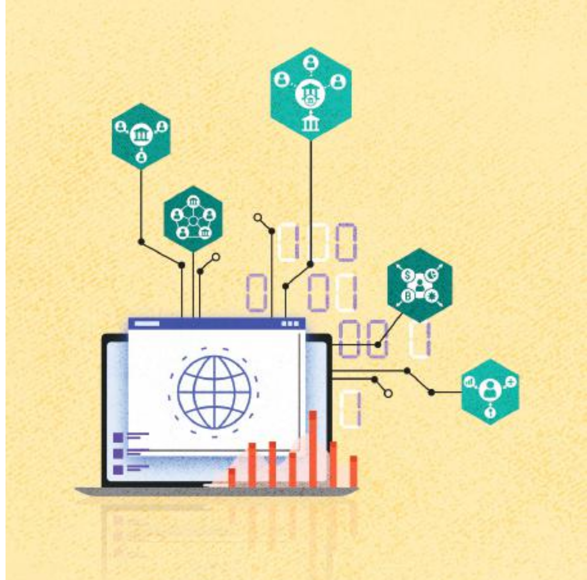

# Summary: Evolution of commercial technologies and impact on business delivery

Part I of five technology-driven megatrends impacting societies and what to expect with Web3

September 2022

**Sandy Kaul**
Head of Digital Assets and Industry Advisory Services
Franklin Templeton

## Introduction

The foundational technologies used to build the worlds of business, government and academia have already undergone three distinct periods of evolution since World War II, each of which has resulted in a re-architecting of the commercial landscape. A fourth cycle is now emerging. Each time the underlying technologies have changed, a new set of capabilities has been enabled and a resulting shift in behaviors has occurred.

Such shifts in behaviors are building upon each other, becoming amplified as new technologies replace obsolete versions. Viewed across several decades, certain behavioral changes are emerging as megatrends. These are not fads that can have a temporary influence on the trajectory of a society and then fade. Instead, these are deep-rooted transformations that are unfolding around us, reshaping our lives, and redefining how we act and operate.

In many ways, the history over the past eight decades has been one of rapid innovation and disruptive change. What was once deemed incomprehensible in terms of behavioral shifts has quickly become common place and normalized. Acknowledging just how much societies have already been impacted is critical because the upcoming cycle of technological change may be the most disruptive yet. The megatrends that have been building are likely to see their ultimate expressions in societal changes that are soon to be enabled.

This paper is Part I of a three-part series that will lay out the emergence and progression of these megatrends. This work seeks to build a layperson's understanding of the technology cycles that are driving these megatrends. The extent of innovation that has occurred since computing technologies began to move from the military and academic realm into the commercial domain has been impressive and iterative. Each epoch of technology advancement has shifted the way in which businesses operate and required enterprises to build and re-build their core infrastructure to keep up with the pace of change.

Understanding how these technologies and architectures have advanced is foundational to tracing the behaviors that give rise to the megatrends and tracking how each successive cycle of innovation helped to amplify their impact, transforming how people work, engage, communicate and pursue entertainment.

## Key findings

Many technologies have contributed to the innovations that have transformed societies since World War II, but perhaps none has been as impactful for commercial enterprises as the emergence of the computer and its related infrastructure, hardware, software, networks and peripherals.

**Since World War II, we have progressed from societies that use machines as tools to societies that forge "human+ machine" relationships that are transforming how we work, live and entertain ourselves. The pace of innovation has been relentless and shows no signs of slowing.**

The processes required to run and deliver business functions have been encoded into software programs and systems; the work documents required to operate a commercial enterprise have been transformed into electronic records that reside on computer databases; the connections that enterprises rely upon to facilitate communications, travel, manufacturing and distribution have been grafted onto a vast array of computer-driven networks; the data and analytics that provide crucial intelligence about the health of a business and the strength of its customer relationships have been enhanced by complex algorithms that rely upon computer processing power and speed; the logic and predictions required to drive personalization engines and run sensors inside the machines that govern our daily lives have been enabled by artificial intelligence (AI) tools that learn through massive data ingestion carried out across huge arrays of networked computers; and the cryptographic protections required for us to share our personal and business information require high-level mathematical calculations made possible by lightning-fast computation.

Since World War II, we have progressed from societies that use machines as tools to societies that forge "human+machine" relationships that are transforming how we work, live and entertain ourselves. The pace of innovation has been relentless and shows no signs of slowing.

