INDUSTRIAL ECONOMICS OF NANOTECHNOLOGY

HYPERCHOICE AND MILESTONES OF THE MANUFACTURING WORLD AT THE NANOSCALE :

Contribution to the France-St anford Foundation workshop on nanotechnology and ethics

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INTRODUCTION

Nanosciences and nanotechnologies hold promise for competitiveness and social benefit, supported by large-scale public initiatives. How is the map of the world's nanotechnology industry being drawn today? Are current decisions setting the stage for a nanometric divide? Is there room for a responsible innovation in the field of nanomanufacturing? Does the nanopatenting model inherited from the 20th century remain appropriate to address the systemic nature of the nano-enabled industries?…

The development of nanotechnology expertise over the next eighty years will be one of the keys to the international specialization and competitiveness of the world's major regions for the next half-century[1]. The pace of development of nanotechnologies and their gradual incorporation into market as well as non-market goods and services therefore constitute a crucial challenge.

No doubt unfairly, the shaping of public opinion by the global media industry – especially the Anglo-American science fiction industry – has veiled the reality of choices for which the world's dominant economies have assumed responsibility, and which translate to specific and richly endowed public support policies.

The economic and social issues that surround nanoscale scientific developments will continue to be a focus of the debate over support policies, as is already manifest in the proliferation of websites that "recycle" opposition to genetically-modified organisms and similar issues into protest over the presumably harmful applications of nanotechnology.

One possible answer lies in the hope that nanotechnologies – due to their potential to save energy, material and time – will be discovered to offer clean, resource-efficient solutions to permit sustainable industrial development. Research, development, test and evaluation will constitute prerequisites, in order to fulfilling major gaps in the fundamental knowledge of matter, in imagining and designing fundamentally knew, pervasive applications, and in strengthening and standardizing emerging industrial prototyping and trade.

The greatest challenges of the XXIst century wait for appropriate solutions, several of them could emerge from CTTs. For instance, food and agricultural engineered production for 10 billion people; health improvement through body and mind (re-)building, targeted cancer therapy, enhancement for active and autonomous ageing, and for other purposes related to security and the military; cheap and spreading sources of energy for all, water treatment and management are examples of "the bright side of competition", which allows accountability for public investment in fundamental and applied pre-competitive research.

Because of the high revenues expected from intellectual property protection and licensing, designing the building blocks of the matter and incorporating them in new materials and living organisms is at the heart of the nano economic race. We think that, provided they actually expand on those borders, CTTs have the potential to be an important part of the solutions to major global threats and diseases. Nonetheless, because they are highly enabling and highly disruptive, they also are supposedly at the origin of some of them; for instance by allowing dissemination of artefacts in the nature and living bodies. Bionic weaponry, by nature, disseminate with the mobility of living bodies, which can, or cannot, be under control. There is no possibility of sealed storage as in the field of classic, mechanical armaments, so dispersion is inevitable.

More precisely, the design and synthesis of materials at the atomic level for desired properties and functions, appears to be the leading force of nanoscale science, engineering, and technology developments. In the future, design and synthesis of new materials at the atomic level will be accomplished using only the electronic structure of the elements. According to the Department of Energy, "the properties of new materials will not only be a function of their composition but also of the conditions under which they were synthesized. New synthesis conditions might include non equilibrium, high pressure, high magnetic field, and high energy density. Also, massively parallel fabrication/characterization combinatorial approaches will be employed. The new field of functional materials would include the design of molecular building blocks, the design of multicomponent structures, and the design of molecular machines."[2]

Nanotechnology-enabled and converging transformational technologies (CTTs) bring with them an entirely new, unthought world with huge potential advantages for the people, as well as an hyperchoice's era. The conditions of a fair competition amongst stakeholders – private as well as public ones- leading to better, sustainable and appropriate technical solutions at more affordable price, may not be spontaneously provided. Nanotechnologies exports control, industrial secrecy and intellectual property rights models, inherited from the industrial revolution, need to be challenged and renewed to suit a knowledge-based society, as well as the ways and means by which democracies sort out the useful or acceptable finalities of nano-enhanced progress from harming finalities requiring repressive measures.

We found the opportunity to introduce the CTTs concept in the special interest group report dedicated to economic effects of the High level Experts Group "Foresighting the New Technology Wave". This group decided to propose a more synthetic concept for NBIC, the one of *transformational* , recognizing that those technologies, because of their pervasive effects and powerful leverage capabilities on almost all daily activities, are key drivers of productivity and growth.

