**MICHAEL J.T. STEEP**

A group of people in a room

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**DISRUPTIVE TECHNOLOGY COMPANION GUIDE**

With Michael Malone, Silicon Valley Press, and Dr. Herman Alexander Donner, Principal Researcher & Investigator, Stanford University Engineering

**A person smiling for the camera

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**Introduction and About the Author**

In April 1968, Stanley Kubrick's masterpiece, *2001: A Space Odyssey*, premiered at the Loew's Capitol Theatre in New York City – the same theater where classic movies, including *Gone with the Wind* and *The Wizard of Oz,* had opened in the 1930s. I was a boy of 15 at the time, on a school field trip to New York City. I could never have imagined that a science fiction thriller would have the impact on my life that this movie did.

As I left the theater afterwards, I was determined to create the mythical and omniscient computer in the film, the HAL 9000 series – a quest that ultimately would lead me to Silicon Valley. That decision, which would ultimately result in a forty-year career working with companies such as Hewlett Packard, Software Publishing Corporation, Apple, Microsoft, and Xerox PARC, led me to where I am today.

Although I never did achieve my quest to create HAL, I did participate in the launch of the first minicomputers, the personal computer, and Microsoft's Azure Cloud Service. My team licensed Software Publishing's *PFS Series* business suite to serve as the software for the launch of the IBM PC. In the 1990's, while at Apple Computer, we introduced the world's first consumer digital camera called the *QuickTake*®, and we developed the *Apple LaserWriter* as part of the desktop publishing revolution. At Microsoft, I witnessed the rise of the mobile phone, managed the transition from packaged software to software-as-a-service, and worked with the Azure team on its first Cloud Offering as part of the Enterprise Partner Group. At PARC, we developed and licensed early stage technologies crossing advanced material sciences, predictive data analytics, clean energy, and behavioral software. We witnessed the introduction of the BMW *iSeries* electric car and the first electric airplane flown from England to France.

Now, as the Co-Founder and Executive Director of the *Disruptive Technology and Digital Cities Program* at Stanford Engineering School, I realize that the enormous growth in technology during my career was simply the opening act to an even more dramatic play. We are now in the midst of a monumental global change in scientific invention and innovation. This exponential growth in disruptive technologies is greater than anything that has come before, outpacing our ability to manage it, and changing the way we conduct our business and personal lives. Pandora's Box has been opened for the human race.

All of these advances in technology – data analytics, computing power, cloud, networking, and a host of other technologies – are converging to create a perfect storm. Every major commercial company in every global industry now faces unrelenting disruption of their business models. At the same time, the human ability to understand and manage the integration of disruptive technology is rapidly falling behind. This massive gap between exponential growth and our linear human ability to cope widens by the year. As a result, humans have, for all intents and purposes, lost control of the pace and impact of technology change.

Another thought for the read to consider – just as we are experiencing an exponential explosion in technology, we are also facing other potentially cataclysmic changes, including global warming and the political-economic upheaval of globalization. We are at a turning point for the human race, perhaps more dramatic than any other time in human history. In his address to the 2018 Climate Change Conference in San Francisco, Thomas Friedman spoke about, "These simultaneous accelerations in the Market, Mother Nature, and Moore's Law together constitute the 'age of accelerations,' in which we now find ourselves."

Technology can be both a blessing and a threat. But the one thing I would encourage us all to do is to pause and consider the unintended consequences of each of our actions. The power of disruptive technology is now unleashed, but we still have the ability to direct how it will be used, for better or worse. The ultimate question we all need to answer is what path will we choose?

**Companion Guide**

We are currently experiencing a time of unprecedented technological progress, with science fiction rapidly becoming reality and AI surpassing the cognitive abilities of humans. In *The First Light of Day*, we see how key technologies have driven disruptions in the way we live our lives, do business, govern, and make war. This guide offers a comprehensive overview of these technologies.

We anticipate that technologies currently in development will have profound consequences on society, some of which will be unintended. Already, many experts are concerned that "super intelligent" AI can pose a significant and existential risk to humanity. This concern becomes even more urgent as we now can create applications that learn, adapt, and act – a development driven by a **Quantum Engine**[[1]](#footnote-1) of rapidly increasing computing power, virtually unlimited free storage, smart algorithms, AI, and new smart materials.

As these fields converge, advances in applications such as autonomous vehicles, speech recognition, and machine translation improve exponentially. Thus, while the human ability to predict or even to manage future development is linear, technology is developing at an exponential pace, creating what can be described as a 'technology gap' in which catastrophic events might occur at a dizzying speed. This technology convergence is driven by the massive development and launch of new applications for consumers by private companies such as Google and Facebook.

Such new technologies, applications, and services are quickly being adopted by billions of people, without reflecting on the consequences of what can be described as their love affair with technology. The advent of "alternative truth" is a result of this inherent trust in technology. As each social media platform repurposes information for its target audiences, truth is interpreted differently for each. As a result, many people believe without question that the information they see on their social media channels is correct despite the presentation of facts that would indicate otherwise. As a result, social media, driven by technology developments, has contributed to polarization and extreme social tensions in the United States.

A screen shot of a computer

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As innovation is driven by commercial interests and people increasingly trust technology more than each other (not least because we cannot question the intent of a machine as we can other humans) – all of this produces a perfect storm. People adopt new applications that simplify communication, travel, shopping, and planning of work and social activity with little thought about the kinds of information they are sharing, what that data is used for, and how it, in turn, changes the content to which we are exposed.

Where will this lead us? This guide offers food for thought about technology's impact on our lives, both positive and adverse. More importantly, it reflects on what our children and grandchildren are likely to face as we move into the future.

**Topic 1. Agents and Devices**

Much of the future technology described in this book already exists in some form, although it is not yet used to its full potential.

Most notably, the way of life depicted in the novel is powered by present-day and rapid developments within the field of **Artificial Intelligence (AI)**,the science of intelligent agents that implement functions based on percepts (inputs that are perceived at a given moment) that result in action[[2]](#footnote-2).

The type of function implemented depends upon how one defines *intelligence* – an important distinction. If the aim is to achieve intelligence in the sense that a machine's decisions are to resemble human *behavior*, that is very different from a definition where ideal *performance* is desired. The latter is known in the AI world as 'rationality'. In the novel, the form of intelligence varies, according to the type of agent.

Current AI technology is based on what are known as **Artificial Neural Networks (ANNs)**. ANNs aim to replicate the biological neural networks of the brain. Simply stated, our brain's neurons communicate with each other and pass messages along, if the sum of input signals from the neurons exceeds a certain threshold. This is what makes us think and send instructions to our muscles, organs, and body. Examples of input signals include our senses and our ingestion of food.

ANNs imitate this process through algorithms that learn and constantly adjust weights on paths between neurons, tuning the desired output for each percept signal. In the depicted future, sensors[[3]](#footnote-3) provide percepts for AI-based agents to act on through the monitoring of environments, creating percepts of our movement, body language, and speech. In relation to the novel's predicted future machines that develop self-consciousness, these types of neural networks are described as a **Consciousness Neural Networks (CNNs)**.

Mikhail's morning routine illustrates a future in which human interaction with technology encompasses virtually all aspects of daily life. At the heart of this interaction are voice-activated intelligent agents that receive information about the environment, location, news, and other sources, and then perform actions that simplify how the humans they serve interact, consume, work, exercise, and plan their days[[4]](#footnote-4).

Mikhail's day-to-day life is handled through interaction with his AI-based agent, *The Voice,* through *His Masters Voice,* a voice-actuated iOS made possible by increasingly advanced **Automated Speech Recognition (ASR)** algorithms. Today those algorithms already are advanced enough both to identify the person speaking and to interpret what is said. Simply put, these technologies are based on linguistics and statistical methods, known as Markov models, that estimate the most likely word or sentence based on what is said.

Advances in AI and **Machine Learning (ML)** – algorithms that learn and adapt when exposed to new data –are driving constant improvement by estimating new probabilities of sentences, so that today's agents can increasingly understand variations in pronunciation, as well as the context of words[[5]](#footnote-5).

Similarly, increasingly advanced **Video Analytics** will allow for interpretation of movement and body language. Current algorithms are already used to identify age, gender, and ethnicity of people, allowing retailers to identify customer characteristics, movement patterns, and time spent in stores[[6]](#footnote-6).

An important aspect of the described technology is that the agent is device independent, meaning that it is integrated into cloud technology[[7]](#footnote-7). In other words, it is not tied to any specific device, such as the very basic voice-operated assistant *Siri* on the iPhone of today. As the agents in the novel are based upon **Cloud Computing**, today's devices, such as smartphones, have become redundant. They have been replaced by communication through voice iOS[[8]](#footnote-8) on any device, including headphones, screens, or fixed microphones in the characters' homes.

In the future, agents will follow us everywhere, providing us with services and communication. The basic premise of cloud technology is that the sharing of computing and storage resources over the internet will create economies of scale and the ability to make complex computations without restrictions posed by individual devices or the need to invest in a massive **Information Technology (IT)** infrastructure.

Current **Global Positioning System (GPS)** technology is a good analogy for cloud computing and storage. With GPS, vehicles send their position and destination through networks to a central computer that estimates the most efficient driving route and then sends this information back to the vehicle. Similarly, when Mikhail tells *The Voice* that he wants dinner reservations, the agent connects to another agent, like the Yelp of today, that stores information on restaurant reviews, prices, location, and available tables. Mikhail is then provided suggestions of restaurants by *The Voice,* based on his stated preferences and earlier reservations. Lastly, when Mikhail approves the choice, *The Voice* connects back to the restaurant agent and makes the reservation.

Future society will be composed of a hierarchy of cloud-based agents with varying functions that collect information from devices and interact with each other. Like the hierarchy of servants in pre-20th century England*,* the personal agent is the equivalent to a head butler who in turn interacts with agents that fill varying functions. In the novel, these agents include *Andréas,* which monitors Mikhail's health and exercise through its collection of sensor data on heart rate, sleep, and movement.