Yet, these capabilities have not come about all at once, and the impacts that they have had on how we design and deliver commerce have been iterative. Indeed, it is possible to identify a cycle that governs how these dynamics unfold: 1) New innovations occur and result in upgraded technology, 2) which in turn requires enterprises to rethink their business practices and 3) rebuild the infrastructure they utilize to deliver their goods and services. In this paper, we lay out three distinct periods in which this cycle has already repeated itself, and we make the case that a fourth cycle is emerging.

Each cycle has had profound impacts on the way that a business works and on the relationship between a commercial enterprise and the individuals that make up its employee and customer base. Understanding how significantly these processes and relationships have changed in each period of technological progression already completed or underway is crucial to appreciate how disruptive the next set of changes may be and to anticipate what may soon lie ahead.

### First cycle of commercial technology—automation

The first cycle of commercial technology emerged in the 1960s. Innovations in the way that computers functioned—processed information, stored data and programs, and enabled data retrieval—allowed for the size of computers to become more compact (no longer requiring vast air-conditioned facilities)—and for the way that computers operated to become more efficient (using hard-coded software programs instead of relying on dedicated teams of punch card operators to perform business functions).

Whereas only governments, the largest universities and manufacturing giants such as General Electric could afford computers and the teams required to run them in earlier years, the new miniaturized, chip-built computers became affordable and accessible to a far broader array of commercial enterprises. New peripherals—items that could plug into the computer to extend its functionality, such as work terminals and printers—became useful business tools as the outputs they were able to produce moved beyond huge computer printouts to more recognizable documents. Word-processing solutions that stored their outputs on magnetic tapes allowed for far more data to be captured and made retrievable electronically. These outputs were stored in hierarchical databases that used file-based systems to associate and organize information. By the end of the period, microcomputers that were small enough to fit into individual offices were emerging. These devices could be networked via hard-wired solutions to share outputs across a set of local users.

**Business practices changed as automation occurred. Organizations described what they were experiencing as a "knowledge explosion." The time required to complete business tasks fell sharply, productivity soared, and the amounts of data being collected grew exponentially.**

Business practices changed as automation occurred. Organizations described what they were experiencing as a "knowledge explosion." The time required to complete business tasks fell sharply, productivity soared, and the amounts of data being collected grew exponentially. However, there was almost immediately an emerging concern about the societal impacts of the new technologies and how they might replace the need for human workers.

A trend toward decentralization of enterprises that had been unfolding over prior years reversed. Data and work outputs were no longer dispersed across a robust network of powerful branch offices. Businesses centralized their data collection and processing efforts in the hub that housed their mainframe. This allowed them to reduce or redeploy a significant percent of their workforce. Those that controlled the access and dissemination of information at the central hub gained organizational power. Enterprises hired and built information technology (IT) teams to support these business leaders, further centralizing the resources of the organization. Ambitious managers no longer sought out jobs in more remote locations, instead wanting to be as close as possible to the central hub and data to further their career options.

A monolithic architectural approach dominated in these early years of computing. The infrastructure, hardware, software, network technologies, databases and peripherals required to run the enterprise were typically supplied by a single provider that had its own service and support teams. Internal technology teams facilitated the set-up of individual users, the maintenance of the networks and the execution of data inquiries.

### Second cycle of commercial technology—digitization

The second cycle of commercial technology innovation began in the late 1970s as microcomputers became increasingly compact, morphing into personal computers (PCs). What started as an offering for hobbyists quickly began to grow as the smaller computers were able to run programs on portable software and, later, use a mouse to give x-y directional commands that could interact with icons on a screen to launch and control programs using a graphical user interface (GUI)—thus removing the need for a user to utilize program commands.

The line between business and personal usage of computers began to blur with the entry of IBM into the personal-computing space in the early 1980s.

To speed time to market and reduce the cost of its PCs to be competitive, IBM veered away from their prior monolithic approach and used an open-sourcing model to construct their offering, contracting with several suppliers for various components, software and peripherals, and making its machines open architecture so that other providers could begin to build and launch IBM-compatible products. The marketplace exploded with offerings from multiple manufacturers, creating more competition and allowing costs to come down so that smaller as well as larger enterprises could begin to consider automating their white-collar worker functions.

Commercial off-the-shelf technology systems emerged, focused on providing discrete functions such as content management, enterprise resource management and accounting.

