Chapter 1: GENIE OUT OF THE BOTTLE[1] (Version 0.1) –

The digital revolution on its way

by Dirk Helbing

The information revolution, or "digital" revolution, may fundamentally transform our economy and societies within a short time. We need to prepare ourselves for this transformation and the new era to come. We might just have 20 years for this. Even though we may dislike such socio-economic change, we will probably not be able to stop it. While the breath-taking advances in information and communication technologies are challenging us, they also create great opportunities we haven't had in hundred years. If we understand the fundamentally new logic of this digital future world and use its forces for our purposes, we will be able to benefit tremendously and fix a number of problems humanity has long been struggling with!

Never before have we so urgently needed politicians, business leaders, scientists, and citizens to master the challenges ahead of us. In the past we have had the agricultural society (with its "economy 1.0"), the industrial society (with its "economy 2.0"), and the service society (with its "economy 3.0"). But now, driven by computers, the Internet, social media, cognitive computing, and robotics, we are currently experiencing a third socio-

[1] Dear Reader,

thank you for your interest in this chapter, which is thought to stimulate debate.

What you are seeing here is work in progress, a chapter of a book on the emerging Digital Society I am currently writing. My plan was to elaborate and polish this further, before I share this with anybody else. However, I often feel that it is more important to share my thoughts with the public now than trying to perfect the book first while keeping my analysis and insights for myself in times requiring new ideas.

So, please apologize if this does not look 100% ready. Updates will follow. Your critical thoughts and constructive feedback are very welcome. You can reach me via dhelbing@ethz.ch or @dirkhelbing at twitter.

I hope these materials can serve as a stepping stone towards mastering the challenges ahead of us and towards developing an open and participatory information infrastructure for the Digital Society of the 21st century that would enable everyone to take better informed decisions and more effective actions.

I believe that our society is heading towards a tipping point, and that this creates the opportunity for a better future. But it will take many of us to work it out. Let's do this together!

Thank you very much, I wish you an enjoyable reading,

Dirk Helbing

PS: Special thanks go to the FuturICT community and to Philip Ball.

economic transformation, the "digital revolution," which is creating the "economy 4.0". While we see the symptoms, such as mass unemployment, mass surveillance, cybercrime and cyberwar, we haven't understood the implications well. The emergence of movements such as the *Occupy, Wikileaks, Anonymous,* and the *Pirate* party has been controversially discussed in countless newspaper columns, but no one agrees on what they imply or where they are heading. My judgment is that we are in the middle of a socio-economic transformation. We are entering a world that will be ruled by a different logic. But who will rule it? Big business, governments empowered by Big Data, a computer-based super-human artificial intelligence, or its citizens?

The digital revolution arguably deserves even more attention than climate change. It will have dramatic impacts on almost every single aspect of our economy and societies within our lifetimes, and the pace of technological advances in the area of information and communication technologies is exponentially accelerating. Ten years ago, most of us had not the slightest idea that *Facebook*, *Twitter*, and *iPhones* would emerge. Even *Microsoft* and *Yahoo* didn't see these things coming. But now we talk about phenomena like "*twitter* revolutions." What can we expect to happen in the next ten, fifty or hundred years? In the following, I offer some suggestions – not wide-eyed futurology, but considerations based on evidence and trends existing already. But before we discuss these trends, let’s look how the current situation emerged.

How the digital revolution came about

In 1943, Thomas John Watson Sr. (1874-1956), the chairman of IBM, is claimed to have said: "I think there is a world market for maybe five computers." At that time, almost nobody could imagine a mass market for computers. Today, we know how wrong these people were, but for decades,

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computers were barely useful to anyone. Even in 1968, an engineer at the Advanced Computing Systems Division of IBM asked of the microchip: "what ... is it good for?" Bill Gates is said to have suggested in 1981 that a computer memory of 640 K “ought to be enough for anybody." Today, our smartphones have a hundred thousand times more memory than that, and an iPhone has more processing power than the Apollo rocket required to fly to the moon and back.

The innovators of information technology did not have an easy life. The founder of Apple Computers Inc., Steve Job (1955-2011), remembers the failed attempts to get Atari and Hewlett-Packard interested in his and Steve Wozniak's personal computer: "So we went to Atari and said, 'Hey, we've got this amazing thing, even built with some of your parts, and what do you think about funding us? Or we'll give it to you. We just want to do it. Pay our salary, we'll come work for you.' And they said, 'No.' So then we went to Hewlett-Packard, and they said, 'Hey, we don't need you. You haven't got through college yet.' " Later, Steve Jobs even had to leave Apple for some time, before he came back to build the *iPod, iPhone, iPad* as well as *iTunes* and the *AppStore*, which made Apple, for several years, the most valuable company in the world.