Similarly, Mikhail has an agent, *Christina,* to handle his travels. It can connect to other agents that, in turn, are linked to timetables, data on the location of stores, restaurants, and work, as well as data from sensors that measure congestion and movement of people and vehicles, to make real time estimates of arrival times.

Sensor-equipped devices are an essential part of this new society, as they gather information on citizens' preferences, habits, movements, and work, providing percepts for AI-enabled agents to collect and act upon.

Recent advances in **Metamaterials**, engineered to have properties that leverage the laws of physics and energy, enable Mikhail's bedding to monitor his heart rate and body temperature, then send this information to his cloud-based health agent for analysis. Based on this analysis, his blanket's temperature will be adjusted in real time for maximum comfort.

Metamaterials are created by changing the arrangement of elements, known as meta-atoms, in conventional materials. Metamaterials gain their properties from their re-designed structures, rather than from their composition alone. This changes how the material responds to electromagnetic radiation, such as light. Metamaterials already are being used to improve performance in antennas, fiber-optic broadband, and the creation of super lenses.

A recent development is a new, low-cost Metamaterial cooling film that can self-cool in broad daylight[[9]](#footnote-9), decreasing temperatures by as much of 13 °C (23° F). That's enough to make a profound impact on energy consumption by cooling buildings, cars, spacecraft, and tents. This material can even be designed to self-adjust to keep a constant temperature.

Metamaterial science also allows for extreme miniaturization, thus offering the potential to create powerful antennas to fit into smartphones and power the creation of super camera lenses. Further, these materials can harvest power directly from the atmosphere.

Altogether, technologies that, until recently, we thought we purely science-fiction are now possible. Researchers even are working towards creating invisible cloaks[[10]](#footnote-10) as described in *Harry Potter*. This new approach to advanced material science now creates a super low-cost platform for extremely innovative applications considered unfeasible until now.

In the novel, the interactions we see between humans and artificially intelligent agents, and the enabling technologies that allow the collection and analysis of massive data – people's movements, social networks, preferences, health, and consumption – illustrate a likely future based on already present trends. This development is a result of commercially-driven services that simplify daily life and result in a near-total erosion of personal integrity and privacy.

At the heart of innovative breakthroughs, convergence will further accelerate the explosion of technology development. Just as metamaterialsenable a new platform for innovation, other breakthrough concepts also will emerge.

For example, solid-state metamaterial radar has now been developed to mount in automobiles that can not only increase the resolution and identification of distant objects regardless of weather conditions, but also direct beams into buildings to gather information while disguised as 5G cellular signals. Thus, a single technology is now capable of disrupting at least three industries: automotive, infrastructure inspection, and telecommunications.

In another example, faculty researchers at Stanford have created a new stretchable material that not only allows for dramatic reductions in manufacturing cost but enables a wide range of new applications for the **Internet of Things (IoT)**.

The challenge for corporate internal research and development (R&D) organizations across all industries is to become aware of these new developments and identify how emerging technologies, like metamaterials, will likely disrupt their companies' business models.

The CEOs of Fortune Group companies have acknowledged the importance of innovation but have also recognized that they are failing to produce the breakthroughs that will drive new revenue growth. Apple's weak history of R&D since the death of Steve Jobs reflects this kind of problem. Although the company is an outstanding operationally-focused organization, the introduction of the iPhone X is incremental and not strategic for driving revenues forward. Apple needs to develop new categories of innovative products. Whether the company can still achieve that level of innovation remains to be seen.

**Topic 2. Privacy and the Acceleration of Moore´s Law**

Mikhail's morning commute is a vastly different experience from today's, although it is based on already present technologies.

This future public transport system uses technologies that can track the location of individuals, and then forecast commuter flows and congestion using **Predictive Analytics (PA)**.

This term refers to the use of historical data, statistical algorithms, and **Machine Learning (ML)** to estimate the probability of future outcomes[[11]](#footnote-11). Rather than just giving computer instruction about what to do, ML uses algorithms to learn and adapt through experience, with models independently changing when exposed to new data.

Currently, applications of AI and ML illustrate that it will be possible to gain knowledge about almost all aspects of society. For example, it is possible to predict voting patterns across the US just using pictures of cars. Stanford researchers found an 88 percent higher probability of a precinct voting Democratic if sedans outnumbered pickup trucks, with the opposite pattern producing an 82 percent likelihood of a precinct voting Republican[[12]](#footnote-12).

ML applied to Google Street View imaging already can predict income levels and house prices[[13]](#footnote-13), and satellite imaging produces remarkably accurate estimates of gross domestic product (GDP)[[14]](#footnote-14).

Increasing amounts of available data, combined with more powerful processing, have led to predictive analytics transforming many business models. PA is often used to optimize marketing campaigns, detect fraud, reduce risk, and improve operations. Common uses include retailers making predictions on customer responses to marketing campaigns, cyber-security identifying patterns in network usage to predict criminal activity, and hotels making daily predictions of numbers of customers to maximize revenue.

We are exposed to services based on PA daily, through the movies that Netflix suggests, products presented by Amazon, and the ads displayed on Facebook. With increasing amounts of available data on our habits, consumption, and preferences, in addition to the necessary processing power and algorithms, targeted marketing will become even more accurate and pervasive in the year 2050.

In the future, our cloud-based and personal agents will manage product delivery as well. So, if Mikhail were to tell *The Voice* that he will be going shopping for new business shirts, it in turn would suggest shirts based upon his earlier purchasing patterns and stated preferences. Cloud-based agents will provide information about product availability and locations, and they will enable real-time purchases. So, Mikhail's personal agent would connect with agents linked to stores and their sales systems that in turn are continuously determining inventory using predictive analytics.

Besides information on our consumption and preferences – traced through social media and search history – our movement will also be monitored to an increasing degree. When these data layers are matched with our identities, goods and services will be tailored to our personal needs, although little will be left of personal privacy.

In this world, the presentation of advertisements and other information across cities will follow people's movement as well, so that billboards and displays will show individualized content, displaying what is relevant for the person in the immediate vicinity, in the same way that today privacy screens on computers make content visible only for the user. Thus, when Mikhail takes the escalator down into the subway, screens show him personalized ads, alongside information on his schedule for the day or public messages from city government.

The efficiency of public services also will be supported by an increased digitalization of the environment[[15]](#footnote-15), with millions of sensors on buildings and autonomous vehicles, identifying phenomena such as road maintenance needs, traffic, pollution, utility usage, accidents, and crime, all in real time. This technology is already rapidly developing across cities. In Sacramento, California, microphones are used to recognize and track gunshots to detect crime. In San Diego new street lights are going to be sensor-equipped to capture features such as pollution, light, and movement. In Boston, an app detects when a car hits a road bump, by using smartphone sensors to identify vertical movement, and sends this information to city road maintenance[[16]](#footnote-16). Elsewhere, sensor-equipped water pumps detect leaking pipes and can be used to identify drug usage and bacteria outbreaks through water testing.

The benefits of identifying movement have been tested and analyzed on various public transport systems[[17]](#footnote-17), typically through smartphone applications. This allows for the allocation of resources so that capacity follows expected flows, and so travelers can make more informed decisions on how to travel within the city, utilizing accurate, real-time information.

Seoul, South Korea, serves as an example of smart transportation management. There the number of commuters using the subway is counted continuously, sensors on roads monitor congestion levels, and taxis are tracked by GPS, all so that real time information and prognosis can be provided on signboards across the city.

The London Cross Rail system of 2050 takes this further, using data not only to allocate resources and the provision of information, but also to tell people when and where they can travel, a notion inconsistent with freedom of movement and democracy as we currently know it.

When paired with already available face recognition technologies and a database linking faces with identity, it will be possible to identify *everyone* at a given location. This type of machine learning is already being used by Facebook, such that people in pictures are automatically identified, with an accuracy of 98%, if they have been manually tagged in pictures several times previously.

Police cars already automatically scan license plates in nearby cars to determine if they have been stolen. From there it is a relatively small step to an application that analyzes video surveillance across a city to identify the location of any wanted person.

The basic premise of face recognition technology is that each pixel in a picture is analyzed in relation to the surrounding pixels and then replaced with an arrow pointing towards the direction in which the picture is getting darker, called a gradient. The reason for replacing pixels with gradients is that although pictures vary in brightness, gradients of the same person will have the exact same representation each time.

In operation, pictures are broken down into larger squares in which the sum of the gradients that point in each major direction are counted. Each such square is then replaced with the strongest arrow direction, capturing the basic structure of the image. We see one application of this operation in face detection, such as that used for automatic focus on cameras. To handle the more difficult step of recognition (rather than just detection) of faces, something called *Face Landmark Estimation* is applied. Essentially, it finds 68 specific points – *landmarks –* on a face, such as the inner edge of an eyebrow, using a machine learning algorithm. After rescaling the picture so that the eyes and mouth are centered, and if we have a link between the patterns of a face with an identity, it is possible to identify specific faces. In the case of Facebook, this is done through comparison of previously tagged pictures, so if an unknown face looks similar enough to that of a tagged face, it is determined to be the same person. To simplify computing of, say, a database with millions of pictures, only a few basic measures are typically compared, such as the spacing between the eyes and the length of the nose. Machine learning is then applied to figure out which measurements are most relevant for face recognition.

An additional example of the use of ML on photos or video content is the website by Microsoft that predicts the age of people in photos (although not very accurately so far)[[18]](#footnote-18). It is not far-fetched that eventually it will be possible to determine someone's demographic characteristics based on the clothes they are wearing.

As smartphones are network connected and equipped with cameras, microphones, and sensors, they present enormous opportunities for data collection. Although, in the novel, device independent and voice-operated agents are predicted to replace smartphones, the same functionality could be provided by any sensor-equipped device. If this data is merged with other personal data, such as consumption data, the possibilities for tracking an individual's activities and preferences will be unprecedented, resulting in the 2050 London described.

