Megatrends: Shaping the Future

Implications for people and businesses

June 2018

Introduction

There is so much change happening around us today. How we live, work and play in both developed and developing countries will look very different in the next ten to thirty years. Underlying this change are key trends, many having disruptive implications for people and businesses, including HP. It is vitally important that we do our best to discern what the future *may look like, developing our own point-of-view on potential future states and their implications,* in terms of threats and opportunities. Understanding Megatrends gives us the ability to frame and make more informed, strategic long-term decisions and avoid surprises we could have anticipated and even exploited.

Megatrends are those global socio-economic, demographic and technological forces that we think will have a sustained, transformative impact on the world in the years ahead. On businesses, societies, economies, cultures and our personal lives. Our objective with Megatrends is to directionally point to where the world is going, the potential future states that may result, and then to frame implications in terms of threats and opportunities for Customers and HP. We use Megatrends work to help inform our long-term strategic planning thinking and to support Customer and HP thought leadership and communications with employees, customers, partners and market influencers around technology Vision for the future.

We have identified four major Megatrends and a wide range of underlying sub-trends. We cover each Megatrend and an illustrative set of the sub-trends in this paper.

- Rapid Urbanization
- Changing Demographics
- Hyper Globalization
- Accelerated Innovation

Overview of Megatrends

1. Rapid Urbanization

The world's rapidly growing population is moving to cities at an accelerating rate. An average of 1.5 million people globally move to cities every 10 days. By 2025, an estimated 5 billion people will live in cities, 2.5 billion of them in Asia, mostly in China and India.

As more people flow into urban areas, cities are becoming larger and more cities with populations over 10 million people are forming. We call these "Megacities." There are 21 Megacities today and by 2030, there will be an estimated 41 megacities, with 11 of the top 15 in Asia and 3 of the top 10 in Africa.

As people move into cities and their standard of living increases so does their spending power. By 2025, urbanized areas will welcome an additional 1.8 billion consumers, 95% of them in emerging markets.

Consumers in emerging markets are forecast to spend $30 trillion in 2025 (up from $12T in 2010) or 50% of the total global spend by consumers.

The evolution of how we live and work in larger and larger cities is forcing questions of sustainability. Cities will need to evolve to meet increased demand or collapse under the pressure. Technology has enabled some of the response to this with an increasing number of *Smart City* projects around the world. Technology advances include, but are not limited to, sensors, edge computing, networks, data platforms, and cloud services. Together, these are the foundational elements, plus additive manufacturing for Industry 4.0.

As more people move to cities, demand for housing increases and drives up home and rental prices. For the Millennial generation (twenty and early-to-mid thirty's) looking to rent or buy, affordability of housing is increasingly a challenge in large cities and urban areas. To deal with the supply-demand imbalance, micro-housing has become a key trend. This is reflected in cities including San Francisco, Seattle and Boston, each of which has passed zoning laws to allow apartments of 400 square feet or less. Co-working spaces are also springing up to compensate. Freelancers, startups and even corporations are using co-working spaces like *WeWork* to spark creativity as well as save real estate costs in the largest urban areas.

Urbanization is driving economic growth and changing how people buy. Increasingly, people in cities and especially the younger generations prefer access models to ownership. They want access and usage on demand – giving rise to the *Sharing Economy*, which is forecast to grow to $330 billion by 2020. People are increasingly sharing their homes, cars, even energy, wi-fi and parking spaces. Uber and AirBnB are two better known examples of Sharing Economy businesses. The accelerating trend is for more and more things to be offered not as products for sale, or even lease, but 'as-a-service.' To Millennials this translates into use of the product and the experience it delivers rather than ownership. These micro-contractual (vs. transactional) models combine technology and innovative business models to support new value propositions to meet shifting customer expectations.

2. Changing Demographics

We are facing dual demographic phenomena we have not seen in our lifetimes. The population is both aging and becoming younger, creating an hour-glass-shaped age distribution.

