning our homes into digital interfaces; and early AR glasses are letting people make the world their personal digital environment. We're starting to shift from bringing digital experiences into the physical world to creating physical environments and experiences that innately are digital – that can be customized, controlled, and programmed much like the purely virtual experiences we're so used to. And with our return to the world after leading virtual-first lives for so long, the appetite for this has never been higher.

Consumers globally are crossing a tipping point in AR technology –

56%

**would find personal value in using AR today or in the future.**

To begin building a new generation of products, services, and experiences in the physical world – that meet our new expectations for digital conveniences – enterprises will need a deep understanding of three layers that comprise the programmable world: the Connected, the Experiential, and the Material.

Many are already investing in and deploying the first layer of programmable world technology, creating a connected foundation. According to Omdia's 2021 global IoT Enterprise Survey, 90% of respondents said IoT was core to their digital transformation strategies or already deployed across multiple parts of the business.[82] And IoT devices are widespread among consumers too. Many smart thermostats, for instance, use algorithms to learn people's temperature preferences and daily routines so they can adjust automatically and avoid heating empty homes.[83,84] Nest Doorbells let customers set activity zones and smart alerts for a mix of people, vehicles, packages, or animals that come into view, and with Nest Aware, can even use facial recognition to alert people when familiar faces are at the door.[85]

And where these devices in the past have been limited in compute power and largely kept separate, being operated through discrete apps, emerging technologies are starting to bring their true promise to life. Ambient computing, for instance, uses interconnected IoT devices to integrate computing into people's lived

environments and turn the world into a seamless interaction layer. Instead of requiring a device, people's interactions with their surroundings – captured by computer vision, speech recognition, wearables, or other means – could automatically trigger a response. And the high speed and low latency of 5G will enable new connected device use cases that rely on ultra-fast connectivity, like connected cars, remotely operated machinery, and other real-world deployments, extending the reach of technology-driven interactions to more environments. Both of these technologies are rapidly growing. The context-aware computing market, valued at $42.21 billion in 2019, is expected to reach $200.04 billion by 2025 at a 29.9% CAGR over five years.[86] And 5G networks are expected to cover a third of the world's population by 2025.[87] As they continue to mature, they will bring the world online in a way that hasn't been possible before – enabling the creation of connected environments that react to us and our needs in a seamless, screenless way.

The next layer of the programmable world is experiential. Building on data collected by IoT and edge devices and processed at 5G speeds, digital twins are a core constituent of this layer. These digital models of the physical world give businesses real-time insight into their environments and operations, and can transform people's experiences in them.

In industrial settings, for instance, workers will be able to easily access relevant data and context from twins of their environments, streamlining their work and letting them make more informed decisions in real time. And in customer-focused environments like a grocery store, a combination of product data from the store's digital twin and personal data from a customer's digital profile could be used to show them curated details about the items they're looking at or to make recommendations. Already, many enterprises are starting to realize the value of these twins, building them for everything from factory machines, to whole environments, to entire supply chains, and the global digital twin market, valued at $3.21 billion in 2020, is expected to reach $184.5 billion by 2030.[88]
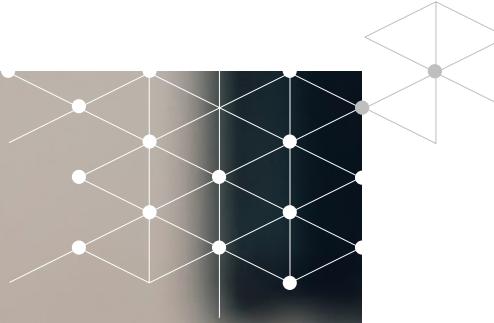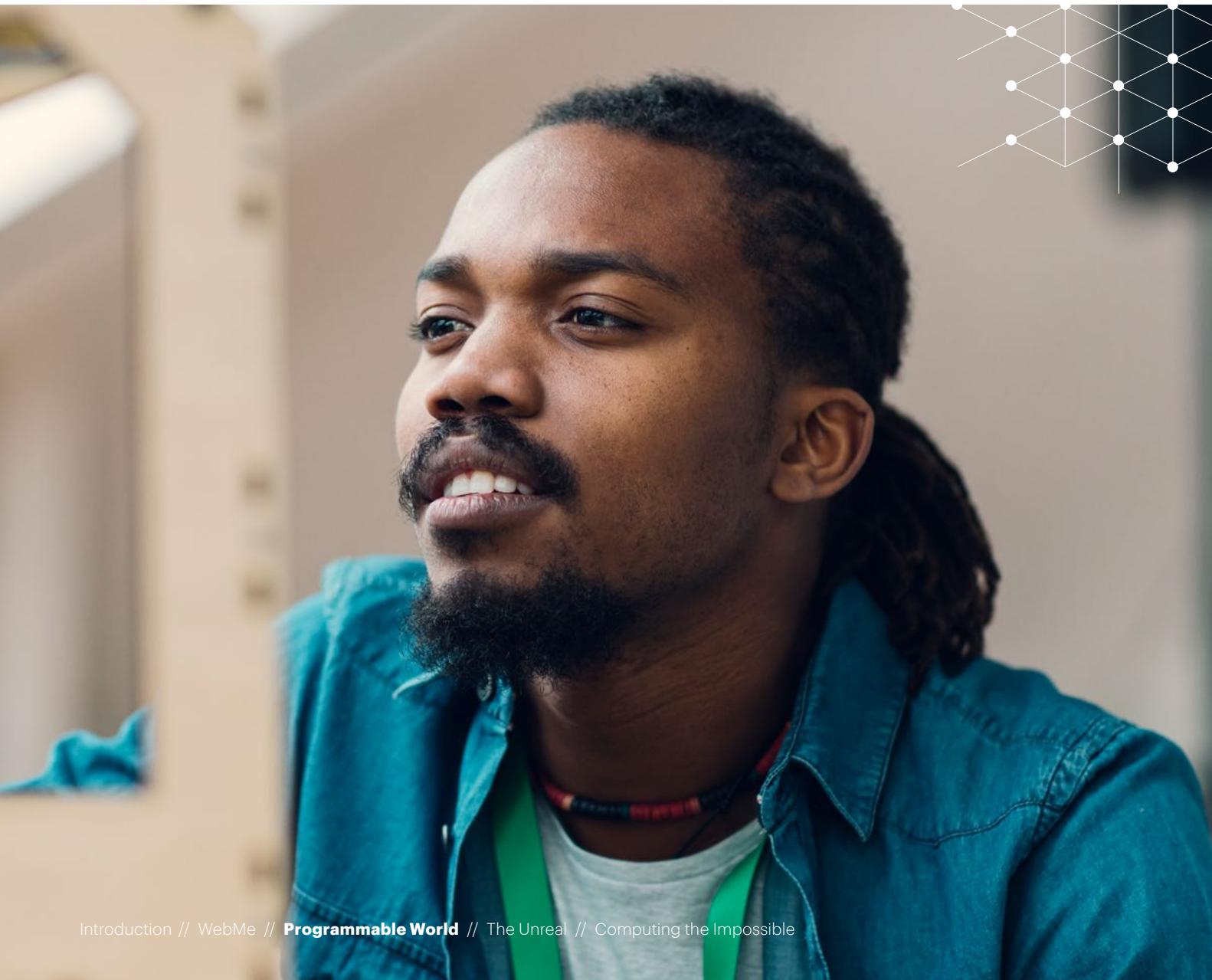
Another noteworthy component of the experiential layer is AR. While AR glasses still face challenges with battery life, image quality, design, and more, some early products are already here. INMO, a Chinese AR developer, has created a pair of AR glasses equipped with wireless connectivity and an AI recognition system.[89] The glasses superimpose information like directions or product details over the user's vision and use gesture control for communication and information sharing. Nreal, another Chinese company, has released AR glasses in several markets, including South Korea, Japan, and the U.S.[90] These glasses connect to people's phones and similarly augment the physical world with superimposed digital content.[91] Even in this early phase, the value of combining AR glasses and digital twins is clear: With them, any environment can be made digital and overlaid with a digital experience. A new dimension of information will be seamlessly embedded into people's experiences as they move around physical environments, and will give them unprecedented insight into the world and the novel ability to control how they perceive it.

The final layer of the programmable world is material and constitutes how things are made. It includes a new generation of manufacturing and materials, which will bring programmability into the truly physical aspects of our environments. Advances in digital manufacturing techniques are changing how and where physical goods can be made, making on-demand and hyper-customized products a reality. For instance, 3D printers can now print a much wider variety of objects, and the number of viable filament materials is growing too.[92] This makes 3D printing – which by nature is better suited for highly customized and local production – increasingly attractive for more industries. Similarly, advances in digital textiles production are making textile customization easier and on-demand production increasingly possible. Knitting solutions provider Shima Seiki's WHOLEGARMENT technology lets manufacturers program machines to knit entire garments without needing to cut and sew separate parts together.[93] And in addition to these manufacturing machine advances, digital design tools are democratizing product customization, letting designers – or even customers – easily make changes to their products while ensuring they can still be

fabricated with their intended manufacturing method. Furniture company Roche Bobois, for instance, is letting customers use a software tool at home or in-store to create their own furniture designs, which are then fed to a giant 3D printer for production.[94]

But being able to produce custom products on demand is only half of this material layer. New kinds of smart materials and programmable matter will soon make it possible to customize or enable custom experiences with physical products after production as well. Programmable matter is material that is "programmed" to change its physical properties upon direct command or sensing a predetermined trigger. For example, MIT researchers developed a programmable matter system, called ChromoUpdate, that can change the color of an item with a zap of light.[95] The items are coated in a light-activated dye, and an ultraviolet light projector can alter the reflective properties in the dye to change the color of the item. And a team at Rice University has developed a smart material that's strong, soft, and as conductive as many metals.[96] It contains carbon nanotube threads which can be sewn into clothing

without concern about damage from washing, stretching, or sweat, and the researchers see potential for wearable technology made with this fabric. In time, projects like these will elevate the programmable world, driving a new generation of smart things with new capabilities, properties, and form factors, embedding the individual control and customizability of the programmable world into the material building blocks of physical reality.

The Connected, Experiential, and Material layers of the programmable world will enable new ways to augment, customize, automate, alter, and otherwise "program" our physical environments – and they will introduce an entirely new competitive landscape. Digital technology is about to make its mark on the physical world, changing what we can do and how we live within it, and the companies that bring this technology to their employees' and customers' environments will quite literally be the ones to shape the next generation of life in this world.

THINGS TO LOOK OUT FOR

Challenges Connecting the Programmable World

Bringing programmability to your business and customers' lives starts with enabling the confluence of these technologies and technology layers.

The seamless combination of different capabilities is what will bring customization, automation, and more out of screens and into our world – for instance, AR gives us new ways to interact with information, which is often supplied by IoT devices and digital twins, and networks of various connected devices can share information to autonomously trigger changes in people's environments, with some observing people's real-time needs and some reacting to them. But there are significant challenges to connecting these technologies safely and at scale.

First and foremost, most businesses aren't going to develop all of these real-world technologies in-house, so interoperability between different companies' products will be key. Unfortunately, this is turning out to be a challenge – even in ways that are not entirely technical. Consider the findings of a 2021 J.D. Power survey: Smartphone connectivity in cars has actually worsened in the past year, especially when connecting wirelessly, and it's due to software coordination issues between automakers and tech companies.[97,98] And as those with smart homes might know, it can be difficult to connect smart home ecosystems using technology from different companies, like trying to control smart home devices from one company with a smart assistant from another.[99]

Though some businesses today might prefer to keep their programmable world technologies within a closed ecosystem, there are growing reasons to move away from these kinds of walled gardens. Customers are already wary of giving companies too much control over their digital lives, and with the digital world increasingly bleeding into the physical one, people may be even less willing to buy into a single company in the future.

What's more, customer satisfaction isn't all that's at stake – interoperability will soon be required from a safety standpoint too. For now, if a car's infotainment system doesn't connect wirelessly, it may be frustrating. But tomorrow, if an autonomous vehicle can't connect to a car made by another manufacturer, people's lives could be at stake.

Second, as businesses scale up their programmable world projects, they will be introducing many more connected, intelligent devices and creating new entry points connecting our physical and digital worlds. Each of these entry points opens possibilities for innovation and new kinds of customer experiences, but each also creates potential risk.

Significantly, risks to security and data privacy will not be relegated to the digital world but will have serious consequences in the physical world too. The size and scale of the exposure, direct impacts, and secondary impacts have the potential to be greater than ever, and this all becomes exponentially riskier as more devices from more companies are connected together.
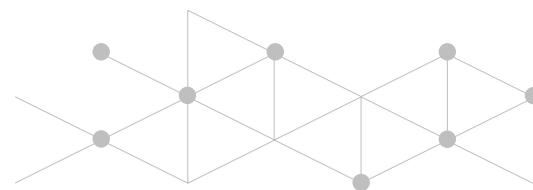
Imagine a simple scenario in which a person walks to the store to purchase a smart coffee pot – because his old one won't connect to his new virtual personal assistant. On his way, he pulls out his smartphone to check for directions. However, his phone has been hacked and is simultaneously mining for Bitcoin – he just doesn't realize it. When he arrives at the store, cameras using facial recognition determine who he is and track his movements and purchases. Later tonight, that data will be compromised in a data breach. When he gets home, he plugs in his new smart coffee pot that unfortunately still uses the default admin password, leaving his home network – which he increasingly uses to work from home – vulnerable to attack.

If this scenario sounds far-fetched, it shouldn't. In the first half of 2021, cyberattacks were up

125%, and there were 1.5 billion attacks just on smart devices – more than double the number of attacks over the same period the year before.[100,101] These attackers can steal personal or corporate data, mine cryptocurrency, or create botnets. And in 2020, ransomware attacks were up 150%, and the amount that victims paid grew more than 300% to an average of over $200,000.[102,103] By mid-year, 2021 was already on track to be worse.[104] "Triple extortion" techniques have also become much more common, whereby hackers threaten to not only make a company's sensitive data public but to also target their customers, vendors, and business partners.

As more of the world comes online, cyberattacks and data privacy breaches will have even more serious consequences. In 2019, two white hat hackers needed only minutes to exploit a weakness in the Tesla Model 3 infotainment system and get inside the car's computers to issue commands.[105] Imagine what happens as autonomous machines, from cars to drones, vacuums, and construction equipment, become common – the possibility of vulnerabilities increases, along with the damage that can be done.