From a commercial perspective, this will provide knowledge of the where's, who's, what's, and when's of consumption and social activity across a city, creating the opportunity to predict what someone is going to buy, where they might buy it, what their insurance and credit risks are, and even what personality type and physical illnesses[[19]](#footnote-19) they might have.

Rapid technological advances now allow for the collection, storage, and processing of **Big Data**[[20]](#footnote-20). A well-known and a prevailing "truth" in the technology sector is **Moore's Law**, the observation that computing power doubles approximately every 18 to 24 months. Although originally referring to just logic chips, this development has become pervasive across technologies, with storage, algorithms, and AI developing at an astonishing pace. To illustrate this rapid development[[21]](#footnote-21), consider that only five to ten years ago it would have been too costly to store and process vast data, while it is now possible to store information on, say, a million car rides, and apply algorithms that find patterns of interest, at a reasonable cost. Central to this development is cloud storage and computing, leveraging technology by providing economies of scale to new storage technologies[[22]](#footnote-22) and to increasingly powerful computers.

Looking forward, the development of **Quantum Computing** will constitute an exponential leap in Moore´s Law and revolutionize computing possibilities. The term refers to a wholly new way of making computers, one that will provide a means to solve problems not computationally possible on traditional computers.

This type of computing is still in its infancy. It differs from traditional, transistor-based computers that store information in bits that are either zeros or ones. Put simply, in quantum computers, data is stored as zeros, ones, or any quantum superposition of those states, meaning that any state can be represented by the sum of several different states. This characteristic comes from the physical phenomenon known as **Quantum Entanglement**,meaning that the "quantum state" of a particle can only be described as part of a whole system. Characteristics of particles, such as their position and spin, are all correlated across the system. When two particles are entangled, no change or measurement can be done on either without impacting the other. Basically, one particle "understands" when some type of measurement has been done on its entangled twin particle, and the matching outcome. This works even when particles are separated by large distances – even across the universe – and without any known way for particles to share information.[[23]](#footnote-23) This phenomenon, which Albert Einstein referred to as "spooky action at a distance,"[[24]](#footnote-24) goes against the traditional laws of physics.

Notable is that quantum entanglement allows for putting particles in a quantum "superposition" where their properties have multiple states simultaneously, and if any other entangled particle is measured or changed, that determines the state of the other particles. This allows a quantum computer with *n-*number ofqbits to be in any superposition of 2*n* states at the same time, while normal computers can only be in one of state at a time. So, a 16-bit quantum computer can store (and compute) 216 = 65,536 states, while a traditional computer only does one computation. This will constitute a true quantum leap in technology, with virtually unlimited computational possibilities. That in turn will allow for identification of new patterns of interest on data that can be described as gargantuan in size, driving our knowledge about society and allowing for unprecedented levels of AI.

Quantum computing is in fact a technology that illustrates the rapid – and largely unnoticed – rise of China as a center for development of cutting-edge technology for both civilian and military applications. In the city of Hefei of the Anhui province, the Chinese government is overseeing a $10 billion research center for quantum applications[[25]](#footnote-25). Its two main goals for 2020 are to build a quantum computer and to realize so-called **Quantum Meteorology**[[26]](#footnote-26). The latter refers to new ways to measure miniscule physical effects and changes in gravity. This technology allows for accurate navigation without the need for any external system that sends and receives signals, such as GPS. This would allow autonomous vehicles and submarines to navigate without being dependent on signals that can be disturbed, blocked, or used to detect their location. Current work on quantum technology in China is focused on building a nationwide network for military communications and financial transactions, where quantum technology can provide vastly improved speed and encryption[[27]](#footnote-27).

China's advances in quantum computing can be viewed as the equivalent of producing the first atomic bomb by the United States. The technology is critical to national security in that the first to operationalize quantum computing is likely to become the dominant superpower of the next century. The technology in and of itself is capable of enabling intelligent self-thinking beings.

The speed of processing complex data with quantum computing makes it difficult, if not impossible, for humans to comprehend. In *The First Light of Day*, speed of execution is very important, allowing the character to execute his plot before anyone can respond. It becomes virtually impossible to stop what Mikhail puts in motion.

**Topic 3. Supersonic Transport**

New technologies and applications have increased connectivity through free and reliable methods of communicating and spreading information, integration of financial markets, and facilitating trade of goods and services. Services once sold only locally – often requiring physical interaction – are increasingly sold on the global market, as buyers and sellers gain knowledge about each other and are provided with a means of service delivery[[28]](#footnote-28).

As with improving digital connectivity, innovation in travel also will decrease physical distances through increased speed. The supersonic **Boom** commercial airplane that Nigel flies between London and Chennai is currently being developed and scheduled for a first test flight in 2018. Being slightly faster than a Concorde at Mach 2.2, a flight on Boom between London and New York will take three hours and 15 minutes, rather than the seven hours of traditional commercial airplanes. This, at prices equivalent of the cost of a business class ticket, and with a sonic boom – the sound blast that made the supersonic flight unsuitable for flight over land – 30 times quieter than the Concorde.

This type of flight is only one end of the spectrum of future air travel, likely to be reserved for the affluent and time-pressed. In addition, it's not exactly environmentally friendly, though fuel-burn per seat and mile is also equivalent to the business class of today.

A current project that is likely to illustrate the future for much of the commercial air industry is the electric **Airbus E-fan** program for electric and hybrid airplanes. In 2014, a two-seater plane equipped with lithium-ion batteries powering two electric motors had its initial test flight, and a longer-range hybrid version debuted in 2016. Current work towards a commercial regional airplane is underway, with Airbus and Siemens having 200 employees dedicated to working on demonstrating the technical feasibility of hybrid airplanes by the year 2020.

The modern history of the aviation industry is a good illustration of the way sensors, and the ability to gather and analyze data with predictive analytics, are changing business models, with an increasing emphasis on service delivery rather than physical construction. For example, airplane engine maker Rolls Royce now sells the service of providing, say, 10,000 hours of engine operations, rather than selling the actual physical engine.

This is made possible by sensors that monitor engine performance and then send data back to the manufacturers, something that is now prevalent across most transportation industries[[29]](#footnote-29). Network-connected cars and airplanes continually exchange information with their manufacturers. For example, Tesla continually performs over-the-air software updates of their cars.

Just as Rolls Royce has transformed the way it sells airplane engines, automakers will move from being in the business of selling cars, to providing the service of transportation[[30]](#footnote-30). Car ownership will become increasingly less important for people, with transportation being sold either on the aggregate vehicle level through car-sharing services such as Zipcar, or on the level of individual trips such as with UberPool or LyftLine.

A focus towards price-per-mile and marginal cost of use, rather than the up-front fixed cost of buying a car, is going to be amplified by electric vehicles that offer significantly longer mileages, as the high cost of batteries can be amortized over many trips. Added to this are sensor technology and AI that make **Autonomous Vehicles (AV)** a reality. That revolution will decrease costs for car sharing services by about 70 percent per mile.

It is likely that car sharing services will become the major buyers of cars, which will change business models and depress margins for auto makers. The shift towards per-mile-pricing will increase car usage and lead to more rapid replacement cycles, meaning that new technology will be implemented at a faster pace. Cars also will be designed with an increased focus on passengers, such that, in the novel, Mikhail can communicate with his personal agent, *Christina,* through the audio and video system of the car to make dinner reservations.

AVs currently tested by Google are equipped with several sensors: a rotating sensor that creates a constantly updated 3D map of the environment, a camera that detects traffic lights and moving objects, a sensor that measures sideways movement and the vehicle's position on the map, and four radars that measure distance to identify any kind of obstacle. AVs navigate using radars like those on airplanes, emitting radio frequency waves to determine how far away an object is.

Metamaterial[[31]](#footnote-31) and AI development also are rapidly improving AV technology. Engineered materials now enable highly-directed radio frequency beams that produce a true 3D vision of the surrounding environment, determining the location and speed of all surrounding objects, even in bad weather and cluttered environments. This gives the AI better percepts, so that the vehicle can "see" around corners, apply predictive analytics of traffic patterns, identify dangerous situations and prevent accidents before they occur[[32]](#footnote-32).

**Topic 4. Self-Conscious Artificial Intelligence**

The meeting between Nigel and Tharra, and their discussions on the meaning of self-consciousness with the Indian guru Chandrashekhar Sekhar (CS) illustrate that artificial intelligence is unlike any other new technology.

AI enables new analysis of data by finding patterns in enormous data caches beyond any human's limited cognitive ability. AI faces no such limitations. While humans have always created tools that enable us to create great things, this is the first time in history when we can create something with the potential to have its own will and cognitive abilities far beyond our own.

As many have stated, the impact of this revolution is so enormous that it is impossible to predict what can be achieved when artificial intelligence surpasses human intelligence[[33]](#footnote-33). For example, AI is already able to identify skin cancer based on smartphone pictures with a higher accuracy than 21 experienced physicians[[34]](#footnote-34). Increased knowledge of our DNA, paired with AI, predictive analytics, and robotics can revolutionize health care through prediction and treatment of disease, all performed by robots at a low cost.

The potential downside of AI does however require attention, as illustrated by weapons manufacturers who are already planning for autonomous weapons that select and attack targets. Similarly, AI will have profound impact on labor markets and wealth inequality, with many jobs becoming redundant.

Thus, when CS cautions about the unknown consequences of self-conscious AI, as developed by the company ***M****/The Year One Million,* he is in fact in agreement with many of today's leaders in technology who raise concerns about the potential dangers of AI[[35]](#footnote-35).

What is especially worrisome are the unintended consequences that might follow when machines become "super intelligent." On this, a group of world-leading scientists state that "One can imagine such technology outsmarting financial markets, out-inventing human researchers, out-manipulating human leaders, and developing weapons we cannot even understand. Whereas the short-term impact of AI depends on who controls it, the long-term impact depends on whether it can be controlled at all[[36]](#footnote-36)."