An Aging and Shrinking Workforce

People are living longer and having fewer children, which is driving an older population overall in most places around the world. Exceptions to this include large parts of Africa, where the younger demographics are growing dramatically and as a proportion of different African countries' total populations. By 2030, nearly one billion people globally, or twice as many as today, will be over 65. This will increasingly lead to a shrinking and aging workforce, but also a larger mix of older people in the workforce. Globally, more than 30% of the workforce will be older than 55 by 2030, and there will be fewer working people to support retirees. An aging population will drive escalating healthcare needs. And, fewer people in the workforce proportionately will lead to increasing economic strain and pressure on governments.

A Younger Population Courtesy of the Gen Zeneration ("Gen Z")

On the other side of the age spectrum and younger than Millennials is the demographic group known as "Gen Z". Born beginning in the late 1990s, Gen Z numbers around 2.6 billion globally, and constitutes about a quarter of the U.S. population. Gen Z is on track to account for 40% of all U.S. consumers and 36% of the global workforce by 2020. They have only ever known a mobile and connected world and are the first true 'digital natives'. Gen Z expects instant gratification and access to information and services anywhere, anytime and on-demand.

Gen Z also has different views on business and work than their millennial brothers and sisters or Gen X and Baby Boomer parents. Just over three quarters of Gen Z globally believe businesses should make 'doing

good' a central part of their business, and not just by giving to charity. And while only a small percentage of Gen Z are now over age 18, early signals point to significant differences from older generations' views of work. Workplace evidence for this can be found in the U.S. military, where the front-end of Gen Z constitutes the bulk of the military force. Just how different is Gen Z?

- 32% of Gen Z wants to find their dream job, while 34% of Millennials want financial stability
- 67% of Gen Z is willing to relocate for a good pay
- 58% of Gen Z says "bring it" to working nights and weekends for a better salary vs. 41% across all working generations
- Workplace flexibility is ~5% more important to Gen Z than being covered for healthcare

The impact of Gen Z for the workforce, emerging consumers, and businesses should not be underestimated. It is estimated that the average Gen Z member, in developed countries, will have 15 homes, 5 careers and 17 jobs during his or her lifetime. Ownership models may become more unusual as members of this generation choose to move around the world at regular intervals and seek jobs in different regions that are best suited to their passions / interests. Their career choices are likely to be very different because of the rapidly changing technologies and the rise of automation. Of children entering school today, 65% will work in jobs and in industries that do not currently exist!

Some even believe that Gen Z may well be the first "Immortal Generation." Researchers have proposed that it is likely that the first human to live for a 1,000 years is already born and most likely part of Gen Z. The media today discuss Millennials as the 'disruptive' generation using digital technologies (e.g. internet and mobile) to change things, but Gen Z is poised to disrupt our world and redefine every aspect of life including business.

Healthcare Problem

The aging population is driving a growing healthcare problem. Globally, healthcare today drives $7.7 trillion of annual economic activity, making it one of the largest segments of the world economy. Along with other basics like water, food and shelter, healthcare is one of the few things that applies to everyone, everywhere. An aging population and growth of chronic diseases is combining with a shortage of doctors to increase economic and social pressure. Hospitalizations alone drive more than $1.2 trillion in annual costs globally, many of which could be prevented with more affordable and accessible medical testing to catch issues earlier in patients' disease lifecycles.

An increasingly older and aging population means greater prevalence of chronic diseases, among the most expensive areas of healthcare. In the U.S. today, roughly 190 million people are affected by chronic disease. The total cost of chronic disease in the U.S. is forecast at $42 trillion from now through 2030. This is more than twice the size of the current U.S. *GDP ($18.7 trillion)* and on an annual basis equates to ~20% of U.S. GDP.

A growing and aging population will require more doctors per capita, a metric defined by the World Health Organization (WHO) as 'physician density'. Today there are just over 800,000 doctors in the U.S. mapping to 29.4 doctors per 10,000 people. This physician density is a surprisingly low number when compared with many other developed countries. The WHO's estimate of a 95,000 doctor shortfall in the U.S. by 2025 should therefore not come as a surprise. The shortfalls are much worse in many countries around the world, not just in emerging markets.

