Computers, Time and Speed: Five Slow Tech Case Studies

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Abstract. This chapter examines briefly the notions of time and speed. It introduces the notion of Slow Tech: information technology that is *good*, *clean* and *fair*, and places an especial emphasis on technology that is *clean*. This chapter does not delve deep into the Slow Tech concept. Rather, it highlights a set of arguments about why speed is not always important or necessary. People are now increasingly beginning to think about much longer periods and phases that may extend at least as long as the existence of human beings on the globe. As illustrations, the chapter explores five specific case studies. Each comes from a different location, yet all describe global implications and challenges. One example is in fact a mathematical model. Two sites, in sympathy with the location of the Human Choice and Computing 11 (HCC11) conference, are from Scandinavia – one from Onkalo, Finland, and a second from Svalbard, a northern Norwegian island. A further two cases are from the United States of America. The logic behind these five case studies strengthens the arguments about why − with the support of the Slow Tech concept − it is increasingly important for society and its many stakeholders to question the current information and communication technology (ICT) obsession with speed and rethink the relationships between society and technology.

Keywords: Action, case studies, life cycle, myth, slow, Slow Tech, speed, thought, time.

1 Time and speed: their relationship with Slow Tech

It is important to investigate the limits of time. In the 21st century, a whole new set of questions are arising. Is ICT changing very fast the human concept of time? How is ICT changing people's everyday lives, i.e., what human beings do and who they are? Is ICT improving people's quality of life? Can ICT contribute to people's well-being without having detrimental side-effects on them, their social structures, and the planet? Can people identify guiding values that could influence the development of ICT from the point of view of society itself?

As a result, is it possible to build a set of positive, ethical guidelines for ICT development? If so, could this set of guidelines be called Slow Tech, an initiative to build *good*, *clean* and *fair* ICT [1]? While this chapter acknowledges its debt to Slow Tech ideas (see, for example, Patrignani and Whitehouse [2] elsewhere in this volume), it describes them only briefly here.

Similar challenges to those facing the technology industry today faced the agricultural and food sectors in the late 20th century. These challenges generated a new approach to food: Slow Food. The Slow Food movement was born in 1989 in Italy: "*... a global, grassroots organization ... linking the pleasure of good food with a commitment to ... community and the environment ... to counter the rise of fast food and fast life, the disappearance of local food traditions and people's dwindling interest in the food they eat, where it comes from, how it tastes and how our food choices affect the rest of the world*" [2]. This slow philosophy provided people with a new ecology of mind [4]. Today's challenge is not only to consider the benefits of Slow Food, but also to develop an appropriate Slow Tech philosophy and, ultimately, perhaps a Slow Tech movement.

Slow Tech offers people the opportunity, on the one hand, to spend more time on thought, observation, and choice and, on the other, to enjoy their short lives more. Slow Tech introduces the time dimension into thinking about technology. It means that, while people continue to use ICT in the future, they may do so in a more conscious and responsible way. It implies that people will need to regain control of the pace of their days and lives, by designing technologies that are more respectful of their brains and bodies and that are not necessarily based on a continual increase in clock speed. It highlights the importance of starting to examine longer-term, human-oriented perspectives.

2 Time and speed: their relationship with ICT

This section of the chapter explores human fascination with time as well as the myth of speed. Today, ICT is at the core of many of society's critical processes: the speed of ICT itself controls the tempo of these activities – whether involved in communication, hardware development, manufacture, processing, software development, storage or retrieval and indeed, the obsolescence of the technologies themselves. The multitasking capability that many people are experiencing as a result of using ICT may offer them the illusion of compressing time and may offer them a range of different opportunities and even challenges (some would say, dependent on their gender). People may try to undertake different sets of activities, to complete more than one scenario or task at any one moment. They are attempting to control several processes that are evolving in parallel. Computers appear to increase people's productivity and performance. Thus, it may look as though ICT provides people with incredible speed in the management of information.