In addition to these risks, providers of cloud-based agents – in this case the fictional company that delivers *His Masters Voice –* will have unprecedented knowledge about people and will control what information is presented to them. We already see this trend reflected in today's business models, which are based on identifying people's needs and preferences and knowing what product to sell to which customer.

In fact, information is rapidly becoming a new asset class, with some stating that personal data is the "oil of the 21st century[[37]](#footnote-37)." Take Google for example. In addition to knowing what users search for, Google also has the ability to decide what to present to users. Using similar capabilities, foreign governments, through Facebook, may have influenced the US presidential election of 2016.

When personal agents begin to handle our travel, work, consumption, communication, and searches for information, collecting and analyzing more data and thereby creating a fuller picture of our personal characteristics, this type of influence will be amplified. It is not unthinkable that commercial interests will influence these services. For example, they might provide us with a route to work that passes by sponsored retail locations, or the agents might frame sentences to influence our opinions in some way[[38]](#footnote-38). So besides leading to the end of privacy, new technology might, subconsciously, infringe on our decision-making.

Consumer demand for new technology has created a **democratization of technology** phenomenon. Large enterprises are now influencing government policy based upon their ability to use consumers to circumvent government policies. Apple's refusal to deliver content to the NSA and other government organizations exemplifies the power of this new phenomenon.

Finally, we should say a word about the role of government and cities in this new world. The largest, richest, and most heavily targeted markets in the world are in cities. Commercial companies, including Apple, Facebook, Uber and others, are spending enormous R&D budgets developing applications for urban markets. City, State, and Federal government spending on the digitalization of cities pales in comparison.

It is the commercial companies that will decide how citizens in cities will function and what applications they will use. Most of our city governments are legacy-based systems that were designed for the immediate demands of the post-war era before technology exploded to the forefront. As such, their policies, expertise, and aptitude are woefully unprepared to deal with the new world realty. Perhaps the best example of this is Silicon Valley, the heart of global innovation and technology risk-taking.

Here in Silicon Valley we have terrible traffic congestion, failing infrastructure, city governments that do not coordinate to solve regional problems, and a near complete lack of expertise in city planning for future needs. In fact, along with incompetence in city planning comes arrogances and these alarming statistics. Silicon Valley has, among other things, the highest poverty rate in the country, the most expensive housing, some of the worst infrastructure costs, average public education, and high rates of homelessness. No matter how advanced the knowledge in technology, social and government expertise is way behind the curve and not likely to catch up.

**Topic 5. Encryption and Crossing the Data Layer**

London of 2050 is now not just a physical city of roads and buildings, it is also a collection of three-dimensional commercial and city data layers, such that every aspect of human existence within cities can be analyzed, understood, and predicted for future advantage.

Much of the technology represented in this depiction of London 2050 already has been described in this companion guide, most notably sensors. Today, sensor data is often collected, although not yet centralized for entire cities or crossed with other data, a development that will create true value, leading to a real-time digital representation of almost every aspect of a city.

Current research on merging datasets will lead to the ability to visualize an entire city and analyze "What if?" scenarios using predictive analytics[[39]](#footnote-39). For example, consulting company WSP has developed a modelling platform of the entire city of Seattle. It is used to simulate the impact of an earthquake, based upon data about durability for all buildings and infrastructure.

The power of this platform comes from its visualization of outcomes. Using highly credible data, it can show what an earthquake will do to the city. This same technology can be used to "drop new buildings" into the model to see the impact on traffic, power, consumer locations, and building return on investment (ROI). Any data type may be used in the model, such as commercial transactions or movement.

A viewer of the model can "fly" over the city of Seattle or dive underneath the city to see the utilities, power lines, and water delivery systems. Eventually, it will be possible to look at city economics in a rather new and dramatic way, seeing how money moves through the city, where it stops, where it grows, and where it exits. Commercial companies will be able to leverage this experience to make consumer-facing marketing decisions and to develop commercial markets within urban locations.

As data crosses the layers of the city, it will be combined to create a new in-depth profile of who we are, where we work, where we shop, recreate, and entertain. The financial power of the model will test our ability to maintain the legacy concept of individual privacy.

Even today, we see rapid expansion underway in the availability of various kinds of information, such as digitized public records, so data on matters such as crime, taxes, and education can immediately be applied to monitor the impact of policy. For example, law enforcement could use real-time updates on crime within very small geographies[[40]](#footnote-40).

Commercial applications and social media also provide vast opportunities when crossed with other data[[41]](#footnote-41). For example, a dataset combining demographic information, movement, and preferences for every individual in a city can tell us what kind of services, products, or housing people are most likely to want or buy, and where these individuals live and spend their time. The real estate listing service *Zillow* already provides information on housing preferences; the restaurant booking, and review platform *Yelp* tells us the preferences of demographic groups and the location of various types of establishments. In fact, restaurant reviews are currently used to allocate scarce resources for health and safety inspections in New York, so that restaurants with bad reviews are checked more frequently[[42]](#footnote-42). Similarly, the location and timing of Google searches can tell us where outbreaks of influenza are taking place so that public health resources can be more efficiently directed. Now imagine these and other services becoming more capable by orders of magnitude when powered by quantum computing.

Sensors on buildings and on handheld devices can tell us the number of people at a certain location, in what direction they are walking, and what kind of activities are taking place (such as waiting in line, eating and drinking, or walking). In the future, data on movement from smartphones could tell us that people who live at location A often work in location B and then eat lunch at location C, providing valuable insight for new real estate and infrastructure development, marketing efforts, and public transport.

This type of data gathering does raise issues concerning personal privacy and data integrity, with some sort of **encryption** of data vital. The basic premise of encryption is to scramble data, so it is illegible for unintended parties. This kind of data protection goes way back – even Julius Caesar camouflaged important messages with encryption. Today, the key between the actual information and the encrypted data, **the cipher**, is created through more complex algorithms, with the main differences between various technologies being key size and strength. Early data encryption often followed the common **Data Encryption Standard (DES)**, which was adopted by the United States in 1976 and subsequently spread across the world. A variety of subsequent standards have emerged since the late 1980s, being both faster and more secure.

Modern encryption takes two primary forms: **symmetric key algorithms** and **asymmetric key algorithms**. The former is comparable to multiple users having identical keys to the same lock, while the latter means each user has a unique key. In this case, when person A sends information to person B, it is sent with a lock that only B can open – and vice versa for the reply. Basically, two sets of keys are used, a public and a private, so that anyone can encrypt information with the receiver's public key. The receiver then decrypts the information with his or her private key. This type of encryption prevents third parties from gaining access to the key and prevents security breaches from spreading, for if A's key becomes known, it does not provide access to B's data.

Although generally considered to be secure, asymmetric encryption technology is dependent upon how much computing power someone trying to break the encryption has at their disposal. Current super-computers can now crack standard encryptions, and rapidly increasing computing power will only further accelerate the need for better – supercomputer-proof – encryption.

Just as quantum computing will revolutionize our ability to process data, **quantum mechanics**[[43]](#footnote-43) will also transform encryption[[44]](#footnote-44). The basic (and still somewhat complex) premise of **Quantum Encryption,** is that the key is incorporated into a photon – a light particle – that is correlated with a second photon in quantum entanglement[[45]](#footnote-45) – meaning that any attempt to measure or observe one photon also impacts the other, correlated, one. The photon in which the key is embedded is sent to a receiver through fiber cables[[46]](#footnote-46), making it unlikely that someone could break into the data when it is between sender and receiver on the network. Since the pair of photons are entangled, any such interruption would alert the sender as it would impact the correlated photon.

One obstacle is that it is difficult to create databases that are both encrypted and useable. That said, researchers recently have found a fast and efficient way to make computations without ever decoding the data[[47]](#footnote-47). So, in the novel, when Mikhail addresses the privacy concern raised by Tharra regarding data that tracks schedules, work habits, home behaviors, and transactions of all London residents, it is this new technology that allows for query-into-encrypted-data computations on encoded strings of numbers that yield decoded results that are identical to those produced if the data hadn't been encrypted at all.

It is however important to note that encryption does not imply privacy. The main drive for encryption is to protect the value of the information, rather than the privacy of individuals. In the scenario depicted in *The First Light of Day,* de-personalized encrypted information is used to target potential customers who subsequently voluntarily opt to turn over their information to the service provider – like the terms and conditions of most commercial and social media applications of today. Then as now, most people voluntarily provide various companies with information such as their travel, consumption, and income every time they use a service.

**Topic 6. Cyber Security and Warfare**

New vulnerabilities emerge because of our increasingly digitalized society, part of the so-called **Internet of Things (IoT)**.

**IoT** refers to network-connected devices such as smartphones, vehicles, sensors, home appliances, and even infrastructure such as water pumps, which send and receive information. This development is exponential, with the number of Internet-connected devices predicted to reach 200 billion by the year 2020[[48]](#footnote-48), compared to 15 billion in 2015 and just two billion in 2006. Growing in parallel, cybercrimes are estimated to have cost the global economy more than $450 billion in 2016, with two billion personal records ending up in the hands of criminals[[49]](#footnote-49).

This is not only a commercial problem, for as society is becoming reliant on technology, the ability to damage or destroy digital infrastructure will become an increasingly important part of warfare. Records and services that are central to the work of government, military, and financial entities, are also increasingly digitalized. The advent of cloud computing and Big Data increases incentives for attacks. We see the associated risks in the novel – Russia's spying on both *His Master's Voice* and the personal information of millions of people, provided through their interaction with personal agents.

The basic premise of cyber-attacks is to exploit computing vulnerabilities relating to what is knowns as **Information Assurance (IA)**, namely the process of storing and processing data and ensuring that the correct information is provided to the right person at the right time. The field of cyber-security is concerned with three principles[[50]](#footnote-50): first, that there is a flaw in the system that is subject to attack; second, that the attacker has insight about this flaw; and third, that the attacker also has the capabilities to exploit that flaw.