Digital Health

Technology advances have opened opportunities in Digital Health -- going from standardized, reactive, and in-person care, to personalized, preventive and remote diagnostic testing and care. Digital Health has grown from ~$61 billion in 2013 to ~$136 billion in 2017, and is on track to reach $233 billion by 2020. The technologies helping drive Digital Health include miniaturization of computing, artificial intelligence (AI) /

machine learning, big data from sensors, as well as biotechnology. As other technologies mature, we are going to see a rapid shift towards 'Healthcare everywhere' and potentially the 'democratization' of healthcare. This would be a world where instead of a $1000 test at the hospital (sent to a centralized lab, which takes a week for a result) you would have a $5, $10, or $50 test that's mobile and available at the Doctors' office, or even in your home. The best example of democratized testing today is home blood glucose monitoring, costing less than 25 cents per test today and a $12B market. Only two decades ago it costs hundreds of dollars, was administered at hospitals and clinics, and was available on a monthly, or at best weekly basis.

What might 'Healthcare everywhere' look like in 2030 and beyond? Imagine augmented reality glasses that provide hands-free and timely information to doctors and caregivers. This is a future where surgery is robotic, data-driven and governed by AI. Genetic engineering may eliminate many diseases. Here is just a glimpse at what we may see in Healthcare *before* Gen Z reaches 40.

A Glimpse into What Digital Health may bring in the next 10 to 25 years

- *Democratization of Healthcare Testing & Diagnostics:* Dramatically more affordable and accessible medical testing solutions become available to consumers; and testing for diseases and conditions is possible in minutes (not days or weeks) for just a few dollars
- *Google Brain / Neural Lace:* digital selves and AI/brain increasingly merge to create self-diagnosis in real-time, a sort of predictive telemetry and maintenance alert for the body
- *Personalized Genomics:* Disease prediction and alteration of an individual's DNA to prevent and treat diseases with customized solutions for each person
- *Recreational Cyborgs:* Repair defects as well as create superhuman characteristics
- *Medical 3D Printing in the Field:* Disruption of the pharmaceutical and prosthetics industries
- *Reformed Medical Education:* Augmented reality and true telemedicine become the norm for medical learning using visualization

3. Hyper Globalization

The pace of global interconnectedness has continued to intensify, and 'Disrupt or be Disrupted' is one of the most common sub-trends within Hyper Globalization.

It is worth briefly taking a step back and looking at changes that have occurred in global trade of goods, services and capital. Together, these reached $26.5 trillion in 2013, and included cross-border flows of 232 million migrants and 1 billion tourists.

Despite recent anti-global and protectionist flare-ups including Brexit, the U.S. election, and nationalists in France and Germany, at least for now, the overwhelming trend towards globalization and connectedness continues. Changes in trade-flows over the past two decades illustrate the dramatic expansion in bi-lateral trade that underlies globalization.

Changes in Goods Flows Globally: 1990 to 2012

- 50% of all goods flowed between developed markets and 6% between emerging markets in 1990
- By 2012, only 28% of goods flowed between developed markets; 24% flowed between emerging markets
- Emerging economies accounted for 40% of all goods traded in 2013; 60% went to other emerging markets

A more connected world is also allowing new entrants to establish themselves quickly and grow to global scale. It has never been easier for entrepreneurs to leverage digital platforms and tools and services needed to fund, start and scale businesses that digitally disrupt traditional workflows. In emerging markets alone approximately 143,000 new Internet business are currently launched every year.

The connected world is also enabling emerging market companies to grow at a rapid pace. By 2025, ~46% of Global Fortune 500 companies will be headquartered in *emerging markets*. China will be home to more large companies than the U.S. and Europe combined. This is astounding considering that as recently as the year 2000 less than 5% of the Fortune 5000 Global companies were headquartered in emerging markets.

At the rate of current corporate churn, 75% of S&P 500 companies will be removed from the index by 2027. This is amplifying competitive pressures and creating the need for constant corporate reinvention.

The diffusion of technology has further amplified global interconnectedness and catalyzed disruption. Various technology advances have led to the increasing digitalization of workflows and rearranging of value chains that often prove disruptive to incumbents. Here is a look back at one iconic company that was disrupted in the earlier stages of its industry's digitalization. Why? - Because the company failed to redefine itself and execute a successful pivot for survival.

> **Case Example: Kodak.** As the the world's long-time leading photo imaging and printing company, Kodak saw revenue decline from $13.3B in 2003 to $6B in 2011 and shortly thereafter filed for bankruptcy. Kodak considered itself to be a digital photography and imaging company, while long-time competitor FujiFilm considered itself to be a chemical company and pivoted into pharmaceuticals and cosmetics. Today, Kodak is virtually non-existent and FujiFilm has twice the revenue it had in the early 2000s.