Yet people still need to reflect on the limits of human minds and the consequences that arise as a result of speeding up of all life's processes, including those with impacts on the environment and on the consumption of limited resources. In this chapter, therefore, the authors support the notion of the design of complex ICT systems, together with a human-centric approach − where sometimes speed is needed and sometimes not. Therefore, they query the myth of speed *per se*.

2.1 Human fascination with time and speed

Time is a convention that has been evolving throughout human history. People started to measure time at the very beginning of their history, when they looked at the sun rising every morning and the stars or the moon moving throughout the sky at night: time was measured in terms of natural events that recurred regularly, such as the new moon occurring over a period of about twenty-eight days, and the birth and re-birth of the seasons – through spring to summer, autumn, and back to winter before the beginning of the new year. Indeed, human beings perceive the passage of time according to what happens around them.

As a consequence of scientific enquiry and technological development, human beings have refined and extended the measurement of time as they have become aware of processes that are not readily perceivable. These processes include phenomena in particle physics, such as the decay of a quark, that − in order to be measured − need only a yocto-second (10^{-24} sec) or less. The decay of one of the known quarks, the top-quark, requires only 0.5 yocto-seconds. Artefacts, including containers for nuclear waste, are therefore built to last for thousands of centuries − for tera-seconds (10^{12} sec.).

Speed is also a matter of fascination. A 2011 update on supercomputer competition indicated that Fuijtsu’s K-Computer runs at more than 10,000 TeraFLOPS (Floating Point Operations per Second), which is 10,000 x 10^{15} FLOPS, or 10 x 10^{18} FLOPS. Just a single operation needs less than 0.1 x 10^{-18} sec. or 0.1 atto-seconds to be executed [5]. The fastest computer on the planet is Chinese. Called Tianhe2, it runs at more than 33,000 TeraFLOPS [6]. Artefacts are now built that are planned to last for thousands of centuries, tera-seconds (10^{12} sec.), including deposits of nuclear waste.

2.2 The myth of speed

Speed is indeed a physical variable. At times, it can be useful to act fast. When people are at risk – and even society as a whole is in danger – and when the aim is to protect people, society, infrastructure, and frameworks, then it is important to act quickly. For example, an accident victim must be brought to hospital in an ambulance, a child saved from falling from a chair, the behaviour of an incoming hurricane simulated to prepare for mass evacuations, or people’s lifestyles modified promptly so as to cope with climate change. Ultimately, a long-term view on the impact of human activities on the environment needs to be developed.

Otherwise, while speed is seductive, it may often prove to be an illusion. There are lots of ways to look at the history of speed as “faster-is-better”, and many ways to interpret the motivation to go faster. It is important too to examine speed’s benefits and shortcomings. In terms of physical transportation: speed helps to transport raw materials, perishable goods, manufactured goods and people quicker. Yet it also has effects on many other socio-economic factors: the profitability of trade; the type of diet people eat; the time passengers and goods spend in transit; and comparisons of the time at destination to that of arrival. With regard to communication: there is also, historically, a variety of speeds at which messages have been sent. These include via hand, drum or flame for physical messages and via courier or stage coach for letters.

More recently, messages have been sent through non-material transmission by telegraph, radio, telephone and the Internet. Unfortunately, it seems to have been assumed that the speed at which humans – and groups of human beings – can process these messages and formulate a reply will keep pace – naturally – with the transmission speed. While computer programs were initially devised to mimic, electronically, the application of a clearly-defined procedure that was to be applied to quantitative input data, it must be borne in mind that these procedures had themselves been developed and adopted over long periods, which involved decades and centuries, by experts in a field.

Early in the twentieth century, speed became to be seen as a myth. Almost every human activity began to look better if it was faster. Speed was at the core of the Futurist movement: progress and modernity were synonymous with its writing and activities. Futurism was considered to be the avant-garde of culture: its leaders wrote that "*...the splendor of the world has been enriched by a new beauty: the beauty of speed*" [7]. The desire was there to celebrate modern engineering achievements that were measurably faster than those available in the previous century: vehicles that included automobiles, ships, trains and, later, aircraft. 'Slow' was associated with the previous (nineteenth) century and was seen as a drag on progress. This movement in support of speed can also be associated with the cultural background of the dictatorships of the twentieth century, and the eventual drive towards war. The perceived beauty of speed at the start of the twentieth century was based at least partly on the conviction that human power could dominate and over-ride nature. It is now acknowledged what a terrible mistake this illusion was with regard to the control of nature.