Attacks on computer networks are typically initiated by the installation of malicious software – **malware**[[51]](#footnote-51) – that can provide hackers with access to the user's information, such as banking, passwords, and files. Alternatively, malware can destroy data, cause system failures, and drain computing resources.

The initial installation of malware typically requires some sort of human action, such as so-called *phishing,* where attackers attempt to get sensitive information, such as passwords, by sending emails asking for information or linking to counterfeit websites. As malware is typically designed to spread across networks, increased connectivity leads to greater risks associated with malware infections.

Cyber threats are posed by individuals, groups, and governments aiming either to shut down a nation's networks and computers, to disrupt delivery of essential services, or to steal information or money. Criminals often steal identities and personal information to use in illegal activities, such as to make online purchases, to blackmail victims over sensitive information found on targeted computers, or to commit so-called **cyberextortion,** shutting a system down and demanding money in return for restored access.

An example of this is the malware **WannaCrypt**,which exploited a vulnerability in Microsoft software on more than 75,000 computers in 99 countries. It allowed for the encryption of content on victims' computers. The attackers subsequently required payment of $300 worth of bitcoins to decrypt the files so that the user could regain access to the information[[52]](#footnote-52).

Another major cybercrime was committed by a criminal campaign based in Russia, China, and Europe, known as **Carbanak**. This organization managed to steal an estimated $1 billion from numerous banks, from 2013 to 2015, through the installation of malware that tracked every move on bank computers that handled bookkeeping and wire transfers[[53]](#footnote-53).

It all started with bank employees installing the malware through emails that looked like normal office correspondence. The malware went undetected, while intercepting the screens of bank employees and sending back images and videos that gave the criminals insight into bank routines and systems. The criminals even managed to maintain continuous access to the bank system through remote access tools similar to those used by IT support functions.

Being able to make transactions – and make them look normal – enabled the criminals to transfer funds to other accounts and to order cash to be dispensed from ATMs. This strategy is, in fact, commonly used to enable penetration of the first line of network defense, **firewalls.[[54]](#footnote-54)** These have the primary function of monitoring incoming and outgoing traffic and deciding whether that traffic should be allowed or not. When hackers gain insight into organizational routines, firewalls become a less efficient means of protection. Because Carbanak's transactions looked like normal transactions and followed regular procedure, they could get past the firewall.

Hackers can also gain access to data through bypassing of normal authentication, by what is often referred to as a **backdoor** that is typically included in systems either intentionally, by mistake, or by installation through attack. In fact, in 2013 it was revealed that a backdoor was installed by the NSA into the encryption standard NIST[[55]](#footnote-55), supporting global surveillance of Google and Yahoo accounts, phone records, e-mail, and instant messaging content.

Data security is a perpetual arms race between developers and hackers, illustrated by the recent revelation that Intel processors – used in most of the world's computers, tablets, and smartphones – have two major flaws, known as **Meltdown** and **Spectre**, that potentially can provide hackers with access to their memory. This is especially problematic for cloud storage providers, with hackers being able to access information such as customers' passwords. Current information suggests these flaws can be addressed with a so-called **patch**, which is a piece of software that updates or remedies a problem with a computer program or supporting data. However, such a patch also can decrease computer performance by as much as 30 percent[[56]](#footnote-56). Spectre is even more problematic. It might not be possible to address this flaw without a full architectural redesign of the processors themselves – meaning that the computer may also need to be replaced.

Besides attacks by criminals with financial motives, nations are increasingly using cyberwarfare in conflicts. A prominent example is the malware **Stuxnet**, which is thought to have destroyed upwards of one-fifth of Iran's nuclear centrifuges before being discovered in 2010. It is the first known use of cyber weapons and is likely to have been installed through USB flash drives. In operation, it changed the centrifuge controls so that the fast-spinning centrifuges tore themselves apart.

Although not confirmed, Stuxnet is widely believed to be part of a US-Israeli operation, known as "Operation Olympic Games," aimed at sabotaging the Iranian nuclear program, an operation that is thought also to have included the so-called "Flame" computer worm that infected computers across the Middle East[[57]](#footnote-57). Masked as a Microsoft software update, the code quickly spread across highly secure networks and went undetected for years, all the while controlling computer functions such as activating microphones and cameras, logging keyboard strokes, taking screen shots, and transferring stolen information to distant hackers.

Warfare of the future will be increasingly fought online, with large-scale cyber-attacks having the potential to obstruct access to the services of banks, government, and communication technology, all of which would cause havoc to every corner of society. It is in fact theoretically feasible for hackers to gain control of airplanes, flight control systems, and power grids[[58]](#footnote-58). Experts are raising the alarm that current security levels and preparation for cyberattacks are far from sufficient.

A scenario such as a large-scale attack on the US – resulting in inaccessible on-line banking sites, disabled ATMs, and non-functional internal accounting systems – would paralyze the nation's economy. And the perpetrators would be all-but untraceable[[59]](#footnote-59).

Complicating matters, in cyberwarfare the likelihood of unexpected consequences and collateral damage are much higher compared to traditional weapons, as malware typically is designed to replicate and spread across networks. A cyberattack on the power supply at a specific location might very well spread beyond its intended target and shut down the electrical supply for an entire region[[60]](#footnote-60).

In fact, Stuxnet was intended for a specific Iranian network, yet it was discovered only after having spread beyond its intended target. It did not conduct further attacks, only because a self-destruct date was included in the code. Had the hackers been less careful, the attack would have been far more widespread. Of course, the potential for accidental conflict only increases when it is difficult to understand the intent of attacks and the consequences of retaliation[[61]](#footnote-61).

These technologies, strategies, and cybersecurity concerns come into play in the novel, which depicts a future where increasing amounts of personal data, connectivity, and cloud storage have intensified the arms race between developers and hackers.

**Topic 7.** **Human-Machine Interaction**

Current technologies, and the advent of personal agents, will have a profound impact on how humans communicate with each other, and with machines.

Much of the future depicted in *The First Light of Day* illustrates how the line between real, human interaction and comparable interactions with technology will be increasingly blurred. For example, texting between humans will be handled by AI, and daily interactions between people will be managed by agents whose actions are almost indistinguishable from humans.

Day-to-day activities that used to require interaction between humans will now be completed by machine, spanning everything from making purchases online to ordering fast-food through a touch-screen to ordering drinks in a bar after work. This development will continue as advances in AI lead to algorithms that not only, like today, recommend products on Amazon and video content on Netflix (acting on our behalf), but also offer more advanced services such as bookkeeping, taxes, and basic legal work.

Efficiently giving instructions to machines and in turn receiving useful information from them – this essential transaction is part of a field of research known as **Human-Machine Interaction (HMI)**[[62]](#footnote-62).Broadly, thisencompasses studies on the design, evaluation, and implementation of systems for human use. Current initiatives in this area include improving the interaction between humans and technology. In the case of a computer system, for example, much work centers on the usability of systems and the computer's interface.

By nature, this is an interdisciplinary field, relating technology to questions of culture, values, and social norms that can and should impact computer systems. Part of this is so-called **Augmented Reality (AR),** which means that layers of information are added to our perceived reality, such as a system that adds information about the people we are talking to on a screen, or through AR eyeglasses such as Microsoft HoloLens or Google Glass. This is slightly different from the better-known **Virtual Reality (VR)**, which refers to a fully virtual experience, rather than one that is only partially augmented.

Research on such eyewear is part of a subfield of AR that specifically refers to changing the perceived reality through wearable computers or hand-held devices, a subfield known as **Computer-Mediated-Reality (CMR).** Such AR enabling devices have much in common with the AI based agents depicted in *The First Light of Day*, as Microsoft's virtual agent, Cortana, is one of several applications for the HoloLens.

Various applications also use an AR display's ability to display holograms. The "Sidekick" project, a collaboration with NASA, is one such application. This initiative will enable a HoloLens to transmit the exact same perceived reality the astronaut sees, in 3D, to the ground crew, who in turn can give the astronaut instruction and support by adding illustrations to the image. This system is currently being deployed on the international space station, replacing printed instruction and voice-based communications. It is both increasing the efficiency of complex tasks associated with space exploration and potentially decreasing the need for training.

A commercial application of this technology is HoloTour, which allows for realistic 3D virtual tourism that creates the experience of moving through any place without actually traveling there. Google Earth is another well-known, primitive example of this type of VR, offering a similar experience in which one can walk through any city at the street level.

In the novel, most of Mikhail's interactions are with AI agents: chatting with his personal agent about his schedule, work, and shopping; gaming his social life through texts he's not actually writing himself; and experiencing a therapy session in which AI and ML enable a realistic interaction with his dead childhood friend, Sasha.

This is not science fiction. VR already is being used by psychologists as a cost-efficient way to study human behavior, including such phenomena as how humans react to "being in someone else's shoes," how digital influences alter perception and emotions, and how technology has changed social interaction[[63]](#footnote-63). Other uses for VR include training for doctors, flight simulation for pilots, and the training of astronauts while still on earth. The last, an application of VR used by NASA for more than 20 years, simulates zero-gravity environments.

Understanding how interaction occurs in a virtual environment has widespread importance for applications built on this type of technology. Perceived trustworthiness becomes hugely important, implying that AI-based agents should be made more attractive and life-like to make humans trust their instructions or, in the case of commercial transactions, buy recommended products or services. Adding to the overall complexity is that exposure to virtual or augmented reality is likely to impact our psyche in ways not fully understood, as little research on this impact exists. It is not unlikely that long-term exposure – where the line between reality and "synthetic" reality is blurred – ultimately will result in physical disorders and impaired decision-making when real-life choices are based on virtual experiences.

The increasing number of tasks being conducted by machines raises the question of how much we should trust technology. Some research on human-machine-team-performance is in fact already aimed at calibrating the appropriate level of trust that should be given to a machine[[64]](#footnote-64) (as AI also make mistakes, especially in settings characterized by uncertainty and doubt).

