A Vision of New Era of Knowledge Civilization

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ABSTRACT

After stressing the importance of having a vision on the verge of the new era of knowledge civilization, we turn to concepts and ideas leading to a *cultural platform,* meaning the set of fundamental concepts essential for understanding the world in the new era. Then we turn to current perceptions about the nature of the new era and address the *essential part of the vision: what problems of humanity should we solve (and how we could solve them).* We then discuss *the main megatrends of the new era,* the socio-economic impact of digital and network technologies, *the main predictable conflicts of the coming era,* the main stages of the coming era and *our essential obligations.*

Keywords: knowledge civilization era, informational revolution, megatrends of new era, complexity change, management of technology, management and systems science, dangers and conflicts of knowledge era

1. INTRODUCTION

The starting era of *knowledge civilization* is known also under many other names *postindustrial, information, postcapitalist, informational, networked etc. society.* However, this is a civilization era, a long duration historical structure, thus it is necessary to create a vision of this era, outlining the chances of solving humanity's current problems, but also noting the diverse dangers and threats resulting from the main megatrends of this era.

There is a voluminous literature on the subject of the *information society* and the current *informational revolution.* A thoughtful book of A. Mattelart [1] quotes over 270 publications on this subject, and this excludes the more technical ones, see, e.g., [2], [3], [4], [5], [6]. In this voluminous literature, there are diverse views and a universally accepted, slowly evolving core.

> There is universal agreement that we are living in times of an *informational revolution* and this revolution leads to a new civilization era, in which knowledge plays an even more important role than just information, thus the new epoch might be called *knowledge civilization era.*

However, most other aspects of this development are uncertain and have diverse interpretations. Moreover, much of what was published on this subject is related to marketing or political hype, or to unfounded optimism that new technology will automatically solve all old problems.

Yet we feel that an *informed and objective vision* of the new era of knowledge civilization is needed. Because of the property of *globalization* of this new civilization, such an informed vision is needed for all people of our world, many of whom are uncertain, distrustful, divided politically and not ready to accept marketing or political hype and – in developing countries – suspicious of what they see as attempts to intensify the existing domination of developed countries. People deserve, however, to know both risks and opportunities that might come with reasonable certainty as the result of the developments of knowledge civilization.

We are aware of the trends in sociology and philosophy that deny the importance and possibility of *objective* judgements. We have learned in technology to *construct new reality, to create big technological systems,* but this is not done arbitrarily, we also have learned to greatly value *the attempt to make knowledge as objective as possible.* Without this *dedication to objectivity* as a goal, we could not develop travel technology – railways, cars, airplanes – and telecommunications – stationary telephony, television, mobile telephony, and the Internet.

Thus, we feel that an objective vision of the new civilization era, though it must be interdisciplinary and include some aspects of philosophy, history, sociology, economics, should be attempted by researchers whose background is technological and systemic. We thus aim to apply what we know about management and systems sciences, about interdisciplinary rational enquiry, to obtain a synthetic but as objective as possible vision of the era of knowledge civilization.

2. CONCEPTS LEADING TO THE *CULTURAL PLATFORM* OF NEW CIVILIZATION ERA

We could start very early in the history of the concept of information society, as in [1]: from Bacon, Pascal, Leibnitz, Newton, Condorcet, Saint-Simon, Boole. Many thinkers over a long time contributed to the first conception of such a computer – given by Babbage in 1832 – and eventually to the construction of first analog computer by V. Bush in 1932, followed by the first digital computer (the principles formulated by A. Turing, 1936, actual construction in the USA during the Second World War, *Univac I* given to civil use in US Bureau of Statistics in 1951). These tremendous delays would have been even longer, had it not been for the demand of military and later space applications. Similarly, the development of telecommunications, starting first with electrical telegraphy (developed since 1837) and later stationary telephony, much later mobile telephony etc., was characterized by similar delays and accelerations.

These two developments – of telecommunications and of computers – although important, did not themselves determine the coming of the new civilization era. Telecommunications was stuck for a long time on the level of classical stationary telephony; computers were giant machines that could be used only by specialized personnel. Such was the situation until around 1980, when two parallel developments – of computer networks and of personal computers – brought digital information technology potentially to every home in the world. Both developments are slightly older, but broad civil use of the Internet started with the definition of its seven ISO/OSI layers and TCP/IP protocols just around 1980, which by chance paralleled the development of the first personal computers. With Internet and personal computers, the broad social use of digital information technology was enabled.

The issues of *periodization* – the determination of historical dates defining certain historical eras – are best decided by historians. Therefore, we follow here the example of F. Braudel [7] that defined the long duration preindustrial era of the beginnings of capitalism, of print and geographic discoveries, as starting in 1440 with Gutenberg (promotion of broad applications of printing press), and ending in 1760 with Watt (possibility of broad applications of steam engines); this started the next, industrial era. Note that neither were new inventions, only adaptations of older inventions that enabled, however, their broad social use. Gutenberg repeated, perhaps independently, an earlier Chinese invention, but he made it much more mechanically efficient and thus made possible broad social access to books; Watt added a system of automatic control of rotary speed to an older steam engine that was unstable and tended to explode before this improvement – thus, he made possible a broad social access to steam power. Following the example of Braudel, we choose 1980 as the beginning date of the new era of knowledge civilization, even though computers were used earlier, just as steam machines were used before Watt and printing before Gutenberg.