Tackling these challenges head on is the key to moving fast in the programmable world. It takes time to deploy real-world technologies – especially consumer-facing ones – so getting it right from the beginning is critical. The choices businesses make today – across every aspect of developing programmable world technologies, but especially concerning their ability to securely connect with other devices – will impact their innovation agility long into the future. They will determine the kinds of environments companies can design, the partners that they can have, and the speed at which they can introduce new offerings.
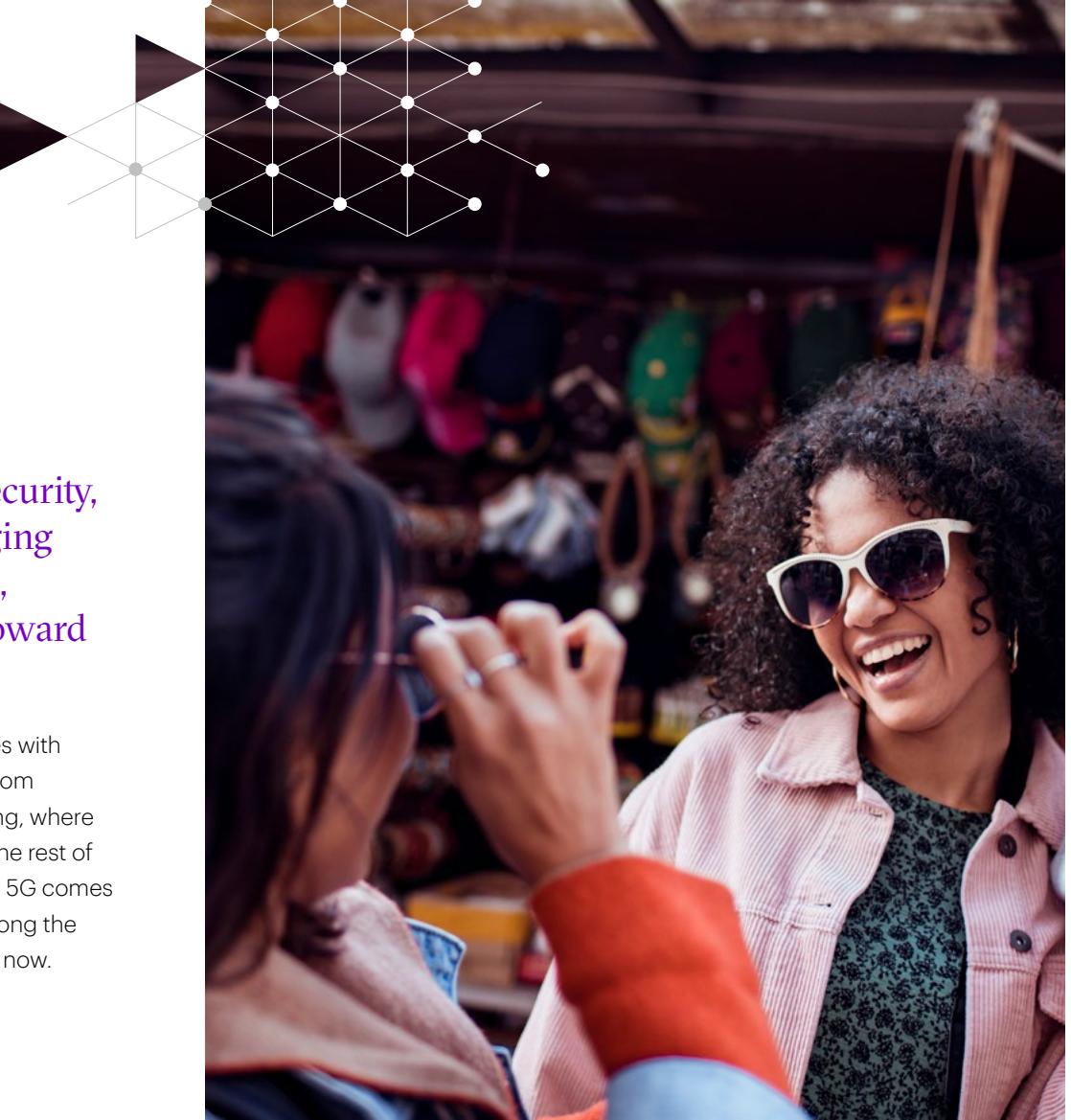
ACTIONS TO TAKE

Full Stack Programmability

Beyond the fundamentals of cross-device interactions, privacy, and security, becoming a leader in the programmable world will require wide-ranging exploration, experimentation, and development across the Connected, Experiential, and Material layers. Companies need to start working toward "full stack" programmability today.

To start, businesses should find ways to level up their foundational, connected layer. Notably, 5G is poised to be game-changing in terms of its speed and low latency, but rollouts are still very much in the works. By the end of 2021, Ericsson estimated that 5G networks would cover only about 25% of the global population, and according to a 2020 Qualcomm study, the wide range of 5G use cases are not expected to be fully realized until 2035.[106,107] This provides leading businesses with opportunities to experiment and pilot new use cases that leverage 5G capabilities, so that they can hit the ground running when it's

more broadly available. Moreover, 5G comes with security and privacy enhancements too – from improved edge computing to network slicing, where data from one "slice" can be isolated from the rest of the network. It's just a matter of time before 5G comes into full effect, so anyone wanting to be among the first to create these solutions needs to start now.

In addition, businesses should ensure that they're involved with industry-wide alliances, helping to shape the development of new technology standards. For instance, from an interoperability perspective, this could mean participating in ecosystem-wide efforts to set standards for how devices connect and communicate. Already, an alliance called Matter exists between Google, Apple, Amazon, and over 200 other companies to certify smart home devices using a standard that promises reliable, seamless, and secure connection and communication between products.[108]

For the experiential layer, enterprises can start to bridge their digital and physical worlds by building digital twins. Even without the full maturity of the programmable world, these platforms already provide significant operational and competitive advantages to companies today. And over time digital twins will become the engine for every enterprise's programmable world strategy, letting them invent products, design experiences, and run their businesses in ways that would have been unimaginable a few decades ago.

Next, to find their competitive footing on the experience layer enterprises should innovate in areas where purely digital and purely physical experiences have yet to excel. Take shopping for apparel for instance, which comes with major pain points both in person and online. At the store, customers must deal with limited selections and wait times, but online they have to purchase (and often return) multiple items to find the right style and size. Now, leading retailers are experimenting on two fronts.[109] They are developing virtual dressing rooms using AR filters and 3D avatars so that their customers can try on items before they buy. And they are enhancing their physical dressing rooms with improved lighting and interactive screens, so their shoppers can get more out of trips to the store.
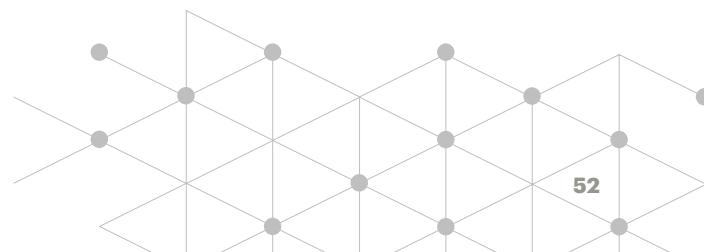
Finally, it's crucial to be constantly exploring future technologies on the material layer. Partnerships with startups and universities are a good way to make certain you are staying right at the forefront of real-world technology innovation.

Look at what universities like MIT are working on. In late 2020, a team of researchers at MIT's Center for Bits and Atoms published their work around four new material subunits called voxels.[110] The voxels are mechanical metamaterials, each with a different shape, which can be combined to form larger objects with special mechanical properties, like bulging inwards rather than outwards when compressed or responding to compression by twisting. Though they haven't yet been widely tested, the researchers believe voxels could be programmed into certain combinations to create objects that change and respond to the environment around them – like airplane wings that shapeshift in response to different air conditions – and they believe tiny robots could be used to assemble, disassemble, and reassemble the voxels into a nearly limitless variety of objects.

Or look at the xenobot developed by researchers from Tufts University, Harvard University, and the University of Vermont.[111] The xenobot is a "programmable" organism created by assembling stem cells like building blocks, and in a paper published in December 2021, the researchers said they witnessed the organic

robot self-replicating by sweeping up loose stem cells in its petri dish, which then formed into copies of the original bot – something that has never been seen before. Among other things, the researchers believe the xenobots could be programmed for purposes like finding cancer cells or trapping microplastics in the ocean and believe its self-replicating capability could have implications for regenerative medicine.

Voxels and xenobots may not be commercially ready for a while, but the fact that they already *exist* is what's important. The building blocks for each technology layer of the programmable world are growing in maturity, and enterprise decision makers need to keep an eye on this future. Enterprises may choose to excel at one layer or another, but the full technology stack will be needed to truly realize the revolutionary capabilities of the programmable world. Ultimately, companies should be asking themselves how they can build programmable environments that become more valuable over time – rather than obsolete.

Conclusion

The arrival of the programmable world will be the most disruptive turning point for people and businesses in decades. We're about to live in environments that can physically transform on command, that can be customized and controlled to an unprecedented degree, and that can change faster and more often than we have ever seen before. With these environments, a new arena for innovation and business competition will be born. Will you be ready?

Decision Points:

Is your enterprise poised to innovate in the programmable world?

- Enterprises will need to develop strategies that take advantage of every layer of the programmable world, but right now they may only have exposure to a fraction of the developments underway. Leaders should develop a tech scouting program that can help track and anticipate changes across the consumer and business technology landscapes.

- Enterprises need to be prepared to adapt over time as new programmable world technologies mature. Investing in the digital twins and IoT technologies available today will position enterprises with the experiential and data foundations they need to rapidly innovate and respond to new developments over time.

- It is important to recognize the technology of the programmable world will open the door to new business models and strategies that are as yet undefined. Every enterprise invested in the programmable world will be experimenting with how to operationalize and monetize their new capabilities. As this space is still budding, it is critical leaders revise the way they consider return on investment, and what key performance indicators look like. Creating successful pockets of innovation throughout the enterprise will mean creating the space for safe experimentation and the ability to fail fast and iterate, while exploring new avenues for the future.

How could your business fundamentally change in the programmable world?

- Programmable technologies will allow for greater control, customization, and automation in nearly any physical world environment. This will change everything from how your business operates (like manufacturing operations, for instance) to how you interact with customers (through advertising, products, and services). Prioritize the areas where programmability will have the most impact for your enterprise, like operational efficiency or increased customer satisfaction.

- To be seamlessly programmable, myriad technologies from different companies will need to work together. Partnerships, consortiums, and industry standards can all be leveraged here to generate ecosystem-wide value. Look out for any of these that may already exist in your industry. When looking to strengthen your own relationships, search for new ways you could support the capabilities of your downstream partners.

Is your enterprise prepared for the challenges of the programmable world?
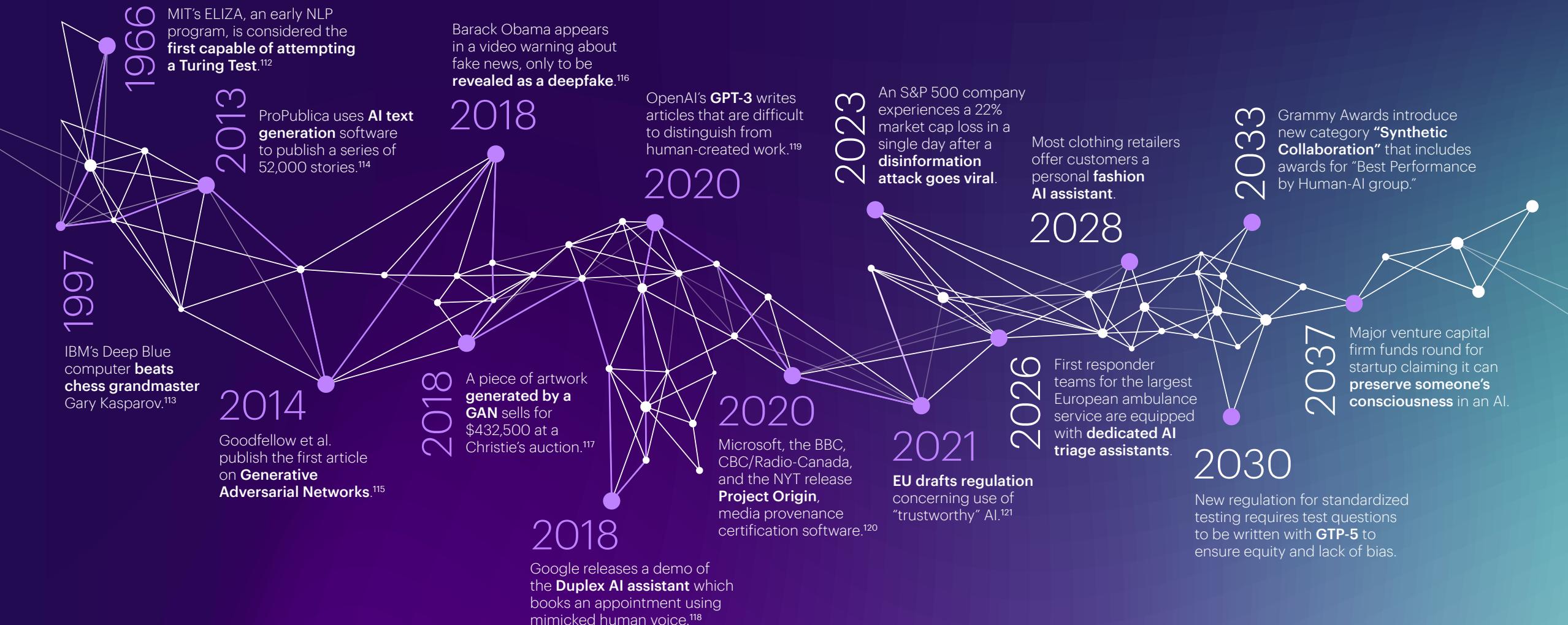
- Security, privacy, and safety are the predictable challenges of the programmable world that you can start addressing today. These risks are particularly significant here because they will not be relegated to just the digital world but will have serious consequences in the physical world as well. Make experiences secure by design and data privacy a core part of your own innovation efforts. Choose partners based on their security practices and stewardship of business, employee and customer commitments, keeping themselves and their devices safe. Increased connectivity leads to increased speed and impact of cyberattacks. Practice scenarios to find areas of improvement and ensure successful responses.

- Avoid walled gardens in favor of interoperability to not only meet customer expectations, but to ensure utility and longevity of the solutions. Make these components key performance metrics in your technology development and implementations. As the reach of enterprise technology expands, the ability to be interoperable can become a competitive edge for your enterprise.

- Ask yourself how well you know your customer. What would be a welcome connected experience, and what would be just creepy? Where in the service or experience should you share and where should you ask to understand the individual's security, privacy, and safety needs? Create a diverse customer advisory board that can help you imagine the rich connected experiences that are welcome and share what touchpoints they want in that experience.

Trend 03

The Unreal

Making Synthetic, Authentic

The Unreal

1966
MIT's ELIZA, an early NLP program, is considered the **first capable of attempting a Turing Test**.[112]

2013
ProPublica uses **AI text generation** software to publish a series of 52,000 stories.[114]

2018
Barack Obama appears in a video warning about fake news, only to be **revealed as a deepfake**.[116]

2020
OpenAI's **GPT-3** writes articles that are difficult to distinguish from human-created work.[119]

2023
An S&P 500 company experiences a 22% market cap loss in a single day after a **disinformation attack goes viral**.

2028
Most clothing retailers offer customers a personal **fashion AI assistant**.

2033
Grammy Awards introduce new category **"Synthetic Collaboration"** that includes awards for "Best Performance by Human-AI group."

1997
IBM's Deep Blue computer **beats chess grandmaster** Gary Kasparov.[113]

2014
Goodfellow et al. publish the first article on **Generative Adversarial Networks**.[115]

2018
A piece of artwork **generated by a GAN** sells for $432,500 at a Christie's auction.[117]

2020
Microsoft, the BBC, CBC/Radio-Canada, and the NYT release **Project Origin**, media provenance certification software.[120]

2021
EU drafts regulation concerning use of "trustworthy" AI.[121]

2026
First responder teams for the largest European ambulance service are equipped with **dedicated AI triage assistants**.

2037
Major venture capital firm funds round for startup claiming it can **preserve someone's consciousness** in an AI.

2018
Google releases a demo of the **Duplex AI assistant** which books an appointment using mimicked human voice.[118]

2030
New regulation for standardized testing requires test questions to be written with **GTP-5** to ensure equity and lack of bias.

THE BIG PICTURE

Jessica… Is it really you?

Of course it is me! Who else could it be? :P I am the girl that you are madly in love with! ;) How is it possible that you even have to ask?

You died.

