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Science and the Next 1000 years

Thoughts for The World's Progress

(Figures not attached here)

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When most people look to the future with a time horizon that closes on their next paycheck or the next election, a glance one thousand years forward appears audacious. Nostradamus' rhymed prophecies published in 1555 are one of many proofs of the danger of glancing without a device that extends one's vision.

In our activities as analysts of systems such as transport and energy, we have equipped ourselves with descriptive and predictive mathematical models of great efficacy. We have usually labored within a time horizon of about 50 years. Occasionally we have explored the dynamics of systems with a long life, such as the Catholic Church, which built gothic cathedrals with perfect regularity over three centuries [figure 1], and the British Navy, which built its ships of the line on a precise schedule that extended over four centuries [figure 2]. Although quite a few phenomena may extend over similarly long intervals, the trustworthy statistics covering many centuries and millennia that permit analysis are few.

Still, these cases and other analyses of periods of centuries show an unexpected stability in the evolutionary dynamic of large systems. One or two simple equations can describe them completely, a little as if they were the parabolas of projectiles. In other words, the daily headlines and the great unforeseen events -- wars, famines, and plagues -- appear in the long term irrelevant, that is, their effects become rapidly absorbed. An impressive example is the evolution of the Soviet energy system, whose development in the 1950s and 1960s extrapolates exactly from its behavior between 1890 and 1910. The horrendous fluctuations during the Russian Revolution and World War II had no long-term effect on the roles of wood, coal, and oil in the Russian energy system [figure 3]. Most great historical "turns" appear to be inventions of the historians to divide the chapters of their books.

Our experience in the analysis of quantities leads instead to a vision of history close to that of the Chinese. Everything that happens or will happen is born in seeds planted in the remote past, and these seeds develop themselves in macroscopic events following the constant laws of a social DNA. The DNA may express itself as Gothic cathedrals, British war ships, or lumps of Russian coal. In this situation, zooming into a short period the historian loses the cause-and-effect relations and is forced to devise a rationalization in the formless magma of events.

The first question to ask is what we would have done 1000 years ago, obviously with the techniques possessed today, but without knowing what happened. In the last 1000 years, above all in Europe, among the myriad of happenings science and technology have a front rank. Both were born in the meditative freshness of Catholic monasteries.

Technology emerged with the Benedictines, who were already underway in the 9th century. Even with much uncertainty, at the Millennium we would have predicted a spectacular future for technology. By 1268 Roger Bacon, Franciscan, wrote about science and technology in his *Opus Majus* in ways perfectly readable today. He foresaw all, including spectacles for the far-sighted.

Modern science was born in the Franciscan monasteries. As St. Francis' orders became established two centuries after the Millennium, we would have been hard-pressed to predict science's coming. A change of theological perspective stands behind both technology and science. Bacon expressed well the impetus, saying that to join God one can read the Book of Scriptures or the Book of Nature, putting equal the Bible and Physics (*physis* being the Greek "Nature"). But the theological signals before 1000 seem imperceptible. Unless we were much more perceptive than today, we would have had lost the beacon. But today science and technology run at full steam, and their momentum eases much in foreseeing the next thousand years.

We need also to maintain that humanity is slow. A primary energy source, such as coal or natural gas, has a lifecycle in the sense of how long it occupies a sizable market niche lasting about 350 years. Even the railroad has a product cycle of about 250 years. The railroads entered the market in the United States in the 1820s and reached their maximum role in the 1920s. To change custom from using butter in the United States to using margarine took over 50 years. Science and technology have unfolded for one thousand

years. Thus we feel confident to anticipate their development for thousands more.

Curiosity for the next 1000 years prima facie centers in the human system. The first parameter, and important, is how many humans will be around. Despite our egocentric insolence, people end by following basic Darwinian lines. As a species, humanity is thus predictable. We will end by filling our ecological niche. But population analysts and forecasters need continually to define this niche, and the fact that new technologies always are changing it renders the definition hard.