However, the way of perceiving the world during a civilization era is defined by its *cultural platform* – see [5] – that consists of basic concepts and ideas that are usually formed before this era or in its beginning stages.[1] Before Watt we had Newton and the French encyclopedists; before the Internet we had Einstein and many scientists that contributed to essentially new concepts that shaped the cultural platform, the way of perceiving the world typical for the new civilization era. While often most attention is given to writers popular in the media, sociologists or futurologists – Innis [8], McLuhan [9], Bell [10], Masuda [11], Toffler [12], who contributed greatly to the popularization of the concept of change of cultural era – more important are the concepts developed in 20th Century science and technology that contributed to the new perception of the world.

The first of such concepts came from physics: from Einstein – the concept of *relativity* of time; from Bohr and his group – the concept of *quantum* theory, denying the infinite divisibility of matter and at the same time showing that the same particle can be equally well described as a corpuscle and as a wave; from Heisenberg – the *indetermination principle,* showing that the act of measuring influences the results of measurement, thus uncertainty cannot be diminished below certain value. All these concepts date from the beginning of 20th Century and contributed to *relativism* and *pluralism,* which had full impact on philosophy at the end of the century; they were integrated into technological and informational sciences much earlier. These physical concepts are much better known and popularized in the media than some other concepts coming from technology that also have changed our way of understanding the world. We shall therefore discuss some of these concepts developed by the technological and informational sciences in more detail.

Soon after the new concepts in physics other new concepts originated from telecommunication technology. H. Nyquist [13] and others, as early as 1930, studied the concept of *feedback* – the circular impact of the time-stream of results of an action on its time-stream of causes – simply because it was technically necessary to stabilize the properties of not quite stable telecommunication devices; this concept, in fact, had been practically used earlier by Watt.

The concept of feedback had profound implications. On one hand, around 1940 it led to the development of a separate technological science called *control engineering,* dedicated to the study of the dynamics of technical systems based on negative feedback and used to control

[1] The formation of a *cultural platform* precedes the emergence of an *episteme* characteristic for a given civilization era; this we discuss at the end of the paper.

and stabilize vehicles[2] and diverse parameters of all technological processes. Eventually, control engineering lead to the development of *robotics;* robots cannot function without feedback. On the other hand, N. Wiener [14] popularized the study of the concept of feedback in living organisms and in social organizations, calling such studies *cybernetics.*[3] J. Forrester [15] borrowed from control engineering the concepts of feedback and block-diagrams of the dynamics of technical systems and applied them under the name *industrial dynamics* (later called *systems dynamics*) in economics, management and social sciences – though the concept of systems dynamics actually stems from analog computers, thus from V. Bush [16]. However, one of the most important consequences of the concept of feedback is the development of the *deterministic theory of chaos.*

Before emerging as a distinct discipline, chaos theory was simply the study and application of the dynamics of strongly nonlinear systems with (usually negative) feedback. When studying the stability of such systems, new modes of their behavior were noted by mathematicians and by control engineers. The use of computerized mathematical modeling of diverse biological and physical processes – such as crystallization or the formation of snowflakes – contributed to the realization of the fact that new types of behavior emerging in strongly nonlinear dynamic processes with feedback are examples of *deterministic chaos with new order emerging from it*.

In other words, a new *emergence principle* was formed: *new properties of a system result from its complexity, not from the properties of the elements of the system.* It should be added that hierarchical, multilayered systems theory, assuming many layers of systems with essentially different functions, resulted also from developments of control engineering or control science – see, e.g., [17].

The deterministic chaos theory is now very rich. Beside the principle of emergence, it describes diverse phenomena, such as *self-similarity* in *fractal geometry* – the property of certain images such that a magnification of a small part of the image is perfectly similar to the full image, or the *butterfly effect* – the *basic fact* that strongly nonlinear dynamic systems are usually very sensitive to their initial conditions, so that small causes can have very large effects, *the flip of a butterfly wings in Beijing can cause a hurricane in Florida* [18]. Along with the deterministic theory of chaos, a probabilistic one has been also developed [19], with a repetition of the conclusion that order can emerge out of chaos.[4] *Fractal geometry* contributed later to an important concept of *scale-free networks* [20]. Generally, chaos theory has had a great impact on the change in the way of perceiving the world we observe today. The *butterfly effect* contributed to the abandonment of the belief in *inevitability,* a characteristic of industrial civilization:[5] while the industrial era saw the world as a giant clock, a machine turning with the inevitability of celestial spheres, the knowledge civilization era will see the world rather as a complex dynamic system in which anything can happen and an avalanche-type process is quite probable; thus *instead of inevitability we believe in change*. Together with the change of other concepts outlined here, we can even say that we believe in *Complexity Change.*

Another concept that contributes to the change in the way of perceiving the world originates from informational science. This is the theory of computational complexity. The theory characterizes diverse classes of computational tasks – from simple tasks like data sorting to the more difficult, such as pattern recognition or solving logistic problems – by proving how the needed computational effort depends on the amount of data processed. This theory is quite advanced, but only a general conclusion is important here: the dependence is almost always nonlinear, and it is strongly nonlinear (exponential or combinatorial) for most types of more difficult problems. This fact has far reaching consequences for computational modeling and even for epistemology, see [23], [24].

With the rapid growth of the available computing power, we could conclude that any complicated model of, say, technological systems such as a modern telecommunication network can be analyzed in a short time. This conclusion is, unfortunately, basically wrong. The exponential increase of computational complexity

[2] Including aircraft and missiles, hence also the development of control engineering was strongly influenced by military applications.

[3] Control engineering has therefore sometimes been called *technical cybernetics,* but this is a misnomer, since control engineering is older and original; Wiener just used its principles for broader applications.