Indeed, approaches alter. Speed is no longer a value in itself. In the twenty-first century, it is becoming increasingly clear that the complexity of natural systems is so sophisticated that it is more effective to find new ways to co-exist with such systems than to attempt to dominate them. Rather, there is an growing fascination with the opposite – with slow. A message is emerging that – before initiating new ICT projects and initiatives – more time is needed. It is important to consider the impact that initiatives and advances relating to ICT may have on natural and social systems. Alternative solutions or different approaches or projects could be found rather than risking damage to the natural environment.

As Italian journalist, Giovanna Giuffreda, says: there is a real need for society to slow down [8, 9]. In order to face current societal challenges, innovation is certainly needed. However, it must occur in a way that enables people to use the incredible power that lies in their hands, with care, and without destroying living environments. This is especially pertinent in the field of ICT. According to a 2011 report from the European Commission: "*... (ICT) Responsible Innovation ... must be socially desirable and inclusive, ... environmentally sustainable, ... ethically acceptable ...*" [10].

2.3 Dealing with limits and with myths

Human beings tend not to like limits: they are constantly looking for new challenges. Since people need challenges in their lives, they need to continue to make use of fascinating myths, such as speed and time. However, people have to be conscious that many of the novel challenges that they face are now actually located inside themselves – intellectually and emotionally – rather than outside.

Human beings are also living on a finite planet [11]. People's continuing exploitation of natural resources, based on processes that are increasing in speed, need to be re-examined. Computers are the core engines that are speeding up many incompletely defined or tested processes. Instead, perhaps human beings now need to accept and embed the concept of limits − limits that are imposed by the current environmental and social crises − in their plans and endeavours, including those including new ICT initiatives. This is today's challenge for human beings.

Today, ICT and computers lie at the core of the increasing speed of technical processes, and indeed also social and societal processes. Yet are faster and faster processes always needed? Are there limits to this growth in computers? Is it time to rethink computer speed? Should computers be introduced into society not just because they are available but when and where they really make sense, and at speeds that make sense? Can good ICT (that is, is it ICT that is good for human beings) be designed and built? Is there likely to be a revival of interest in appropriate technology [12]?

3 Case studies to illustrate the challenges of time and speed

Case studies can often paint clear messages. To introduce a set of arguments about the many possible views of time and why speed is not always important or necessary, five case studies have been selected by the authors. Each comes from a different location around the globe. Many relate to technology and its implications, although not all.

The first use case is simply a model. The Lotka-Volterra model shows the systemic and natural balance that occurs – over the very long-term – between prey and their predators. It provides a fundamental reminder of how different animal or human development can look when it is examined over a sufficiently long time. The second case is located in Onkalo in Finland: it contains a long-term danger since it is a storage space for nuclear waste. The third case, Svalbard, is based in northern Norway, a place dedicated to beneficence: it stores examples of plant seeds for future, long-term usage. The fourth case, to be found in Van Horn in the United States' state of Texas, is also a building with a benevolent message. At Van Horn, a clock which is intended to run for at least 10,000 years is buried deep in the desert. The fifth and final use case alerts human beings to the dangers inherent in a reliance on computers that run critical systems. The 2010 New York Stock Exchange crash is a frightening illustration of an event that shows that human beings are no longer totally in control of banking and financial systems.

Today, people are beginning to think about very long periods and, indeed, phases that may extend beyond the existence of human beings on this globe. Three of the cases introduced here draw people's attention to this long-termism and the responsibility that is needed over lengthy periods. Most look a considerable time ahead, and at least one of them looks ahead for the lifetimes of 300 generations of people. They are all illustrations of means of facing, and overcoming, disasters. Some raise the challenge, whether for good or bad reasons, of how to alert future generations to the location of the materials and equipment that they house.