Cyber Trust and Security

By 2020, there will be an estimated 20.4 billion connected devices. More network connections increase the supply of cyber targets and we are seeing a commensurate rise in cyber-attacks. Cyber-attacks today are motivated by disruption, outright destruction, by desire for economic gain as well as espionage. The estimated global economic impact from cyber-attacks is $445 billion. This is greater than the gross domestic product (GDP) of 171 of the 195 countries monitored by The World Bank.

The majority of data records exposed in *reported* cyber-attacks have come from the business sector. In total data breaches from cyber-attacks in 2016 exposed roughly 4.2 billion records. From a global risk perspective, the World Economic Forum lists cyber-attacks as one of the greatest threats for the world. They consider cyber-attacks to have greater potential negative impact than terrorist attacks, extreme weather events, spread of infectious diseases, food crises or asset bubbles. The only global risks rated greater in projected impact are global water crises, global financial crises, weapons of mass destruction, and failure to mitigate climate change.

All of this is spurring the increasing demand for *trust in the digital sphere* and *cyber security*, a market which is forecast to grow to more than $200 billion globally by 2021.

4. Accelerated Innovation

The rate of innovation itself is accelerating to such a degree that corporate reinvention must increasingly be proactive – in advance of competitive threats that may loom over the horizon. This acceleration is comparable, at least metaphorically, to waves in the ocean. If you believe there's a tsunami over the horizon, which by definition you *cannot see*, you don't want to wait on the beach to see the tsunami before you decide to take action and move to higher ground.

In just 2 years (2020), we will have wireless speeds estimated to be 66x faster than today, supporting 20.4 billion connected devices globally and generating 50x more information. That is more information generated in the next 2 years than generated in all the previous history of humanity.

Innovation Building Blocks

At the heart of this change is low cost availability of more and more advanced *innovation building blocks* including computing power, storage, and bandwidth. Open platforms layer atop this infrastructure and provide modular, utility-based digital services. These allow the creation of entire ecosystems at a fraction of the cost and time previously required.

The innovation building blocks of the mid and late 2000s enabled digital disruption of information and commerce-driven business. A good example of this disruption is the web and e-commerce revolution of the mid-to-late 2000s, part of what's commonly referred to as 'Web 2.0'. Building a web store during the 'Web 1.0' era (e.g. Dot.com period) required time and cost intensive custom engineering. Once built, ongoing web store management required software developers to recode web pages for merchandising and look-and-feel changes. Today, web store creation is highly democratized. Easy-to-use platforms like *Shopify*, *BigCommerce*, and *Magento* are now available 'as-a-service' and provide individuals and small businesses with modular WYSIWYG tools (e.g. What You See is What You Get). Web store configuration and launch now takes as little as *a few minutes*, with costs for web store operations starting at as little as $29 a month.

The platform-based 'as-a-service' approach to web store publishing and management, profiled above, has spread over the last decade to a wide range of tools and workflows. From the most basic infrastructure IT services offered by Amazon Web Services (AWS) to artificial intelligence 'as-as-service', and very soon to blockchain as a service.

AI / Machine Learning & Smart Systems

At the core of disruption going forward is the combination of *artificial intelligence (AI), machine learning and big data* to create *Smart Systems.* Such systems will enable virtual machines (software) and physical machines that are increasingly self-directed and autonomous.

In a *Smart Systems* world, we will see *Intelligence on Tap* become available as a key innovation building block. In part, this will be possible through a move to *Conversational Interfaces,* such as Voice, that remove physical human exchange (e.g. keyboards, mouse, touch) requirements between humans and computers. The app paradigm we have become used to over the last decade will give way to interactions based on *Voice* and other natural interfaces that are heavily dependent on AI.

As Smart Systems become more autonomous, we will see the *Rise of the Autonomous Workforce*, a looming scenario that is driving governments around the world to figure out what it means for policy and regulation.