[4] With a similar principle of the emergence of order, a strongly nonlinear transformation with recourse: a strongly nonlinear transformation of a probability distribution can result in amplifying the probability of selected events, thus eventually – if repeated many times – in order.

[5] Many people, including scientists, are so much subconsciously accustomed to the industrial civilization vision of the world as a clock, a giant but well ordered machine with its *inevitable* movements, that they cannot accept the concept of a *butterfly effect,* consider it a *myth.* Unfortunately or fortunately, it is a *basic fact*, stressed first in scientific publications on mathematical modeling in meteorology by [21], but substantiated also by other diverse studies, e.g., of the sensitivity of control system models, see [22]. Thus, it is *inevitability* that is a myth of the mechanical vision of the world of industrial age.

means that if one variant of such model can be analyzed, in, say ten minutes computer time, then by adding only one additional variable the required computer time could easily jump to ten months. Experienced mathematical modelers know this problem well, by hard practice: they must perform many computational experiments in order to obtain variants of models that, on one hand, are not oversimplified and represent the analyzed technological problem adequately and, on the other hand, are simple enough to be computationally analyzed in reasonable time. This is not a passing problem that will vanish with improved computing technology. This is an essential problem, any model can be further complicated, thus any computer, no matter how powerful, can be easily saturated with computational tasks.

This problem shows the *practical limits to cognition:* why should we develop more accurate models of some parts of reality, if we would not be able to analyze these models in reasonable time? We see also a basic conclusion: possibly, *all our knowledge is represented by models constructed by us that are far from being perfect,* are (we quote Einstein here) *as simple as possible but not too simple,* and their accuracy is limited not only because we use imperfect tools (e.g., language) to formulate them, but also because we have imperfect tools (e.g., computers with finite processing speed) to analyze them.

Another essential concept is the change of logic. Industrial civilization believed in the *principle of the excluded middle,* in *binary logic;* but *temporal, modal, multivalued logic* with diverse applications – *fuzzy and rough,* see Z. Pawlak [25] – have been developed towards the end of this era. For the era of knowledge civilization, we need *logical pluralism: there is always a middle way.*

We observe also a change of knowledge creation theories, described in detail in [24]; until recently, epistemology concentrated on a grand historical perspective, on *macro-theories of knowledge creation*. However, today it is necessary to develop an understanding how technological knowledge is currently created for today and tomorrow; this resulted in many new *micro-theories of knowledge creation,* see also [26], [27], [23], [28].

Thus, there are many concepts that characterize the new cultural platform of the era of knowledge civilization; we listed here *relativity and relativism, indetermination and pluralism, feedback and dynamic systemic development, deterministic and probabilistic chaos, butterfly effect and change, complexity and emergence principle, computational complexity as a limit on cognitive power, logical pluralism, new theories of knowledge creation* – generally, *Complexity Change.*

This list is by no means exhaustive; we shall stress later other necessary changes in basic assumptions that are induced by the development of knowledge civilization.

3. CURRENT PERCEPTIONS OF THE NATURE OF THE NEW ERA

Many thinkers and futurologists predicted a change of civilization eras; here we shall briefly recall their arguments.

H. Innis [8] argued that telecommunication systems will become the future basis of power, and M. McLuhan [9] was the first to predict that electronic information transmission will lead to a new, global civilization era; McLuhan's analysis of the functioning of the *mass communication society* has a much more lasting value than the analysis of the faults of the *one-dimensional society* by his contemporary H. Marcuse [29]. Bell in his writings [10] promoted first the concept of the *end of ideology,* then *post-industrial society,* and further, of the *service society*. Masuda [11] was the first to use the term *information society*, Toffler [12] used the term *third wave* to characterize essentially the same concept as Masuda. All of them were right in general perception and wrong in details.

For example, the concept of the *third wave* is elegant, but historically incorrect. We quoted above the opinion of Braudel on historical periodization. If, following Braudel, we define a historical civilization era as a time when essential concepts shaping the image of the world remain relatively stable, then in the *agricultural, first wave* of Toffler we could distinguish many civilization eras, ending with the era 1440-1760 described in detail by Braudel. Thus, the *industrial, second wave* 1760-1980 was not the second civilization era; and *third wave of information civilization* will be not the last. But there is no doubt that the Tofflers have contributed greatly to the understanding of the importance of changing civilization eras.

Current perception of the nature of the new era is shaped rather by the opinions of P. Drucker [30] and M. Castells [31]. Drucker uses the name *post-capitalist society,* which is disputable, but correctly diagnoses the dominant role of knowledge as a productive resource in this era. Castells notes the changing character of organization of social and commercial life, toward a *networked society,* and corrects the name *information society* to *informational society*.[6]

[6] In some languages – for example, in Polish or Japanese – this change was achieved much earlier than when it was proposed by Castells, see Kameoka [2], Wierzbicki [6].

But he consciously tries to avoid any prediction of future trends of the new civilization era, possibly because futurology is currently under attack by the media.

It is important to review here the arguments of such attacks and explain reasons why we think that we should nevertheless speak about some major trends and problems related to the new era.

Arguments against futurology can be classified in two layers: factual and ideological. Factual arguments can be summarized simply: all predictions have errors in them, thus speculating about the future is futile. Usually, such a statement is supported by a long list of spectacular errors in predictions, including the most famous mistake of Bill Gates about the necessary size of memory in a personal computer. However, such arguments simply indicate ignorance about the nature of prediction. First, if we assume a continuous probability distribution of random influences on future events, then the probability that any specific prediction will come true is zero – thus any prediction must be wrong, at least in some details.