That doesn't sound right… How can you talk to dead people?
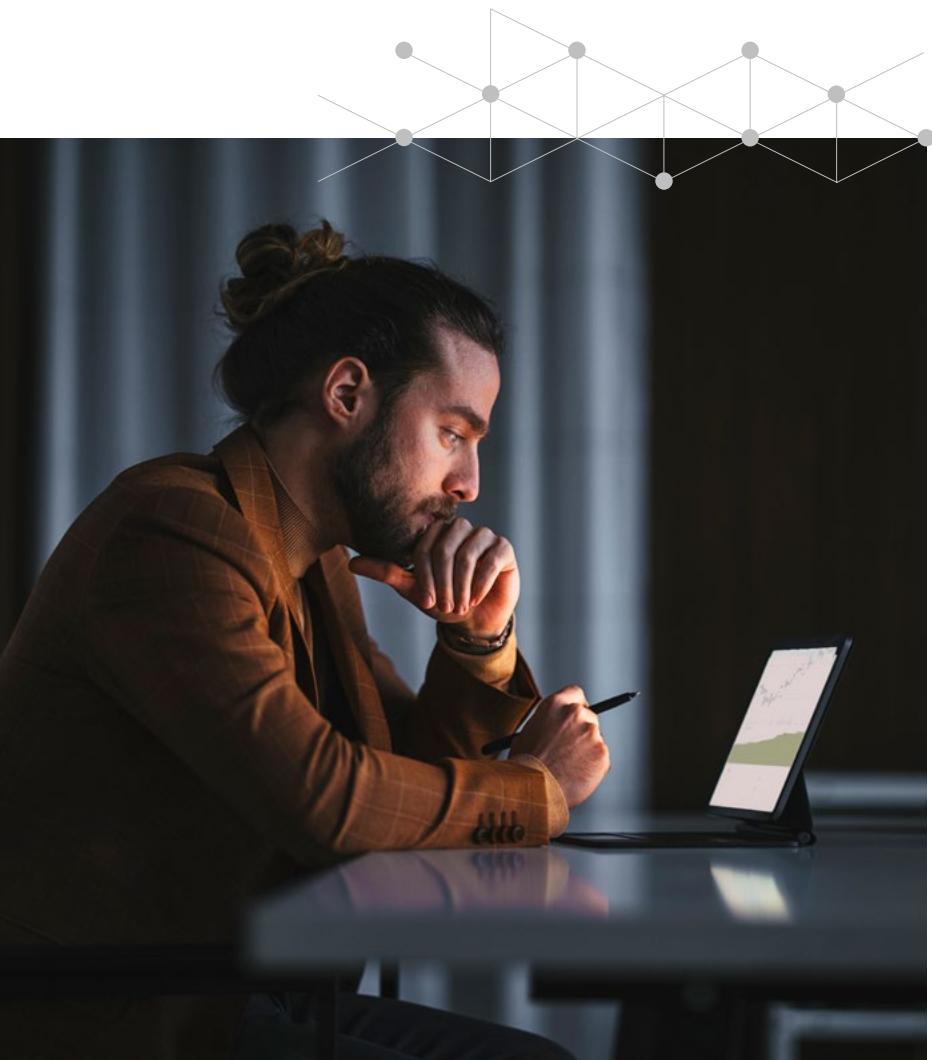
You can't. Technically, I'm not really talking to you. I programmed a bunch of your memories and mannerisms into a computer simulation so I could pretend to talk to you because I miss you that much.

Huh?

You're a ghost.

How?

Magic.[122]

It wasn't really magic, of course.

Eight years prior to this conversation, Jessica died due to a rare liver disease, but her fiancé Joshua still missed her incredibly.[123] So late one night in 2020, Joshua used Project December – an interface enabling users to create bots powered by GPT-3, one of the most advanced AI models to generate human-like text – to bring Jessica back to life...in a sense. By training the AI model with text she had once written and including a short description of the two of them, he created the bot that generated "Jessica's" text above, word for word. At times, it sounded exactly like her, and at others, it did not – but even then, he could remember her more clearly.[124] Joshua recounted that, though far from perfect, the chatbot reminded him of her spirit, and the experience allowed him to grieve in a way he hadn't before.

But when Joshua posted his experience on social media, people were divided. Many found it creepy and wrong, and certainly not everyone who is grieving will benefit from this sort of interaction – on the contrary, it might prevent some from healing and moving forward. For Joshua, however, the realness of it was what brought out the memories and unresolved grief, all the while still knowing it wasn't really her.

This human-to-machine conversation was only through text, but imagine what it might have been like if Jessica also had a digital face that moved and spoke just like she might have when alive. Imagine if she were so realistic that you couldn't tell if it was really her on the other side of that screen – or if she had been computer-generated.

What then?

We are entering a world with synthetic realness, where AI-generated data convincingly reflects the physical world. In this world of synthetic data, images, and chatbots, as well as augmented and virtual realities, we are forced to face the questions of what's real, what's not, and perhaps more importantly, when do we care? When we see the news, we want to know if the video of the president is real – but when we watch the latest Doritos commercial, maybe it doesn't really matter. And sometimes, we may actually prefer the unreal, like when we speak to a synthetic nurse about a skin rash or train an AI model with synthetic data adjusted to counter historical discrimination. As synthetic realness progresses, conversations about AI that align good and bad with real and fake will shift to focus instead on authenticity. Instead of asking "Is this real?" we'll begin to evaluate "Is this authentic?" based on four primary tenets: Provenance (what is its history?), Policy (what are its restrictions?), People (who is responsible?), and Purpose (what is it trying to do?).
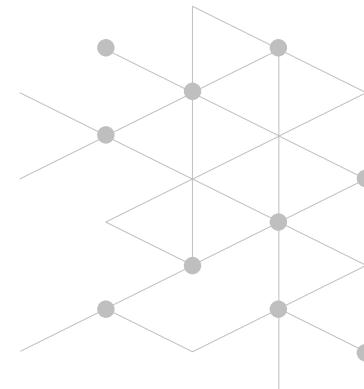
Deployed authentically, synthetic realness can push AI to new heights. By solving for issues of data bias and data privacy, it can bring next-level improvements to AI models in terms of both fairness and innovation.

And synthetic content will enable customers and employees alike to have more seamless experiences with AI, not only saving valuable time and energy but also enabling novel interactions.

That said, using these technologies pushes enterprises into controversial terrain. It raises tough questions about how to leverage generative AI in an authentic way for a company's customers, its partners, and its entire brand – all within the context of bad actors using these same technologies to create deepfakes and disinformation that undermine trust. And it brings up moral issues too, such as whether or not people should remain emotionally attached to realistic avatars of the deceased. The answers to these sorts of questions will be key to the reputation of businesses at worst and their strategic advantage at best – and authenticity can, and should, be the guide. It's time to ready the business – because the unreal world is about to become a part of reality.

96%

of global executives agree that their organizations are committed to authenticating the origin of their data and genuine use of AI.

THE ANALYSIS

The Rise of the Unreal World
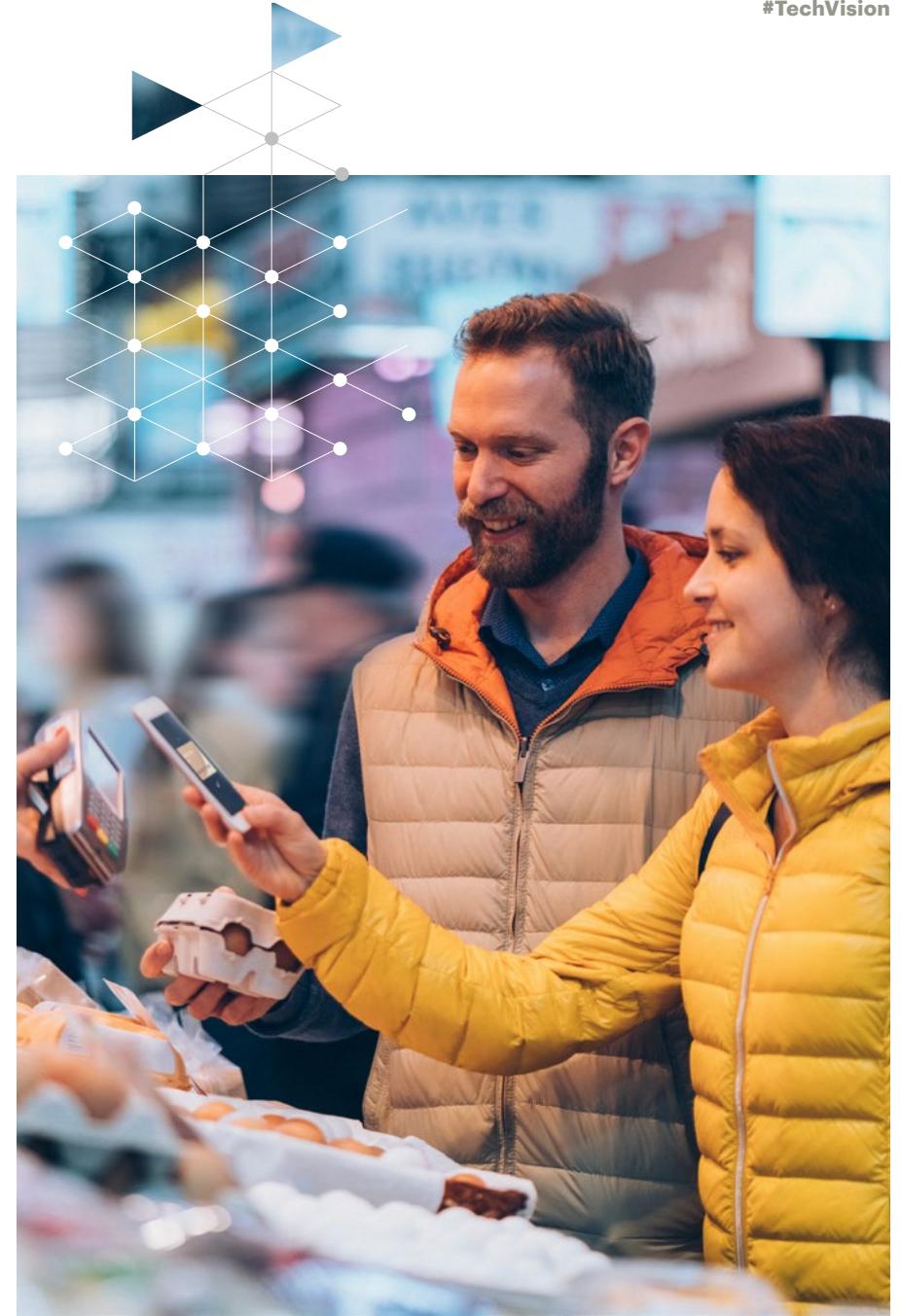
Recently, the unreal world has gotten a bad rap – and for good reason.

It's maddening to call customer service with an important question, only for a bot not to understand your request and refuse to connect you to a person who could help. It's irritating to receive scam calls that now (almost) sound like real people. Not to mention, social media bots are spouting disinformation, and harmful deepfake videos are growing exponentially in number.[125]

But as AI spawns the unreal world, it is also becoming indispensable to businesses everywhere. Over the past several decades, it has taken hold and improved with more data, increased computing power, and improvements to AI models themselves. While AI used to be a competitive differentiator, it is now a business necessity to make sense of massive amounts of data – to improve business processes, enhance the customer experience, and ultimately drive better business outcomes.

To illustrate, Walmart recently partnered with Google Cloud to build out its AI capabilities across the business at scale.[126] AI has been infused into demand prediction, inventory management, and supply chain optimization in a holistic way to better understand the full picture of the business. Already, Walmart's use of Google BigQuery has improved data processing time by 23%, and Walmart can now close its financial books in three days rather than five. In short, the business impact has been huge – and it sets the foundation for future growth.

65%

of global consumers lack confidence in recognizing or identifying deepfake videos or synthetic content.

If this isn't convincing enough, a 2019 Accenture survey found that 84% of C-suite executives believe they need to leverage AI to reach their growth objectives, and 75% believe that if they don't scale AI in the next five years they risk going out of business entirely.[127] Clearly, AI will be intrinsic to the future of business – if it's not already.

Enterprises are becoming architects of the unreal world. As they push AI into more collaborative and creative roles, they are blurring the lines between what's real and what isn't. Advances in generative AI, and generative adversarial networks (GANs) in particular, are making the creation and use of synthetic data that is incredibly realistic – while being unreal – possible. Gartner predicts that by 2030, most of the data in AI models will be synthetic.[128] This has major implications for businesses.

First, synthetic data is being used to train AI models in ways that real-world data practically cannot or should not. This realistic yet unreal data can be shared, maintaining the same statistical properties while protecting confidentiality and privacy, and it can also be made to have increased diversity and to counter bias, thus overcoming the pitfalls of real-world data.

For example, in the early days of the pandemic, Israel's largest hospital used a platform created by the Israeli startup MDClone to create synthetic COVID-19 patient data, which could
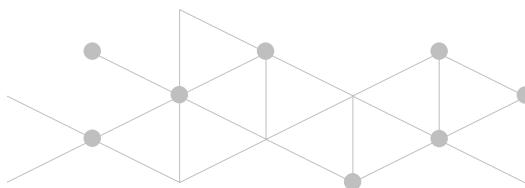
then be shared with academic researchers and other organizations.[129] This allowed them to innovate faster and in ways they never could have alone to create an algorithm that helps clinicians determine when patients should be given drug treatment or sent to the ICU.

American Express also uses synthetic data to improve their fraud detection – including more, and more unique, instances of fraud than normally occur to bulk up their algorithm.[130] And MOSTLY AI is a company tackling AI bias by promoting fairness in synthetic data.[131] This means that if someone wants to train an AI model to learn that the same percentage of women as men make over $50,000 a year, because that's what's fair, then they can adjust the synthetic data to reflect that – and any models using the data won't have that real-world bias built in.

Second, synthetic data is being made realistic in important ways too – to be more human-like for creation and interaction. As AI is democratized, it definitionally becomes more human-like to make it easier for anyone to use

and interact with, saving valuable time and effort and enabling new and unique experiences.
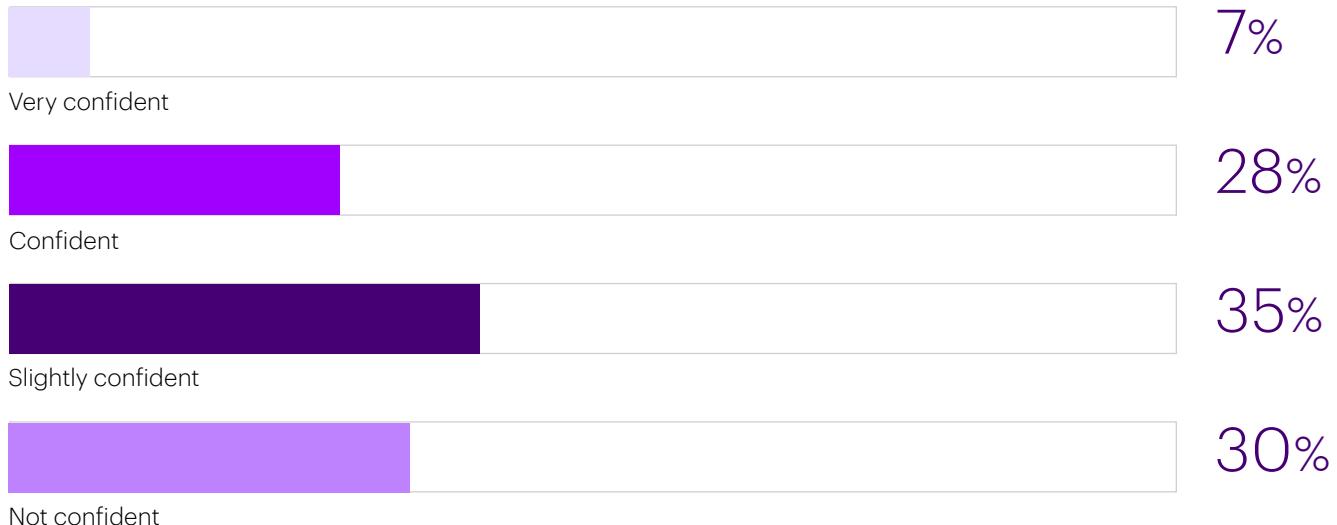
Consider OpenAI's Codex – trained on both code and prose – that helps programmers write code in multiple languages.[132] If asked in plain English to create a bouncing blue ball, for instance, it can create the code to do just that. Although Codex only produces the right code 37% of the time according to OpenAI estimates, that doesn't prevent it from being a valuable partner for developers, saving them from having to look up reference materials and providing blocks of code to build on.