We are already seeing the rise of autonomous automobiles. The shift to driverless vehicles will accelerate and create a *Butterfly Effect* on the surrounding physical and economic landscape – spanning many industries. We take them for granted today, but suburbs, shopping malls, convenience stores, gas stations and trucking jobs all exist as secondary effects to the 20th century's rise of the (human-driver) automobile proliferation. Just consider the impact on jobs when trucks become autonomous, as truck driving is one of the most numerous jobs in more than 20 U.S. states.

What will Smart Systems mean for the office and the home, your business and customer needs in the future?

Blended Reality

Smart Systems are just one of the many disruptive changes as we accelerate out of the digital age and into the Cyber-Physical era. We refer to HP's vision of this latter era as BLENDED REALITY.

Security will become more and more important in a Blended Reality world, because the explosion in cyber-physical systems increases vulnerabilities and the consequences of security breaches. Cyber-physical systems will take on a greater role in managing, often autonomously, mission critical operations in the physical world. These ensure safe operation of planes, trains, automobiles, power plants, and other types of machines and infrastructure. The consequences of breaches in digital systems is loss of privacy, fraud, financial loss, and business disruption. Security breaches of mission critical cyber-physical systems can cause injury, even death.

Let's take a closer look at four major areas of BLENDED REALITY

AI and Smart Machines

As greater numbers of physical systems become cyber-connected, Big Data will grow exponentially. This data will be combined with *AI and machine learning* to create smarter machines. Autonomous cars are the most obvious example of *smart machines*. Fundamentally, *smart machines* are not only "aware" of their operations and even external events, they are able to learn and improve in a self-directed manner over time. These machines will be able to get better and better at predicting problems before they arise and executing self-healing actions when they do. They will run more efficiently and effectively over time with little or no human intervention. In practical terms, this means that to remain competitive, companies that make devices will not only need to make their machines 'smart', they will have to have a core competency in AI / machine learning and translate that competency into machines that are 'smarter' than those from competitors.

Digital Manufacturing

The cyber-physical age will also disrupt the $12 trillion global manufacturing sector. *Digital Manufacturing* will supplant today's traditional manufacturing, which is highly industrialized, complex and very inefficient at enabling anything other than mass production of standardized product designs.

Traditional Manufacturing. *Industrialized, Complex & Inefficient.* Product design typically takes place in one location and links to centralized production that is often on the other side of the world. Design is highly iterative and involves multiple stages of trial-and-error proto-typing before large final "production" runs of finished goods. The supply created from production goes into inventory across the geographically dispersed supply chain. Because it takes months or years to go from design to final products at the customer destination, supply-demand mismatches are structurally part of the traditional manufacturing paradigm.	**Digital Manufacturing.** *Decentralized, Continuous & On-Demand.* Digital Manufacturing involves far more than production. It covers the entire design-to-production lifecycle. This eliminates the need for physical proto-types, enabling design to skip traditional proto-typing approaches and go straight to production. Design is linked to production through a fully-digital chain or *Digital Thread.* A *virtualized representation of the* product replaces the iterative trial-and-error proto-typing process. AI and machine learning combine to enable real-time simulation and validation of designs *without* having physical proto-types. A digital file that contains all the final product information can be sent digitally to a production facility anywhere. The digital thread links it all together and enables more efficient, faster, flexible manufacturing, and the ability to move to more decentralized production that tightens the supply-demand relationship.

Internet of All Things

We have all heard about the 'Internet of Things', where end-point computing devices have an internet address and relationship to the cloud. Digitally connected does not apply to just computing devices. It can apply to all physical objects, ranging from packaging to spare auto parts. We call this the Internet of ALL Things or IoAT. With the rise of the *Internet of All Things,* every physical product or good will be able to have a unique Internet ID / address. These items will become connected to the Internet, and their ID will enable them to be tracked / traced and even authenticated. Today we see a simple version of this with printed bar codes and RFID tags. FedEx and UPS packages serve as a terrific example of unique tags (2D) that when scanned link to the Internet and enable different types of tracking and tracing. Packages are one thing, products and physical goods are another. As 3D printing and Digital Manufacturing replaces traditional manufacturing, we will have the ability to print a unique tag *as part of each* individual product, and even the parts that make up the product. The tags will be the physical part of the Cyber-Physical link to the Internet for 3D printed items. When this happens radical new business models and value propositions will be possible such as reducing the world's $1.7 trillion annual counterfeit products market.