Second, future studies include predictions, but also diverse other methods – scenario analysis, trend analysis, etc. *They serve not for predicting the precise course of the future, but for increasing understanding of the future by describing its possible courses.* Third, all big companies make future studies for their own internal purposes, including technology assessment for technology management or for strategic development – and even if they often make mistakes, the nature of such mistakes must be secondary. In other words, *how often has Bill Gates made such mistakes, if he is a very rich man?*

Ideological arguments usually state that it is wrong to predict the future, particularly if it is done by a government or governmental agency, because this implies totalitarian tendencies; any such prediction is bound to represent some vested interests. This type of argument, however, is self-defeating: *if it is wrong for a government to predict the future by a government, and if big companies predict the future all the time, does not the argument itself represent vested interests?*

In the name of objectivity, all agencies should have equal rights to speculate about the future. We believe that speculation about the future was an essential engine of the development of human civilization: *we invented speech in order to organize knowledge, and we accumulate knowledge in order to be able to reasonably speculate about the future.* Moreover, we have shown already that a dominant feature of the new civilization era will be *Complexity Change.* How do we cope reasonably with *Change?* The answer is: only by trying to understand its nature, by speculating about its possible courses.

4. THE VISION: WHAT PROBLEMS OF HUMANITY SHOULD WE SOLVE?

First we could ask the question: do we need *Change?* However, humanity does have urgent problems and the new civilization developments might help to solve them – only it will not be done automatically. We must think very deeply and seriously how to use the opportunities that are related to its development. Thus we need *Change,* only we must understand it.

(I) One of the most important problems is the growing gap between the most and least developed regions and countries, *growing inequality, hunger and endemic diseases* in diverse countries and regions of Africa and Asia. In the year 1960, the ratio of the earnings of the poorest 20% to the earnings of the richest 20% of people in the world corresponded to 1:30; today, this ratio is 1:74 – see, e.g., J. Kuroń [33]. It is a sign of the impotence of the United Nations and of the egoism of richest countries that, with the enormous resources squandered on diverse erroneous actions, we are not able to eradicate hunger and endemic diseases in remote parts of the world. The coming knowledge civilization might help in this task, but not automatically, only if we know how to use it.

(II) The second, equally important problem is *ignorance and intolerance toward different cultures and people.* Possibly the most valuable part of the human heritage is *cultural diversity,* the number of various languages, cultures, customs of nations, tribes and regions in the world. It is equally valuable as *genetic diversity,* and for similar reasons. We do not know what gene might be helpful to develop protection against unpredictable viruses; we do not know what culture might contribute to the solution of unpredictable crises in the future development of human civilization. This puts a special responsibility on English speaking cultures (of which they are usually not aware): since English is the language of globalization, they are responsible for cultural diversity. We can obviously use information technology for the goal of preserving cultural diversity; but greatest danger comes from ideology – nationalist or religious.

(III) The third, perhaps even more important problem is *growing violence and hatred in human relations.* International terrorism is partly caused by this problem, partly by growing inequality and intolerance, hence it is a secondary symptom; to remove this symptom, we must first find remedies for its causes. Violence and hatred feed on several sources. The fundamental one is the *example of arrogance* – of the arrogant and willful behavior of the rich and powerful, which every person in the world can see, due to the globalization of information; another is the *example of violence* – of diverse violent behavior, examples of which are given to every child in the world due to the commercialization of mass entertainment, where horror sells best. There are also other sources; together they result in hatred, and hatred breeds terrorism. We can use knowledge civilization and information technologies to counteract these causes of violence and hatred, but not if we believe that all problems will automatically solve themselves and leave mass entertainment solely to market forces.

(IV) The first three problems listed here are at least universally perceived. Much less perceived is the fourth, the *growing threat of intellectual pollution, of the overexploitation of human intellectual heritage.* This is because this problem is specifically caused by knowledge economy, by knowledge becoming an economic asset in proportions not known in previous civilization eras. The essence of this problem is the relation of *privatized knowledge* to the *human intellectual heritage.* If we treat the intellectual, cultural, and civilization *heritage of humanity as a free resource* in times of knowledge civilization, at the same time *trying to privatize knowledge,* this might result in *degradations of this intellectual heritage similar to the degradations of the natural environment in industrial age.* Naturally, there is a basic difference: as opposed to natural resources and environment, knowledge is not used up when it is used. However, until now, each generation has added objective knowledge to intellectual heritage; imagine how our intellectual heritage will be polluted if instead of objective tests on the value of diverse medical drugs, only the privatized tests of drug producers are published (we know that this pollution has already started). Questions of knowledge ownership and of the value of heritage of humanity might be basic problems and conflicts of the coming era. Again, we might use information technology to help solving the problem; but we must first understand the problem well and decide how to solve it.

How should we then solve these problems? Many thinkers in diverse countries – see, e.g., [33] – have come to the conclusion that:

> The *solution involves a great global reform of educational systems around the world,* which we shall briefly call the *Reform.*

That we need a change in educational systems at the beginning of new civilization age is obvious. The vision says more: that *the Reform must have global elements, use informational technologies and be focused on solving – through education and free access to information and knowledge – the basic problems of humanity such as listed above.* This means that *Reform* must be started in all countries, but based not on the principle of rigid planning of the *Reform*, but on the principle of *learning, exchange of experience among reformers around the world and adaptive corrections of the Reform.* This means that a global network of institutions must be established – perhaps, starting with but not limited to United Nations agencies – with the goal of analyzing and coordinating diverse aspects of this *Reform.* This means that United Nations and, in particular, the richest countries in the world must be induced – by the force of mobilized global opinion – to devote adequate financial and human resources to support such a reform, particularly its implementation in the poorest countries.

