Road-mapping the Digital Revolution: Visions from COST Foresight 2030 (An exercise in multi-disciplinarity)

Afonso Ferreira

COST Office, Av. Louise 149, 1050 Brussels, Belgium
(on leave from the French CNRS)
afonso.ferreira@cost.esf.org

***Abstract*—From innovation triggered by user virtual communities to remote surgery and new financial instruments, the creative power of individuals is being fostered at proportions previously unseen. The main driver enabling such a pace of innovation, scientific progress, and user adoption is the Digital Revolution. One consequence is that interrelationships between science, technology and society are increasing in complexity and harder to understand.**

COST Foresight 2030 is an initiative encompassing a set of events designed to explore a multi-disciplinary vision for a future permeated and shaped by the digital revolution. The first of such events is a brain-storming workshop on Computer and Communication Sciences and Technologies, whose objective is to identify key technologies available by year 2030 and the corresponding benefits for Individuals, Society, and the World, in terms of Devices, Systems, and Services. The outcomes of this workshop will serve as the basis for experts in other scientific areas to envision how challenges in their respective disciplines will be tackled when such technologies are available. Such outcomes will be presented at the IEEE VITAE conference.

***Index Terms*— Digital Revolution, Research, Innovation, Computer and Communication Sciences and Technologies, Information and Communication Technologies, ICT, ICT, Foresight, 2030**

I. INTRODUCTION

The Digital Revolution is the main driver behind the current accelerating pace of scientific progress and innovation. The creative power and technological productivity of individuals are being enabled at proportions previously unseen, unstoppably yielding new products and inventions in almost all areas of human knowledge.

Surprisingly, though, even if the large contribution of the Information and Communication Technologies (ICT) sector as a share of world's GDP is well understood and recognized, the actual impact of all Computer and Communication Sciences and Technologies as enablers of innovation and progress in other economic sectors and scientific disciplines, which also impact society, is largely overlooked.

The Information Economy Report 2007-2008 of the UNCTAD details how the ICT industry is growing faster than many industries globally [11]. Currently the ICT sector accounts for roughly 7% of world GDP, with almost 9% growth in Western EU in 2003-2007 and employs over 15 million people in the OECD countries [9]. The top 250 ICT firms (making up around 70% of OECD ICT employment) grew by 12% in current terms in 2007 and their worldwide revenues reached USD 3.8 trillion [10].

Another trend described in the same reports is that the ICT industry is increasingly shifting to the developing world, mainly Asia. This industry not only includes the assembly of hardware or consumer electronics, but also the delivery of ICT services, such as those related to software and consulting, telecommunication and call-centre activities. As a matter of fact, recently China became the world's largest exporter of ICT goods, and India leads in international sales of ICT services.

As stated by Kofi Annan, Former Secretary-General of the United Nations: "If the world is serious about achieving the Millennium Development Goal of halving the number of people living in extreme poverty by the year 2015, ICT must figure prominently in the effort. Everyone – governments, civil society and private sector businesses – has a vital stake in fostering digital opportunity and putting ICT at the service of development." [12]

It is hence in this context that the European Cooperation in Science and Technology (COST) framework decided to launch an interdisciplinary strategic initiative, called COST Foresight 2030, in order to understand how scientific and societal actors may react when they realise what kind of technologies stemming from ICT will be at their disposal in future to tackle the challenges in their own areas.

The areas of interest and application of ICT as *enablers* of future development are numerous. In order to be able to deliver promising insights and results, COST Foresight 2030 focuses on the fields of life enhancement, energy, food security, natural resources management, and society.

COST Foresight 2030 is composed of six workshops organised during the year 2009. The first of these workshops, on ICT, is scheduled in April 2009. As a consequence, at the time of this writing its results and outcomes are not yet known. Therefore, this paper is organised as follows. COST is briefly

introduced in the next section. The concept on which COST Foresight 2030 is based is presented in Section 3 and its structure is described in Section 4. In Section 5 some preliminary ideas about the best ways to harness the Digital Revolution are discussed. Sections 6 and 7 review some related foresight exercises and provide some concluding remarks, respectively.