LOOKING BACK TO LEAP AHEAD

The next decade will bring with it challenges and innovations that are nearly impossible to comprehend today.

We believe that humanity is at the dawn of a new global industrial revolution. For centuries major technological advancement has fueled new industries, markets, and economies. The productivity gains unleashed by innovation freed workers to achieve greater production and take on new tasks and opportunities.

If we look at the 1800s and early 1900s, the invention and mass adoption of steel and steam-powered engines is considered by many to be the building blocks of the Industrial Revolution. These innovations led to huge productivity gains and economic growth, by enabling factories to move from producing dozens of products a day to thousands. This pioneered faster and more efficient transportation. And it transitioned labor from man-powered to machine-powered. All helping to grow the global economy to $1.2 trillion in 1817.

The 1900s brought new technological triggers for economic growth and efficiency gains with the adoption of petroleum, antibiotics, and electricity. While slow to scale, these innovations helped usher in new forms of heat, transportation, and extended life expectancy. It also catapulted the global economy to approximately $5 trillion in 1917.

As we move farther into the 21st Century, we see new technologies converging that, together, will generate the same kind of growth. In the process, they will change how the entire world makes, sells and lives.

- **BioConvergence:** The science of Biology in combination with compute is accelerating. Over the next two decades, the way we make things will change radically. We are seeing the radical acceleration of biology as AI changes how analysis is done and robotics/sensors increase the speed and precision of testing.

- **Beyond Human:** New sensors and interfaces change the nature of human computer interaction. Over the next decade, the way we do work will be reinvented as computation integrates itself seamlessly into the biological processes of our bodies and cognitive processes of our minds. We are already starting to see the early glimmer of this in wearable sensors, in pace makers, and in voice assistants.

- **Frictionless Business:** Technology is changing the size and speed at which transaction and coordination are possible in business processes and markets. In the next ten years, the way business is transacted and coordinated will likely change tremendously. Business processes are being reinvented by concurrent innovation in AI, IoT, Blockchain and applications that automate and create smart-streamlined activities managed by software instead of humans. Markets are also being reinvented when these technologies are used in a distributed (vs. centralized) fashion along with innovative business models.

Let's take a closer look at these three topics

BIOCONVERGENCE: Entering the age of nature inspired fabrication

It was Day Zero in Cape town on April 16th, 2018. That's when a city of nearly 4 million and one of the greenest cities in Africa was predicted to run out of water -- a painful reminder of what happens when populations outgrow resources, and nature fails to cooperate.

The global population will grow by about a billion people between now and 2030 and require 40% more goods and resources. Supply simply won't be able to keep up – not if we continue using current manufacturing approaches. The ingredients for manufacturing and the basics of life - water, energy and minerals, will be severely strained.

Confronting the Supply-Demand Mismatch by Using Nature

This supply-demand mismatch will force us to make things in a dramatically more efficient manner. Fortunately, we need look no further than the trees and Nature's other creations to find guidance. Think of Newton, who found his inspiration for the theory of *gravity* simply by experiencing an apple fall from a tree. Just like Newton to the 18th century, our future in a world of mismatched supply and demand may depend on dramatically more efficient manufacturing that's possible by looking to Nature's lessons. Nature-inspired fabrication is part of the larger concept of *Bio-Convergence,* and refers *to* making things using the principles, materials and processes used by Nature.

Look at the trees around you and the structure of a single leaf. Made up of different microstructures working together, a leaf's composition enables it to repel water. A leaf shows us how miraculously efficient Nature is at creating complex structures with wonderous material properties (e.g. hydro-phobia) all while not wasting any material. The leaf has only what it needs – no more. What's fundamentally different about Nature's way of 'manufacturing' is that it's additive. Whether a leaf, a single cell amoeba or a human being with 37 trillion cells, Nature builds from the bottoms up.

The majority of the world's $12 trillion Manufacturing economy today is, in contrast, based on 'subtractive' processes. To understand 'subtractive' approaches, think about Michelangelo chipping away at marble to reveal his famous statue of *David*. Today's manufacturing is a sophisticated and mechanized version of the approach Michelangelo perfected in the early 16th century. Only, instead of using marble blocks, manufacturers today use molds, casts, dyes – combining them with computer-driven machining and tooling to subtract excess material.