But this is still the smaller part of the story. There was, in fact, another important development. In the late sixties, *Arpanet* was created to allow a few military computers to exchange information with each other. *Arpanet* was later opened up for civilian use, and thereby became the Internet. This "going public" eventually unleashed the power of information. Later, to support the collaboration between Swiss and French teams contributing to the CERN elementary particle accelerator, physicist Tim Berners-Lee (*1955) invented a hyperlink protocol allowing web pages to be linked with each other. This gave rise to the World Wide Web (WWW) and eventually made computers useful for ordinary people rather than just experts. It also made the Internet attractive for doing business. However, Berners-Lee’s ideas did not have an easy start either. At CERN he did not get the support he was asking for, so he went to

the Massachusetts Institute of Technology (MIT), where he founded the World Wide Web Consortium (W3C).

Eventually, with the creation of Facebook in 2004 and Twitter in 2006, a billion people became part of a giant global information system. We are no longer just users of this system; we are also generators of data and services, and are in effect embedded in the system as “human processors.”

Computers more intelligent than humans?

Since decades, the processing power of computers is doubling roughly every 18 months. If this trend continues, then in 10 to 15 years from now we will have computers exceeding the processing capacity of the human brain. Computers are already out-performing humans in ever more ways. They are far better at doing calculations – and at chess. In 1996 IBM's Deep Blue computer defeated the best chess player in the world at that time, Garry Kasparov (*1963). In 2011, IBM's Watson, a “cognitive computer” that is able to judge the relevance of information from the Internet, beat human players in answering questions in the game show "Jeopardy." Now Watson is taking care of customer hotlines, as the computer is better at managing all the knowledge required to answer customer questions. Watson understands natural language and comes increasingly close to what humans can do – and in many respects even better. Now, by investing 1 billion dollars in Watson’s technology, IBM hopes to earn 100 times that amount in the years to come.

Europe wants to invest a comparable sum – 1 billion Euros – to build a supercomputer performing like the “human brain.” The USA decided to spend even 3 billion dollars on a brain project. The Google Brain project, led by the technology guru Ray Kurzweil, is a further attempt to turn the Internet into a intelligent entity that can think and decide.

While building brain-like performance will still take a few years, the Google car, which does not need a driver anymore, is already there. Furthermore, about 70 percent of all financial transactions in the world's stock markets are now performed by autonomous trading algorithms. Therefore, computers and robots are increasingly doing our work, and they will replace many jobs that can be performed according to logical routines and rules. We may even lose highly qualified jobs, which depend on skilled judgments, including medical doctors, care workers, scientists, lawyers, managers, and politicians, to some degree even teachers – and parents, with Korea engaging into robot-based child care. So what role will humans play in the future?

What are the socio-economic forces that will be created when, within the next 10 to 30 years, computers, algorithms and robots increasingly take over our roles and jobs? Remember that the first sector of the economy to emerge historically was agriculture, followed by industry and services. Now we are seeing the emergence of a fourth, "digital" sector – that of information and knowledge production. But history tells us that the emergence of any new economic sector often leads, decades later, to social and economic unrest, because the innovations behind the rise of the new sector undermine the basis of the previous sectors. As a result, not only are societies and the economy transformed, but our established worldviews are questioned as well: new socio-economic and political systems emerge. We must expect the same from the rise of the information sector.

The digital revolution is coming

We can already be sure that the digital revolution will fundamentally change many of our institutions and modes of action: how we educate (with open on-line courses and personalized education), how we do research (with the analysis of Big Data), how we move around (with self-driving cars) or transport goods (with drones), how we shop (with *Amazon* and *eBay*, for example), how we produce goods (with 3D printers), and also our health systems (with

personalized medicine). Our political institutions (with evidence-based decision-making and citizen participation) and the basis of our economy (with production and sharing on the side of the consumer) will change as well. Financial business, which used to be the domain of banks, is increasingly replaced by algorithmic trading, *Paypal*, *Bitcoin* and *Google Wallet*, and so on. Therefore, banks such as the Credit Suisse are now building on advice of experts from the Silicon Valley. Moreover, the biggest share of the insurance business is now in financial derivatives traded at the stock markets. By now, they amount to a multiple of the global gross domestic product. Military experts believe that even wars may change from conventional to cyberwars.