These offerings made the deployment of new capabilities simpler. An evolution in the design of storage technology shifted the standard from hierarchical to relational databases and made it easier for information to be extracted and distributed to business users without the need for centralized IT teams to run queries. The growing expansion of commercial, off-the-shelf software gave business users the tools to enter data, create spreadsheets, run macros, author, and save documents and presentations—thus allowing decades of paper files to be digitized and starting a new epoch of office automation. The creation of intellectual property inside organizations surged.

**Though computer networking had been possible through local area networks and organizations had tied into wide-area networks that allowed data to be transmitted over telecommunication lines, the introduction of the internet and the World Wide Web significantly changed the way that businesses operated.**

Proprietary systems development also emerged as a necessity. The variety of commercial off-the-shelf products being brought into the organization made it difficult to deliver complex, multistep business processes that utilized discrete functions and data from several underlying applications. Enterprises began to build their own user interfaces, business logic and data mappings to tie together these various offerings. All of these increased the complexity of the organization's technology infrastructure.

A new practice called enterprise architecture emerged to better align business needs and technology delivery. Early architectures followed a client-server approach—separating out the interface and user commands (the presentation layer) from the back-end business logic and data that delivered the required functionality and was stored on the organization's processing backbone. These architectures began as two-tier—client and server—but moved quickly to three-tier as a new type of facilitative technology called middleware was integrated, making it easier to knit together multiple systems. The emergence of web technologies changed this approach further, adding a fourth or n-tier as web browsers and interfaces had to be integrated.

Though computer networking had been possible through local area networks and organizations had tied into wide-area networks that allowed data to be transmitted over telecommunication lines, the introduction of the internet and the World Wide Web significantly changed the way that businesses operated. Public domain internet protocol suites (TCP/IPs) were created and began to be publicly disseminated in 1989 by the University of California, Berkeley. The growth in the number of website offerings exploded by 2000. New web-based businesses began to emerge, many of which sought to disrupt traditional business models and give consumers direct access to transactional opportunities via online channels. Soaring valuations for these companies pressured traditional business participants to speed their own launch onto the web.

This created massive pressures on the organization's technology as already complex enterprise architectures had to be rebuilt to expose certain functions to website offerings, and lapses in system response time became a brand issue as clients could now access the organization 24/7/365 (24 hours a day, 7 days a week, 365 days a year). A new approach called a service-oriented architecture (SOA) was developed that broke down system functionality into a set of services that combined the business logic and data required to fulfill that discrete task and "containerized" them, creating an index of such offerings and making them callable through a new messaging layer called an enterprise service bus.

### Third cycle of commercial technology—virtualization

The third cycle of commercial technology innovation began in the early 2000s. Three computing trends that began in earlier years came together at the turn of the century to help lay the foundation for distributed processing and cloud computing.

Time-sharing began as a way for multiple programs to run simultaneously on large mainframes to improve the efficiency of their operation, leading to a vision of computation being shared, and offered as a utility like telephony and electricity. Technologies emerged that allowed computers to create computer workstations and virtual terminals, allowing multiple distinct computing environments—each with its own operating system—to exist within one physical environment. This allowed for scaling the number of users that could utilize a common architecture. Finally, networking technologies matured, first allowing for the transfer of data packets over telecommunication lines, then incorporating TCP/IPs, and later allowing for the development of application processing interfaces (APIs).

**For the first time, a new shared infrastructure was enabled that allowed software to be developed or accessed on a pay-as-you-go basis, and hosting of an organization's data, networks and processing capacity to be rented on an as-needed basis.**

By the early 2000s, Salesforce.com became the first commercial enterprise to offer its software as a service (SaaS) rather than requiring customers to purchase a commercial off-the-shelf system. Google had demonstrated the power of distributed processing, using vast arrays of low-cost computer servers networked together to increase their computational abilities. Amazon began to provide merchants a development toolkit that allowed them to plug into Amazon's shopping carts and fulfillment infrastructure and, later, realized a broader vision of providing the "operating system for the internet" through Amazon Web Services (AWS), which launched in 2006.

For the first time, a new shared infrastructure was enabled that allowed software to be developed or accessed on a pay-as-you-go basis, and hosting of an organization's data, networks and processing capacity to be rented on an as-needed basis.