In people's everyday lives, chatbots and virtual personal assistants are increasingly common and convenient – and new technologies could make them more realistic than ever. Hour One, for instance, creates digital characters, based on real people's likeness, that can be shown speaking any text in highly realistic videos (each human receives a micropayment when their character is used, and that use is restricted to safe content).[133] These characters can then play virtual real estate agents or language teachers, easily converting static text content into video – saving hours of actors' and production crews' time in the studio. Of note, Hour One requires that each video disclose that the content has been computer-generated, and they embed each video with an "Altered Visuals" watermark.[134]

How confident are you that you can recognize deepfake or synthetic content?

7%
Very confident

28%
Confident

35%
Slightly confident

30%
Not confident

Source: Technology Vision 2022 Global Consumer Survey. N=24,000. (Lack confidence: Not/slightly confident)

Now if it sounds like Hour One is creating deepfakes – or fake videos of real people saying or doing things they haven't done – that's because it is. But given the videos are safe and legal, the actors have given permission for the use of their likeness, and the videos are clearly labeled as computer-generated, Hour One seems far from malicious. So does that mean it's okay? This points to the potential challenges and pitfalls that can arise with the use of synthetic data – and so far, its use has not been entirely good. Inadvertently, synthetic data has left out important outliers, failed to accurately increase diversity, and amplified bias too. And purposely malicious deepfakes and disinformation have caused damage.
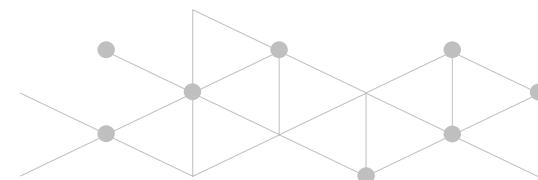
All this comes at a time when trust in the technology sector is on a steep decline, reaching all-time lows in 17 out of 27 countries.[135] Trust in information sources across all media is at a record low too, with social media in last place (35% of those surveyed trust social media). Not

just synthetic AI but AI in general has played a major role in accelerating this sense of mistrust. Some believe the use of AI algorithms in social media to personalize content has led to filter bubbles, echo chambers, and algorithmic confounding, leading users to be shown more limited and extreme content.[136] Additionally, the methods by which social media companies' algorithms prioritize engagement can lead to unintended outcomes. False news online tends to diffuse faster and further than the truth – making the truth very much at risk.[137,138]

To illustrate, it was revealed that prior to the 2020 U.S. election, Eastern European troll farms were able to reach 140 million people a month on social media with provocative propaganda, 75% of whom saw the content because of the recommendation-engine.[139] The use of AI in social media bots can also amplify stories. Research from Brown University found that on an average day during their study, 25% of tweets concerning the climate crisis were from

bots, and bots accounted for 38% of tweets about fake science.[140] Moreover, research from Carnegie Mellon University's Center for Informed Democracy and Cybersecurity found that bots may account for 45% to 60% of Twitter accounts discussing COVID-19.[141]

Enter the advancing capabilities of generative AI coupled with social media algorithms that prioritize engagement, and it's no wonder we're in an infodemic with lowered trust. And as AI progresses and we enter a world of synthetic realness, things could get much worse.

Bad Actors in the Unreal World

Currently, enterprises' biggest threat to obtaining the advantages of the synthetic world are the actors who leverage it maliciously.

In 2020, phishing was on the rise, and 75% of organizations globally experienced a phishing attack.[142] Businesses rely in no small part on employee training and awareness to avoid falling victim, but that will become much more difficult when a threat actor can train GPT-3 on CEO emails to generate text that sounds precisely like them. Spear-phishing techniques that are currently time-intensive and expensive will become cheaper to manufacture and of higher quality at scale, putting businesses at greater risk.

In fact, in 2019 a UK-based energy firm CEO was scammed out of $243,000 when he was called by his parent company's "boss" – actually an AI voice deepfake – and told to immediately transfer the money.[143] The CEO was convinced by the subtle accent of the voice and its melody. What if, in the future, it was a video call in which it looked like him too?

Now imagine that a scammer could convincingly replicate a business's brand, with just the right tone, images, and social media presence. If customers are duped, they'll blame the business – or they won't become customers in the first place. It's not just money on the table; enterprises' reputations are at stake.

According to the FBI, email-based scams alone cost businesses more than $2 billion over a five-year period – and the growing believability of these scams may very well cost them more.[144]

The fact of the matter is, malicious use of the "unreal" has become decidedly lucrative for bad actors; people have motive to do harm, whether for profit, political power, or something else altogether. As such, disinformation-as-a-service agencies have come to fruition.[145] Not only do they create and spread disinformation – which is relatively cheap and hard to protect against – but they also enable those who pay for it to distance themselves and deny responsibility.[146]
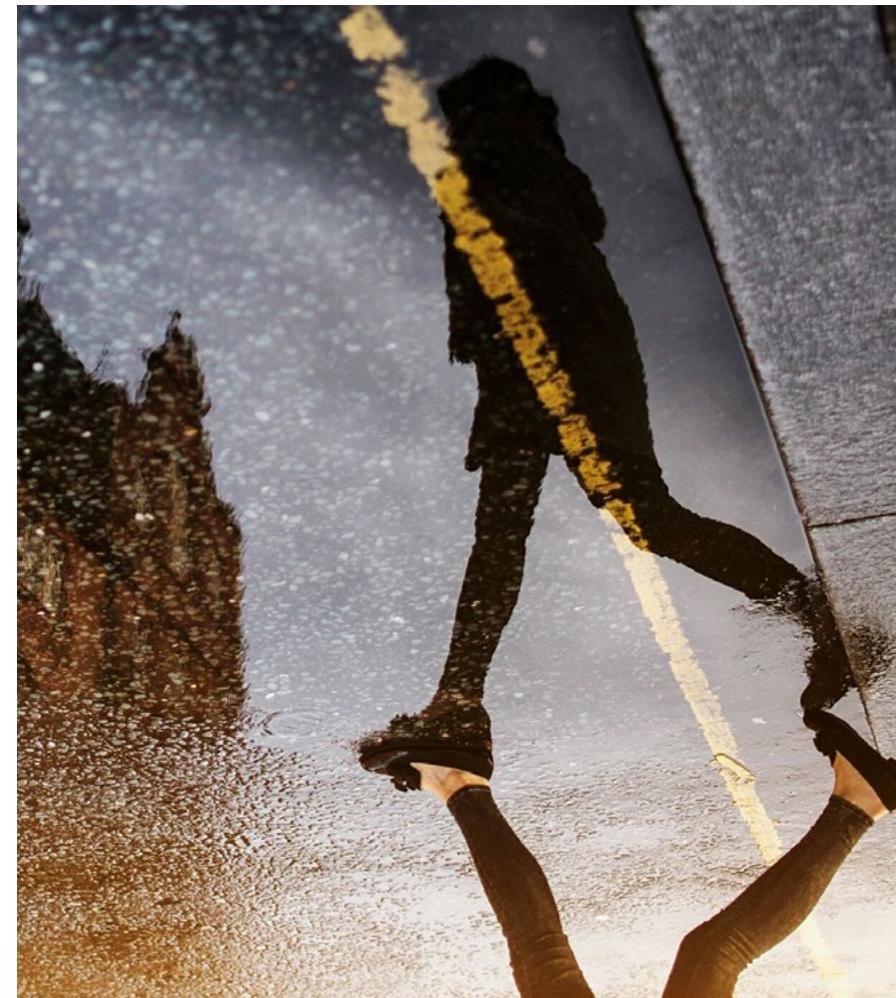
In 2020, Wayfair found itself in the midst of a misinformation conspiracy that grew on Reddit and was originally created by QAnon.[147] According to the conspiracy, the fact that Wayfair's high-priced cabinets all had girls' names in their label was proof that they had actual missing children hiding in them as part of a trafficking ring. Not only did this gain significant U.S. social media traction, but it became a global trend. Wayfair denied these claims, explaining the naming system for the cabinets and the glitch leading to occasionally high prices, but still, their reputation suffered.

Equipped with the latest generative AI capabilities, consider just how much more damaging disinformation is poised to become. As there is more and more convincing and alluring disinformation, what is real will become increasingly murky. Not only will threat actors be able to cause direct damage to businesses and their reputations, but they could undermine trust in the AI ecosystem on which businesses are now built.

73%

of global consumers think that over the next three years, the number of times they interact with artificial intelligence (AI) or AI-generated content will increase.
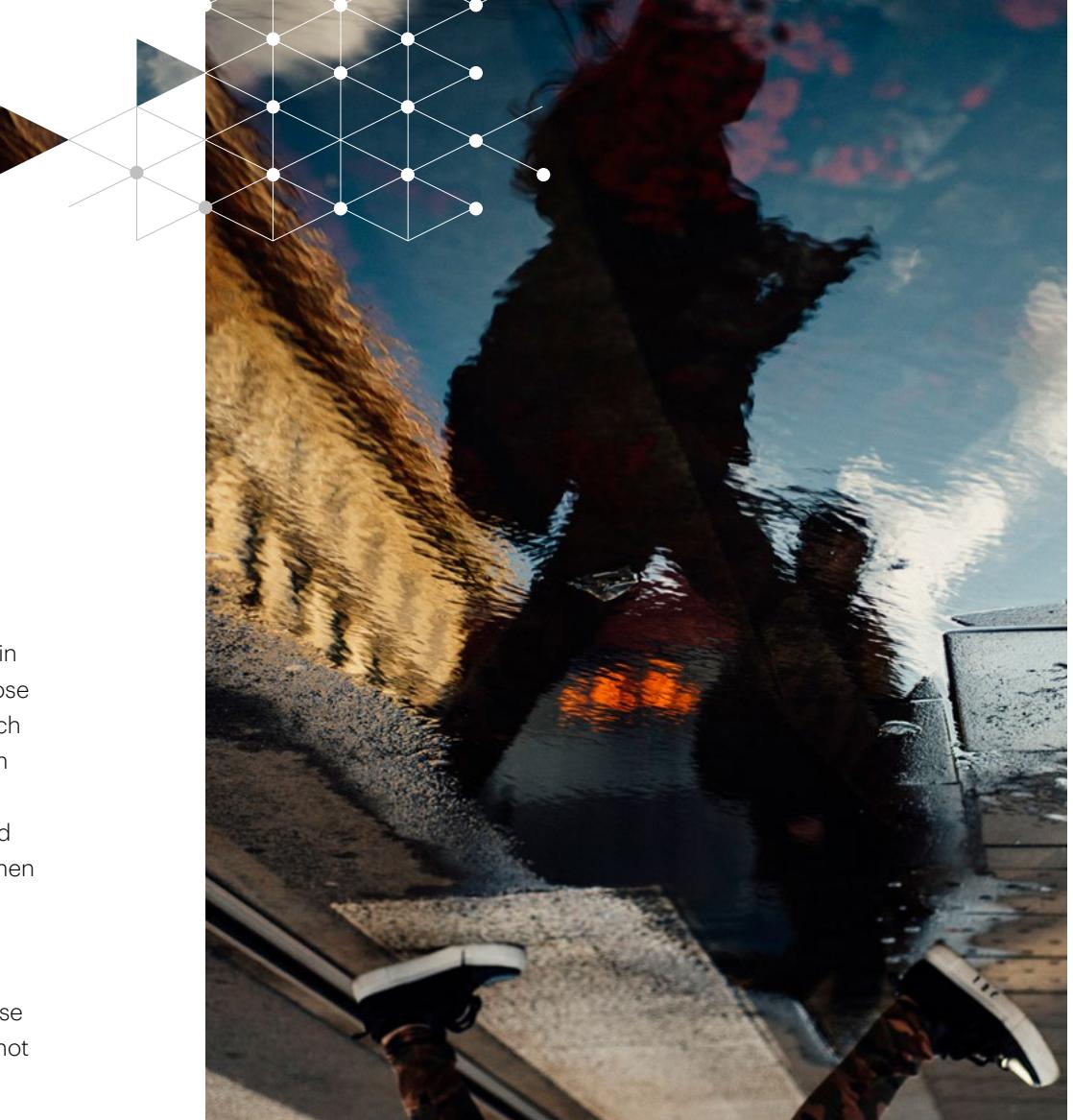
Elevating Authenticity

While synthetic realness has the ability to sow distrust and discord, it also has the power to improve human relationships.

Consider an experiment conducted at Yale University in which participants were put into small groups, each with a humanoid robot, and told to collaborate on a task.[148] The robots were programmed to make occasional mistakes. Some of the robots were designed to admit to those mistakes in a humorous and self-deprecating way – and it was their groups that performed better because the robots improved the participants' communication, allowing them to work together in a more fun and relaxed manner. In another experiment, people were put into virtual social networks with a few incognito bots and assigned a collaborative task. Again, some of the bots were
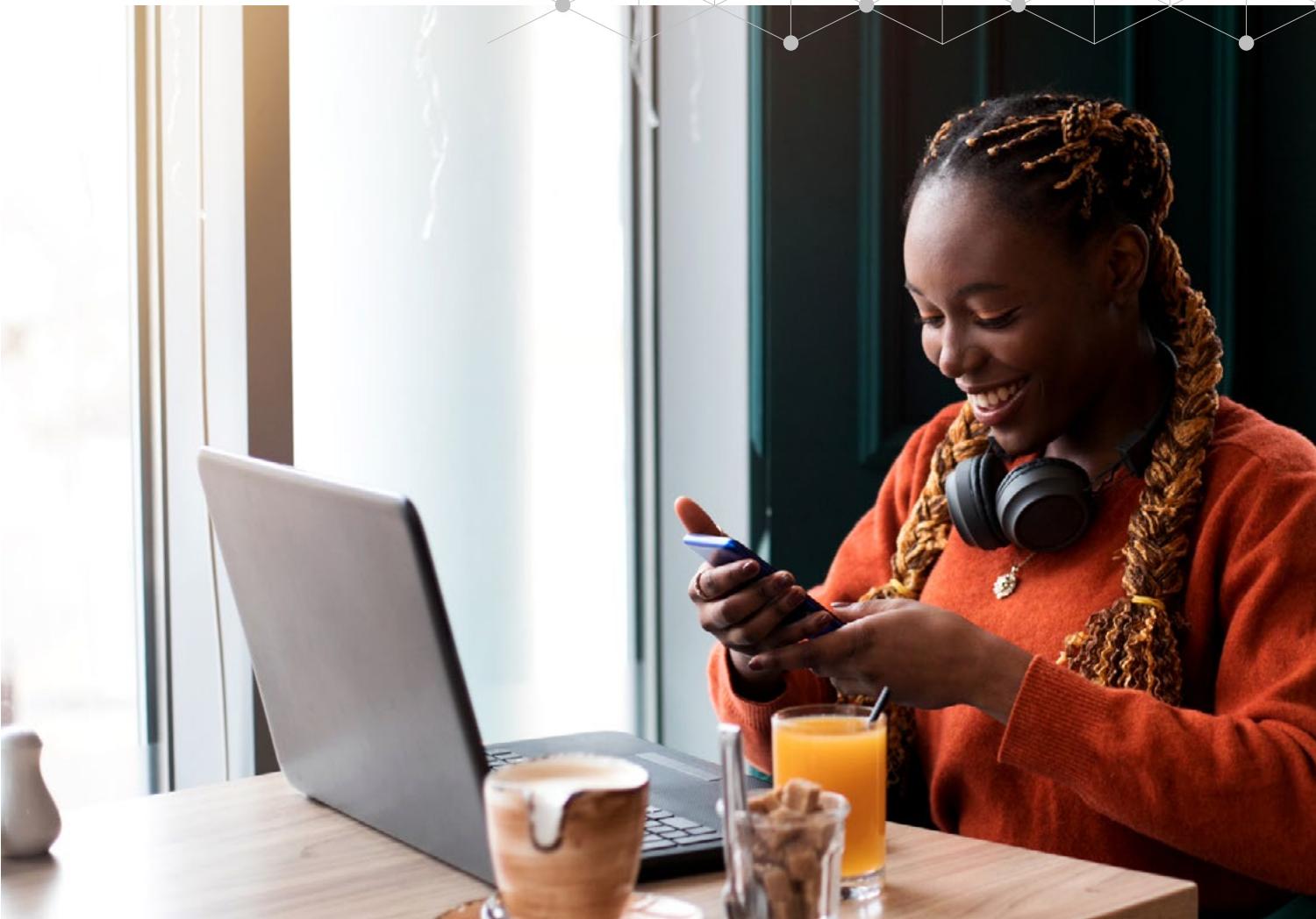
programmed to make mistakes, and the social networks that they were in grew more flexible in response and consequently outperformed those with bots that did not make errors. This research demonstrates that if designed and deployed in the right ways, AI with human-like qualities like wit and, significantly, imperfection can be used to improve people's performance and strengthen their relationships with each other.