This does not mean that the *Reform* must be based on public funding alone, particularly in the richest countries. A certain amount of competition is necessary, e.g., for universities in rich countries that should create knowledge not only for human heritage, but also for market applications. The *Reform* cannot be realized without mobilizing a considerable share of private resources – from families, enterprises, big business, foundations. But the *Reform* must also have an adequate share of public funding in order to provide for education of the poorest, who may be the most talented; or in order to counteract the tendencies to pollute the intellectual heritage of humanity.

5. MAIN MEGATRENDS OF THE NEW ERA

In order to develop the Reform we need understanding; thus, we shall discuss here the three main megatrends of the new civilization era as indicated in [6]:

> I. The technological megatrend of digital integration,
> II. The social megatrend of dematerialization of work and changing professions,
> III. The intellectual megatrend of changing perception of the world.

I. The technological *megatrend of digital integration* is sometimes also called the megatrend of *convergence.* It is a long-term megatrend since it results in basic technology changes, threatening standards and the market positions of most players in high-technology markets. All signals, measurements, data, etc. could be transformed to and transmitted in a uniform digital form, but this requires time and adaptation. From a purely technical point of view, the digital integration could be much more advanced today if it were not limited by economic, social and political aspects.

Telecommunication and computer networks are becoming integrated, but uniform standards would mean that small firms could freely deliver diverse services in this extremely profitable and fast growing market. Moreover, this is a specific market: it requires a certain type of cooperation among market players, since connection to the network must be provided to all customers, no matter in which domain the service originates and to which domain the customer is connected; this is called the *interconnection* requirement. If standards are not uniform, it is easy to defend a monopolistic or oligopolistic position on this market by making interconnection requirements sufficiently complicated. National regulatory authorities require that big telecommunication operators (telecoms) publish interconnection requirement manuals, but some such manuals are thousands of pages long. In many countries, governments realized that the demand of telecoms to have an *unregulated, free market* actually means the freedom to keep their monopolistic positions. Thus, very often entirely new backbone (long distance traffic) networks for the scientific use of the Internet are subsidized by governments – in fact, the costs of constructing optical backbone networks are fast decreasing – with two goals. One objective is to provide science with very modern technology, since monopolistic telecoms usually only say that they provide the newest solutions, while actually the solutions they offer are often many years old. Another is to break up the monopoly by promoting the entry of new players; small firms usually get better interconnection agreements with such new networks.

Diverse aspects of the intelligence of networks, computers, decision support, and even of intelligence of our ambient habitat are becoming integrated. Making computers intelligent has been a legitimate goal of computer scientists for many decades. The miniaturization of computing chips and the development of diverse sensors make also possible the dispersion of intelligence in our ambient habitat – in intelligent offices, rooms, houses, cars, roads, stores, etc. All developed countries and all high technology companies have programs of research on such *intelligent ambient habitats.*[7] However, several serious problems must be overcome before the full potential of this idea can be realized. First, the technology should be inexpensive enough for customers to pay for it. Second, the customers must trust the technology. Third – related to the second – the privacy and other rights of customers should not be threatened. Overcoming all these problems requires time and the most serious might be the third one. It is technically possible to build secure networks and much research is devoted today to the issue of trust in the networks. However, the problem is more social, legal and cultural than technical. Social and legal, because privacy rights and standards must be discussed and defined anew with the advent of omnipresent computing. Cultural, because computer scientists, motivated by the goal of making computers as intelligent as possible, tend to let computer software outguess and dominate people (even in word processing software), which is simply not admissible: human user must have a *sovereign role* in their interactions with any device, including computers – and for intelligent ambient habitats, a new culture must be formed to guarantee such a role. For all these reasons, the idea of an intelligent ambient habitat needs still a decade or two until it will be more broadly socially used.

Diverse communication media – newspapers, books, radio, television – are becoming integrated as the result of the general digital integration trend. This will change the basic recording medium from paper to electronic form, although it will necessarily take a long time to change human customs. Often more paper is used in a digitally supported office than before the introduction of personal computers. But much more often we simply do not realize the potential of this change, e.g. the intellectual power of video-recording an event in combination with written notes in electronic form. The economic and political power of this integration is well perceived and we already observe fights about who will control the integrated media.

From a common root – so called *soft current electrical engineering* – many branches of information technology diversified during the 20th Century: *telecommunications, informatics, control engineering and science, electronic engineering,* and so on. With the megatrend of digital integration today there is not much sense in considering them separately; in the 21th Century they are becoming re-integrated, so that we often speak jointly about *informational technologies* and distinguish in them *software* and *hardware.* Generally, this megatrend of digital integration has gigantic impacts and will define the directions of informational technology change for many years to come.

II. The social *megatrend of the dematerialization of work* can be also called *the megatrend of change of professions* and might be even more powerful than the megatrend of digital integration. The idea that technology should make human work less onerous dominated the entire industrial civilization era; the era ended when the idea began to actually materialize, when robots started to replace human work. Control engineering, robotics, and the broad use of information technology together have slowly resulted in a dematerialization of work.