How should the intent and honesty of an AI-based agent or robot be determined? This question will become increasingly important given that many, if not most, financial, medical, and legal issues will be handled online. In fact, most of us feel far more comfortable giving up information in an online questionnaire than we do in an interaction with an unfamiliar human – something that often is far from rational, given the commercial use of personal data.

**Topic 8. Cryptocurrencies**

The way we conduct transactions in the future will be very different from how we do so today. This will have an impact on when and where we spend money – such as making a purchase through a conversation with your personal assistant in an autonomous vehicle on your way to work. Part of this is also how the transaction is done and the means of payment, where government-backed currency transferred through cash, credit, or debit card is the typical transaction of today.

We now have developed new mediums of exchange. Traditional currencies – such as the US dollar, the Euro, Chinese Renminbi, and Japanese Yen – are "free-floating fiat-currencies," meaning that exchange rates are determined on the open market, and their underlying value comes from being backed by a central bank promising payment and a legal system to resolve conflict. Thus, a US dollar is basically an IOU backed by the US Federal Reserve.

This type of currency, backed by a central bank with a monopoly on money supply, has been the prevailing system, with alternative currencies (not recognized by the legal system as mediums of exchange, contrasting from so-called "legal tender") having had limited use. But the advent of **Bitcoin** in 2009 has changed everything.

Bitcoin is one of the first and perhaps most famous of **Cryptocurrencies** offering a digital asset and medium of exchange, and an alternative to traditional currencies. At the heart of cryptocurrencies is cryptography – the encryption that secures the supply of new units of currency and verification of transactions, thus providing heightened trust to users.

The backbone of cryptocurrencies is **Blockchain**, a public ledger of all bitcoin transactions. The system is decentralized and is supported by "nodes," which are computers connected to the Blockchain network that administer the task of verifying transactions that are added to the Blockchain.

Each user is identified with a unique number, known as a "Blockchain address." It is between these addresses that transactions are executed. Once a transaction has occurred, records are impossible to change, as each transaction is linked to the previous transaction (that is the "chain" part of Blockchain; "block" refers to groups of transactions that are continuously added).

Validation[[65]](#footnote-65) of blocks of transactions is handled by administrators who, in return for conducting this task, compete to win Bitcoins by solving mathematical problems. This practice, known as "mining," is how new units of cryptocurrency are created. In the case of Bitcoin, the maximum number of units is set at 21 million, with a supply of about 16.6 million coins available by the end of October 2017. Thus, where supply of traditional currency is at the discretion of central banks, and subject to change based upon economic necessity, a cryptocurrency has a predetermined upper limit to supply.

Anonymity and lack of centralized control do, however, pose issues, most notably a concern that cryptocurrencies already are used to enable illegal activities, including tax evasion, money laundering, extortion, and a bypassing of trade restrictions. In addition, there is the risk of theft. Cryptocurrency theft is often attempted by North Korea through cyber-attacks on cryptocurrency exchanges[[66]](#footnote-66). In terms of anonymity, so-called "altcoins" are highly preferred by criminals, as any identifying information is removed from the Blockchain of transactions[[67]](#footnote-67). In relation to the novel, crypto-currency enables illegal and clandestine activities.

Blockchain allows digital information to be distributed, but not altered or copied. The technology therefore has the potential to offer a transparent and predictable way to store not only cryptocurrency, but any type of sensitive data. If contracts are embedded in code and protected from being changed or deleted, and signatures are identified and validated via Blockchain, the need for intermediaries, such as lawyers and brokers, will diminish[[68]](#footnote-68). This does, however, raise some questions: if the technology proves not as perfect as it currently is believed to be, dependence on it might have catastrophic consequences.

**Topic 9. Climate Change**

Climate change and global warming[[69]](#footnote-69) are going to have a profound impact on society, likely resulting in large-scale migration, land loss, and wealth redistribution, as land, infrastructure, and buildings become uninhabitable.

Although the climate has changed throughout earth's history, with the last Ice Age 7,000 years behind us, most of these changes have occurred due to shifts in the earth's orbit, varying the amount of sun our planet has received. However, recent changes have been extremely rapid, with a 2.0 degrees Fahrenheit (1.1 degrees Celsius) increase in temperature during the 20th century, with most of that change occurring during the last 35 years. In fact, 16 out of the 17 warmest years on record have occurred since 2001. During 2016, eight months experienced the highest temperatures on record for their respective months[[70]](#footnote-70). This increase in temperature is due to the heat-trapping nature of carbon-dioxide and other gases, the **greenhouse effect**, which has been known since the mid-19th century[[71]](#footnote-71).

There is no scientific doubt that greenhouse gases are the root cause of climate change[[72]](#footnote-72), a consequence of human behavior, and that future developments will be impacted by human behavior[[73]](#footnote-73). Even the most conservative estimates of future climate change will require massive adaption to new circumstances, with more extreme weather, changed sea lanes, and mass extinction of species.

Already we are experiencing rising temperatures on land and in oceans. Ice sheets in Antarctica and Greenland are melting, as are glaciers on the top of mountains elsewhere across the planet. Seasonal snow covers are decreasing. And sea levels rose by eight inches during the 20th century, with the rate of increase doubling during the last two decades[[74]](#footnote-74).

A major theme of the novel is that technology is developing at an exponential pace, and that humans, who tend to think linearly and in their comfort zone, can't keep up. Climate change is another example of the human inability to handle rapid change, illustrated by our lack of preparation for rising sea levels and more extreme weather.

A good illustration – although far from a unique case – is the San Francisco Bay Area, home of Google, Facebook, and Apple, and research institutions such as Stanford and UC Berkley. There, investors seem to have ignored climate change – with 27 large construction projects, totaling $21 billion in value, proposed in areas vulnerable to flooding in the coming decades[[75]](#footnote-75). Between 2010 and 2015, the city of San Francisco alone approved nearly 50 residential, retail and office developments in locations fewer than eight feet above sea level[[76]](#footnote-76), even though real estate less than 10 feet higher than sea water level is at risk for recurring or complete flooding by the year 2100. This, despite the fact that shortly before his death, Ed Lee, the Mayor of San Francisco, stated that the city would standardize prediction of a 66-inch rise in sea water over the next five decades. Politics seems to have outweighed protecting citizens.

The city also faces a major crisis with an existing sea wall which, if ruptured during a severe earthquake, could result in flooding of most of the city's downtown, including the financial district. Yet, despite the potential for such an enormous catastrophe, just as we don't prepare for the unintended consequences of exponential technological development, neither government nor private investment is taking notice of this threat. Climate change will have a dramatic impact on business and governments. For example, insurance companies will have to change dramatically the way they price and evaluate risk, and governments will have to find new ways to finance infrastructure, such as sea walls.

**Topic 10. Humans and Work**

We are currently experiencing an unprecedented pace of technological advancement. This will have a profound impact on labor markets, with many administrative jobs being at risk for replacement by machines and cloud agents.

The consulting firm McKinsey estimates that upwards of 800 million jobs are at risk by 2030 as a result of robotics and automation[[77]](#footnote-77). The advent of autonomous vehicles will put professional drivers out of work, and warehouses that used to be run by a large staff handling forklifts will be run by a few people overseeing fully automated robots. Fast-food orders can be made on touch screens, and a robot that makes hamburgers without any human ever touching the meat already exists[[78]](#footnote-78).

Increasingly complex tasks are being automated, resulting in improved speed, higher quality, and lower production costs for goods and services. On a positive note, AI will allow us to spend our time more efficiently, with technology performing routine administrative tasks, such as taxes and bookkeeping, so that humans can spend more time on activities we find more important or pleasurable.

But this transformation also raises the question of what is to happen to those who are no longer "useful," as they have been outperformed by machines. The US already has experienced a dramatic increase in the number of workers who have left the workforce permanently, having given up on any prospect of finding a job. Although unemployment numbers are at a record low, these workers who have left the workforce are not included in the numbers.

Even those workers who don't lose their jobs are likely to experience downward pressure on salaries as the number of unskilled jobs become comparably fewer in relation to the pool of jobseekers. The UK national job exchange, as depicted in the novel, with people competing for day-to-day employment, is in fact just an extrapolation of current trends away from long-term employment.

Sharing services illustrate this development well. Where cab drivers used to have secure employment, they are now contractors for Uber or Lyft who must bear the full consequences of changes in revenue and costs. Similarly, renting a room through Airbnb is a substitute for staying at a hotel, where concierges, maids, and other staff enjoy a more secure form of employment. On a higher level, firms are increasingly outsourcing services that are beyond their core business[[79]](#footnote-79), such as a construction company that outsources invoicing and legal services.

In many sectors, the outsourcing of services happens at the level of the individual. For example, news outlets often hire journalists on a contractual basis, and universities increasingly hire PhDs for specific research projects or teaching assignments, rather than providing secure jobs that lead to tenure.

Besides the move away from employment security, several trends are concurrent and intertwined with the rapid rise of technology, most notably inequality and urbanization. Much of the current transformation of society that is attributed to technology is happening in cities. There already are substantial gaps in employment and wages between urban and non-urban areas[[80]](#footnote-80), as highly educated households concentrate in cites. Because of agglomeration economics, due to the value of the concentration of human capital, people make more money in cities regardless of their level of competence. The concurrent trends of automation, specialization, urbanization, and the rise of technology are likely to exacerbate the income gap between low- and high-skilled individuals.

Government policy, most notably regarding taxation, will have to change as business owners will need fewer workers, increasing profits and lowering overall tax revenue. In a 2017 interview, Bill Gates proposed a robot tax[[81]](#footnote-81). When a factory worker makes, say, $50,000, that results in income taxes and social security payments. When that job is replaced by a robot, Gates proposes that a similar level of taxation should be imposed on the employing company to temporarily slow the spread of automation and to finance other jobs, such as taking care of the elderly or teaching, which are believed to be better performed by humans.