3.1 Long lifecycles: the Lotka-Volterra model

Human beings are simply small animals on a single, limited planet. When analysing a number of physical variables to see their evolution over time, all functions are in fact limited. Although some forms of (short-term) "exponential" growth can be observed, sooner or later, all growth is saturated and reaches its limit. On planet earth, in the long-run, only self-sustaining systems can survive. On the earth, nature is indeed composed of a collection of cycles. Examples include the carbon cycle, the water cycle and the life cycle.

The Lotka-Volterra Prey-Predator Model is a pertinent case in point (see Fig. 1). It is a long-term natural cycle. The figure illustrates complete life cycles. The model was described by the American demographer, Alfred J. Lotka, in 1924 and the Italian mathematician, Vito Volterra, in 1926. It is a linear system of differential equations of the first order. It describes a simple system formed by two species: one is the prey (for example, small fish) and the other is the predator (such as large sharks). The following assumption can be made: a population of prey increases exponentially in the absence of predators, and a population of predators decreases exponentially in the absence of prey. Yet, if predators consume too many prey, they will have less food available to them and the population of predators will decrease. The population of prey then increases. Finally, the population of predators will again have more food. Of course, however, sometimes something goes catastrophically wrong, and extinctions occur that cause animals and other beings to disappear.

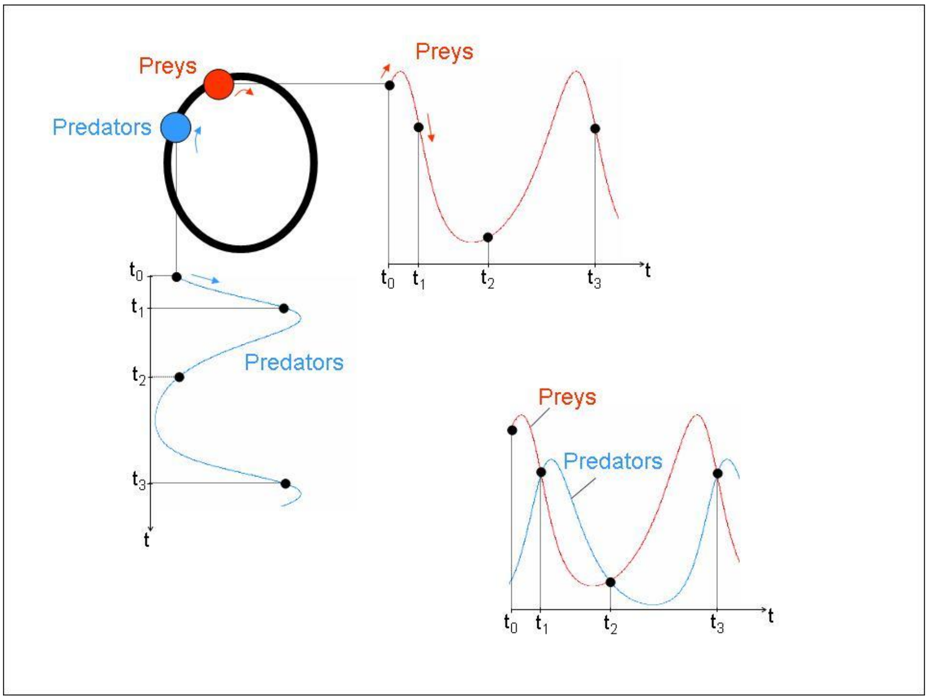

Fig1. Lotka-Volterra's Prey-Predator Model (source: authors' own)

3.2 Long-lasting dangers: Onkala, Finland

Some human activities necessitate long-term planning and building, as the Onkalo nuclear waste depository illustrates. Onkalo provides a concrete means of avoiding catastrophe. In Finnish, Onkalo means a "hiding place". It is also the name of the facility that will act as the long-term storage for all nuclear waste produced in Finland. It is to be found at a few miles from the Olkiluoto nuclear plant located about 280 kilometres north-west of Helsinki. This cave, which is built in the granite bedrock and constructed in a spiral shape, will be 520 metres deep when it is completed.