The whole set of visions, recommendations, and roadmaps from COST Foresight 2030 are shown at the conference presentation and are available in the COST Foresight 2030 website [1].

II. The European Cooperation in Science and Technology

COST (European Cooperation in Science and Technology) is one of the longest-running European instruments supporting cooperation among scientists and researchers across Europe, having started its operations in 1971. COST is an intergovernmental framework composed of 35 countries, allowing the coordination of research that is funded otherwise on a European level, through the provision of platforms for European scientists to cooperate on a particular project and exchange expertise. These projects are called "Actions" [2].

As a precursor of advanced multidisciplinary research, COST contributes to reducing the fragmentation in European research investments and to opening the European Research Area to cooperation worldwide. It anticipates and complements the activities of the EU Framework Programmes, constituting a “bridge” towards the scientific communities of emerging countries. It also increases the mobility of researchers across Europe, fostering the establishment of scientific excellence. We refer the interested reader to http://www.cost.esf.org.

III. The foundations

The first main seed of Foresight 2030 is a firm belief that the world is living through a real revolution and not only through a sectorial boom. It is true that the ICT economic sector is one of the main drivers of global GDP nowadays. After the convergence of computers with telecommunications, we are now experiencing its further convergence with media and broadcasting. This is well documented and analysed in print and in digital form. However, there is a more important point than the direct impact of ICT as an economic sector or even as a generator of increased productivity, namely that ICT are enabler and constitutive both to themselves and to other scientific, economic, and technological sectors, ranging from Space and Avionics to Architecture, Archaeology, and many others. These aspects are not yet fully integrated in policy-making, at least in Europe.

Furthermore, ICT are transforming and disrupting well known and established processes: who could have guessed that, in just a handful of years, a chimio-mechanical process like photography would be transformed into telephone gadgets? What other seemingly unrelated processes will have been so profoundly transformed – or disappeared altogether – in 2030?

The second cornerstone of this initiative is Ray Kurzweil’s 2001 essay *The Law of Accelerating Returns*, in which Moore's law was extended to describe an exponential growth in all technological progress and not only that related to the micro-processing industry. In such a work, Kurzweil claims, supported by many examples, that an analysis of the history of technology shows that technological change is exponential, contrary to the common-sense 'intuitive linear' view [3].

Taking this view, the technological progress one should expect to witness in the next 21 years that lead to the year 2030 is not proportional to the one experienced in the past 21 years, namely since 1988, but rather exponentially larger. If we include in this analysis the facts that 21 years ago the Internet was in its infancy, the web was embryonic, and that GSM phones did not even exist, we may start wondering what kind of science-fiction technologies are going to be available in 2030.

Finally, the third foundation of Foresight 2030 and perhaps its main innovation is its structure that is completely multidisciplinary. This is made possible by the 12-strong team of Science Officers from the COST Office, whose field of knowledge covers a large range, including Materials, ICT, Environmental and Biological Sciences, and others.

COST Foresight 2030, besides being one of the few relevant examples of pan-European foresight exercises – the majority being carried out at the national level – has some distinctive features concerning its positioning with respect to the Digital Revolution. The main vision is that Europe has to quickly position itself with respect to this revolution. The contribution of COST Foresight 2030 in this respect will be twofold. On one hand there will be a technology roadmap, identifying emerging technologies and scientific developments in the field of ICT that will be available by year 2030. On the other hand, these very same results will be re-examined in the light of the societal implications studied during the course of the Foresight 2030 and revised accordingly.