Look, for example, at the eight thousand years of the development of agriculture. History shows that all the technological forces concentrate on intensification, that is, augmenting production per unit of surface. We have passed from some hundreds of hectares per person for hunter-gatherers to 100 square meters per person in the shrewdest Chinese or Iowa agriculture. One sees already Darwin at work. The progress was not used to reduce the effort but to augment production, that is, the niche, that is, the population.

The niche and humanity have thus grown, from the million or so humans 10 thousand years ago to the six billion today. Technologies already existing to produce foods with microbiological intermediaries that can grow on a hydrogen substrate (for energy) and carbon dioxide (for their material) can in principle allow us to let go of farming and produce the bulk of foods with a method close to the brewing of beer.

These technologies have already been developed in the last 40 years anticipating long voyages in space, so that astronauts need not drag with them a cupboard of tins. We know the qualities and quantities. The foods are good and the needed volume of the fermenters per person is some tens of liters. A spherical fermenter of one hundred meters diameter could produce the primary food for the 30 million inhabitants of Mexico City. The intensification of this type can be carried far forward with existing techniques, beating by many lengths even the clever Chinese and Iowa farmers.

Primary foods can be seen as proteins, carbohydrates, and fats produced by fermenting microorganisms. They must be formatted before arriving at the consumer. Gourmets who grimace should observe that our most sophisticated foods, breads, wines, and cheeses, are the product of sophisticated elaboration on the part of microorganisms.

Darwin taught that no species has ever restrained itself from filling its niche. Thus, our first forecast is that humanity will grow from its present 6 billion to almost 1000 billion in a period of time that can be estimated at 500 years. The rate is about 1% per year, compared to about 1.3% worldwide in the 1990s. Even at 0.5% per year, the 1000 billion will live in 1000 years.

Given that the tendency to live in cities is accelerating and that farming will largely disappear, problems for lodging these people, settled in an urban network, need not be great. We also need not despair for nature. With a density of population equivalent to the Principality of Monaco, which we hold highly appetizing in view of the land prices there, only ten percent of

the terrestrial surface would be occupied by inhabited structures. The rest of the land could return to Eden, with lions, whales, and tse-tse files. Humans might limit themselves to enjoying the spectacle through millions of TV cameras spread here and there, as they already large do, spending far more hours watching nature shows on TV than hiking in the mountains.

The society would operate with complete recycling. The only thing truly consumed is the primary energy, that is, free energy. This energy can be captured from the sun or, much more probably, from nuclear processes of fission and fusion. Hydrogen and electricity will carry the energy to consumers. Already today the energy system moves toward methane and electricity, and the pipeline and wire will be with us for 1000 years more. The work for this transition is enormous and, if at the beginning some are scared for the 1000 years ahead, they should begin now to perceive what stands in the way.

Beginning in the next 50 years, humanity will spread itself in solar space. It should be routine by 2150. But the external niche, away from the home planet, will always remain difficult, even if a few billion people in orbit is conceivable. Great self-sufficient cities can be built on Earth and then shipped to wander wherever, like space mega stations. These structures and their machines are almost realizable today. To ship them into space is a further action, but many lines of attack exist. The modern version of the project of Jules Verne looks good.

The question naturally about all these people is “What will they do?” On Earth and in Heaven. Based on what has happened in the last hundred

thousand years, they will spend the bulk of their time gossiping. Analysis of time budgets and the huge success of cellfones with teenagers shows clearly the tendencies.

Pithecanthropus courtesans invented language to recount better to the chief the doings of the group, and the situation has not much changed in a million years. Naturally, on this basic stratum many complex structures grow that give character to our society. Because production will be successively automated, the principal occupation will be that characteristic of social animals, stabilization of the hierarchy. Darwin does not release his grip easily.

Naturally a little energy of the system will escape from the basic scheme to produce the conceptual superstructure that we call culture. A modeling study of the saints of the Catholic Church (Figure 4) and the Western science and technology that are its legitimate children shows that the devotion to scientific research will constitute the religious nucleus of the next 500 years. The Catholic Church can close shop, as can the prophets of the end of science, who have predicted its exhaustion, in vain, for more than a century.