Construction of the cave started in 2004, and it will be ready to host nuclear waste by 2022 (http://www.posiva.fi). It will then be used for the disposal of nuclear waste for about 90 years. At that point, no further nuclear waste will be taken to the cave, and the tunnel which leads to it will be backfilled. In 2020, the repository will be sealed – it is hoped, forever. This project has been started while today's generation is still living, but its mission will be complete when contemporary adults have been dead for a very long time. More precisely, the nuclear waste that Onkalo contains will remain dangerous for more than 100,000 years.

Onkalo therefore opens up new kinds of challenges related to people's concept of time. Some technologies are pushing people to a point where they simply do not have the intellectual background to answer a number of deep philosophical questions. For example, what will become of the planet over this period of 100,000 years? How can future generations be prevented from entering into contact with Onkalo’s contents? What kind of messages, languages, visual images or symbols can be used to communicate this underground danger? *Into Eternity* is the title of a documentary, released in 2010, that poses difficult questions about Onkalo (http://www.intoeternitythemovie.com).

Human civilisation has existed for only a few thousand years (the Egyptian pyramids, for example, are just 5,000 years old). Human minds cannot easily make projections that extend into such a 100,000 year-long, long-term future. A hundred millennia, on the human scale, is close to eternity − the *saecula saeculorum* − a world without end, that is thought to go on for ever and ever. For human beings, their concept of time is deeply affected by the artefacts, and the technological choices, that they make. The relationship between human beings and time is one of the oldest philosophical challenges to have faced humankind: the questions it provokes have fascinated people from their very origins.

Onkalo is a perfect example of a human attempt to pre-determine the future. The decision to build this nuclear repository extends beyond the limits of scientific acceptability, even if it is one of the few serious projects that exist around the world to deal with nuclear waste management. The developments at Onkalo show where the zeal of dominating nature crosses the boundary of scientific acceptance, and enters the domain of ‘magic’ − stories that proceed beyond science.

It might, instead, be wiser to accept the experience of limits that is strongly associated with the human body and its physical and intellectual experiences. In Germany and Italy in 2011/2012, to offer just two examples, several political decisions were made related to the closure of nuclear power plants and to stopping the generation of nuclear waste. These decisions about plant closure seem to indicate that a number of past nuclear disasters, and their associated security arrangements, have been transformed into real learning experiences (examples include the experiences at Three Mile Island, USA, 1979; Chernobyl, Soviet Union, 1986; Fukushima, Japan, 2011). Increasingly, in these two European countries, and possibly others, planning for the future seems to be based more than it was, in the immediate past, on a concern and consideration for saving and reducing energy consumption, and on developing renewable and cleaner energy sources. On the agenda for exploitation and use are hydroelectricity, geothermal power, wind, solar power, biomass and the waves of the oceans.

3.3 Crops for eternity: Svalbard, Norway

The Svalbard Global Seed Vault provides a form of long-term insurance to provide food for future generations.

Svalbard (formerly called Spitsbergen) is the name of a Norwegian archipelago about 3,000 kilometres north of Oslo. William Barents discovered it in 1596. In the 17th century, it was used by whaling and fishing communities but was later abandoned. At the beginning of the 1900s, coal-mining began there and, in 1925, these remote islands became part of Norway. Travelling around one of the islands, by snowmobile or ship, one eventually comes to a strange construction with a small door: this is the Svalbard Global Seed Vault, a seed bank intended to last for eternity. Its entrance provides access to a 120 metre tunnel under a sandstone mountain that is equipped to cool seeds to -18°C. It is a place able to preserve about 4.5 million seeds so that they can survive for hundreds, even thousands, of years.

The construction was begun by the Norwegian government in 2006, and has cost about US$9 million. The government is supported, in its operational costs, by a combination of international organisations and foundations. Officially opened in 2008, the seed bank and its management is ensured by a three-party alliance: the Norwegian government, the Global Crop Diversity Trust and the Nordic Genetic Resource Center.

The vault was built with the mission to save the most important seeds on planet earth. The goal of the seed bank is to maintain reserves of seed in the event that all other samples of them are destroyed. Indeed, the Svalbard facility stores duplicates of seeds from several other collections around the world (many of them in developing countries and emerging economies). If these collections were to be lost, they could then be regenerated with the seeds from the Svalbard seed bank [13].