IV. The COST Foresight 2030 structure

The break-out of the whole initiative in a series of workshops catering for different, interdisciplinary areas allows for the application of dedicated methodologies to each of the workshops, depending on the output sought, and the invitation of specialised stakeholders to the workshops that best fit them. As an example, the workshop on ICT that constitutes the core of the VITAE conference presentation is composed both of experts who work either in the ICT industry or in Computer and Communication Sciences in academic research and of stakeholders in policy-making in the area.

The cross-fertilisation is ensured by the participation of *Rapporteurs* across workshops and by the Science Officers. Another mechanism to increase synergy among the interrelated areas is the co-location of the workshops on Life Enhancement, Food Security, Energy, and Natural Resources

Management.

Each workshop shall produce its own outcomes. The first one, on ICT, will produce visions of technologies that will be available at the lab and off-the-shelf by year 2030, along with a roadmap detailing the path from 2009 to 2030. Once processed by the COST Office, this information will be fed into the four co-located workshops mentioned above.

The main questions to be asked at these workshops relate to how such technology could be used to solve the great challenges faced in 2030. Their outcomes will then be visions and roadmaps, along with recommendations to the ICT stakeholders about possible technologies that were missing in their original vision, but that are key to address the area-specific challenges.

Once again these outcomes are processed at the COST Office and will serve as input to the last workshop that will try and accommodate all such visions into new models for the organisation of the European society, which will constitute this workshop's output. The structure of COST Foresight 2030 is depicted in Figure 1 below.

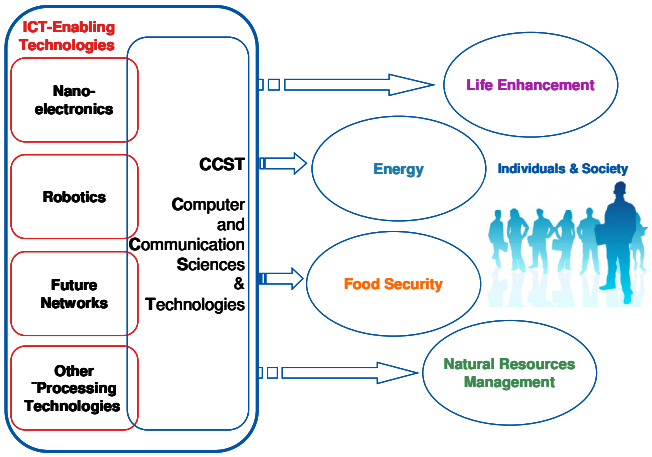

Figure 1: The enabling role of processing technologies and ICT and their impact on different fields relevant for the individuals and society as a whole.

The totality of visions, findings, and recommendations of all the workshops, in the form of proceedings and policy recommendations from the Foresight 2030, will be a valuable tool for researchers, policy-makers, industry, consultants, and strategy managers alike.

V. What is in the future?

Writing about the future is always a difficult exercise. In this case, a disclaimer is needed: the ideas discussed here assume that the future will be here, ie, that worst case scenarios like the human species being exterminated by Global Warming will not materialise.

This said, the vision is that the advent of a world plenty of digital devices is much more than a simple continuation of the Industrial Revolution. As I pointed out previously, the world is witnessing another revolution with maybe a higher impact in the world organisation as we know it. That is the Digital Revolution and should be approached as one such [4][5].

From this viewpoint, here is a very simple statement, whose consequences are still unforeseen: everything that can be digitized will eventually be so.

The impact of this on our daily lives may be enormous. In the beginning of the Internet, the whole organisation of the workplace was turned upside-down by the simple fact that documents could be stored (and hence, consulted) in digital form. Note that talking to someone in the 70's about the possibility of travelling abroad and still being able to consult all the files back in the office might had sparked images of fax-on-demand at best. Then, in 2006, not only documents, but all the different processes involved in the design of an airplane were finally made digital. Not a single bolt was produced and/or tested before the airplane was fully designed, breaking with traditional airplane design thus far.