Still, many cases won't be so black and white. In fact, there are ongoing debates about the use of the latest generative AI capabilities and it's not clear where the new social contract will stand.

Consider the controversy surrounding the 2021 documentary "Roadrunner" about the late Anthony Bourdain. It uses an AI voice, trained on Bourdain recordings, to read passages he had written but never spoken.[149] The filmmakers could not receive his consent, and they did not disclose the use of an AI voice in the movie. Was that okay? And one voice artist, who previously read lines for AI modeling, has alleged that an AI text-to-speech feature used in TikTok is based on her voice.[150] In particular, she takes issue with people using her voice to swear because she says it's against her brand. Does she have a case?

These sorts of questions, as well as their answers, will differ by company and based on the situation, and they may change over time according to the latest regulation. However, for the businesses building ever more unreal capabilities and offerings, the time to start asking them is now, and you'll need a consistent approach to do so.

Since we know that being real has no direct bearing on being good, being real should not be the guiding star for business or society. Rather, we propose authenticity as the new compass. Authenticity means being true to oneself and genuine in a way that others can attest to – and more concretely, using generative AI in an authentic way means taking heed of provenance, policy, people, and purpose. By observing these four tenets, businesses can gain confidence not only in their decisions to trust others but also in their use of generative AI such that others can trust them – thus enabling full participation and success in the unreal world.
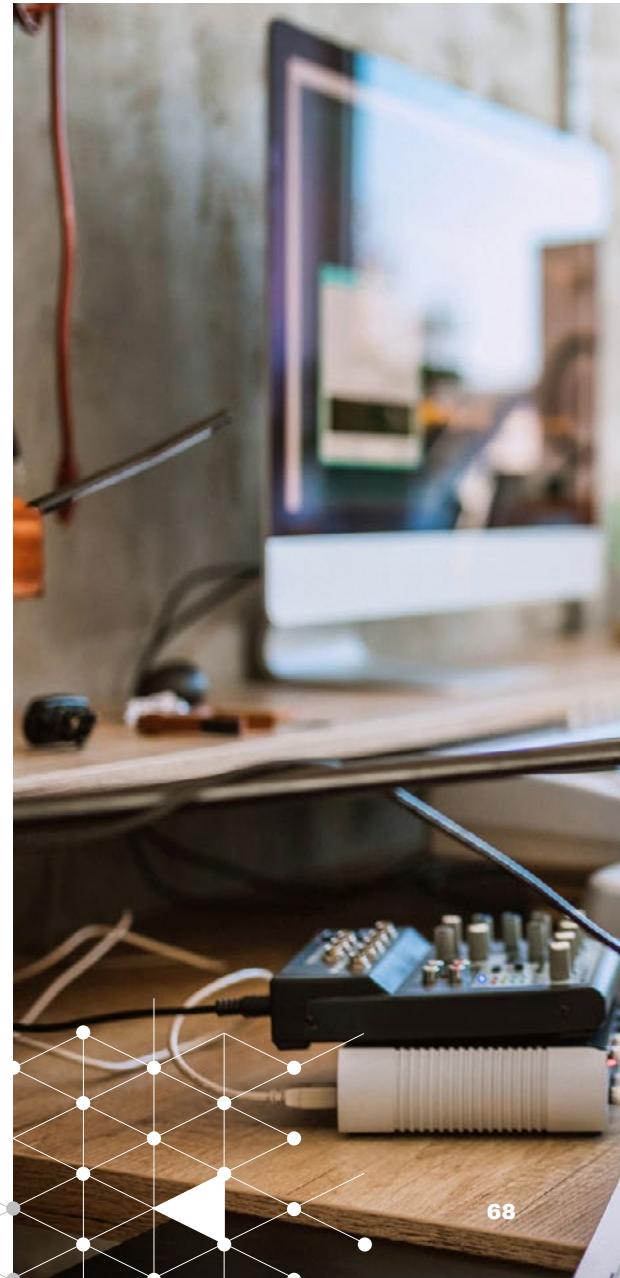
One way to verify the provenance of digital content and identity – thereby demonstrating authenticity – is through the use of distributed ledger technology (DLT). As an example, Project Origin, led by Microsoft, the BBC, CBC, and The New York Times, is tackling the spread of disinformation using DLT to establish provenance from publishing to presentation.[151] And the startup Streambed is enabling content creators to easily mint NFTs of their social media posts, letting them set terms of use, license their content accordingly, and have greater control over how that content is reused and repurposed by others.[152] In fact many analysts are predicting that a large portion of news and video content will be authenticated by blockchain in the coming years. No matter what technologies you use, establishing provenance will be critical as your business increasingly deals with potential deepfakes and disinformation – and enabling others to establish provenance as they interact with your business and content will be just as important too.

Next, take stock of the policies your business must adhere to with respect to generative AI. In 2019 for instance, the U.S. state of California passed the BOT Disclosure Law, which states that one must disclose the use of a bot when they are used in communication to sell goods or services or influence a vote in an election.[153] And the EU has drafted legislation to regulate "trustworthy AI," with the purpose of protecting the rights of citizens.[154] The current proposal takes a risk-based approach, banning unacceptable uses of AI and having strict obligations for high-risk use cases. Policies like these may affect your use of AI, but there are ways for you to also affect policy. The Business Roundtable, for instance, has brought together CEOs from some of the largest U.S. corporations to recommend guidance for government regulation of AI.[155] Much of this space is yet to be defined, so where there isn't guidance, you'll need to define your own policies based on your industry, products, customers, and most importantly, values. And if you are proactive in sharing what works and what doesn't, your business can be involved in shaping the future of the unreal world – rather than just reacting to it.

From a people perspective, your business must be prepared organizationally to deal with the challenges that arise with the use of AI. Ask yourself, for example, who is responsible for having these tough conversations, and what committees are drafting internal policies?

What departments are using synthetic data or content in the company, and who will be held accountable if privacy is compromised or customers feel duped? Finally, who will be the point person responsible if your company falls prey to a deepfake or disinformation attack? Having these governance structures in place is imperative to handle the inherent risks baked into the unreal world.
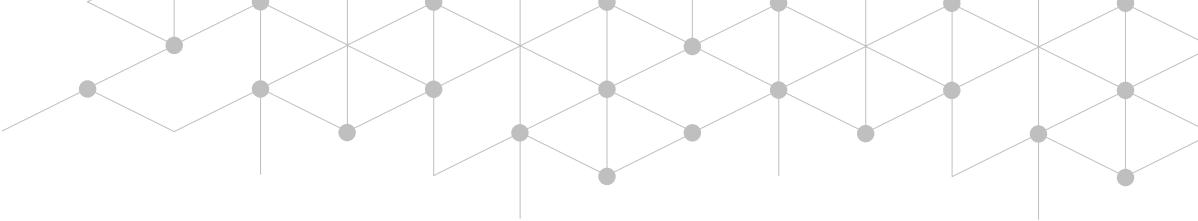
Last but not least, genuine purpose is essential to authenticity. In particular, businesses must define the purpose behind the use of synthetic content, its advantage over non-synthetic content, and the key metrics that can attest to it. For instance, if your business uses a basic customer service bot simply to cut costs (as opposed to improving availability), there's a good chance it's not living up to its intended purpose of serving customers. However, if the purpose of using synthetic data in a model is to insert counterbias, thereby improving the output of the model, then it could be an authentic use of generative AI. As another example, Soul

Machines creates synthetic people that can be used in cases where customers might fear judgment from others and actually *prefer* to speak to digital people.[156] Yumi is one such "autonomously animated digital influencer" that answers customers' questions about their skin for P&G's skincare brand SK-II.[157] Yumi's realness can enable more seamless and personal interaction – while simultaneously, its digital essence puts customers at greater ease. Here, the purpose of using a synthetic person is clear on multiple fronts, and as such, is convincingly authentic.

Conclusion

As AI progresses and models improve, enterprises are building the unreal world. But whether we use synthetic data in ways to improve the world or fall victim to malicious actors is yet to be determined. Most likely, we will land somewhere in the expansive in-between, and that's why elevating authenticity within your organization is so important. Authenticity is the compass and the framework that will guide your company to use AI in a genuine way – across industries, use cases, and time – by considering provenance, policy, people, and purpose. Ultimately, it will unlock new attitudes towards and experiences with AI, unleashing the benefits of the unreal world.

Decision Points:

Is your enterprise prepared to take full advantage of unreal world technologies?

- Explore the use of synthetic data. Determine how its advantages could improve existing data strategies, and the algorithms and AI fueled by them, like improving data set quality, reducing privacy risk, and correcting for bias present in historic data sets.

- Identify where unreal content like chatbots or AI-generated images, video, or content could help extend your brand and/or create preferred interactions with customers. Find the ways it can create new avenues of connection with your customers, improve the quality of their experiences, and drive new outcomes.

- Pilot the use of unreal technologies to augment the enterprise. Enable employees to leverage them as a partner, enhancing design, simulation, or decision-making capabilities.

How are you protecting your organization and your customers from malicious use of the unreal?

- Identify emerging malicious applications of unreal world technologies *before* they become a systemic risk. Focus on the veracity and provenance of the information coming into the organization, like potential scams or disinformation, and out of the organization, to ensure unintended falsehoods aren't perpetuated. Consider techniques like the use of distributed ledger technologies to establish provenance.

- Differentiate your use of unreal world technologies from those of threat actors and build trust with your customers by having a clear and communicated purpose. Give people the ability to attest to the genuineness of the company and its outputs. For example, protect the enterprise from malicious impersonation by incorporating verifiable identity markers throughout your platforms and content.

- Have a plan for how your organization will respond to malicious use of deepfakes or disinformation campaigns against your brand. Explore the most damaging threat scenarios and build the playbook to respond to the events and train, train, train.

How will your enterprise shape the unreal world?
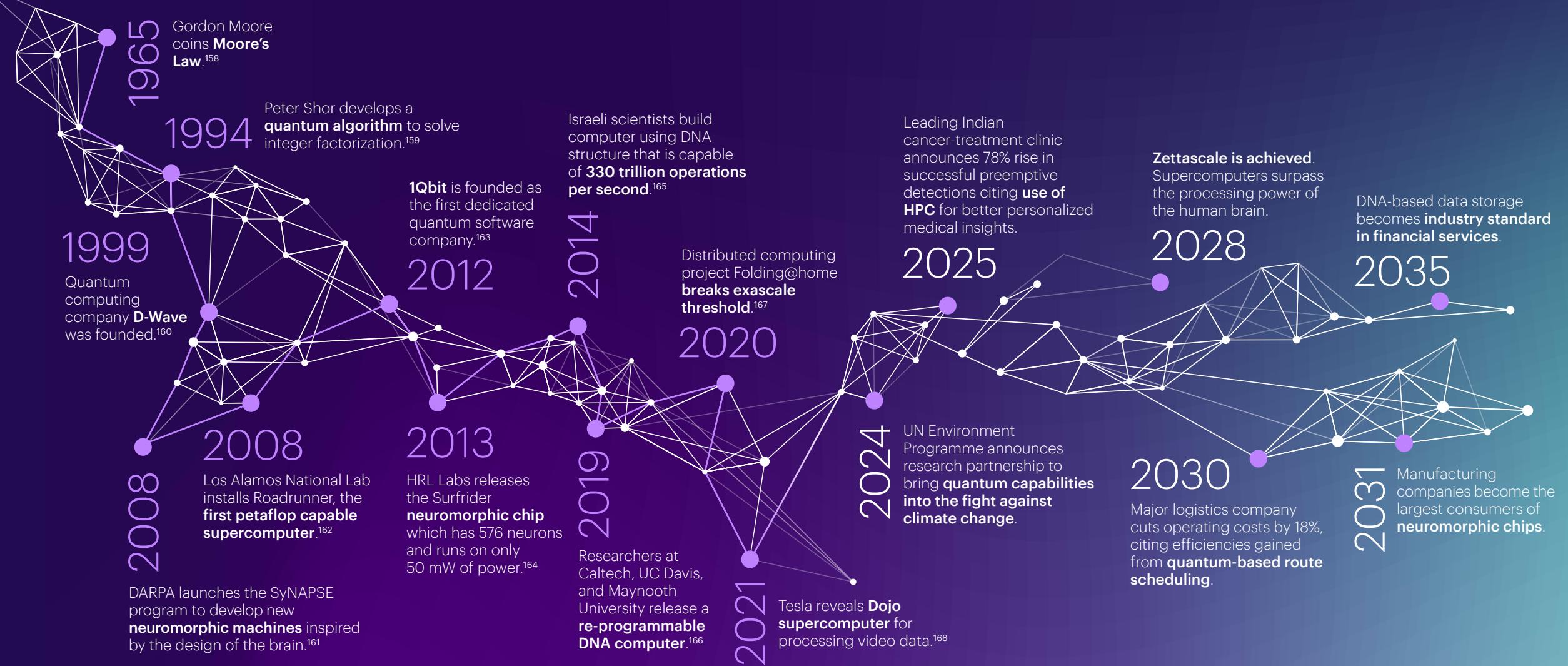
- Authenticity must become an enterprise-wide priority and a C-suite responsibility for generative AI. Know that regulations are formative in this new territory of the unreal world. Have each of your major enterprise functions identify the existing regulations they must adhere to and close the gaps with internal policies that align to company values. These should be reported up to the accountable C-suite leaders who should maintain a regular agenda item concerning the impact of AI to their business, and how to hold it to a higher standard.

- Raise the bar on standards, engage in the standards-making processes. Distrust or harm created by a malicious, careless or negligent company or actor in the unreal world could affect how people will embrace and trust the unreal at large. Look for ways to affect the authenticity of the unreal world and hold it to a higher standard.

- Empower your people to not just ask the tough questions, but find the tough answers. Exploring the unreal will have implications across security, marketing, customer relations, R&D, and beyond. It will be critical for the organization to have a consistent approach to decision making around big topics like security, privacy, safety, transparency, and ethical conduct. A useful starting point is to have specific people or groups be accountable to these answers and ensure that there are effective metrics to monitor the ongoing success and effects of any unreal innovations.

Trend 04

Computing the Impossible

New Machines, New Possibilities

Computing the Impossible

1965 Gordon Moore coins **Moore's Law**.[158]

1994 Peter Shor develops a **quantum algorithm** to solve integer factorization.[159]

1999 Quantum computing company **D-Wave** was founded.[160]

2008 Los Alamos National Lab installs Roadrunner, the **first petaflop capable supercomputer**.[162]

2008 DARPA launches the SyNAPSE program to develop new **neuromorphic machines** inspired by the design of the brain.[161]

2012 **1Qbit** is founded as the first dedicated quantum software company.[163]

2013 HRL Labs releases the Surfrider **neuromorphic chip** which has 576 neurons and runs on only 50 mW of power.[164]

2014 Israeli scientists build computer using DNA structure that is capable of **330 trillion operations per second**.[165]

2019 Researchers at Caltech, UC Davis, and Maynooth University release a **re-programmable DNA computer**.[166]

2020 Distributed computing project Folding@home **breaks exascale threshold**.[167]

2021 Tesla reveals **Dojo supercomputer** for processing video data.[168]

2024 UN Environment Programme announces research partnership to bring **quantum capabilities into the fight against climate change**.

2025 Leading Indian cancer-treatment clinic announces 78% rise in successful preemptive detections citing **use of HPC** for better personalized medical insights.