The idea of protecting seeds from possible catastrophes is not new. However, today's vaults − like Svalbard − have been built so that they can survive doomsday-like events. For example, the Svalbard seed bank is built at 130 metres above sea level, so that it could survive rising sea levels caused by global climate change. Historically, such disasters were the outcomes of natural events such as volcanoes, asteroids or earthquakes: today, humankind is faced potentially with additional, artificial or human-created catastrophes like nuclear disasters, bioterrorism and global warming.

The idea underpinning this seed bank is the very opposite of a nuclear waste management site (such as Onkalo, where future generations need to be kept away from the location). With a seed bank, such as Svalbard, future generations − or at least the human beings who survive a possible cataclysmic event − will want to enter this place, gain access to the seeds, and be able to sow them in the ground as future food sources.

Svalbard therefore illustrates yet another vision of time: one in which human beings are attempting to supplant the tyranny of split-second measures and counterbalancing such foolishness with the generosity of near-limitless time.. Indeed, the official Svalbard Web site announces that " ... *The facility is designed to have an almost 'endless' lifetime*" (http://www.regjeringen.no/en/dep/lmd/campain/svalbard-global-seed-vault.html?regj_oss=1&id=462220).

3.4 Long-term thinking: Van Horn, Texas

This 10,000 Year Clock provides a reminder that civilisation is only about 10,000 years old: a mere moment when set against the 4.5 billion year-old age of the planet. It prompts human beings to ask, "What's the hurry?"

It takes a day's hiking over the mountains in the western part of the state of Texas, in the United States of America, to arrive at a construction site, inside a mountain, that houses an amazing clock. A group of visionary people have united under the umbrella of The Long Now Foundation (TLNF; www.longnow.org) to build the world's first monumental clock, called the 10,000 Year Clock. This is the slowest computer in the world [14].

The Long Now Foundation is behind the development of this clock, as well as several other projects. It has as its mission the goal of enlarging the human concept of time: "*The Long Now Foundation was established in 01996 ... to become the seed of a very long-term cultural institution ... to provide a counterpoint to today's accelerating culture and help make longterm thinking more common. We hope to creatively foster responsibility in the framework of the next 10,000 years.*" [15]. When writing dates, the foundation uses five-digits for each year, so that – to identify 2014, for example – it uses the number 02014. This device is intended to encourage longer-term thinking.

Once finished, the 10,000 Year Clock will be open to visitors who will have to climb a spiral staircase for hundreds of metres in order to see the huge mechanical computer that drives the clock. The complex system that underpins the clock will capture and store mechanical energy as a result of the physical movements made by the visitors themselves. Yet, another mechanism is also operating. Energy is stored by using a smart system that captures different temperatures induced by the rays of the sun that enter through a hole in the vertical tunnel at the top of the clock. The clock uses the power of the sun to correct small variations in the length of the day, making its own self-adjustments. At noon, the sun lies exactly over a tunnel leading to the clock A prism directs the sun's rays inside the mountain, and down, to be captured by the mechanical engine and interpreted as a synchronising signal. This thermal power is translated into mechanical power by transmitting heat inside the clock by means of long metal bars. So, the clock is designed to run on its own. Even if not a single person comes to visit it, the sun will power the clock! It can last for one thousand decades, even if no one comes to visit it. It is built to cope with both human survival, and also its opposite.

The clock itself is huge: it is more than fifty meters high. This monumental device is intended to help human thinking develop over a long period of time. While the engineering challenges in building the clock are immense, its real goal is to stimulate thinking about the long-term future. The clock will, for example, play different melodies, and is programmed not to repeat any of the music it plays for 10,000 years. The main question the clock aims to pose to human beings is: How are we acting today with regard to future generations of people? "*Are we being good ancestors?*" [15].