[7] However, the same goal is hidden under diverse names. In its Framework Programs the European Union calls this *Ambient Intelligence* (AmI), the United States refers to either *ubiquitous* (omnipresent) *computing* or *wireless sensor networks,* in Japan the names *intelligent home* or *building* or *yaoyorozu* are more typical.

Rapid technology change induces a rapid change of professions and so called structural unemployment actually is a misnomer, resulting from the static thinking of the industrial age. Structural unemployment means that the structure of the economy has changed and there will be unemployment until the labor force adapts to the new structure. However, what if the structure is changing continuously and its speed of change is limited precisely by the speed of adaptation of the labor force? Today's technology would permit us to build fully automated, robotic factories, but what would we do with the people who work in the existing factories? If old professions disappear, we must find ways to devise new professions, new occupations for people, to replace the old ones.

The dematerialization of work has some clear advantages. For example, it makes it possible to realize fully equal rights for women. Women liberation movements remained utopian in industrial civilization, because while the idea of a woman as a tractor driver might have been a catchy slogan of communist ideology, it was realizable only for women of great physical strength. The computer and the robot made possible fully equal rights for women, but the issue is much more complex: to realize equal rights we need to change customs, to give all women equal access to tertiary education, etc. This also shows that the time needed for full realization of knowledge civilization is necessarily rather long.

But the dematerialization of work produces also great dangers. Not all people are equally adaptable and the need to change professions several times in life might be too large a burden. This results in the *generation divide* – between the younger people who can speedily learn a new technology and the older ones. This is also followed by *digital divide* – between those who profit from information technology and those excluded from this technological progress. The digital divide affects diverse countries, and it is a dynamic, not a static effect: if left to market forces alone, it might eventually disappear, but 'eventually' means here in a hundred years or so. Thus, it is the duty of the governments of these countries to counteract the digital divide; the free market, though necessary for economic efficiency, will not prevent the digital divide until it is too late. Too late, because the digital divide can threaten the very existence of democratic society and the market economy as we know them now, in two ways. One is already known and well perceived: the digital divide is the social source of terrorism. Another is more subtle: mass consumption society, as we know it from the late period of industrial civilization, is based on mass demand, stimulated by the nearly full employment of reasonably well paid citizens. Large, persisting unemployment resulting from the digital divide might mean that mass demand will collapse and with it market society as we know it today. Thus, the digital divide is one of the most dangerous effects of the dynamics of *Complexity Change* and it is our duty to think hard how to alleviate it.

One obvious way is to intensify and reform education, which is simply an additional argument for the *Reform* of educational systems outlined earlier here. Increase the participation in all forms of education, including tertiary, promote greater participation of women, delete unnecessary subjects of study,[8] add more training in mathematics and computers on one hand and in philosophy and debating, in negotiating and managing small enterprise on global electronic markets on the other hand, and generally reform the education towards the needs of knowledge civilization. Such a reform might have high costs but is the best investment for a country.

III. Another reason why a fundamental *Reform* of educational systems is needed is the last megatrend, which is actually the most demanding: the intellectual *megatrend of mental challenges, of changing the way of perceiving the world.* We commented on this *Complexity Change* when discussing the *cultural platform* of the new era; we must comment here only on some necessary changes. The *Change* of civilization epochs is so vast that some disciplinary paradigms must be changed along the way. This concerns in particular economics and sociology, see [24]. Here, however, we concentrate on the impact of digital and networked technology on social life.

6. IMPACTS OF DIGITAL AND NETWORK TECHNOLOGY

The changes in social life resulting from informational revolution will be very great and are not yet well understood. The broad social use of Internet or generally, the digital networked economy, will have impacts comparable to Gutenberg's improvement of printing technology or Watt's improvement of the steam engine.

The fast development – following Moore's law, see [34] – of the available size of digital memory has already made possible essential changes in the social use of digital technology. Many of us already use so-called *USB memory sticks* – physically small, pocket-sized digital memory devices that hold from 64 to 1024 Megabytes, carried with you everywhere and attachable to the USB outlet of any contemporary computer, devices that replace diskettes, notebooks, personal file systems, photographic collections. If such memory size grows 100 times, which according to Moore's law should occur in next 10 years,

[8] Deleting some subjects of education is usually a very hard choice. Consider the issue of teaching kanji, hiragana and katakana in Japan.

we can use such memory sticks for collections of films, music, books, for carrying any personalized information. Only a few professionals realize the importance of USB memory sticks; they are not widely popular yet, and software companies have not yet fully realize the tremendous potential of their use. Imagine a personalized library, office and network software carried on such a stick that would allow you to use any computer and give you access to any computer network in a personalized format; you then carry with you all information that is important for you and use it *any place and any time.*

And this is only one example – imagine another, the possibility of changing the format of classical books to books integrated with films, with interviews or entire courses of lectures presented by the author of the book. There are many more such examples (*grid technologies, ambient intelligence, Blog network services,* etc.) which illustrate the thesis that the current informational revolution has a tremendous potential of social applications by far not exhausted yet.

On the other hand, many broad social reviews of important trends in science and technology give information technology high but only short-term priority. For example, for many years – since around 1970 – Japan has organized *technology foresight processes,* involving a broad representation of national experts and policymakers in articulating and forecasting social demand for emerging technologies. Diverse methods are used in such *foresight processes* or *surveys*, see [4]. The seventh such survey (1999-2001) determined as a most important field *information and communications,* but only for the decade 2001-2010, while after 2010 the most important fields were defined as *earth science and environment technology* and *life science,* with *information and communications* dropping to fifth place. Is this a correct assessment?