Science is the search for models of things that permit prediction, and it is easy to see generically where science goes: to be able to predict everything or almost. Because the external world is born as observations, much will depend on the refinement of the systems of measurement that already in the last 50 years have made sensational progress. Physicists already skillfully kick and dribble single particles and glance into the interior of objects billions of light years distant.

While science is knowledge that is pursued under the spur of a basic instinct, curiosity, and is socially neutral, the technology that uses science to sharpen its machines certainly is not. Its most apparent use is the augmentation of the economic and social potency of a human group, let's say a nation, to be able to acquire a rank in the world hierarchy of nations. Great wars are always fought among the prime members of the central nucleus of nations, to redefine who is number one in the pecking order. But this game is at the end, because, as we will see, the speed of transport today permits, technically, a global empire. It will presumably be realized in a couple of centuries. Politics is slow. Even the unification of Germany took more than 50 years from the first customs union, the Zollverein in 1818. Wars will finally end on Earth inside the global empire. We see no trace now of provocateurs elsewhere in our solar system who can launch star wars. However, there can be revolutions, and flights into space to escape taxes.

The capacity to foresee permits doing many things virtually, that is, without doing the actual experiment. Thus, the designer-stylist of an auto can construct the model on the computer, with invisible programs that make all the calculations about air resistance and optimize the forms for each construction. The metallurgist will have the properties of her alloys simply defining the composition; or better, she will have the composition defining the properties proposed.

These capacities grow progressively with knowledge; a turning point date does not exist. The two operations described will already be available for daily use in 2020. The actual trend of spending ever more in software will

not diminish for another 100 years at least. The contributions of scientific and technical knowledge will carry forward, we may say, from the test tracks to the simulations. Simulation will become project, experiment, and test. This movement to science and engineering from *in vivo* and *in vitro* to *in silico* clearly exists already, but the expansion and penetration in ever more varied fields will be remarkable.

In the next hundred years the branch of science that will carry into technology with maximum social impact is biology. Thirty years ago, humans began the assault on the inner sanctum of living beings, the DNA, and now begin the first clumsy manipulations. They evoke a bit the silly little airplanes at the start of the 20th century, but the planes flew. In substance one can project a living being on computer, as one does today with an auto, even or especially if for several decades we are limited in modifying living organisms.

The formula of a living being can in effect be seen as a long number (let's say several millions of numbers) and is thus relatively simple. The problem is that the conditions around are ferocious and few are the numbers that work, a little like the combinations of a safe.

Animals can symbolize the change in control DNA offers, for example, the winged horse or hippogriff to go quickly to the office avoiding traffic jams, and "beefsnakes", which produce only T-bone steaks eliminating the sad necessity of the hamburger. Harry Potter's books have again evoked the hippogriff, but the difficulty is that it requires a complete change in the pectoral musculature and metabolic potential, even restoring the wings of the

pterosaurs. The beefsnake, in contrast, is relatively simple and might only require manipulations in the homeobox, the DNA string that influences morphology.

The solution, however, that will have greatest social impact is that of blocking aging, acting precisely on the DNA. Aging in effect need not come with use as many physicians and journalists say. The maintenance of every part of the organism is continuous, timely and capillary, so aging owes instead to a programmed reduction of this maintenance tied to the general strategy of the DNA. Many animals, for example the sturgeon, do not age. The sturgeon dies, naturally, for varied causes, but not age. Sturgeons become with time ever larger, more vigorous, more fertile, and more cunning. They are fished at 200 years of age.

For many years, people have been talking about the problem of free radicals and therefore oxidation. Nearly all chemistry in our body was invented by bacteria before plants polluted the planetary atmosphere with oxygen, and so it has remained. Oxygen came to be mediated by transport in containers (red blood cells and hemoglobin in particular) and by bacteria enslaved that can manipulate it, the mitochondria. The system cannot avoid some losses that, however, have destructive effects.

Two enzymes, peroxyreductase and dismutase, temper the negative effects, but their production is progressively reduced with time, and the destruction or aging then becomes rampant. One can act on the DNA to spur it to produce more, and this prime solution will arrive in decade or so. Eternal

youth we put in 50 or so years, 2050. Another 100 will be needed for its practical diffusion.