A new architectural approach emerged called microservices. Although microservice architectures had similarities to service-oriented architectures, there were some important differences that made interoperating with shared development platforms more economical and effective—namely, adding the data required to run a service into the same container as the service rather than having the service call the data from a central location, and using APIs to have services communicate with each other rather than using an enterprise-messaging bus to send point-to-point instructions.

New types of businesses could be built upon these cloud-based architectures as even start-up firms could access the development resources, bandwidth, scalability and reliability that were previously only available to the most successful enterprises that had built their own proprietary infrastructures. Simultaneous advancements in the scripting languages used for web design and the development of new streaming capabilities allowed for a massive upgrade in the delivery of online services.

Whereas Web1 was characterized by static websites that relied on hierarchical navigation and page links as well as plug-ins to run video or audio content, new Web2 platforms were dynamic offerings that could read and write, built around user-centric views and engagement where content could stream directly. Individuals could contribute their own content, define their own metadata tags to classify their content, and form their own networks. Advancements in mobile technologies—particularly the launch of Apple's iPhone in 2007—freed users from the confines of their desktop computers to engage with these Web2 platforms anytime, anywhere.

The result of these advancements was that individuals began to embed the way they live into these tech-driven networks they use every day for a growing number of personal and business tasks and engagements. In tandem, the machines that societies use to operate—from wearable technology to home appliances, traffic, shipping and satellite communications—are also being enabled with "smart" technology that allow them to communicate their status and operational data via a growing array of sensors delivered via the internet of things (IoT).

Advances in AI are enabling this machine-to-machine communication as well as allowing for the creation of algorithms to make Web2 platforms stickier and more compelling through personalization and behavioral profiling. Key to the creation of AI tools has been the ability to ingest and process massive amounts of data to provide sufficient training sets for computers to apply deep learning techniques. The result has been a set of machine learning, natural language processing, predictive analytics and interactive voice advancements that are transforming the design and delivery of goods and services.

**Both big data and AI tools have become additional capabilities offered within cloud-based development platforms like AWS and its competitors that have emerged since 2006.**

The framework that allows for massive amounts of data consumption and computation is often categorized under the broad term "big data." Based on blueprints shared by Google in 2003–2004, big-data processing reverses the approach to performing data analysis that had previously dictated the way that inquiries were run and data was utilized.

In relational database management systems, the data is imported into the application to perform the analysis. This requires structured, tagged and mapped data stored in tables. In a big-data approach, the computational instructions are sent to the data and the analytic calculations performed in that distributed environment. This allows data inquiries to be run across structured, semi-structured and unstructured data.

Both big data and AI tools have become additional capabilities offered within cloud-based development platforms like AWS and its competitors that have emerged since 2006. Innovations being designed within these ecosystems continue apace with emerging offerings like self-driving cars, private spaceflights and the metaverse, demonstrating the potential that these platforms enable and preview new models yet to come.

### Fourth cycle of commercial technology—decentralization

The fourth cycle of commercial-technology innovation is just emerging, and yet it already marks a significant departure from earlier advancements. The goal of decentralized technologies is to create a free-standing, peer-to-peer economy where the users of networks that enable commercial transactions are also the owners of those networks and can share in the financial rewards they generate. To accomplish this aim, decentralized technologies look to enable a new system of commerce, not just a new set of technologies.

The roots of this vision spring from several seminal works on cryptography that describe how to enable information to be encoded and transmitted over public networks. Much of the early work on cryptography was classified, but by the mid-1970s, the technology and mathematical algorithms to enable encryption were becoming better understood. In tandem—as the earlier commercial cycles discussed above were playing out—many involved in the cryptographic realm were becoming increasingly concerned about privacy and the ill effects that might result from allowing organizations to have exclusive access to huge amounts of data on individuals, their communications and their transactions.

A group of like-minded individuals with technology and cryptographic expertise came together in the late 1980s–early 1990s and dubbed their movement the "cypherpunks." The group put forward two published declarations—the Crypto Anarchist Manifesto and the Cypherpunk Manifesto—that laid out their goal of creating a new system that allowed individuals to operate pseudo-anonymously by relying on cryptographic protections, digital signatures and electronic money to enable any two individuals to directly transact with one another in a trustless manner without the need for intermediaries.