Are our societies well prepared for this digital revolution? Let's look at the problem of the coming economic transformation more closely. In some industrialized countries, the proportion of agricultural jobs is now just 3 percent, while 300 years ago, it stood at 80 percent or more. How did we get there? Among other developments, it was the great success of James Watt's steam engine invented in 1769, which gave rise to the industrial revolution. As a result, many people lost their jobs to automation – in the textiles sector, for example. However, with the industrial revolution came consumerism, such that industrial production eventually created many new jobs. In fact, during its heyday, industrial production provided more than 30 percent of all jobs in developed countries. But later, due to the ever-increasing efficiency of industrial production, half of all industrial jobs were lost. And the number of industrial jobs will continue to fall, probably below 10 percent. Very soon, therefore, only 10 to 15 percent or so of jobs will be provided by the first and second sectors of our economy.

The third sector – services – is the result of another big innovation: the spreading of education at all levels of society from 1870ies onwards. As a consequence, reading and writing were not skills restricted to just a few people, and many more people could perform jobs requiring special qualifications. Therefore, the service sector developed, coming along with an

increase of planning, administrative and management tasks. In modern societies, up to 70 percent of jobs are currently in the service sector. But again, more than half of them will be replaced – this time by robots, algorithms and computers. If we don't find a new way to produce jobs quickly, we will face unemployment rates much beyond the levels that our current socio-economic system can handle. In fact, all previous socio-economic transitions were accompanied by mass unemployment – one of the major forces transforming societies. Given that computers will reach human brainpower in about 10 to 15 years, we have very short time to adapt to the current societal transition. Technology experts say that automation will dramatically progress, leading to a “second machine age.” If we don't adapt fast enough, the transition will be sudden, harsh, and discontinuous.

It is known that delayed adaptation causes systems to become unstable. Financial crises, conflicts, or wars may be the consequences. In fact, there are current signs of destabilization in many countries around the world. These could be advance warning signals of socio-economic transitions to come. The list of countries that have lately seen social unrest includes Afghanistan, Pakistan, Iraq, Syria, Somalia, Nigeria, South-Sudan, Uganda, Congo, Central African Republic, Egypt, Bahrain, Libya, Libanon, Yemen, Tunisia, Turkey, China, India, Malaysia, Thailand, Brazil, Mexico, Ukraine, Spain, Greece, Romania, United Kingdom, and even Sweden and Switzerland. However, these countries are faced with different scenarios. Many African countries are now in a transition from an agricultural to an industrial society; some Asian countries are in a transition from an industrial to a service society; and the USA, Europe, and Japan, for example, are in a transition from a service to a digital society. Of course, these transitions may interact with each other. In the worst case, they might all come at about the same time, and soon.

Can we avoid or suppress these transitions? I don't think so. We may delay historical developments but we cannot stop them, and it wouldn’t be reasonable to try this. No country could afford to miss the long-term opportunities resulting from these transitions, which will lead to more efficient

systems and a higher quality of life. This is all part of the cultural evolution as societies progress, which is driven by socio-economic forces such as the increase of complexity, diversity, and "collective intelligence." With the digital revolution, the genie is out of the bottle. Information and communication systems have grown ever more powerful, but a single mistake can be potentially disastrous. We must, therefore, learn to make the genie work for us. How can we do this? We must learn to understand the new logic of the digital societies we will live in. And we must learn it soon.

Two scenarios: coercion or freedom

Does the digital revolution imply that we will lose human rights such as privacy and freedom, dignity, or informational self-control? Later in this book I will explore whether classical democracies are likely to be replaced by "big governments" or "super-governments" that, in the very best case, would rule like a "benevolent dictator." Or are there any better ways to create social order and socio-economic well-being? Ways that don't use sensitive personal data and mass surveillance to control all individual actions, through methods ranging from speed control to Internet control and, one day, perhaps even thought control?

Hence, the crucial question is: what kind of society will the digital revolution produce? Given that there is ever more data, evidence-based decision-making will certainly spread. Moreover, as computers, algorithms and robots get ever more powerful, our socio-economic institutions will change. Many of our current jobs will be lost, and it will take time to create new jobs and new institutions. This brings us to a crossroads – or a tipping point, as complexity scientists would call it. Hence, we must make up our mind what path to choose. Do we want a super-government that takes all decisions for us in a top-down way or do we want a participatory market society with a large deal of bottom-up involvement?