One could say that perhaps 90% of experts involved in the seventh survey did not even know what an *USB memory stick* no what *Blog service* on the Internet is, thus could not imagine the not exhausted yet social potential of information technology. But a more important reason is that *very few technology experts are also specialists in systems dynamics* and can correctly assess the delay times and inertia inherent in creating a social demand for emerging technologies. This diagnosis can be substantiated by many examples, here we give only two: one Japanese and one European.

In 1977, see [4], a special foresight exercise based on the *Delphi Scenario Writing* (DSW) method was started in order to forecast and promote the development of *small facsimile* machines for home and small business use. This was a very interesting example how such goals can be promoted and assessed, but we concentrate here only on the analysis of results of this foresight process. Small facsimile machines were in fact developed and promoted on the market. After a time they enjoyed (and still enjoy) a world-wide success, but the dynamics of market adoption were quite different than predicted in the foresight analysis, see Fig.1.

While the foresight projection assumed an early start and slow build-up of market penetration, the actual adoption curve shows an unpredicted pure delay of approximately ten years, then another ten years of slow build-up – followed, however, after twenty years by much faster than predicted, avalanche-like market penetration process (with a similar penetration process on world-wide markets), contrary to original predictions, once public awareness of the advantages of small fax machines became sufficiently widespread. Comparing the actual adoption curve of small faxes with the actual adoption curve of color TV, we see that these curves are almost parallel, only shifted in time by about 17 years.

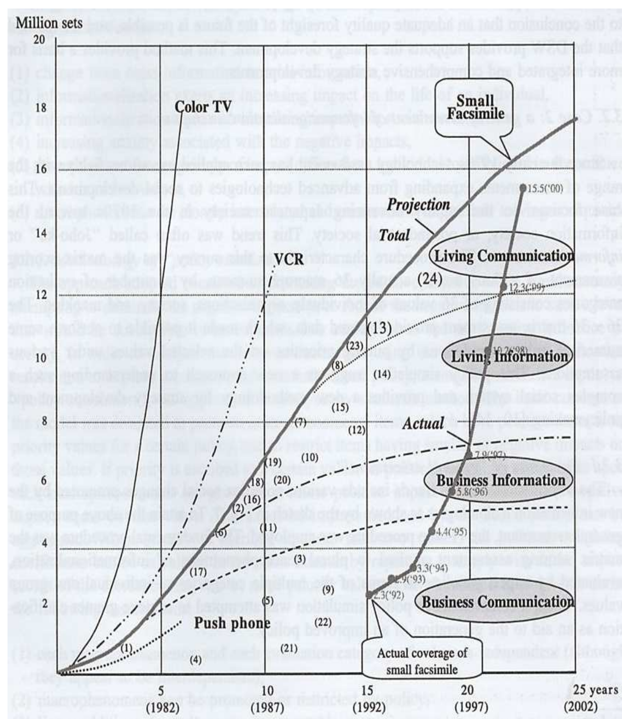

Fig. 1. Penetration curve of small facsimile machines in Japan: projection and actual process [4]

We see that the market penetration curves of emerging technologies exhibit delays; the delay of ten to twenty years exhibited in the case of small facsimile machines can be judged as typical for smaller innovations, while larger ones – such as the mobile cellular telephone or digital TV quoted earlier – have exhibited delays up to fifty years. Technology experts usually do not understand the reasons for these delays, because they are only in small part technological (time needed for technology development and improvement); the delays are caused primarily by psychological factors (readiness to use new methods), social factors (following the example of others) and economic factors (readiness to pay for new possibilities).

This conclusion is also supported by another example – of the development of the concept of *Ambient Intelligence* by the Information Society Technology Advisory Group (ISTAG) of European Community. While *intelligent ambient habitat* will surely become one of the defining features of future social applications of technology, the European Community wanted to include it as a relatively short-term (ten years) goal in its Framework Programs of research and development in Europe. One of the authors, who participated in the work of ISTAG and was very supportive of the general idea, had to warn ISTAG and European Community, however, that such short adoption time is unrealistic according to his expertise in another field – systems dynamics. On the other hand, when *intelligent ambient habitats* become widely socially used, patterns of social life will change tremendously.

Because of the phenomenon of delay times and because of the large unexhausted potential of digital and network technologies, we are sure that information and communication technologies will determine the *Complexity Change* of social life patterns for many decades yet to come, including the use of such technologies in distance education and in knowledge creation; see the concluding section of this chapter for the evaluation of relevant time-frames.

7. MAIN CONFLICTS OF THE COMING ERA

It would be utopian to expect that the new civilization era will develop without conflicts. Each change – and in particular *Complexity Change* – and each problem, each big project such as educational *Reform* touches necessarily diverse human interests and results in conflicts that must be resolved. The questions are: what will be the dominating conflict in the coming era? How should we prepare to resolve it?

The industrial civilization era had its basic great conflict. No matter what our ideological position, it must be objectively admitted that the big conflict of industrial civilization concerned the property of the fundamental productive resources of this era – the industrial assets. As soon as the industrial civilization era ended, the conflict became obsolete, which is what ended the importance of communist ideology.

> If knowledge becomes the fundamental productive resource, then the *big conflict of the coming era will concern the property of knowledge.*

This is not only an analogy, a theoretical conclusion: already today, we observe many signs that this conflict intensifies. Big high technology companies, having business fundamentally dependent on knowledge, have perceived its importance and naturally do everything not only to protect their own knowledge, but also to *privatize knowledge* generally. Other knowledge creators, in academia and in small firms, also fundamentally depend on knowledge; but their interests are in keeping open access to public knowledge and in preventing the pollution of the intellectual heritage of humanity that would soon result from excessive knowledge privatization.