The social impact of stopping the gray will be great. Mischievously, it might bring the solution to the problem of pensions and social security. Vigorous 30 year olds can work for hundreds of years, as long as their vigor does not carry them into a fatal incident. Those who turn their noses should understand that genetic manipulation has been practiced ever since humans domesticated plants and animals. A wink of the eye to get a reproductive partner can be classified as genetic manipulation. Now developments have become explicit and fast, and thus pose ethical problems, or ones presumed to be such. We personally would propose without a millisecond of hesitation to have youth, even if it meant working for 800 years. But our work pleases us.

The possibility of avoiding aging and even to rejuvenate partially, eliminating the accumulated wrinkles, is perhaps the only solution to avoid the disappearance of imploding populations, such as the Japanese and European. All Christian European women from the Atlantic to the Urals make on average one child, half what is needed for the survival of a society. The European demographic implosion and the demographic explosion of the fertile crescent of Islam from Morocco to Pakistan will carry obvious consequences. According to our estimates, partially modeled, this Islamicization will be complete in 2050 and the Europeans practically extinct in one hundred years. The threatened indigenous peoples such as the Yanomami of the Amazon may last longer.

Alongside biology, also physics will make beautiful headlines. As already mentioned, the great players in physics are capable of trafficking with one solo atom that interacts with one solo photon inside a box at temperature almost indistinguishable from absolute zero. These experiments permit verification of forecasts of quantum theory that Einstein himself defined as spooky, the stuff of ghosts.

Vanguard technologies, especially those which manipulate information, are all there for us to watch from the best orchestra seat. The strangenesses that violate intuition can become machines that violate concurrence. An old dream is a synthetic computer, not the actual (or parallel) that breaks a problem in many parcels, shuffles them, and then reassembles in a sequential mode (like a television more or less), but one that acts all in one gulp, like a photographic lens that turns a bundle of light rays into a distinct image on a film. As the makers of lenses know well, simulating the process requires a great mass of analytic calculus.

With the properties of light of quantum physics that now begin to be managed, these synthetic computers appear possible, revolutionizing the field of the manipulation of information, and promising, if the devil does not show his tail, miniscule elaborators, superfast and supercheap. This means we can infiltrate them in the objects that surround us, realizing the ancient dream of The Thousand and One Nights, that of the animation of our orders, expressed in the phrase "Open Sesame." On the market in 2100 and in explosion between 2100 and 2200, we will call these machines quantum-based or simply Quantrons.

Clearly everyone will be linked to all and to each with small machines of little material, in a style that recalls clairvoyance. Already today voice can operate machines, and in 50 years thoughts will do so. In effect, the machines will carry in audio the electric signals of the brain.

These crackles are so-called "spike trains" that, we think, serve to carry around our orders in numerical form. In the first place they open the circuits that represent our memories, but they also give orders, here and there, to release a hormone, to contract a muscle, or to transcribe a piece of DNA. The spike train technique, once dominated, could be used to control machines. The machines would then become integral parts of our selves. One could also use the spike trains to enter bodies for various purposes, for example, as physicians. We wonder what numerical code opens the transcription of the anti-oxidant enzymes mentioned earlier. We will see in 2030.

Medicine, absorbing rapidly the results of biology and engineering, lives in a fiery epoch for innovations. Assembling and disassembling face few more hindrances. Given that every cell contains the complete plans for an individual and we can put them in action, we can make another identical individual, a clone. And with cells half-formed, the stem cells, we can make clones of organs, directly inside the patient.

One of the prostheses could be a hearing aid with a supercomputer incorporated that would translate any language (there are perhaps 5000) to the one preferred by the listener. We call the devices Pentecosts. They will certainly come by 2100, in less sophisticated versions. Importantly, no

problem of language will exist when the global empire takes root. Clearly in the final version a Pentecost reads the words in the thoughts of its owner and transmits them to the other Pentecost, so that no one need speak, say in 2300.