Several innovations designed to fulfill those goals emerged in the following years. Hashcash introduced the concept of "proof of work"—forcing one party to use a significant amount of computer time and resources to encode a set of content and create a cryptographic puzzle that another party would need to solve—using a lesser amount of computer time and resources to unlock the encoded content. A proposal for a digital cash payment system, called B-money, would create electronic coins and apply consensus mechanisms, such as proof-of-work, to get independent third parties to validate transactions. Reusable proof of work (RPOW) was a third innovation that showed how tracking digital transactions sequentially and making all the details available to a group of third-party observers to validate could prevent double-spending of an electronically created coin.

**Bitcoin is a peer-to-peer electronic cash payment system that operates in the pseudo-anonymous manner envisioned by the cypherpunks, allowing anyone with access to an internet connection to participate in the network and use Bitcoin as a payment mechanism.**

Each of these innovations came together with the announcement of Bitcoin in October 2008 and the launch of the network in 2009. Bitcoin is a peer-to-peer electronic cash payment system that operates in the pseudo-anonymous manner envisioned by the cypherpunks, allowing anyone with access to an internet connection to participate in the network and use Bitcoin as a payment mechanism.

In addition to deploying the new technologies that emerged from the cypherpunk movement, Bitcoin also introduced two important innovations of its own. The first was blockchain—a new type of distributed ledger technology (DLT) that recorded transactions and held the data of those transactions in a novel way that made such transactions highly transparent and immutable. The second was the concept of digital scarcity.

Up until this time, there was no way to ensure that a digital asset being sent by one party to another was not just a copy. By coupling the innovation proposed in RPOW's approach to sequential-transaction tracking and third-party validation with the new blockchain ledger that offered full-transparency across a distributed set of network nodes, it became possible to ensure that a payment coin was removed from one wallet before being sent to another wallet—ensuring that it could not be duplicated or double-spent.

In 2015, the Ethereum network launched, expanding the cryptocurrency arena of bitcoins and similar payment coins. Ethereum created more than a payment network, it offered a completely new digital ecosystem and infrastructure tools. Ethereum offers a new open-source development platform that allows for the creation and deployment of decentralized applications that run and have their business logic and transactions housed within a virtual computer that sits on top of a decentralized payment network.

Decentralized applications developed in the ecosystem are based on smart contracts—self-executing bits of code that describe the specifics of a transaction and cause the transaction to automatically take place when an authorizing message is received or a specific data-trigger is activated. Smart contracts use similar or compatible programming languages and are based on templates, giving all developers on the platform a common building block. As such, these contracts are interoperable and the code they contain is composable—meaning that one developer can use another developer's code and build upon it. This is a completely new architectural approach that works differently than service-oriented architectures or microservices.

Ethereum and the other digital ecosystem platforms (L1s) that have launched subsequently have introduced a new Web3 dynamic that is likely to reshape behaviors and societies.

Transactions occur differently in Web3—participants pay to have their transactions recorded in tokens native to the L1 platform that the decentralized app sits within, rather than paying fees in a government-backed fiat currency to third-party processors that record their transactions using government-sponsored bank and payment rails. Decentralized applications can issue their own tokens that serve different purposes—utilization tokens allow the holder to partake in a service, asset tokens represent ownership in a physical or digital item, security tokens convey ownership in a decentralized project or protocol, and governance tokens grant the holder the right to vote on matters affecting the strategic and financial development of the underlying protocol. These tokens have their own individual value based on the relative success of the decentralized application they are associated with, and because they are built on the same template, they can be recognized and used by other protocols as forms of collateral.

**The build-out of the Web3 space is still in its proof-of-concept stage, but unlike any prior technological innovation, this test phase is running 24/7/365 and is fully transparent to the entire world. Indeed, it is critical to remember that digital ecosystems like Ethereum and the other platforms that have been subsequently launched have been around for less than 10 years.**

Because these novel token types are built on smart contracts, they can also deliver certain rights and privileges to the holders. These include the ability to administer copyright protections and automatically collect and distribute royalty payments; encapsulate ownership rights and collect or disperse payments and register title; control access to one's digital identity and personal data and collect payments if an individual chooses to share data; and, grant admittance to special communities, events, products and content. These contracts are embedded into the token, and each time a token is transferred from one owner to another, the rights are automatically transferred and re-registered to the new owner.