More pragmatically, the clock is also intended to avoid anxieties around yet another millennium computer bug occurring in the year 10,000. Most of those involved in this initiative are people whose careers originated in various high-tech domains. They include: Danny Hillis (a parallel computing pioneer, the designer of the clock), Steward Brand (founder of the Global Business Network, Whole Earth Catalog, the Hackers Conference and The WELL), Ester Dyson (pioneer of the digital age and founder of ICANN), Kevin Kelly (founder of Wired magazine), and Mitch Kapor (pioneer of personal computing and founder of the software company, Lotus). This group of people looks as if it is expressing a need: the need to zoom out from the imperceptible intervals of computer clocks (that run at the scale of nanoseconds, a kind of narrow time) to the immensity of a ten thousand year-duration initiative. This collective of leading personalities wants to show a more responsible face to future generations by building the slowest computer on earth. As Steward Brand, President of the Long Now Foundation, says: "*Civilization is revving itself into a pathologically short attention span. The trend might be coming from the acceleration of technology, the short-horizon perspective of market-driven economics, the next-election perspective of democracies, or the distractions of personal multi-tasking. All are on the increase. Some sort of balancing corrective to the short-sightedness is needed, some mechanism or myth which encourages the long view and the taking of long-term responsibility, where 'long-term' is measured at least in centuries. Long Now proposes both a mechanism and a myth.*" [15].

3.5 Limits to the speed of machines? NYSE, New York Stock Exchange

On Thursday, May 6th, 2010, something strange happened on the frantic floor of the New York Stock Exchange. The stock market was down just 1.5% from the previous day. At around 2:30pm something exceptional occurred. At 2:47pm the rate was -9.16%. In just ten minutes, a billion dollars had been lost. In only a few minutes, the indices that enumerate market status had dropped hundreds of points. Some shares lost 90% of their value (the price of Accenture, the business consultancy, for example, dropped to 1 cent); other businesses were traded at incredibly high prices (Apple shares were purchased at $US100,000). Operations were cancelled and the entire financial system stopped. What happened was later described as the "*flash crash*" (see Fig. 2).

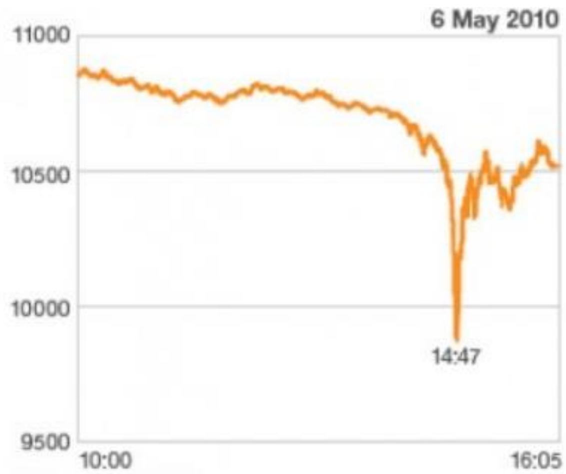

Fig2. Dow Jones Index during the "flash crash"
(source: Bloomberg)

For the first time ever, human beings no longer controlled the execution of trades in the financial markets; computers were in control of the process. Indeed, the trading speed reached that May afternoon was impossible for human beings to follow, whether they were investors or brokers. Nevertheless, the fast-trading software algorithms continued to compete with each other.

It took months for the United States Commodity Futures Trading Commission (CFTC) and the United States Securities and Exchange Commission to produce a detailed report [16] explaining the flash crash. Yet one thing was clear. The cause of the catastrophe was not human beings[1]. It was machines, algorithms, and sophisticated software programs that were able to place 10,000 bids-per-second through computer trading. These algorithms were very similar to each other: one program emulated the behaviour of others that, in turn, influenced other programs. In the end, the process triggered a snowball effect.

Machines can keep millions of variables under their control simultaneously. They are able to trade thousands of stocks at the same time in order to exploit extremely small changes in stock prices. Every day more than 70% of the volume of transactions are now controlled by computers that have taken over the trading industry [17]. The responsibility for the handling of these incredibly fast mechanisms − that are impossible for a human being to control − have been delegated to machines to play stock market games that can change the destiny of entire companies and markets. At these speeds, cause-and-effect explanations of market phenomena become impossible while they are occurring.