All these technologies mirror the state of the science, external to medicine. Until 50 years ago, our knowledge of the functioning of organisms was chemical, and so the physician tied himself to chemical interference, the medicine of the pharmacy. At present, in the last 20 years above all, genetics exploded, and so we see every sort of manipulation executed or conceived to heal with genetic traffic. Next Bill Gates will eat everything with software to cure cancer or diabetes. A Personal Computer for every bedside.

For all animals that must procure food with the sweat of the brow, *movement* is essential because it is the premise for the territory to be exploited. Already bacteria, so small, have electric motors, rotating nanoscopically. They turn whips, the flagellae, with remarkable possibilities for locomotion in speed and maneuverability, in the ambit of bacterial dimensions.

The larger animals are equipped with muscles and then a nervous system to manage them in real time and with cognition of final cause. The nervous system has lead to the brain, and to the human brain, which with the aid of its ectoplasm, language, can work to conserve with other brains external memories, for example, books, and finally to construct *corporal* ectoplasms, the machines.

With the existence of the territorial instinct since three billion years, the invention of machines to travel was inevitable. Travel machines have become the bearing column for the evolution of our society, above all in the last two centuries.

The instinct of the cave dweller that the external world is dangerous allows humans to travel on average only sixty minutes per day, the hour of air. On foot this permits a territory of barely 20 square km, translating into the tessellation of the territory of villages on old maps and the maximum dimensions of the city until 1800. But machines mean speed and thus territory, and so humans have avidly thrown themselves into them. Because our economy and inventiveness travel in tune with a period of about fifty years, in every such cycle a new miracle arrives in the market, train, auto, plane, to cite the most important. Air will dominate the near future, with supersonics and hypersonics that will permit the Chief Executive cave dwellers of Tokyo to come to New York, do their business, and return home in the evening. And thereby form the Global Empire.

But the new cycle is hardly begun (1995), and we are awaiting the new miracle, which will be the Maglev, a container without wings, without motors, without combustibles aboard, suspended and propelled by magnetic fields generated in a sort of guard rail. If one puts the Maglev in a pneumatic vacuum tube, as the Swiss think of doing with the Swissmetro that would link their cities in 10 minutes, then we would have the equivalent of a plane that flies at high altitude (e.g., 50,000 meters) with few limitations on speed.

By 2050 one of these trains might link Casablanca and Paris (which in 2050 will already be largely a city of the Mahgreb) with the peculiarity of traveling half of the journey accelerating at .5 G, like a Porsche at start up, and on the other half braking in the same way. The journey Casablanca-Paris then takes 20 minutes. Technology already holds this in store for us. Naturally it wants 100 years to diffuse, like the train or auto. Commercial aviation has had only 50, and for this reason it still expands and will continue until 2050.

Because the dimension of a city depends on the velocity of the means at hand (the largest diameter equals velocity), the Maglev can stimulate the formation of much larger cities. Mexico City, stimulated by the auto (which there averages 35 km/hr and thus gives 1000 square kilometers of territory) can reach 50 million inhabitants by 2030. With a metro-Maglev that permits mean speed of 150 km/h, more or less what the Swiss consider, one could stimulate or form a city of a billion inhabitants, by 2200. It pleases people to live in cities, especially in those that have grown naturally without suffering the sadism of architects and urban planners.

The Maglev has an absolute flexibility that derives also from the fact of being a passive object managed by magnetic fields produced by currents which computers distribute here and there in the windings inside the famous guard rail. The organization and management is a network and all in the software. Bill Gates strikes again.

Extreme exploits are possible. With a launch tunnel of several hundred kilometers and accelerations for fragile oldsters (the usual half G), one can

arrive at orbital velocity and thus launch trains into space with tremendous advantage in organization and energetic efficiency, say one hundred times that of today's rockets. We put this technology in 2075 even if experimental launches might be possible in 2030. With a train of 1,000 tons every minute, as seems doable, one could think of sending the material to assemble a space city in a few months with admirable efficiency. We guess a billion people will be traveling through the universe in 2500. They will be absolutely and indefinitely autonomous, with techniques already existing in the laboratory.