Nature-inspired manufacturing becomes possible only with the convergence of biology, computing and 3D printing. Advanced 3D printing technologies will be able to jet micron-sized

droplets of different agents onto tiny particles, creating substances with different material properties. This will all happen millions of times per second, but one tiny particle at a time. If we build on this and jet different *bio-chemical* agents onto tiny particles, precisely and *one particle at a time,* it becomes possible to drive bottoms-up 'growth'. But this is tremendously complex and requires a level of computation and machine learning applied to bio-chemistry. Structures created in this way would self-assemble with virtually no waste and in ways like Nature's bottoms-up approach. Just imagine growing translucent and water-repealing screens instead of using the industrial and wasteful processes we see today.

Reverse Engineering Nature

Around the world, scientists are using breakthroughs in computation and robotics to reverse engineer Nature's secrets. For years, this type of work has been done in pharmaceuticals where many of the origins of today's synthetically created drugs took their inspiration from chemical compounds found in rainforest plants. In manufacturing it will be about additively synthesizing new materials and structures we can hardly imagine today.

This isn't science fiction; it is happening now. New materials are already being produced using biotechnology innovation. Companies like *Modern Meadow* and *Spiber* are creating artificial leather, and designing new polymers using DNA from spiders. This entire area of Bio-Convergence, and Nature-inspired fabrication is the promise of what happens when additive manufacturing comes into the mix.

We need orders of magnitude increase in industrial and manufacturing efficiency to solve today's global resource challenges and meet the rising demands of a growing population. Nature has found a way over millions of years to produce things of unimaginable complexity and efficiency. If this new way of bio-converged manufacturing takes off, and we believe it will, it could create as much as a 10 million times improvement in manufacturing and resource efficiency. This is the same productivity jump as going from doing mathematical equations with a pencil to leveraging the capabilities of a modern computer. Over the next few decades, leaps in computing speed, AI capabilities and 3D printing precision will enable manufacturing to occur at such a tiny scale that it will look like 'growing' things.

BEYOND HUMAN: Changing Bodies and Minds

In 1950, the average person in the United States lived for 8 years after retirement. Today, the average person lives for 18 years after retirement. As technology continues to improve health spans around the world, to sustain growth, we are going to need to increase the longevity and productivity of a proportionately shrinking workforce. To enable this aging labor base to compete, workers may increasingly augment their bodies with bio and cyber technologies to increase wellbeing and efficiency. This will likely lead us to go 'Beyond Human,' augmenting our abilities and helping us overcome limitations and obstacles.

And it's not just our bodies that we will be augmenting. Our minds will also benefit from this bio and cyber convergence. We are already seeing the development of software tools and interfaces, ranging from AI assistants to augmented reality that improve our access to information, knowledge, and our ability to make decisions--bringing our minds and computers closer together.

Taken together, these revolutionary approaches will transform how we make things, how we sell things, and how we work and live. In the process, they will drive radical increases in productivity and efficiency--changing everything we know. Creating an opportunity for everything we need; reinventing our future and our world.

FRICTIONLESS BUSINESS

A shift occurred in the late 80's, when we moved from controlling companies via paper networks (Linear Processes) to using digital networks (Hub and Spoke Processes). The large, mature companies, like GE and IBM that reengineered from functions to workgroups, captured massive increases in valuation between 1980 and 1999.

With few exceptions, companies that did not make the transition were replaced by organizations that were built on Hub and Spoke-native processes. Companies that did reorganize saw radical growth. We are seeing the rapid acceleration of three technologies that could have a similar impact on how business is transacted and coordinated in a shift of the future: IoT, AI and Blockchain.

IoT- Increasingly low-cost devices and RF tags make it possible to do more granular coordination, decreasing the search, verification and information costs in transactions.
Blockchain - Distributed Ledger technologies, like blockchain, decrease the policy and compliance cost in transactions, while making them more cyber secure than traditional crypto-graphic and storage approaches.
AI - Makes it possible to manage complex emergent processes, decreasing bargaining and coordination costs in transactions.