The build-out of the Web3 space is still in its proof-of-concept stage, but unlike any prior technological innovation, this test phase is running 24/7/365 and is fully transparent to the entire world. Indeed, it is critical to remember that digital ecosystems like Ethereum and the other platforms that have been subsequently launched have been around for less than 10 years. As these offerings look to rewrite the rules of commercial engagement, it will be critical to watch the traction that they can obtain as there is likely going to be a tipping point that starts to see a wholesale re-architecting of the way we live, work and engage.

## Conclusion and preview of part II

Technology innovation has been a powerful force reshaping the way that enterprises, governments and institutions operate over the past 50 years. One of the most important streams of this work has been the growing ability to use computational power and the networks they enable to automate business interactions, support the creation of intellectual property, access and analyze information, process transactions, facilitate communication and pursue entertainment.

These goals have remained similar for each of the four cycles of commercial technology innovation we discuss in the paper. What has changed has been the sophistication of the technologies that are being used to achieve those aims. Each cycle of technology innovation we discuss in the paper—automation, digitization, virtualization and decentralization—provide new offerings with enhanced abilities. Each time these technologies advance, those pursuing commerce have had to alter their approach to utilize the new functions, and those responsible for delivering the infrastructures that enable suchcommerce have been forced to re-architect the organization's technology to take advantage of new capabilities.

The speed of change over the past 50 years has been impressive as innovation has followed innovation. From early computers that took up entire rooms and required hours to run a single program that was hand-fed into the system by punch cards to today's cloud-computing platforms, where developers can use APIs to subscribe to services from a mobile phone, has already been an incredible progression. Early glimpses of what the emerging Web3 landscape might offer seem to indicate that another paradigm shift is at hand that will foundationally change the way that societies operate.

This paper has focused on the technologies themselves—how they started, developed, iterated and changed over the years. It has also laid out how the deployment of these technologies has shifted, moving from monolithic systems to tiered client/server offerings, to service-oriented and then microservice architectures. For the next cycle of innovation, we have tried to draw out how the design, delivery and operations of the Web3 world might require a growing focus on what having self-executing, composable and interoperable code that sits within self-contained ecosystems might mean for the delivery of services.

In looking across the four cycles of technology progression, we have also begun to lay out a story of how the growing set of capabilities enabled by technology have changed the offerings and behaviors of enterprises providing commercial engagement and individuals consuming those opportunities. Thus far, our exploration of those topics has been cursory. What Part II of this series will lay out is our hypothesis that there has been a discrete set of megatrends that began and has become amplified across each successive cycle of technology innovation already completed and is likely to reach its ultimate expression in the next cycle of decentralization.

The five megatrends have been driven by technology, but their influence goes far beyond the mechanisms by which they are enabled. Indeed, these megatrends have already altered the societies we live in today and are likely to shape the societies that emerge in coming years in even more profound and disruptive ways. A preview of the five megatrends is provided below.

**Democratization of access**

Access to the rails of commerce by which enterprises offer their goods and services is shifting from proprietary to open architecture, allowing for a growing set of direct transaction opportunities that offer both individuals and enterprises unprecedented control over their own buying and selling channels.

**Decomposition of business delivery**

The attributes that define business value are shifting as organizations realize increasing opportunities from their intangible as well as tangible assets and determine more ways to reach customers by offering variants of their core competencies through a growing set of partnerships, service relationships and affiliations.

**Expanding power of the crowd**

The ability for individuals to connect one to another regardless of geographic location or socioeconomic status and coalesce around topics of common interest and concern is creating a group voice that is becoming amplified in ways that shape the supply and demandfor goods and services, leading to a new set of crowd factors that are helping to redefine value in the consumer economy.

**Institutionalization of the individual**

Opportunities for individuals to forge a social or personal brand identity, leverage a growing set of their personal assets, and obtain both the knowledge and access to optimize their personal finances are allowing them to operate in a more strategic manner that positions them to manage their own life as a cause that requires the marshalling of resources to achieve long-term goals.

**Quantification of behavior**

The combination of access to increasingly powerful computational processing and analytic tools together with the growing body of data being generated and collected through commercial and personal interactions has led to new types of analysis that look to extract insights from patterns of behavior and apply those findings to optimize the delivery of goods and services in an increasingly personalized and tailored manner.

**Part II of this series will delve into each of these megatrends and show how they emerged and are becoming amplified across each of the technology cycles, already transforming society in profound ways and potentially providing clues as to how the next epoch of technological opportunities may reshape the ways that we live, work, engage, and invest.**

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