Gates believes that slowing down the pace of automation would allow governments to figure out a way to handle a not-very-distant future when most jobs are replaced by machines. Personally, I don't believe the pace of technology advancement can be slowed and that the outsized influence of corporate donors on Congress will prevent legislation from being passed to slow the speed of innovation artificially.

The novel outlines a society that is far more divided and unequal than what we see today. Current trends suggest we are headed in this direction. Decision-makers will need to address these trends, or greater cultural division and economic inequities may become yet another unintended consequence of progress.

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1. The discussion paper "Digital Cities: Real Estate Development Driven by Big Data" by Donner, H. Eriksson, K., and Steep, M. (2017) describes the concept of the Quantum Engine. In short, this entails rapid development of (1) computing power, (2) free and virtually unlimited storage, (3) smart algorithms, (4) artificial intelligence and machine intelligence, and (5) advanced materials science. [↑](#footnote-ref-1)
2. A central concept for defining the scope of AI is Alan Turing's **Turing Test** (1950), which provides an operational definition of intelligence and requires that a computer can (1) communicate successfully through *natural language processing*; (2) store what it knows or hears, known as *knowledge representation*; (3) use the stored information to answer questions and draw conclusions through *automated reasoning*;(4) adapt to new circumstances and identify and extrapolate patterns, known as *machine learning.* When including the ability for physical interaction, the so-called total Turing Test also includes (5) the ability to perceive objects through *computer vision* and (6) the ability to manipulate objects and move through *robotics*. These disciplines make up most of AI. See: Russel, S. and Norvig, P. (2010) *Artificial Intelligence: A Modern Approach*, Upper Saddle River, New Jersey: Prentice Hall. [↑](#footnote-ref-2)
3. Broadly defined, a sensor is a device that detects any type of event or change in some environment and sends that information to some other device, such as a computer. [↑](#footnote-ref-3)
4. Similar to the concept of a personal agent under development by Microsoft (See: Holley, P. 2015, "Bill Gates on dangers of artificial intelligence: 'I don't understand why some people are not concerned," *The Washington Post*). [↑](#footnote-ref-4)
5. Kincaid, J. (2011) "The Power of Voice: A Conversation with the Head of Google's Speech Technology," *TechCrunch*. [↑](#footnote-ref-5)
6. Gandomi, A., and Haider, M. (2015) "Beyond the hype: Big data concepts, methods, and analytics," *International Journal of Information Management*, 35.2, 137-144. [↑](#footnote-ref-6)
7. Kincaid, J. (2011) "The Power of Voice: A Conversation with the Head of Google's Speech Technology," *TechCrunch*. [↑](#footnote-ref-7)
8. IOS is Apple's mobile operating system. [↑](#footnote-ref-8)
9. This is developed by Parc under the ARPA-E project. [↑](#footnote-ref-9)
10. See https://www.parc.com, "metamaterial devices and applications." [↑](#footnote-ref-10)
11. This definition and some history and information on predictive analytics and machine learning appears on the website of the analytics software provider SAS: https://www.sas.com/en\_us/insights/analytics/predictive-analytics.html [↑](#footnote-ref-11)
12. Myers, A. (2017) "An artificial intelligence algorithm developed by Stanford researchers can determine a neighborhood's political leanings by its cars," *Stanford News Online*. https://news.stanford.edu/2017/11/28/neighborhoods-cars-indicate-political-leanings/ [↑](#footnote-ref-12)
13. Glaeser, E. L., Kominers, S. D., Luca, M., and Naik, N. (2018) "Big data and big cities: The promises and limitations of improved measures of urban life," *Economic Inquiry*. [↑](#footnote-ref-13)
14. Henderson, J. V., Storeygard, A., and Weil, D. N. (2012) "Measuring economic growth from outer space," *The American Economic Review*, 102(2), 994-1028. [↑](#footnote-ref-14)
15. Examples of how city management is supported by digital infrastructure are provided by Glaeser, et al. (2018) "Big data and big cities: The promises and limitations of improved measures of urban life," *Economic Inquiry*, 56.1, 114-137. [↑](#footnote-ref-15)
16. Glaeser et al. (2018) "Big data and big cities: The promises and limitations of improved measures of urban life," *Economic Inquiry*, 56.1, 114-137. [↑](#footnote-ref-16)
17. A study that simulated how smartphones could be used to track public transit usage in Chicago found that this kind of tracking could improve overall transit efficiency, with expected wait times being two minutes shorter if only 5% of transit users participated in the system that allowed for tracking. At a 20% level of penetration, the average wait time went from nine to three minutes (Thiagarajan, A., Biagioni, J., Gerlich, T., and Eriksson, J. (2010) "Cooperative transit tracking using smart-phones," in *Proceedings of the 8th ACM Conference on Embedded Networked Sensor Systems*).

    Another, similar study analyzed prediction of bus arrival times based on tracking through smartphones. Knowing if a bus is going to be late based on information on other travelers, traffic, and accidents allows people to make more informed decisions on how to move within a city. The authors found that this type of prediction system provides outstanding accuracy compared to current systems (Zhou, P., Zheng, Y., and Li, M. (2012), "How long to wait? Predicting bus arrival time with mobile phone based participatory sensing," in *Proceedings of the 10th international conference on Mobile systems, applications, and services*). [↑](#footnote-ref-17)
18. https://how-old.net [↑](#footnote-ref-18)
19. Current research using smartphone tracking has found that movement patterns are linked to personality. An example is that extroverts move in different patterns than introverts, people entering depression will move less, and psychotic episodes are linked to erratic movement. [↑](#footnote-ref-19)
20. The definition of Big Data often varies, although the phrase always refers to very big datasets. A common way of describing Big Data is through three V's: *Volume* (it is very large and storage would have been problematic not very long ago), *Velocity* (it streams and adds up at unprecedented speed, in near real-time), *Variety* (Big Data often stems from various sources such as text, audio, and video, and is often unstructured. This often requires advanced algorithms for data processing). Statistics platform provider SAS also adds *Variability* (data flows are often inconsistent, with periodic peaks) and *Complexity* (data stemming from multiple sources, making it difficult to link and match data). [↑](#footnote-ref-20)
21. The discussion paper "Digital Cities: Real Estate Development Driven by Big Data," by Donner, H., Eriksson, K., and Steep, M. (2017), define this development as a Quantum Enginethat consists of five major technological trends that drive commercial applications of Big Data: (1) rapidly increasing computing power, (2) virtually unlimited and free storage, (3) smart algorithms, (4) artificial intelligence and machine learning, and (5) advanced materials science. [↑](#footnote-ref-21)
22. A platform for storing and processing enormous data is Hadoop, which basically breaks down data into smaller pieces for processing before putting the pieces back together. This allows for parallel processing, so that the time of execution is reduced while keeping processing power, memory, and storage speed constant. [↑](#footnote-ref-22)
23. This is known as the EPR paradox. See: Einstein, A., Podolsky, B., Rosen, N. (1935), "Can Quantum-Mechanical Description of Physical Reality Be Considered Complete?" Phys. Rev. 47 (10): 777–780. [↑](#footnote-ref-23)
24. This quote stems from the fact that quantum entanglement goes against the laws of traditional physics, causing Einstein and his co-authors to believe that quantum mechanics is incorrect or at least incomplete. [↑](#footnote-ref-24)
25. Popkin, G. (2017) "China's quantum satellite achieves 'spooky action' at record distance," *Science*. [↑](#footnote-ref-25)
26. Lin, J. and Singer, P.W. (2017), "China is opening a new quantum research supercenter," *Popular Science*. [↑](#footnote-ref-26)
27. See Chapter 5 of this companion guide for a description of quantum encryption. [↑](#footnote-ref-27)
28. In fact, a study of nine developed countries showed that information and communications technologies (ICT) contribute between 0.2 to 0.5 percentage-points a year in economic growth. See: Colecchia, A. and Schreyer, P. (2002) "ICT investment and economic growth in the 1990s: Is the United States a unique case? a comparative study of nine OECD countries," *Review of Economic Dynamics*, 5.2, 408-442. Similarly, the consulting firm McKinsey has estimated that the internet accounted for 21% of economic growth in mature economies in the early 2000s. See: Manyika, J. and Roxburgh, C. (2011) "The great transformer: The impact of the Internet on economic growth and prosperity," McKinsey Global Institute.

    [↑](#footnote-ref-28)
29. This type of massive data and the ability to optimize performance have led to a remaining challenge for airplane engine manufacturers – data on failures is now so rare that their algorithms for predicting failure are not optimized. [↑](#footnote-ref-29)
30. Ford, B. (2014) "Bill Ford on the Future of Transportation: We Can't Simply Sell More Cars," *The Wall Street Journal*. [↑](#footnote-ref-30)
31. See Chapter 1 of this companion guide, on metamaterials. [↑](#footnote-ref-31)
32. The company Metawave has developed radar technology with metamaterials (known as the WARLORDTM radar) and AI solutions for autonomous vehicles. See: https://www.metawave.co [↑](#footnote-ref-32)
33. Hawking, S., Russell, S., Tegmark, M. and Wilczek, F. (2014) "Transcendence looks at the implications of artificial intelligence – but are we taking AI seriously enough?" *The Independent*. [↑](#footnote-ref-33)
34. # See Esteva, A., Kuprel, B., Novoa, R. A., Ko, J., Swetter, S. M., Blau, H. M., and Thrun, S. (2017). "Dermatologist-level classification of skin cancer with deep neural networks." *Nature*, 542 (7639), 115-118.

    [↑](#footnote-ref-34)
35. In January 2015 dozens of AI experts signed an open letter on the dangers of AI, "Research Priorities for Robust and Beneficial Artificial Intelligence: An Open Letter." The letter has received over 8000 signatures to date.

    Hawking, S., Russell, S., Tegmark, M. And Wilczek, F. (2014) "Transcendence looks at the implications of artificial intelligence – but are we taking AI seriously enough?" *The Independent*.