A direct consequence of the digitization of all processes in an era of instant communications is that, in a production work-flow, every digitized process can be installed at the most cost-effective location. The implications to society at large are manifold, since both society and production will become deconstructed, as in a "Lego" world, and a new way of thinking is emerging, based on instant-communication distributed systems (eg, chat forums and virtual role games). And, evidently, new business models will be invented, most of them unexpected.

Let us try and obtain some insight into the future by looking back at previous similar experiences.

A. *The example of the Industrial Revolution*

The closest example at hand, and perhaps the best one, is the Industrial Revolution, where a new technology (cotton mills) was responsible for the uprooting of many established customs. It started by creating a financial markets bubble. Then, a great deal of agricultural jobs disappeared, causing urbanisation and immigration in scales never seen before – Italy lost almost half of its population, while Ireland lost around two-thirds of its own (the 2005 population of Ireland was still smaller than in 1870). Several wars ensued, including the two World Wars.

On the bright side, that was the start of a long-standing era of economic growth. More importantly still, after the second Great War, a tri-partite balance was found among the main socio-economic forces, namely the Capital, the Government, and the Workforce, which led to the stability that made the "Glorious Thirty" possible [14].

During such high-growth post-war years in the second half of last century, Capital and Government were often represented by the same companies; and national governments and companies that were national champions had a clear meaning as far as the Workforce was concerned. This situation allowed for jobs to be created, for taxes to be collected, for investments to be made, and for social measures to be enforced.

Unfortunately, however, the Digital Revolution, free trade,

and privatisations dangerously empowered the Capital in the Western countries. The holders of big capital were provided with incredible tools for amassing accrued amounts of profit in financial operations, facilitated by instant buy-sell orders around the globe, which would operate on virtual cash.

Therefore, the Capital, being dissociated from Governments, started to flow wherever gains are maximised. Companies settle in tax-heavens, processes are off-shored, hedge-funds reign unchecked over share-holders, etc. How then can Governments protect the Workforce and its citizens if they can no longer collect taxes and sell home-made products? The conclusion is that the Workforce, citizens, and the civil society at large are exposed to a real risk in the Western economies.

B. Back to the present

The discussion above shows that Governments need new strategies to attract Capital, in order to maintain social equilibrium through job creation, tax collection, and production. Their tools are, more than ever, human capital, infrastructures, labour laws, tax breaks, venture capital, patents revenues, and others. Because old-skill jobs are off-shored, brain-capital becomes one of the most important resources in the Western countries, although the processes developed in China and India are continuously moving up in the skill ladder and the scales may reverse, perhaps sooner than expected.

Because the Western countries did not prepare well to tackle the Digital Revolution, the economic slowdown was inevitable and can only be alleviated by increases in the public deficit. Such slowdown was mitigated in the beginning by a large productivity growth yielded by the integration of ICT in the internal processes of companies, but this is no longer enough.

The beginning of this century brought unemployment and social unrest in many countries. Most of the jobs lost require older skills, while, at the same time, countries encountered difficulties finding skilled person-power for the new, ICT-based jobs that were being created. The population was not trained fast enough in order to fill the new positions.

This phenomenon will most likely trigger population unsettlement, like it happened during the Industrial Revolution. The first examples were when, after the recent enlargement of the European Union, some half a million of Poles moved to the UK and whole Rumanian towns transferred themselves to countries like Italy, these two host countries been considered jobs heavens by the migrants. Yet, the places where the majority of jobs are been created are rather thousands of kilometres to the East, namely China, India, and oil producer countries. However, these countries do not share the same culture or religion as the Western countries, discouraging the candidate immigrants from the West. On the other hand, a large number of high-skilled (PhD and others) Chinese and Indians already started going back home after a skill-acquiring spell in Europe and the USA.