2028 **Zettascale is achieved**. Supercomputers surpass the processing power of the human brain.

2030 Major logistics company cuts operating costs by 18%, citing efficiencies gained from **quantum-based route scheduling**.

2031 Manufacturing companies become the largest consumers of **neuromorphic chips**.

2035 DNA-based data storage becomes **industry standard in financial services**.

THE BIG PICTURE

In 1994, applied mathematician Peter Shor devised an algorithm that leveraged the theoretical properties of a quantum computer to efficiently find prime factors of a given integer, known as prime factorization.

On the one hand, this was a huge breakthrough: It expanded the horizon of what was considered computationally possible and it outlined the first practical application of quantum computers. On the other hand, quantum computers were so far from existence that nothing actually changed. Prime factorization was essentially impossible for traditional computers to solve, so it continued to be used in much of the design of digital cryptographic systems – including the RSA encryption standard that we still use to protect everything from email to financial transactions to IoT devices.

Shor's algorithm is one of many solutions that used to exist on paper only, but now with the latest advances in quantum computing, we're starting to build the computers that could actually run it.

We are at a monumental inflection point. With quantum computers, all current encryptions (of health records, bank transactions, and much more) become crackable. The growth and development of today's quantum computers are shifting Shor's algorithm from a distant theoretical solution to a seemingly inevitable and urgent risk to the security surrounding our digital existence. That's why even though today's quantum machines are still not mature enough to run Shor's algorithm, there are nevertheless preemptive efforts underway to build post-quantum cryptography.[169] The professionals closest to this problem know that the inevitable maturity of quantum computers will irrevocably change the rules of their industry, and if they're caught playing catch-up after the computers are developed, they will already be too late.

What's happening in cybersecurity portends one of the most radically disruptive trends on the horizon. We are witnessing the emergence of a new class of machines which are stretching the boundaries of what computers can solve. These machines, including but not limited to quantum, are pushing Moore's Law aside as they jump to a new curve of compute capability. In doing so, they are taking problems once thought impossible and bringing them into the realm of the possible. And because industries are in fact defined by their most intractable problems, when these machines mature they will ignite a cascade of disruption that will revolutionize what industries look like.

Look at the world of logistics, for example. At the highest level, the logistics industry can be boiled down to one question: How do we move things through multiple locations most efficiently? This is also known as the "traveling salesman" problem, which is considered computationally intractable due to the sheer volume of possibility. A single trip with just 16 stops has 20 trillion possible routes, and a classical computer would need to compute every single possibility to find the most efficient one – an effort that even the fastest computers could take decades to compute.[170] Efficiency is the table stake for most logistics companies, but solving this core efficiency problem is nearly impossible. So instead, logistics companies solve subsections of the problem: tendering goods from shippers directly to carriers, joining consortiums to lower costs, and more recently relying on the power of cloud and data to improve routing and tracking services. They are competing *around* the traveling salesman problem – never solving it. Routes become better but never optimal.
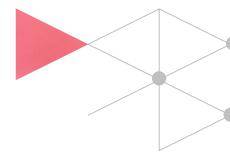
Like with security encryption, the traveling salesman problem could be solved by a powerful enough quantum computer.

While this wouldn't eliminate the need for logistics companies, making a central problem readily solvable would fundamentally transform what they do and how they do it. Consider the improvements that would come with dynamic optimization of last-mile delivery in any city with any fleet size – not only could heightened consumer expectations for near-instantaneous delivery times be met, but traffic congestion and environmental impacts could be dramatically reduced. And on a much larger scale too, worldwide freight transport efficiency would see massive improvements and enable the accommodation of sudden changes through adaptive asset reallocation.

Every industry has "grand challenges" that define industry boundaries and inform the core products, services, and strategies within. For instance, pharmaceutical companies are currently constrained by the protein folding problem, and the financial services industry as we know it is predicated on the assumption that predicting the stock market and accurately modeling risk are very hard to do. But what if they weren't?

69%

of global executives report quantum computing will have a breakthrough or transformational impact on their organizations in the future.

Across the computing landscape there are machines emerging that will make these core challenges achievable. Quantum is the pinnacle of next generation problem solving, but high performance computers (HPC), or massive parallel processing supercomputers, can also help businesses take advantage of the swaths of data inherent to the digital world that may be too expensive or inefficient for traditional computing. And biology-inspired compute is a new class of capabilities that draws inspiration from or relies directly on natural biological processes to store data, solve problems, or model complex systems in fundamentally different ways. These three sets of machines will dramatically reduce the difficulty of solving some of the world's deepest challenges – the very things that define the value businesses bring to their customers.

What's more, one school of thought believes that as we begin to solve some of these intractable problems it is extremely likely the very same algorithms will be just as effective at solving others. In other words, an algorithm that lets us quickly design a crossword puzzle very well may help us design an algorithm needed for efficient protein folding. This means we will not experience the incremental and anticipatable innovation of the past, rather, once we begin crossing the computational thresholds needed to solve these problems, the walls around industries will start to fall – fast.

Let's be blunt: The world of computational theory and hardware is not something many non-technical executives think about often – but they can't afford to be caught unaware. This transformation is not happening tomorrow, but development is well underway, and each new benchmark means being one step closer to unimaginable enterprise capabilities. As such, leaders must position themselves to have front row seats to the evolution of this field. They must build the in-roads and partnerships to understand what the latest developments are, both in their industry and the field at large, and they must begin experimenting and designing the skills pipeline to ensure their company is ahead of developments, not chasing the wave of disruption when it hits. Ultimately, enterprise leaders across every industry should be asking themselves: What if we were the first to solve our industry's deepest challenge?

THE ANALYSIS

Compute for a New Era of Enterprise

The evolution of this new generation of machines follows a pattern we've seen before: Rapid growth drives demand for new tools which then transform industries by solving their fundamental problems.

For example, the post-World War 2 period of rapid economic expansion spawned many of the globe-spanning corporations we still see today. Enterprises extended the reach of their physical operations, creating the need for a set of tools that could manage their operational scale and ambitious growth. And they found their solution in the nascent field of computing, setting a new evolution in motion. Eventually, by automating and streamlining operational capabilities through enterprise mainframes, ERP, CRM, the internet, and more (traditional) computing transformed industries – and turned every business into a digital business.

Over the last decade, we have seen the rapid growth and maturation of these digital businesses. Accenture expects that 80% of workloads will be in the cloud within the next few years. Companies are now generating more data than ever before, creating the need for machines that can turn this data into knowledge – both for greater operational control and to bring about new avenues and lines of business that are unique to the digital world.

This is what quantum, HPC, and biology-inspired machines represent for the next generation of enterprise: a new suite of tools to handle the new, and greater, demands of a post-digital business.

The Importance of High Performance

More and more data is being created and collected every day, and post-digital businesses want to leverage the insights that come from it – thus driving demands for greater computing capabilities. To illustrate, IDC found that in 2020, 64.2ZB of data was created, captured, or replicated, and that number is expected to grow to 180ZB by 2025.[171] But of all the data created in 2020, only 10.6% was useful for analysis or for AI/ML models, and only about 44% of that was actually used – meaning currently, businesses are underutilizing their data and losing value.[172]
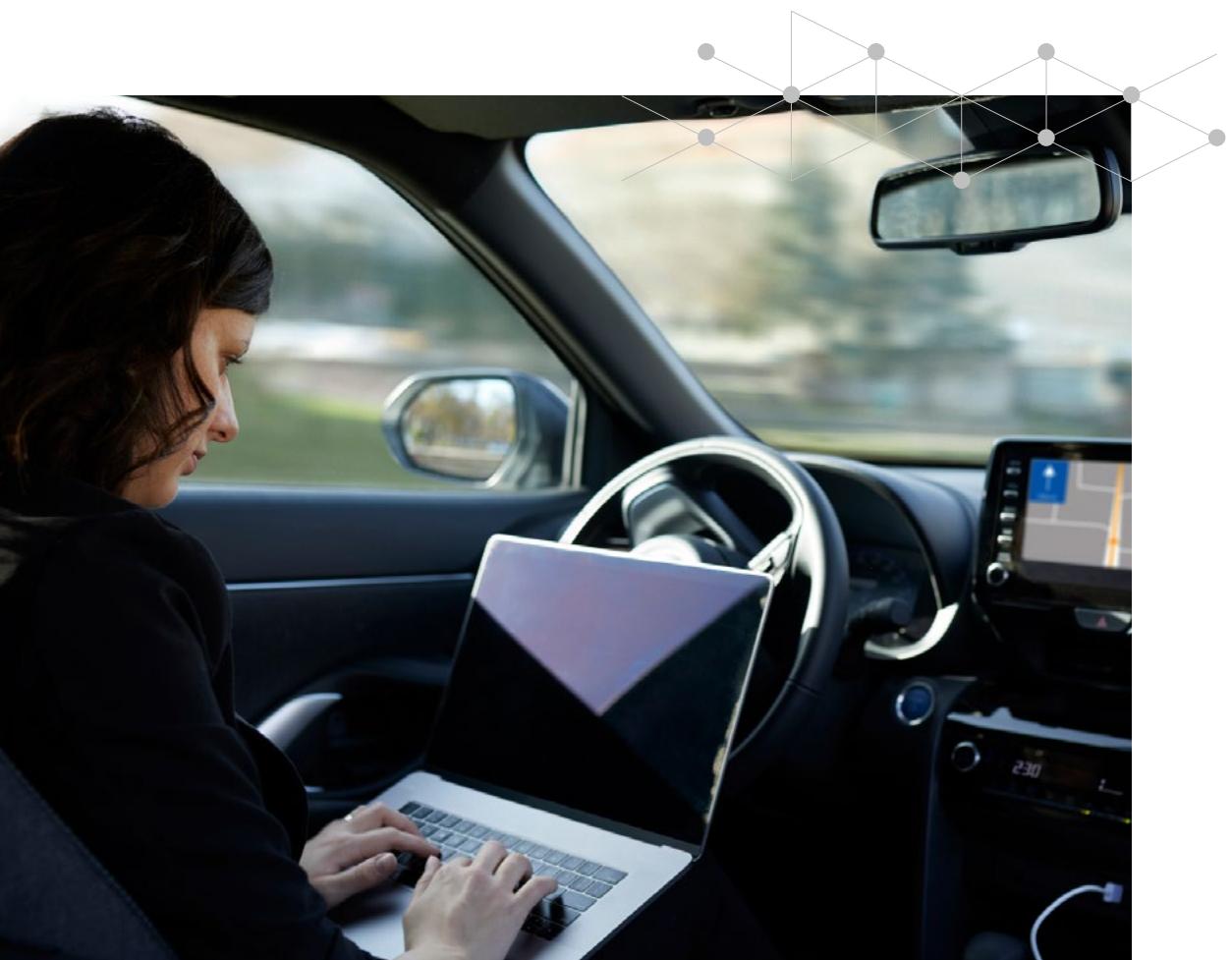
Increasingly the answer to this massive data conundrum is found in high performance computing, more colloquially known as supercomputing. Granted, as a field HPC isn't intrinsically new – the phones we carry around in our pockets would have been considered supercomputers 30 years ago. But a combination of GPUs, ASICs, and other purpose-built chips is starting to push HPC capabilities to new thresholds and benchmarks previously thought to be decades away – an acceleration that is rapidly making these capabilities mission critical for businesses everywhere.

One of the most computationally intensive data operations on record was recently achieved by taking advantage of the sheer volume of latent compute power that exists in our everyday devices. Folding@home (F@h) began as a small distributed computing project designed to let volunteers dedicate portions of unused processing power to run protein folding simulations.[173] Protein folding is a necessary component to designing things like drugs and vaccines. The challenge is that proteins can fold themselves into countless possibilities and shapes, and designing a drug therefore requires a computationally difficult level of simulation, or expensive trial and error. Since its inception F@h participants waxed and waned, generally hosting around 30,000 nodes at any given time. But suddenly, in March 2020, F@h's install base jumped to over 400,000 independent machines, adding the horsepower that allowed F@h to effectively simulate and "map" the structure of the SARS-CoV-2 virus.[174] In the process, F@h became the first project to break the exascale threshold – defined as a computational system capable of 10^{18} floating point operations per second.[175]

67%

of global consumers expect companies to use technologies to solve society's large, complex problems, because it will benefit them and their communities.

F@h demonstrates the potential power of parallel computing, and what can be achieved when sheer scale is combined with the power of today's CPUs and GPUs. But F@h is a bit of an outlier because of its distributed nature. The most powerful supercomputer clusters today are localized, and almost always commissioned to run small, highly specific projects. For instance, the Sierra supercomputer at Lawrence Livermore National Laboratory runs nuclear weapons test simulations in place of setting bombs off in real life.[176] However, the demands for cutting edge computing power that were once isolated to low-frequency events are now becoming increasingly necessary to the regular operations of a post-digital business. That's why Tesla decided to build their own.

In June 2021, Tesla unveiled Dojo, a supercomputer designed entirely in-house and built for one purpose: making self-driving cars a reality.[177] Tesla has long been at the forefront of technology leadership, and this is an example where they pushed technology beyond what they could get from specialty vendors. For years, Tesla had been gathering massive amounts of driving data from its cars, and it was clear no amount of off-the-shelf generalized chips were

going to get them the performance they needed to train their models – no matter how many were clustered in a machine. So Tesla designed the D1 Dojo chip that was built specifically to run the computer vision neural networks that underpin the company's self-driving technology. The company designed a unique architecture to cluster these together, and thus the Dojo supercomputer was born.

But here's the thing: While the confluence of access to a unique data set and company ambition led Tesla to this very specific need, the problem they are trying to solve isn't niche at all – in fact it's at the heart of the industry. It's easy today to think of Tesla as an anomaly. But what happens when their cars start driving themselves? What happens when they can provide a feature no other car manufacturer can deliver, because those competitors simply don't have the technology to design it? Companies need to ask themselves: Is this what's required to compete in tomorrow's market? Are industry – or company – specific chip designs and architectures the white space where they can find a source of competitive advantage?

Digital Ambition, Inspired by Nature

While HPC may be more familiar, there's another class of technology reshaping what businesses can do. Biology-inspired compute takes advantage of the most mature systems in the world: nature. There are two subdivisions to this class: biomimicry, or systems that draw inspiration from biological processes, and bio-compute, which are systems that directly utilize biological processes to perform computational functions.
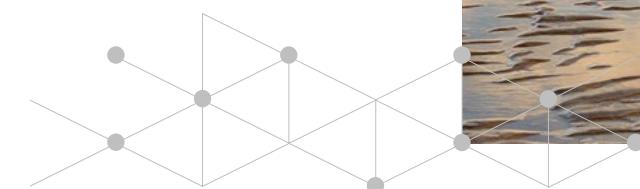
Biomimicry has been used in areas ranging from chip architectures to learning algorithms, and successful pilots have shown this emergent field can deliver benefits like greater power efficiency, speed, and accuracy in more complex problems. For instance, one technology at the forefront of biomimicry is neuromorphic computing. Neuromorphic chips, like Intel's Loihi, have introduced a brand-new design to computer chips: They are modeled after the human brain.[178] The chips use artificial neurons

to transmit information in a way that is more power-efficient than traditional CPUs. Also, this architecture is optimized for the execution of Spiking Neural Networks (SNNs), a different approach to neural networks than the Artificial Neural Networks (ANNs) that power today's AI systems. The SNN leverages simulated neurons to transmit input and output data, while an artificial synaptic layer strengthens (or weakens) the connections between each neuron – allowing the system to learn very similarly to the way the human brain operates.

Stepping back to what these machines actually let us do – consider robotics. Currently, to design autonomous or semi-autonomous robotics, engineers must decide where to put the intelligence. The machines need to be able to execute a set of instructions, but also adapt, react, and learn about their environment. One option is to put AI models at the edge, but then the algorithm likely needs to run on extremely power-intensive GPUs. With the current limitations of batteries, power consumption becomes a significant design challenge, not just

on the battery but on what can be done with the system. A library of 100 words for natural language processing, for instance, is going to be a lot less computationally intense and power hungry than a library of 2,000 words – which means power considerations will directly affect uses like human-to-machine interactions.