At a later date, Mary Schapiro, the then chairwoman of the Security and Exchange Commission, admitted that "*automated trading systems will follow their coded logic regardless of outcome ....*" and "*human involvement likely would have prevented these orders from executing at absurd prices*" [18]. As a result, the United States Securities and Exchange Commission imposed circuit breakers, mechanisms that slow down the speed of transactions (for example by automatically stopping trading if the fluctuations are higher than 10% in five minutes) [17]. More recently, the European Parliament has published guidelines on how to better handle high-frequency trading [19].

Both of these 2011-2012 measures go in the direction of slowing algorithms down. Ultimately, they are admissions that some limits have to be imposed on the speed of execution and operation of computer software.

4 Discussion and towards a set of conclusions

This chapter has dealt with the concept of time and the preoccupation with speed in the context of ICT. It questions the indiscriminate pursuit of faster technologies and the assumption that faster is better. It highlights a set of arguments about why speed is not always important or necessary. In contrast to the technological imperative to measure changes over ever tinier fractions of a second, and in recognition of the need to address longer-term concerns and phenomena, some people are now starting to

[1] One could also argue, of course, that human beings were partly the indirect cause of the failure, since they had not recognised the need to question, nor questioned, their assumptions about market behaviour when designing the algorithms underpinning the trading systems; neither had they, presumably, tested the software sufficiently thoroughly.

consider periods at the other end of the temporal scale: decades, centuries, millennia and beyond.

The chapter illustrates this by putting forward four concrete case studies, and offers a fifth which is more conceptual in its basis, to underline the need for more circumspection in the quest for faster ICT. Important messages that emerge during the course of the chapter include the facts that:

- **Life cycles are long**: this is a valid observation for both for human beings and for technology. Human beings need to consider the use of technologies over time and throughout life cycles.
- **The notion of slow refers to both time and speed**: slow and fast refer to rates of change that take place in conditions or items over a given period of time.
- **Speed may need to be limited**: in appropriate circumstances, the speed of machines may need to be limited. It may not always be a recommendation to push on the accelerator at the maximum speed allowed by technology. Instead, human beings might seek to regain the control of the 'pedal' that drives the speed of technology, and thus avoid a kind of techno-deterministic fatalism.
- **Dangers can be particularly long-lasting**: today, the possibility of immense disasters needs to be faced, whether these are natural catastrophes, such as the failure of crops, or – and especially – human-created ones (examples include atomic accidents and the side-effects of atomic waste).
- **Control on the part of humans is important**: human beings have created more than one technological process – the chief example being trading using financial systems – for which there is a need to reclaim a certain degree of control.
- **Preparing for eternity is important, and long-term thinking and acting, should both be encouraged**: in preparing for the extremely long-term future needs of humanity, there needs to be implicit wisdom, care, and a sense of concern.
- **Links with ICT can be positive**: some of this chapter's case studies are about how technology can help humankind plan long-term, and keep stores and symbols going over the long-term. As examples, Onkala and Svalbard could presumably not exist without technologies to power them, whereas the clock at Van Horn shows that it is possible to do something similar that is kept running by only the sun.

All five of the case studies explored in this chapter relate in some way to nature, ecology, sustainability and the continuity of human life over time. Given this orientation, ultimately, there will be a need to focus on sustainable elements of technologies, what Slow Tech calls *clean ICT*. Clean ICT means taking into consideration the environmental impacts (such as materials and energy consumption) of the manufacture, use and disposal of ICT products [20]. This, technology should respect the environment, and promote biodiversity and sustainability. It will mean undertaking in-depth analyses of the impact of both hardware and software production, use and disposal. It could help people to minimise their consumption of non-renewable resources and materials, and thereby reduce any ensuing pollution. At the same time, it could maximise the contribution of renewable resources in energy production. More specifically, ICT could be recyclable-by-design so that ICT lifetimes are extended and lengthened, and interoperability encouraged.

Ultimately, clean ICT is just one of the three important element of Slow Tech: these are technologies that are *good*, *fair*, and *clean*.

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