We will explore the implications of both, and it is now time to publicly voice our choice to our political representatives. In the future, a super-government might

actually tell us what to do, and it would be able to control everyone's compliance by means of mass surveillance systems. In fact, we are increasingly using surveillance systems in our tax and traffic systems and in a quickly increasing number of other systems. It, therefore, seems that we have currently a trend towards an implementation of super-governments. But do we want to live in such a society? And would it be stable? I personally don't think so. The approach would reduce the innovation rate, and we would, therefore, eventually fail to adapt to technological, demographic, environmental and other change. In the end, a top-down controlled society would fall apart.

A better future ahead of us

Despite the many challenges, I am quite optimistic about our long-term future. We have mastered societal transitions already several times in human history. Therefore, we can master the coming one as well. The industrial societies can help the agricultural societies, the service societies can help the industrial societies. Of course, the service societies also have to manage their own transition towards digital societies. But we can master this.

Each age had brilliant minds, who helped to understand the transformations faced by society and offered their guidance. The philosopher Voltaire (1694-1778) provided the framework for the absolutism of the almighty king Ludwig XIV (1638-1715). The father of modern economics, Adam Smith (1723-1790), worked out the intellectual framework for industrial society. And later, the sociologists Emile Durkheim (1858-1917) and Max Weber (1864-1920) offered a way of thinking about a service society, built on the notion of administrations that try to plan and optimize systems. There will also be people, whose imagination will guide us into the digital age.

This book hopes to make a contribution to a necessary public debate, by discussing the two main frameworks for the digital society to come. One of the frameworks is based on the vision of a super-government, which takes

evidence-based top-down decisions like a "wise king," empowered by huge masses of data ("Big Data") or even by a digital "Crystal Ball." This might be seen as a futuristic instantiation of the "Leviathan," the powerful state promoted by Thomas Hobbes (1588-1679). His credo was that social order could not exist without a powerful state, otherwise we would all behave like wild beasts ("homo hominis lupus").

The alternative framework for the digital society is based on the creation of self-regulating systems, empowered by real-time measurements and feedbacks. This vision takes the concept of the "invisible hand" forward, for which Adam Smith (1723-1790) is known. But financial meltdowns and "tragedies of the commons" such as environmental pollution suggest that the invisible hand often fails, which questions libertarian approaches.

However, will modern information and communication technologies finally allow us to reach desirable systemic outcomes based on decentralized bottom-up decision-making? What would it take? In the past, we have been pretty bad at finding suitable "rules of the game" ensuring desirable outcomes. Can we now make self-organization and self-regulation work? This is an exciting vision, as it could lead to a novel paradigm how to reach socio-economic order and success in the 21st century. It might lead us into an era of "collective intelligence" and an age of creativity, participation, and well-being.

On the long run, I am very confident about our future, because I believe in the power of ideas in the digital age. But no doubt, we could make serious mistakes on the way. Our financial system may fail, democracies may – intentionally or accidentally – turn into surveillance societies, or we may end up fighting wars against each other. Therefore, with this book, I am trying to explain the opportunities and risks ahead of us. For sure, the future world will have properties different from ours. But even though we can't predict this future well, can we get a glimpse of it at least? I believe so, to a certain extent. The properties of our future world will be emergent outcomes of interactions,

and even though often counter-intuitive, we will be able to explain and shape many of them. To be beneficial, we need to understand, how such interactions can be chosen and designed – a capacity that will decide about our future fate. In a sense, this is the holy grail.

The new logic of prosperity and leadership

Most likely, the 21st century will be governed by fundamentally different principles than the 20th century, and I think the organization of our future socio-economic system will be based on collective intelligence rather than planning and optimization. That is why we need to change our way of thinking about our socio-economic systems. We need to recognize some fundamental trends and truths.

Information is ubiquitous and everywhere instantly available, such that borders tend to dissolve. The "second machine age" is coming quickly, challenging established jobs and routines. Most of the knowledge about our world is outdated by the time we learn it. Technological, social and economic system are becoming more variable, less predictable, and less controllable. Their increased connectivity means that they are more complex. The quick growth in the amount of data means that we are overloaded by it – yet we need ultimately to convert it into information and into knowledge we can act on. Furthermore, the more data we produce, the more difficult it will be to keep secrets, and the cheaper will data become. This means that we will make ever less profit from data itself, but more from algorithms that turn data into useful information and knowledge.