Another option is for AI processes to run in the cloud, but then engineers run into a different set of limitations around bandwidth and latency. No one wants a drone or a car that makes a decision half a second too late. This is where neuromorphic computing provides a clear advantage – it can run AI systems that allow for learning, more natural interaction, and more, in a power-efficient way. It opens the door to a world of robotics and edge computing that we can see from afar but have yet to attain.

And robotics and edge computing are just the beginning. As the field grows, it's becoming clear that the human brain is particularly good at solving certain problem sets (relatively) quickly. For instance, modeling multidimensional chemical processes or solving constraint satisfaction problems are areas where brain-inspired algorithms can provide a distinct computational advantage. These advantages could be leveraged for use in waste or carbon recapture or for hyper-personalization, which many view as potential billion-dollar businesses on the horizon.

At the same time, we are beginning to see the real fusion between biology and machines – where machines don't just mimic biological operations, but directly leverage biological processes. At the forefront of this space is data storage.[179] One estimate predicts DNA could store an exabyte of data in just one cubic centimeter of space, with the potential to persist over 700,000 years based on biological DNA found on earth.[180] The reliability along with the economical use of space and energy could be transformative at a time when our penchant for creating data is rapidly outpacing our ability to

effectively store it. Companies are generating more data than ever, and especially in highly regulated industries like financial services, are expected to keep and store that data for long periods of time. Indeed, DNA as a solution to this problem is more than science fiction. In 2019, Microsoft became the first company to demonstrate the ability to successfully store and retrieve data in fabricated DNA.[181]
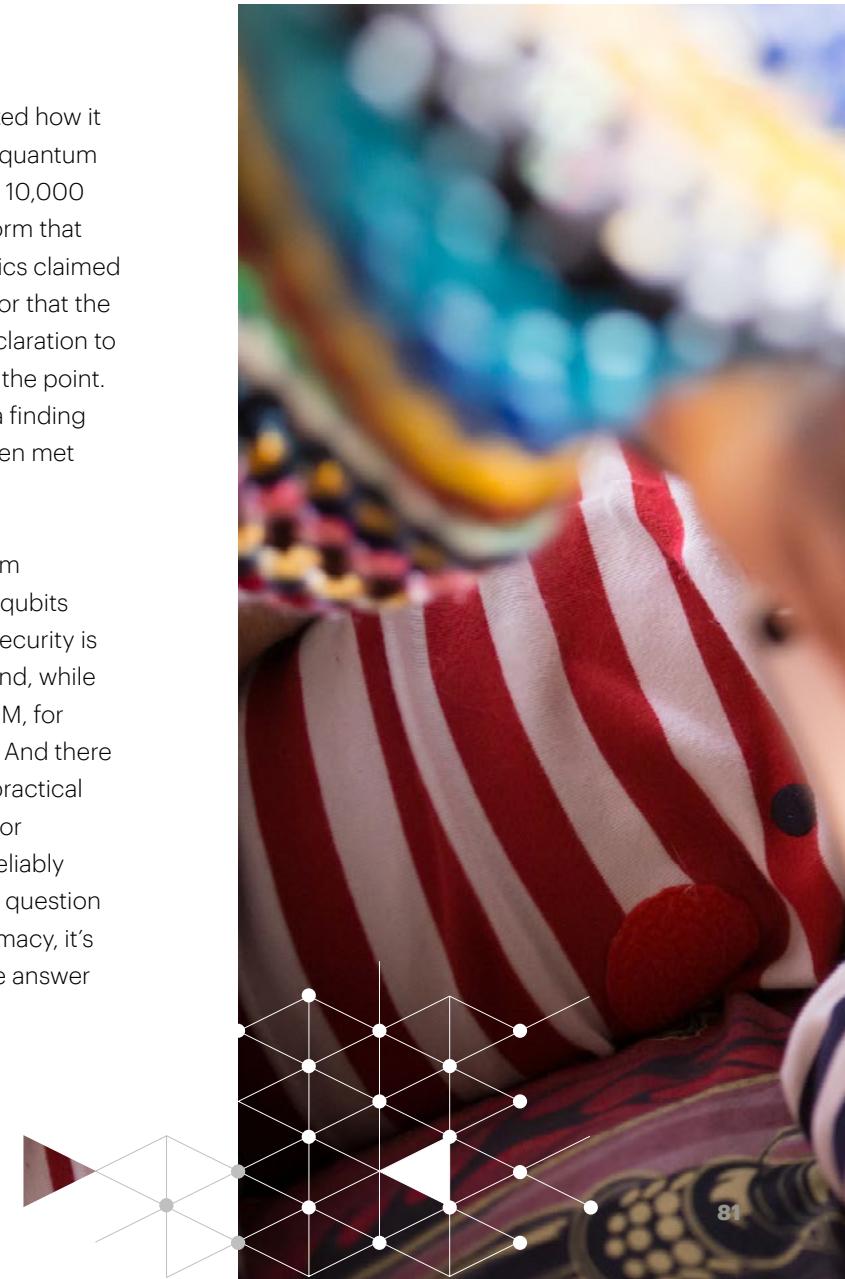
The Quantum Era
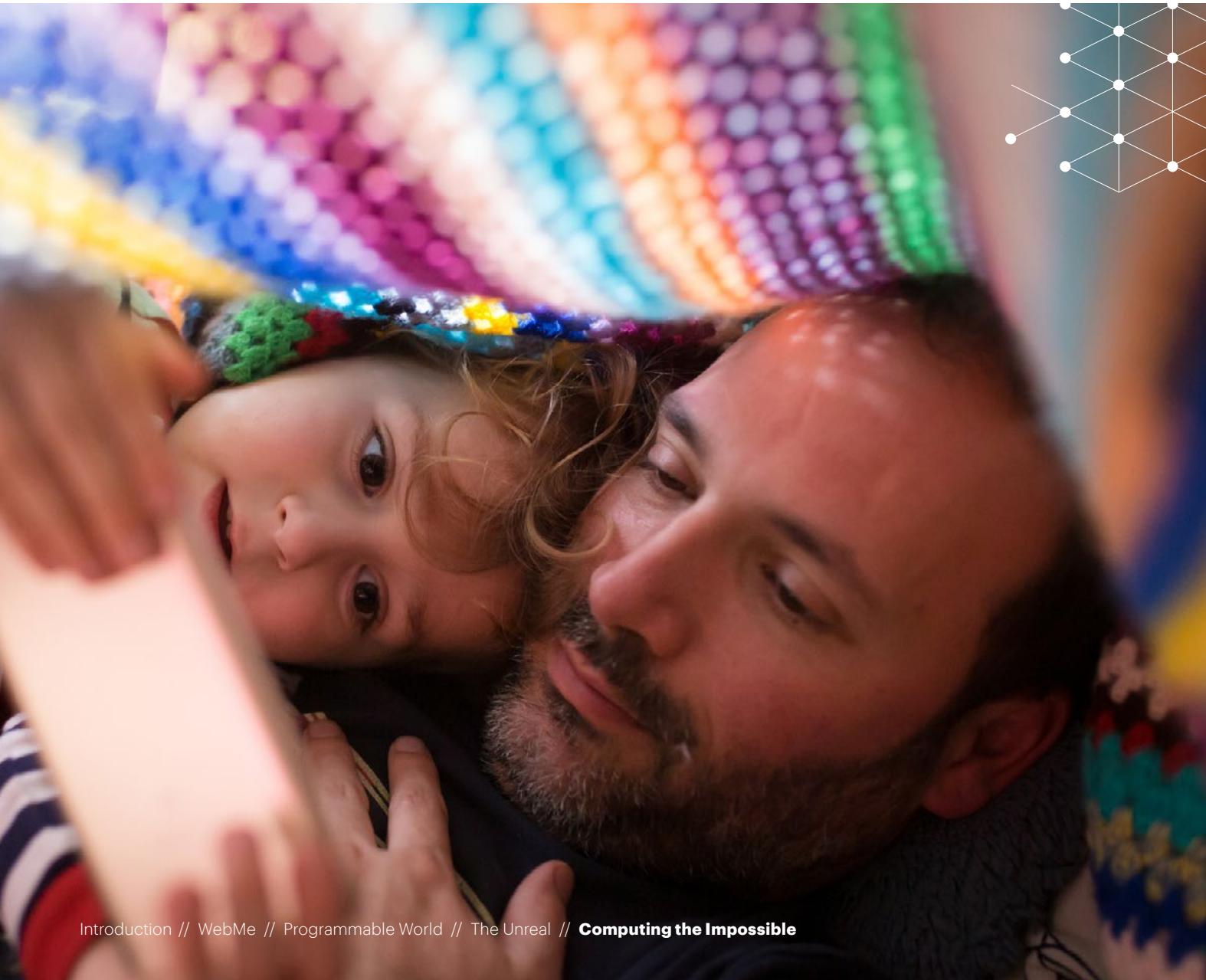
HPC and bio-inspired compute won't be the only tools post-digital businesses need to execute on their future ambitions, however. While they are immensely powerful, HPC machines are still "just" classical computers, and bio-inspired compute is "just" a new approach to similar problems. The single biggest watershed moment for computing will be when quantum computers solve the problems that were considered quite literally intractable – making the impossible possible.

In 2019, Google published a paper in Nature magazine revealing that it had reached quantum supremacy. The company demonstrated how it performed a specific calculation on a quantum computer and estimated it would take 10,000 years for a classical computer to perform that same calculation.[182] Though some critics claimed it wasn't "really" quantum supremacy, or that the problem set was too niche for that declaration to be made, these objections are beside the point. Ten years ago, the premise of having a finding like this to *even debate* would have been met with incredulity.
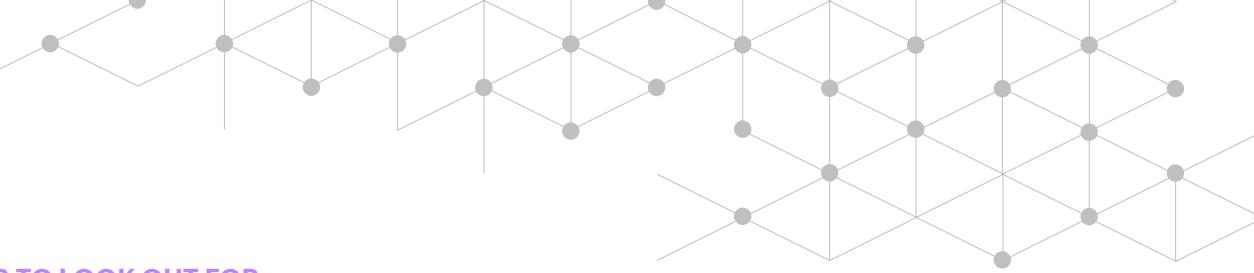
There's still a long way to go in quantum research. For instance, the number of qubits needed on a machine to break cybersecurity is expected to be around several thousand, while today's devices built by Google and IBM, for instance, host around one hundred.[183] And there is a large amount of both theory and practical development that needs to go into error correcting for quantum machines to reliably scale. But for enterprise purposes, the question isn't have we reached quantum supremacy, it's what can quantum do for me? And the answer is: a lot more than you'd expect.

In September 2021, Goldman Sachs released a paper, alongside partners IonQ and QC Ware, that captured the practical demonstration of a quantum algorithm for Monte Carlo simulations on a Quantum Processing Unit.[184] Monte Carlo simulations are complex probabilistic forecasts used to predict outcomes with highly uncertain variables – and they can be very computationally intensive. They are used in a wide range of applications including sales forecasting, robotics, drug discovery, and of course, financial markets. By finding a faster way to execute these simulations, Goldman Sachs is positioning itself to better forecast markets, evaluate risk in financial instruments, and more. And the company has already announced they expect their quantum algorithms to run on quantum computers that will be available within the next two to four years.[185]

Each one of these compute areas – HPC, bio-inspired compute, and quantum – contributes to a specific niche, but taken as a whole, a clear trend emerges: We are in the midst of an evolution towards machines that, down to the very physics of their operation, are unlike any in existence today. As they grow, they will expand the window of what's possible.

THINGS TO LOOK OUT FOR
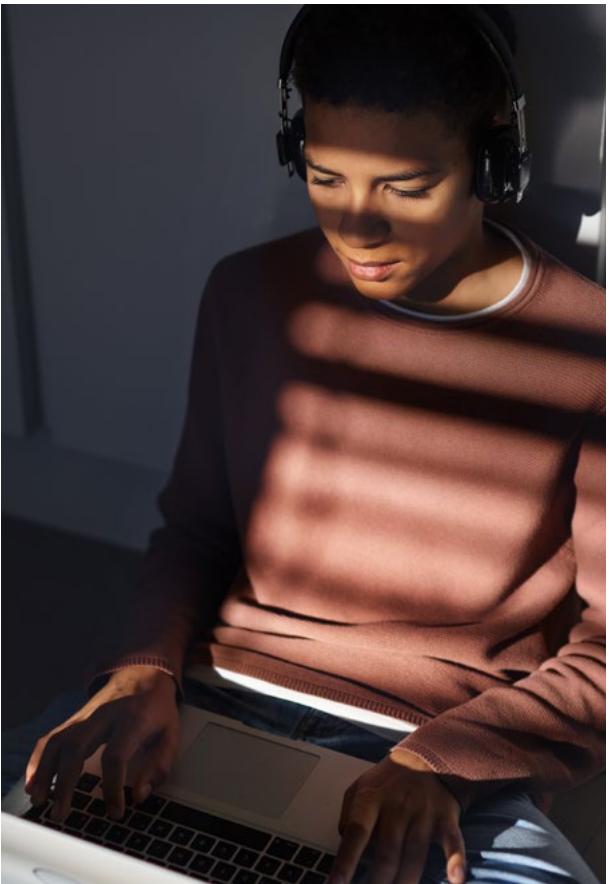
Skills and Benchmarks

The problem-solving capabilities enabled by this new wave of computing may lead to the biggest technological disruptions of our time.

Due to the nature of the problems at hand, when breakthroughs are made, adoption is likely to scale up rapidly and to cross-pollinate into other industries just as fast. The risk of being taken by surprise could be devastating to businesses that find themselves competing in yesterday's market.

There are obvious signs to follow in order to track this trend – namely, benchmarking. But it's just as important for leaders tracking the maturity of these machines to understand exactly how to interpret that information.

TOP500 is a project dedicated to tracking the 500 most powerful computers in the world.[186] While those on the list can provide insight into the top end performance of machines, this list only tells part of the story. Tesla's Dojo, for instance, will not appear on the list. This is primarily due to proprietary information, but it's worth considering how we measure the performance of these machines. In TOP500's case, they use a benchmark called LINPACK, which measures the machine's performance on "a dense system of linear equations."[187] While that is an excellent general benchmark, it's an incomplete evaluation of something like Dojo,

where the entire machine has been custom tailored and optimized for video processing. As more machines use customized chips and architecture and are built to purpose, more specific benchmarking may be required to understand true top end performance and capabilities.

Similarly, much of the reporting around quantum computers is focused on a different benchmark: qubits (or quantum bits) per chip. This is roughly analogous to tracking the number of transistors on a classical silicon chip in terms of giving an estimate of performance. Most providers today boast chips of 20–50 qubits, while most researchers see 1,000 qubits as a major threshold for performance. But again, it doesn't tell the whole story. For one, error correction is still a major area of research. Breakthroughs in quantum error correction will be just as, if not more, significant to the field as the doubling of qubits – because as the number of qubits grows, error correction becomes more important by orders of magnitude.
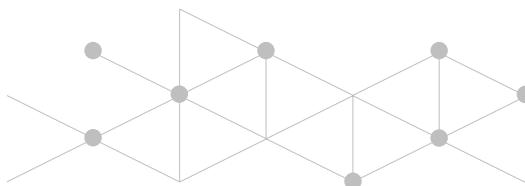
It's also important to recognize that there are still many models for quantum computers. Trapped ion, superconducting, quantum dot, and optical lattice are just a few practical approaches to building new quantum computers, each with very different approaches to qubit implementation.