C. The way forward

Governments must fully integrate the power of ICT. The undisputed and growing weight of the ICT sector in the Economy (hardware, software, and services) makes a clear case for such integration. However, the economic and social impacts of ICT go well beyond its economic sector borders. As mentioned above, they are enabling and constitutive tools for almost every economic sector and for society as a whole. Because at the very core of ICT lay algorithms, the Digital Revolution will bring a new way of thinking, that is solution-driven like algorithms themselves. Microsoft's foresight Science 2020 predicted a departure from a world regulated by systems of formulae in the past century to a new world regulated by systems of algorithms [6].

The most visible impact of the Digital Revolution are instant communications around the world, that give the impression that distances are greatly reduced. However, not only distances and communication time are reduced. The life-time of business processes, including products, is also been constantly shortened. Therefore, flexibility is the new password. Flexibility of skills, flexibility of the job market, flexibility of the labour regulations, and so forth.

One implication is that there is a growing consensus that the best way to cope with the Digital Revolution is through education of the majority of the population of how to learn quickly, in order to cope with both the increased flexibility of our daily-lives and the ever faster business process cycles. Of particular importance is the teaching of Computer and Communication Sciences, again to the majority of the population. Note that the focus should be on sciences and not on technologies. It is the ability of mastering these Sciences that will make the citizens able to cope with the fast pace of change in technology already experienced today.

Countries that will better adapt to the 21st century will be those that use ICT as a strategic weapon to foster their economies and social well-being. The massive intervention by governments in 2008 and 2009, intended to counteract the global economic meltdown, would be used in a wiser manner if it were designed to prepare their societies with investments in ICT research and infrastructures for the 21st century, with focussed attention also on research and innovation enabled by ICT.

VI. A FEW RELATED INITIATIVES

Foresight activities are a major strategic tool for both the public and the private sectors. Thus, many such activities exist. A popular foresight web-site – http://www.efmn.info – lists almost 2,000 examples of recent and future foresight exercises.

In this section only three more relevant recent foresights are mentioned, namely Microsoft's Science 2020, COST strategic workshop on Algorithms Research, and the European Commission (EC) project Beyond the Horizon.

During summer 2005, Microsoft Cambridge gathered 30 scientists to discuss Science in 2020. The main visions are that Computer Science is the revolutionary science of the 21st century and that its impact will be greatest in conjunction with Life Sciences [6].

During the same summer, 7 ICT researchers met in the COST Office to prepare recommendations for the inclusion of algorithms research in the EC Framework Programme 7. Based on the fact that ICT pervades every corner of life and that algorithms are the basic building-block of ICT, they advised that the EC should put some focus on algorithm design, mainly embedded in other disciplines and dealing with the Data Deluge and Computational Biology [8].

Finally, Beyond the Horizon was a Coordination Action with duration of 18 months and composed of 6 subgroups. The findings and recommendations include that fundamental changes will come from cross-fertilisation of ICT with biology, physics, cognitive, and social sciences and that some of the main impacts will likely stem from Human-Computer confluence [7].

VII. Conclusion

The COST Foresight 2030 workshop on ICT is still to be held at the time of this writing and its results will be shown at the IEEE VITAE conference. They can also be consulted at the COST Foresight 2030 website [1]. I hence close the paper with some food for thought, below.

The Finnish government conducted a technological foresight exercise in mid-2005. It concluded that ICT-enabled progress in several health-related fields, like hygiene, nutrition, medicine, prevention, smart health-care, and health-monitoring, would allow many people to live in excess of 120 years of age by the year 2050 [13]. The consequences of such a scenario on Governments economies are big. Is it possible that people will work for 35 years and then retire for the following 60 years? Difficult to say, given that accelerated returns and ICT may play a role again in this case. But it is very likely that new models will have to be found for the organisation of the European society[13].

Individuals and society must realise that in the widely accepted denomination 'Digital Revolution' there is the word "revolution". As the EC Commissioner Viviane Reding said with respect to the current global economic meltdown: "ICT is not in need of a recovery plan. ICT *is* the recovery plan".

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