    Holley, P. (2015), "Bill Gates on dangers of artificial intelligence: 'I don't understand why some people are not concerned,'" *The Washington Post*.

    Holley, P. (2014), "Stephen Hawking just got an artificial intelligence upgrade but still thinks it could bring an end to mankind," *The Washington Post*. [↑](#footnote-ref-35)
36. Hawking, S., Russell, S., Tegmark, M., and Wilczek, F. (2014), "Transcendence looks at the implications of artificial intelligence – but are we taking AI seriously enough?" *The Independent*. [↑](#footnote-ref-36)
37. World Economic Forum (2011), "Personal Data: The Emergence of a New Asset Class" [↑](#footnote-ref-37)
38. See for example the "framing effect," a term from behavioral economics, which shows that choices that are impacted by either highlighting the positive or negative in the same decision. Kahneman, D. and Tversky, A. (1979), "Prospect theory: An analysis of decision under risk," *Econometrica, 47*, 263-291. [↑](#footnote-ref-38)
39. This is part of the "Digital Cities" project at Stanford, taking place at the Global Projects Center at the School of Engineering. A discussion paper on urban applications of Big Data is provided by Donner, H., Eriksson, K., and Steep, M. (2017), "Digital Cities: Real Estate Development Driven by Big Data." [↑](#footnote-ref-39)
40. Braga, A. A. and Bond, B. J. (2008), "Policing crime and disorder hot spots: A randomized controlled trial," *Criminology*, 46(3), 577-607. [↑](#footnote-ref-40)
41. See Glaeser et al. (2018), "Big data and big cities: The promises and limitations of improved measures of urban life," *Economic Inquiry*, 56.1, 114-137, for an overview on how Big Data can be used in cities. [↑](#footnote-ref-41)
42. See Glaeser et al. (2018), "Big data and big cities: The promises and limitations of improved measures of urban life," *Economic Inquiry*, 56.1, 114-137 [↑](#footnote-ref-42)
43. This is also known as quantum physics or quantum theory and refers to the description of the smallest levels of energy on the levels of atoms and subatomic particles. This contrasts from classical physics, the theories of which describe nature at its normal scale. [↑](#footnote-ref-43)
44. See Dillow (2014), "Unbreakable encryption comes to the US," *Fortune Magazine*. [↑](#footnote-ref-44)
45. Quantum entanglement is described in greater detail in Chapter 3 of this companion guide. [↑](#footnote-ref-45)
46. This makes this technology heavily dependent on the quality of fiber networks. [↑](#footnote-ref-46)
47. This is known as "fully homomorphic encryption." See Greenberg (2011) "An MIT Magic Trick: Computing Encrypted Databases Without Ever Decrypting Them," *Fortune Magazine*. [↑](#footnote-ref-47)
48. This is predicted by the microprocessor manufacturer Intel. [↑](#footnote-ref-48)
49. Graham, L. (2017) "Cybercrime costs the global economy $450 billion: CEO," *CNBC*. [↑](#footnote-ref-49)
50. Snyder, D., Powers, J., Bodine-Baron, E., Fox, B., Kendrick, L., and Powell, M., (2015), "Improving the Cybersecurity of US Air Force Military Systems Throughout Their Life Cycles," Rand Corporation. [↑](#footnote-ref-50)
51. Malware are typically categorized as either Trojan horses, computer viruses, or worms. Trojan horses refer to programs that claim to be something that they are not, so that one installs the program (often by downloading an attachment or clicking on a banner) unknowing of it's true (and malicious) nature. Trojan horses are often used to gain access to a computer system, causing loss or theft of data. Computer viruses are programs that change the behavior (i.e. code) of other "infected" programs and replicate themselves through other programs. Worms are like viruses with the main difference being that worms do not need an infected "host file" to spread, unlike a virus. Computer threats are often blended, i.e. being a mix of the above categories of malicious programs. [↑](#footnote-ref-51)
52. Hutton, R., Kahn, J., and Robertson, J. (2017), "Extortionists Mount Global Hacking Attack Seeking Ransom," *Bloomberg Politics* [↑](#footnote-ref-52)
53. See Sanger, D. and Perlroth, N. (2015) "Bank Hackers Steal Millions via Malware," *The New York Times* and Cook (2015) "This is exactly how a gang of incredibly patient hackers stole up to $1 billion from banks around the world," *Business Insider*. [↑](#footnote-ref-53)
54. A firewall can be hardware, software, or both. Various types of firewalls exist, such as proxy firewalls that serve as a gateway between networks (offering protection by preventing connections from outside the network), stateful inspection firewalls that monitor all traffic through a connection while it is open, with filtering decisions done by set rules and administrators, and unified threat management (UTM) firewalls that combine firewall capabilities with antivirus software that prevents, detects, and removes malicious software. Newer generation firewalls now focus on identifying the greatest risks within a network and quickly identifying and reacting to suspicious activity within the network. [↑](#footnote-ref-54)
55. https://www.wired.com/2013/09/nsa-backdoor/ [↑](#footnote-ref-55)
56. Metz, C. and Perlroth, N. (2018), "Researchers Discover Two Major Flaws in the World's Computers," *The New York Times*. [↑](#footnote-ref-56)
57. Nakashima, E., Miller, G., and Tate, J. (2012), "US, Israel developed Flame computer virus to slow Iranian nuclear efforts, officials say," *The Washington Post*. [↑](#footnote-ref-57)
58. Loria (2015), "Cybercrime poses a potential existential threat to our society, and we're completely unprepared," *Business Insider*. [↑](#footnote-ref-58)
59. Chivvis, C. and Dion-Schwarz, C. (2017), "Why It's So Hard to Stop a Cyberattack – and Even Harder to Fight Back," The Rand Corporation [↑](#footnote-ref-59)
60. This example came from the article Chivvis, C. and Dion-Schwarz, C. (2017), "Why It's So Hard to Stop a Cyberattack – and Even Harder to Fight Back," The Rand Corporation. [↑](#footnote-ref-60)
61. Chivvis, C. and Dion-Schwarz, C. (2017), "Why It's So Hard to Stop a Cyberattack – and Even Harder to Fight Back," The Rand Corporation. [↑](#footnote-ref-61)
62. Also known as human-computer interaction (HCI), man-machine interaction (MMI), or computer-human interaction (CHI). [↑](#footnote-ref-62)
63. The field of study how social interaction occurs in virtual environments is known as Transformed Social Interaction (TSI). [↑](#footnote-ref-63)
64. This research is a collaboration between the Massachusetts Institute of Technology and Singapore University of Technology and Design. DeLaughter, J. (2016), "Building better trust between humans and machines," *MIT News Online*. [↑](#footnote-ref-64)
65. This design is intended to keep bitcoin safe by preventing "double-spending," i.e. someone spending the same bitcoin twice by illicitly making copies of a unit of bitcoin. [↑](#footnote-ref-65)
66. Nakamura, Y. and Kim, S. (2017), "North Korea Is Dodging Sanctions With a Secret Bitcoin Stash," *Bloomberg Businessweek*. [↑](#footnote-ref-66)
67. Bloomberg, J. (2017), "Using Bitcoin or Other Cryptocurrency to Commit Crimes? Law Enforcement Is onto You," *Forbes*. [↑](#footnote-ref-67)
68. Iansiti, M. and Lakhani, K. (2017), "The Truth About Blockchain," *Harvard* *Business* *Review*. [↑](#footnote-ref-68)
69. NASA's website provides a thorough overview of the evidence of climate change, its causes, its effects, and ways to tackle it https://climate.nasa.gov/evidence/ [↑](#footnote-ref-69)
70. https://climate.nasa.gov/evidence/ [↑](#footnote-ref-70)
71. Physicist John Tyndall recognized the so-called Greenhouse effect and its potential impact on climate in the 1860s. Swedish scientist Svante Arrhenius predicted that higher atmospheric levels of carbon dioxide could increase surface temperatures in 1896. See: https://climate.nasa.gov/evidence/ [↑](#footnote-ref-71)
72. The probability that human activity is the root cause of climate change is greater than 95%. See: https://climate.nasa.gov/evidence/ [↑](#footnote-ref-72)
73. Such as how much such we emit by burning fossil fuels when running vehicles and powerplants, keeping livestock that release methane gas, and continuing deforestation of trees that absorb carbon dioxide. [↑](#footnote-ref-73)
74. "Climate Change 2014 Synthesis Report Summary for Policymakers," Intergovernmental Panel of Climate Change (IPCC) and NASA, https://climate.nasa.gov/evidence/ [↑](#footnote-ref-74)
75. This includes projects that have been withdrawn due to opposition. See Orozco, L. (2015), "Interactive Map: A Baywide Building Boom Threatened by Rising Waters," San Francisco Public Press. [↑](#footnote-ref-75)
76. Stark, K., Bird, W. and Stoll, M. (2015) "Major S.F. Bayfront Developments Advance Despite Sea Rise Warnings," San Fransisco Public Press. [↑](#footnote-ref-76)
77. Manyika, J. et al. (2017), "What the future of work will mean for jobs, skills, and wages," McKinsey Global Institute. Also, Manyika, J. Et al (2017), 'Harnessing automation for a future that works,' McKinsey Global Institute. [↑](#footnote-ref-77)
78. Delaney, K. (2017), "The robot that takes your job should pay taxes, says Bill Gates," *Quartz*. [↑](#footnote-ref-78)
79. McArdle, P. Et al. (2008), "Outsourcing comes of age: The rise of collaborative partnering," PricewaterhouseCoopers [↑](#footnote-ref-79)
80. A large body of research supports a positive relationship between city size and growth in employment and population. Studies also support a positive relationship between city size and wages. See: Donner, H., Eriksson, K., and Steep, M (2017), "Digital Cities: Real Estate Development Driven by Big Data," and references therein. [↑](#footnote-ref-80)
81. Delaney, K. (2017), "The robot that takes your job should pay taxes, says Bill Gates," *Quartz*. [↑](#footnote-ref-81)