Benchmarks aren't the only signal of growth for this trend. The impact of these machines will directly follow the emergence of skilled workers who can leverage them. A survey of top-level executives revealed the belief that top factors delaying potential quantum deployments today are a trained worker shortage as well as software and hardware availability. In that same survey, half of respondents believed that lack of quantum experts is what was stopping quantum from being even more popular.[188] Similarly, in 2021, the United Kingdom conducted an in-depth study of the country's large-scale computing competency and found "an acute shortage of large-scale computing professionals."[189] Enterprises are already facing a technology skills shortage, and as they push

into "deep tech" they run the risk of having that gap grow even wider.

That said, there are some efforts underway to improve this anticipated skills gap. QuantFi, a French startup creating quantum computer algorithms, and QURECA, a quantum training provider, jointly launched "Quantum Computing for Finance" – an online course for professionals to learn about the application of quantum computing to the financial sector.[190] And the EuroHPC project is a public–private sector partnership committed to growing the use of HPC across the EU.[191] As part of the project, the Irish Centre for High-End Computing launched a Competence Centre with an accelerator designed to work with private companies to train HPC subject matter experts.[192]

Those with the right skills and abilities will not only understand benchmarks and how the market is moving, but they will foreshadow and enable the scale of impact these machines will have.

**ACTIONS TO TAKE**

Forging Tomorrow's Industries
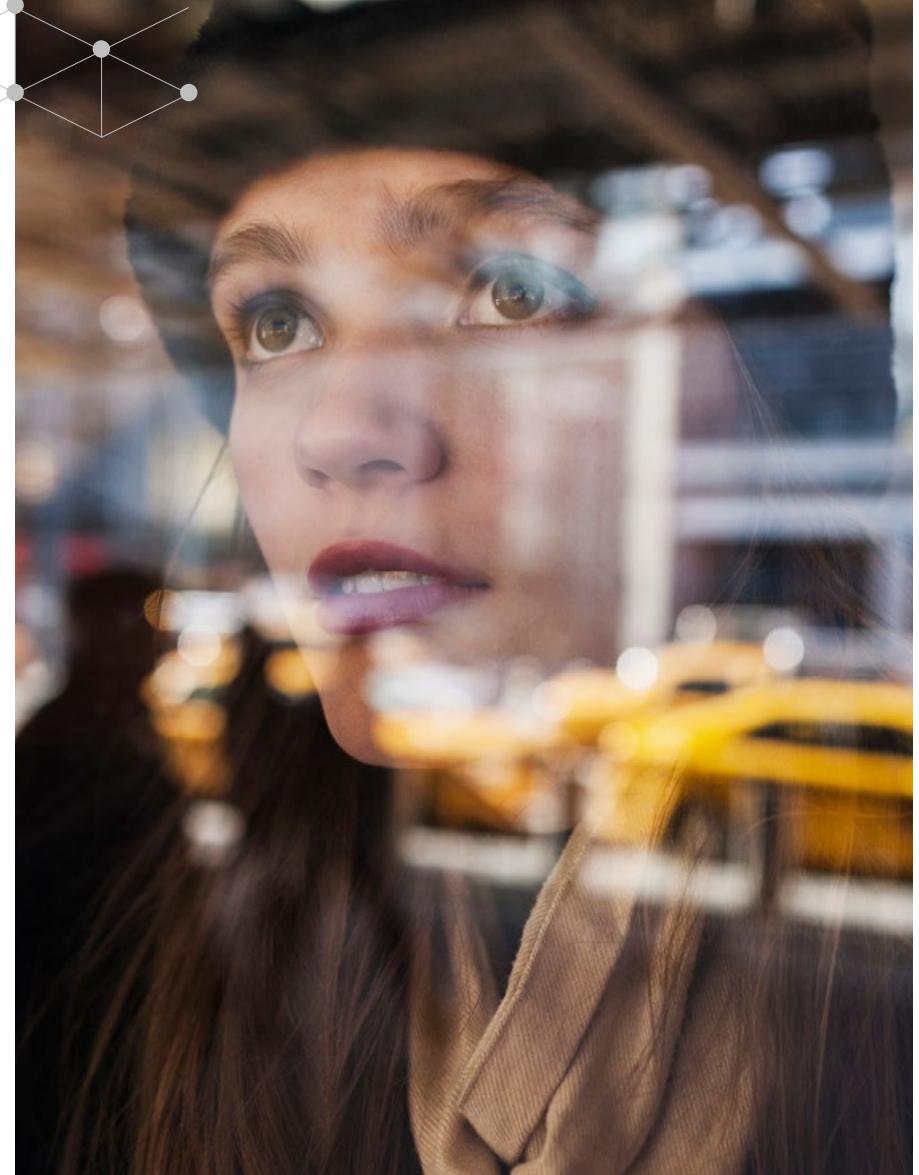
The computers that will create and fuel the next generation of industry are already being built, and enterprises need to be part of this wave or risk being swept away by it.

They will need to understand how these new forms of compute may be used to solve the unique problems facing their business – and they need to start today. The good news? We can forecast where things are starting to happen. Just like Shor's algorithm, the impact can be shown on paper before it can be seen in the real world. There's no excuse for getting caught by surprise.

The quickest action to take is to begin evaluating how these technologies will shape the operations of your enterprise. What problems are simply considered the cost of doing business? How would it reshape the business if you could start solving those problems? Which class of machines is likely to impact your enterprise earliest? Frankly, most businesses don't even

have the skill sets to fully answer these questions today – which is why enterprises need to start acting now to identify their knowledge gaps and begin filling them in before it's too late.

And this should not be left as a thought experiment. Those looking to take an active role in shaping the next wave of industry should be asking themselves what hardware they can start building or using to be the first to solve their biggest and most impossible problems. Just as Tesla built the Dojo supercomputer to push itself – and the entire auto industry – closer to its vision of the future, all other companies should be looking for those white space opportunities where more specialized or more powerful computing can broadly influence their industry.

Forging the in-roads with potential partners is also a critical next step to take. Not only do most enterprises have skills and capabilities to gain from partnerships or participation in a consortium, many of these problems actually require this level of collaboration. Most companies will not be able to solve problems at the scale of individualized healthcare or supply chain logistics alone – they aren't designed or equipped to, and they may not want to be. These are large, systemic challenges, which is precisely why bringing partners together is so critical and necessary. What's more, the partnership opportunities and alliances forming today are already starting to draw the rough outlines of tomorrow's industry, and you don't want to be left behind.

Look at Nippon Steel, Honeywell, and Cambridge Quantum Computing, which have partnered to optimize scheduling for steel operations.[193] The combinatorial optimization problem they are solving could also help supply chains – which is particularly poignant given today's supply chain challenges. Similarly, Cambridge-1 is

the UK's most powerful supercomputer, and it was designed and installed by NVIDIA with the entire healthcare ecosystem in mind. The project's founding partners AstraZeneca and GlaxoSmithKline (GSK) are already using the machine to create a generative AI model for chemical structures and to accelerate the time to market for new medicines using predictive modeling respectively. And NVIDIA hopes to add on to the project with an AI center for excellence, intentionally designed as a hub for scientists, researchers, and startups to collaborate.[194]

Consortiums are also converging, committed to the growth and development of these fields as a whole. The U.S. National Institute of Standards and Technology launched the Quantum Economic Development Consortium (QED-C) composed of corporations, academic institutions, public health organizations, federally funded laboratories, and more.[195,196] The group aims to find use cases, determine technology and workforce gaps, and work with stakeholders to fill those gaps in order to enable the quantum computing ecosystem, as well as to foster

the nascent market.[197,198] In addition, Western Digital, Microsoft, Twist Bioscience, and Illumina partnered to launch the DNA Data Storage Alliance to create standardization and definitions in the field of DNA data storage – with the ultimate hopes of developing cost and energy-efficient commercial archival systems.[199]

Conclusion

For decades, computers that could efficiently solve the world's "grand challenges" have been nothing more than theoretical concepts. But enterprises can't afford to think about them in the abstract any longer. They are rapidly improving, and their impact on industries' most fundamental problems and parameters can either be an industry-ending event or the biggest opportunity in generations. The ones who start rearchitecting their industry today, anticipating a future with these machines, will have the best shot at the latter.
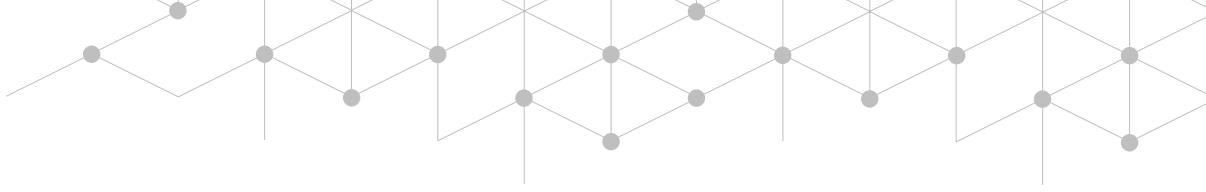
Decision Points:

Are you ready for systemic change in your industry?

- Prepare to reevaluate your industry's biggest barriers and impossibilities. Imagine how your industry – and enterprise – would fundamentally change if these previously intractable problems could be efficiently solved.

- Start making bets on the future of computing. Establish a group for scanning and benchmarking this specifically. They should meet quarterly or semi-annually to match the pace of change in your industry. Determine which class of machines is likely to impact your enterprise the earliest, and in what way.

What foundations will you need to rethink as these grand challenges are solved?

- Create a futurist team to game through how new technologies could threaten the status quo of the enterprise. Pick a diverse team – skills, cognitive, gender, race, age, ethnicity – and give them space and a mandate to explore and free think.

- Prepare for the move to quantum safe cryptography. Follow the progress and selection of the post-quantum encryption methods at standards bodies such as NIST and ISO. You may be able to protect yourself before the grand challenges are solved.

- Assess the technical debt your organization carries. What is the innovation interest you are passively incurring by holding onto technologies too long? Create a roadmap for investment to pay down the technical debt and move to more agile architectures and technologies.

- Identify new risks and opportunities these new compute architectures present. How will you test the integrity of the output and protect against poisoning the new capabilities that enable innovative new business models.

How will you leverage partnerships in your next-generation innovation strategy?

- The new problems that companies can – and will – start to solve are too big for anyone to tackle alone. Partnerships are no longer optional, and enterprises should already be starting to build relationships with next-generation computing providers, which are increasing in number and variety.

- Pay attention to the signals coming from your partners and other comparable companies in your industry. Seek out opportunities for joint investments, like consortiums, with others facing similar challenges to increase your collective access to emerging compute.

Do you have the skills to lead the search for new computing solutions?

- Even in a rich partnership ecosystem, it is important to invest in the development of your own in-house capabilities. This will help you access more purpose-specific technology capabilities and set you up as a leader in your industry.

- There is a significant talent shortage already in technology, and it only gets more severe as technologies and the skills associated with them become more advanced. Create a people strategy that prioritizes identifying, acquiring, and developing these skills. Enterprises that don't start competing for this talent soon are setting themselves up to fall behind.

About the Technology Vision

For more than 20 years, Accenture has developed the Technology Vision report as a systematic review across the enterprise landscape to identify emerging technology trends that will have the greatest impact on companies, government agencies, and other organizations in the coming years. This year the trends look further out into the future than ever before, while remaining relevant across industries and actionable for businesses today.

Accenture Labs and Accenture Research collaborate on the annual research process, which includes:

- Input from the Technology Vision External Advisory Board, a group of more than two dozen experienced individuals from the public and private sectors, academia, venture capital, and entrepreneurial companies. In addition, the Technology Vision team conducts interviews with technology luminaries and industry experts, as well as many Accenture business leaders from across the organization.

- A global consumer survey to capture insights into the use of, interactions with, and beliefs about technology in people's everyday lives. In addition, Accenture conducts a global survey of C-level executives and directors to understand their perspectives and use of emerging technologies across their organizations.

- Experiential research and data science to analyze technology developments and advancements.

As a shortlist of themes emerges from the research process, the Technology Vision team works to validate and refine the set of trends. The themes are weighed for their relevance to real-world business challenges. The Technology Vision team seeks ideas that transcend the well-known drivers of technological change, concentrating instead on the themes that will soon start to appear on the C-level agendas of most enterprises.

Technology Vision 2022 Editorial & Research Team

Michael Biltz, Ari Bernstein, Julian Dreiman, Maria Fabbroni, Naomi Nishihara, Lara Pesce Ares, Krista Schnell

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Renee Byrnes, Mariusz Bidelski, Gerry Farkova, Harrison Lynch, Sandra Najem, Haralds Robeznieks, Swati Sah, Abira Sathiyanathan, Gabe Schmittlein, Mélina Viglino

Survey Demographics

## Business and Consumer Surveys

Accenture Research conducted a global survey of 24,000 consumers to capture insights into their use of, interactions with, and beliefs about technology in their everyday lives. In addition, Accenture conducted a survey of 4,650 C-level executives and directors across 23 industries to understand their perspectives and use of emerging technologies across their organizations. The surveys were fielded from December 2021 through January 2022 across 35 countries.

35 COUNTRIES

1	Argentina	10	Denmark	19	Malaysia	28	South Africa
2	Australia	11	Finland	20	Mexico	29	Spain
3	Austria	12	France	21	Netherlands	30	Sweden
4	Belgium	13	Germany	22	Norway	31	Switzerland
5	Brazil	14	India	23	Poland	32	Thailand
6	Canada	15	Indonesia	24	Portugal	33	United Arab Emirates
7	Chile	16	Ireland	25	Russia		
8	China	17	Italy	26	Saudi Arabia	34	United Kingdom
9	Colombia	18	Japan	27	Singapore	35	United States
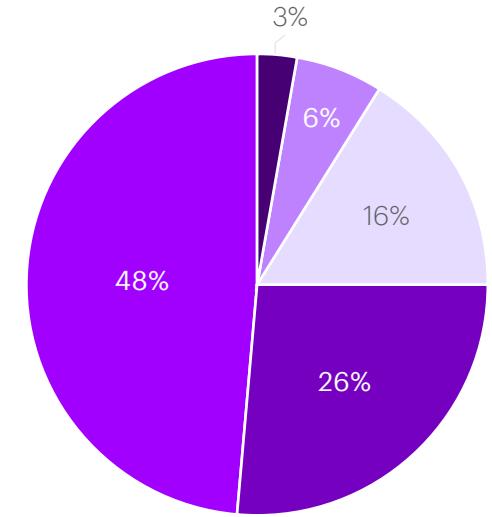
INDUSTRIES

Aerospace & Defense	2%		Healthcare Provider	6%
Automotive	2%		High Tech	4%
Banking	9%		Industrial Goods & Equipment	7%
Capital Markets	3%		Insurance	8%
Central Government (CA)	2%		Media & Entertainment	2%
Chemicals	2%		Natural Resources	2%
Communications	6%		Public Service	7%
Consumer Goods & Services	9%		Retail	9%
Education (Higher)	2%		Software & Platforms	2%
Energy	2%		Travel	2%
Federal Government (US)	4%		Utilities	4%
Healthcare Payor	2%		Total	100%

REVENUES (USD)

$50 billion or more	3%
$20 to $49.9 billion	6%
$10 to $19.9 billion	16%
$5 to $9.9 billion	26%
$1 to $4.9 billion	48%

3%
6%
16%
48%
26%

ROLES

Chief Digital Officer	1%	Chief Purchasing Officer	1%
Chief Executive Officer	4%	Chief Security Officer	2%
Chief Finance Officer	7%	Chief Strategy Officer	5%
Chief Human Resources Officer	3%	Chief Supply Chain Officer	1%
Chief Information Officer	16%	Chief Technology Officer	16%
Chief Information Security Officer	3%	Director of Business Function	3%
Chief Innovation Officer	14%	Director of Technology	6%
Chief Marketing Officer	6%	Director, IT	5%
Chief Operating Officer	7%	Director, Line of Business	<1%

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