In a digital world, ideas can spread more quickly. Digitally literate people will be better informed than experts used to be, and therefore classical hierarchies may dissolve. Moreover, we are entering an increasingly immaterial age, determined by an abundance of information and ideas rather than objects.

Data can be replicated as often as we like. It's a virtually unlimited resource, which may help us to overcome conflicts that scarce resources used to imply.

Services and products will be more individualized, personalized, and user-centric. Moreover, what used to be science fiction may become reality one day, actually more quickly than we think. The countries first recognizing these new principles and turning them into their advantage will be the ones that lead. Those failing to adapt to these trends in a timely manner will be in trouble. Given that computers may soon reach brain power, our societies may just have about 20 years for this adaptation – a very short time considering that planning and building a road often takes 30 years or more.

Creating a resilient society

The best way to prepare for the hardly predictable future to come is to create a society that is able to flexibly adapt to new kinds of situations. The digital revolution can certainly cause disruptive change. Hence, are our societies well prepared for shocks? Our response to September 11, 2001, questions this. Even though it was initially a local event, it has changed the face of our entire world. In the aftermath, we have built a security architecture to prevent us from terrorism. But with mass surveillance and armed police, are we now safe?[2] Less than 10 years later, we saw another, probably even more serious event that changed the face of the world: the financial crisis. Again, this started locally, but it had a major impact on the entire world.

Therefore, what can we do to be better prepared for future challenges? There is a whole bundle of measures, ranging from risk assessment, prediction, prevention, intervention, insurance, and hedging. However, we must recognize that, in a world that is not totally predictable, problems will always occur, and accidents will always happen. That is why we need resilient, "survivable" systems.

[2] The events in Ferguson rather suggest that they create new problems.

Increasing resilience will simultaneously fix a number of problems our world is currently suffering from. But what exactly is resilience about? It means the ability of a system to absorb shocks and to recover from them quickly and well. If we fall and get wounded, we will usually recover from this, because our body is resilient to such shocks. So, how to increase societal resilience? First of all, we need systems with redundancies, reserves, backup strategies, and alternatives (a "plan B", "plan C"). Second, we must have mechanisms to deal with speed and complexity. Third, diversity increases the survivability of a system, and its adaptability to new circumstances. Forth, one may reduce system size and interdependencies, i.e. use modular designs. Otherwise dynamic decoupling strategies, engineered breaking points, or shock absorbers are a "must have" to avoid cascading failures. Think of the electrical fuses at home or the crush zone of your car, which are there to protect the sensitive parts of the system (your home, your life). Fifth, adaptive self-regulation mechanisms or, in other words, stabilizing real-time feedback, can increase resilience tremendously. And finally, transparency, accountability, responsibility, awareness are important to increase resilience as well.

Thus, are we well prepared to master the digital revolution? Does mass surveillance, together with armed police, create a resilient society? They are certainly intended to be tools to prevent bad things from happening, but is this good enough? Or is it even counter-productive, as they suppress societal change and, hence, needed societal adaptation to a changing reality? Aren't we, in fact, trying to fight the outcome of innovation, or even innovation itself? I personally believe that we must – and can – prepare ourselves much better, in a different way.

Let us for a moment discuss the illustrative problem of traffic safety. We know that accidents keep happening, and this is bad. But how would it be to live in a world without traffic? Our economy would not work, and we would not be able to live in modern societies. Therefore, we have come up with measures to reduce the number and impact of accidents. How have we done this? We have improved traffic rules. We have developed better technology. We have

created emergency services and built hospitals. We have developed better brakes and driver assistance systems that empower drivers to do a better job. We provide traffic information to prevent single accidents from messing up the entire system. And we have designed cars in better ways. Decades ago, a car's body was often little damaged by an accident, but driver and passengers frequently died. Now, cars are constructed to be shock absorbers: even a small accident may destroy the entire car, but the risks of injuries and deaths have been dramatically reduced.

This can guide our thinking of how to deal with challenges of society. It shows us that the idea to protect institutions from changing is just the opposite of what would make societies resilient. This is like the stiff car body, which in case of an accident is not made to serve the life of the driver. For resilience, our institutions must be able to flexibly adapt in ways that serve the citizens best.

But why at all do we see so many global crises now? In just a few months, our world was confronted with three new problems: the Ebola epidemics, a crisis in Ukraine endangering world peace, and the Islamic State fighters. These problems, too, started locally, but their implications might become relevant for all of us.