Together, these will enable the automation of processes that today require brokers or multiple specialists across departments within a firm. As AI, IoT and Blockchain technologies converge, they are likely to redefine the firm, much as occurred in the 1980s,

3 new processes will sit on top of these technologies:

- Autonomous Negotiations – AI-powered agents that meet and influence each other to forge increasingly complex mutually beneficial agreement.
- Smart Contracts - A computer protocol intended to facilitate, verify, or enforce the negotiation or performance of a contract.
- Generative Product Planning – A computational design method that can simultaneously consider multiple constraints, like, regulatory compliance, product features, user preferences and materials constraints, to speed design.

These new processes will make it possible to manage increasingly dynamic, emergent processes and remove the hubs that platform companies, like AirBNB, Amazon and Uber, use as points of control in their value chains.

Uber is a transitory, early form of Frictionless Business. Uber's platform removed transaction and coordination friction from the livery (taxi & car services) market by using early Frictionless Business technologies combined with an innovative new business model:

- Machine learning coupled to GPS location tracking (a variant of AI)
- Mobile devices (an early form of IoT device)
- Digital Payments (a precursor to Blockchain currencies)

As Uber demonstrates, when friction is removed from transaction and coordination *in a market*, it often enables new value creation. In the process, Uber has created 4x growth in the livery market by creating exactly the value consumers want, when and where they want it.

How Frictionless Business Will Change Business

We see 3 key workflows being reshaped by emergent processes. These are the exact same workflows that were reengineered in the 1980s because of microcomputers and digital networks. They are likely to have similar implications for labor and workflow automation.

Procurement: The production and receipt of goods will be reshaped by IoT Tracking, smart contracts and autonomous negotiation.

- "Just in Time" moves to "Right Now". Expectations for increased speed of delivery throughout the value chain are likely to drive the growth of outcomes-based value propositions and streamlined cross-function decision making.
- Brokerage relationships breakdown or are redefined as producers start to negotiate through peer-to-peer marketplaces instead of through systems integrators.

Channel: As new players can run around existing channels and build new processes, they will reinvent the way we all do business.

- Autonomous distribution and coordination will change the way manufacturers do demand generation and delivery of goods.
- Retail channels will continue to consolidate to compete with lower-friction, direct-to-producer and marketplace options.
- Services-led sales will grow as 'intelligence in everything' changes the nature of buyer-seller relationships.

Production: Digital Manufacturing and Generative Design (possible using AI) will change the development costs and customer expectations. SKU mix, feature sets, design process, manufacturing methods will be reshaped by

- Product managers will increasingly delegate to software instead of engineers and ODMs.
- Smaller-batch production will be possible as the costs of managing design libraries, rights management and compliance decreases.

Together, these three trends: *Bio-convergence, Beyond Human and Frictionless Business* have the potential to change how goods are made, how we work and how we do business. They will drive radical increases in productivity. They will change everything we know. The economy, the shape of the firm, the shape of our lives.

Implications for our customers

Megatrends help us with foresight on what is over the horizon, and it's from potential future states that we can work backwards to better inform our long-term strategic choices. The accelerating pace of change and history seem to tell us that we should pro-actively create and preserve options to exploit longer-term future states that would otherwise be highly disruptive to us. As Bill Gates said, "We always over-estimate the change that will occur in the next two years and underestimate the change that will occur in the next ten years."

Now is the time to queue up and consider long-term key choices that involve small starts in the near future to preserve future options. Here are examples of key questions we've heard in relation to the implications of Megatrends:

Labor – Talent/Skills/Workplace/Demographics/Education

- What are the job types, skills & people we will need to stay relevant?
- What issues may arise with Gen Z joining a more multi-gen workforce?

Sales and GTM – Megacities, Socio-economics & customers

- How do Megacities change potential location strategy & sales approaches?

Automation – AI and Robotic Process Automation

- What's the potential impact of automation on savings, people & locations?

Frictionless Business & Blockchain

- How can we use Blockchain for disruptive new biz models?

Tech-lash – Backlash & Regulatory impact of emerging tech

- What are the potential political, regulatory & market backlashes we may see?
- How might these affect where, what and who we sell to?

Products & Retail – New purchase models & demo-targeted products

- What do demographic changes mean for our product portfolio & requirements?

Sustainability & Resource Limitations – Energy, minerals, water

- Can we do more to be sustainable?
- Can we leverage sustainability for growth?

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