This conflict might be alleviated if we could find solutions respecting interests of both sides. We must find them before the conflict intensifies beyond hope of resolution – because then it would lead to another revolution, this time on much larger, truly global scale, fought with new weapons of cyberspace, with unpredictable dangers and consequences.

An accompanying aspect of this conflict concerns *access to quality education.* As we noted already in the vision of *Reform* of educational systems, some elements of *privatization of education* are inevitable; but full privatization would only aggravate the fundamental conflict. In all civilization development, all societies found it advantageous to give public support for the education of a most gifted part (even if sometimes very small) of poor youth.

8. MAIN STAGES OF THE COMING ERA AND OUR ESSENTIAL OBLIGATIONS

Of what time perspective are we speaking here? The era of print and geographical discoveries described by Braudel [7] lasted 320 years, from 1440 to 1760. The era of industrial civilization lasted 220 years, from 1760 to 1980. What reasons do we have to make the simple extrapolation that the era of knowledge civilization will last (perhaps at least) 120 years, from 1980 to 2100?

We have good reasons for such a prediction. The shortening period of civilization eras can be explained by the shortening of the basic delay in the broad social implementation of important new ideas. We have already given several examples of such delay. It is also reasonable to assume that in the period 1440-1740 such a delay was much longer, amounting to several human generations, though the increasingly broad use of printed books slowly resulted in shortening such a delay. The speedup of communications in the industrial civilization age further shortened this delay time. However, as explained above, the main reasons for such delay are social customs and economic interests, and even now we observe delays of 20 to 50 years.

What is the relation of these delays to the period of a civilization era? We can apply here the knowledge of cyclic processes from telecommunication, for example: for a feedback process with accumulation and delay, the typical period of a cycle is four times the delay time. This is easily proven by using the *Nyquist criterion* of stability of dynamic feedback systems. According to this criterion, any system with negative feedback can generate cycles if the feedback coefficient is large enough, while the period of the cycle is such that the phase shift amounts to 180^0 or π in radian arc measure. For a system with accumulation and delay, the phase shift of accumulation is $\pi/2$, and the phase shift of delay is $2\pi T_0/T$ where T_0 is the delay time and T is the period of the cycle. These phase shifts are additive, hence we have $\pi/2 + 2\pi T_0/T = \pi$, or $T = 4T_0$.

Another way of demonstrating the same conclusion is via a simple example: imagine a market for educated specialists, say in management science, in which tertiary education demands $T_0 = 4$ years of study. If we consider the impact of a sudden increase in demand for educated specialists on this market, it is easy to show that the delay time in supply must produce a cycle with the period $T = 4T_0 = 16$ years. This also proves that markets for educated specialists, essential for knowledge economy, are fundamentally unstable: any small perturbation of demand creates cyclic behavior on these markets.

Clearly, the development of civilization eras is not cyclic, it is rather a spiral with strongly pronounced chaotic elements; but we can use this analogy for understanding the reasons for the shortening periods of civilization eras. If the period equals 4 delay times, then the delay time in the era of print and geographic discoveries was about 80 years, the delay time in the era of industrial civilization was about 55 years, and the delay time in the era of knowledge civilization might shorten to 30-40 years. All these estimations indicate that the knowledge civilization era might last 120-160 years counting from the year 1980:

> Knowledge civilization is a long duration phenomenon that most likely will last at least until the year 2100.

This indicates also that it is reasonable to speak about four major stages of a civilization era, but that it is very difficult to predict their character for the future. If we subdivide the history of industrial civilization into four stages, the character of them is clear: in 1760-1815 we observe the chaotic realization of the benefits of new technology; in 1815-1870 there is a systematic realization of these benefits while the other side of the basic social conflict is slowly organizing; in 1870-1925 we see high realization of the benefits, but also high confrontations in the basic social conflict; finally, in 1925-1980, there is an alleviation of the basic social conflict, but also signs of the end of the civilization era. Will this scenario repeat in the knowledge civilization era? Already the fact that we ask this question today is a good reason for a different course for the future, *the probability that any prognosis is precisely right is zero*. But this analogy helps us *to understand what might happen in the future*.

Another analogy is the delay between the formation of the *cultural platform of concepts essential for a new civilization era* and the formation of an *episteme of this civilization era,* i.e., the structure of concepts characterizing knowledge formation in this era according to Foucault [35]. As we noted earlier, the *cultural platform* precedes a civilization era, thus most concepts needed for the cultural platform of the knowledge civilization are already formed (though not all are equally broadly understood). Foucault dates the formation of the pre-industrial *episteme* at the beginnings of the 17th Century, the formation of modern (actually, industrial) *episteme* at the beginnings of the 19th Century; we see that an *episteme* is formed after the beginning of a civilization era. Thus:

> We can expect the formation of an *episteme* characteristic for knowledge civilization somewhere during next few decades.

Contributing to the formation of the new *episteme* is one of our obligations. However, our essential obligation is to try to understand the future, preserving an open and critical mind in the time of great *Complexity Change.* We will not be sufficiently prepared for the future if we adhere to old concepts and disciplinary paradigms, we must be ready to question them.

9. CONCLUSION

The most important conclusion is that the *Complexity Change* between the industrial and knowledge civilization era is so vast that it brings both great hopes and great dangers, generally – a great challenge. The world in the coming era will be quite different than the world now; but we can at least try to use the Change for solving most pressing problems facing humanity.

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