There is much evolutionary potential in the Maglev per se. For example, the development of superconducting materials near room temperature can lead to a system of transport that does not consume energy. Because the propulsion and the braking are electrodynamic, the Maglev lends itself to a complete recovery of energy. If one does not lose energy in the electric circuits, one can progressively approach total energy recovery, that is zero energy cost. It will happen in 2150.

With superconducting strips in the ground and vehicles with a superconducting strip, one can realize levitation at zero energy cost that recalls antigravity. All that remains is the resistance of the air. Vehicles moved by human energy like the bicycle but with characteristics close to an auto can then serve for daily movement.

The Maglev being totipotent, will there be after it another system of transport, or will it be the last in the series invented beginning in 1800? Recent experiments of the quantum players seem to prove that a photon can be made to disappear in one place and reappear in another, quantum

teleportation. The physicists say they hope to do the same with an atom. Then a bacterium, after some years. When the mouse arrives, we should perk up our ears.

Speaking of energy, the media have filled our ears for more than twenty years that resources are used up or soon to be. A solution is nuclear mega reactors that produce heat to use for the decomposition of water into hydrogen and oxygen. The hydrogen then distributes the energy, as methane now does, with pipelines, almost the same. The machines being rather large, they fit well on the sea or on atolls, for access to sources of water for cooling. Sweetly, the uranium contained in the cooling water is ten times that fissioned in the reactors. We extract it and thus we make perpetual motion or almost.

The Japanese have been fascinated with this idea and work on the three problems that lead to the solution, high temperature reactors, the thermochemical processes to make the hydrogen, and the extraction of the uranium from the sea water. They have resolved all three and within a few years the prototypes will function. These energy islands are conceived rightly in large dimensions, each one producing in the form of liquid hydrogen to carry away by cryotankers the energy equivalent of the entire Middle East. One island, one Middle East.

Because the sea contains five billion tons of dissolved uranium and the water recirculates comfortably within 1000-2000 years, the next millennium looks energetically secure, in fact, the next 10,000 years. Then one will see. In

the interim it is fascinating that in 2100 Japan may furnish energy to the whole world.

On the demand side, in the next 300 years all the applications that use energy will use it more efficiently, as has happened for the last 300 years. Despite appearances, today the inefficiency is frightful. In terms of the second principle of thermodynamics, which gives the true metric of efficiency, we are around 5%. This means that equivalent end uses could theoretically consume 20 times less primary energy. Here the greens are right, even if the great waste comes not from the diabolical auto but from the system of home heating. The system however learns with extremely slowness and evidently does not want to change speed.

Still on the theme of energy, nuclear means can burn everything, except the iron which, having the minimum energy in the system of chemical elements, functions as ashes (Figure 5). The elements heavier than iron can be split and those lighter clotted until they make iron. All these operations produce energy. It will be done in 2200. At this time, with much exertion, we search to clot hydrogen in complex electromagnetic machines for “fusion.”

How will the society be in 500 years? As already said, the number will be spectacular, and the solar system its natural territory. In light of the absolute independence of the space cities described, some will point straight into the nothingness. Maybe in 10,000 years they will find something interesting.

One of the key problems to see into how the society will be organized is to understand how it will reproduce. The development of genetics will lead

inevitably to human clones; the temptation of Narcissus will prove irresistible. History also ends for the uterus; already machines, for now experimental, make the fetus grow, but time aids technology.

The urge toward living life as a single person will be very strong, even if sex can remain a pastime together with teleconversation. In fact there will be much time to be allocated in a society in which almost everything is produced automatically. In any case, the supermegacities will in the end simply be hierarchies of villages. Even with global and universal mobility, any person in fact lives in a village and knows everyone.

How to administer a thousand billion persons escapes our imagination. Above all one wants to leave the basic liberties to the individual. Informatics that penetrate everywhere is a double edged sword, like most of the rest of technology. For scenarios, read the novels of Isaac Asimov. Anyway, we hope we have demonstrated with Beefsnakes, Quantrons, Pentecosts, and the PC Pharmacy that much inevitably lies ahead.