We agreed that the most important shift in models for the future would be brought, not only by converging technologies, but also by convergent technologies that, taken individually, have the power to transform, in depth, their global environment. This is the case for information technologies, for nano-, bio- and cognitive neurotechnologies. Transformational, yes, each of those technologies is. They represent key drivers for productivity and growth, because of their pervasive effects and powerful leverage capabilities on almost all activities, as well as for pervasive adoption of virtual reality tools, perceptions, and nano-enabled, mind-controlled remote action.

Subsequently, when transformational technologies enter a trading zone between at least two of them, this is not only the intensity, but also the very nature of effects on environment, economics and human organisations, who change. Here, uncertainty can no longer be addressed by the classic linear approach of causality, which implies tremendous difficulties in identifying and, if appropriate, sharing the eventual liabilities, in case of disaster, injury or pain.

CTT's competition is now open, beginning with nano-metrology, laboratories and fabrication lines equipment, new materials engineered at the nano-scale, taken as enabling technologies for innovation and competitiveness.

This essay will address successively the unlimited supply side expectations, the very nature of limits to the demand side's expansion, the forces in motion to go beyond this dilemma and the conditions to perform this transition.

I. MANUFACTURING AT THE NANOSCALE: CONDITIONS FOR AN ECONOMIC SUCCESS ON THE SUPPLY SIDE.

This field which is only now being defined, does not form a distinct sector or branch in the industrial input-output matrix. It is not exempt from the need to meet the three criteria of rational anticipation, public good and confidence, that influence public funding decisions. The considerable funding for nanoscience and nanotechnology and its steady rise since 2001 up to 10 billion dollars on a worldwide basis in 2006– while not yet constituting a *speculative bubble* – does indicate a significant indicator of the impact of their diverse applications over a period of fifteen years or more, whether or not they become driving sectors of the economy.

The nanotechnology worldwide market has been estimated by the US National Science Foundation (NSF) at 1000 billion dollars in 2015, against 54 billion dollars in 2001. It could represent 15% of the industrial production including nanostructured synthetic materials. The market size would be around 220 billion dollars in 2010[3], 61% of which in the production of nanoparticles and nanostructured materials. The Chinese market, estimated at 5,4 billion dollars in 2005, should be of 31,4 billion dollars in 2010 and reach 144,9 billions in 2015[4], representing 2/3 of the worldwide market. The number of firms from global groups to local starts-up already is impressive.[5]

After discussing the main nanotechnology-related markets, I will present an overview of the main public initiatives launched in support of nanoscience developments and their initial applications, in the dual context of apparently plentiful public funding coupled with interest on the part of private venture capitalists, in search of new opportunities after the worldwide stock market correction which affected the information technology sector in 2001.

1.1 The economic basis of nano-related industrial policies

Public support for research and civilian development of nanotechnologies amounts to about $3 billion dollars per year worldwide. This does not include R&D investments in micro-electromechanical systems (MEMS), even though the recent industrial applications of MEMS already use nanoscale synthetic components. When considered along with private funding, the worldwide effort is estimated at more than 4 billion for 2005, of which $1.3 billion[6] estimated for FY 2006 in the United States[7] (1.250 in 2005).

On the surface, it appears that Europe, Asia and North America each put up a third of this funding in 2005. However, a closer analysis of military budgets shows a picture quite different from this even balance, tipping it in favor of the United States in the short run, and in favor of East Asia in the medium run. At the stage of basic research, there is no distinction between civilian, defense and national security applications; at the nanoscale, the research is not finalized with the potential for use in either realm.

At the present stage, the future industrial and commercial market that will be spawned by nanotechnology R&D is remains indeterminate. It will lie at the intersection of imagination and expertise; of chance and necessity. The NSF evaluated the market at one trillion dollars per year by 2015, shared between information technology (57%), materials science (32% – $340 billion per year) and life sciences (17%).[8] The American group NanoBusiness Alliance evaluated the market at $45.5 billion in 2002, and is projecting $700 billion per year from 2008. This estimation looks like a pessimistic scenario in 2006, compared to an optimistic scenario provided by the European commission indicating 2.5 billion dollars at least in 2015.[9] Beyond those scenarios and according to Lux Research in 2006[10], the nanotechnology industry is expected to grow to 2.6 billion dollars in manufactured goods by 2014.

R&D public spending in nanosciences and nanotechnologies worldwide were estimated in 2004, without military spending, at 3.850 billion euros, including 224M€ for France[11]. The 6th framework program (FP) of the European commission provided 1 429 M€ and the 7th FP is to finance up to 3 467 M€ in cooperative research for the period 2007 to 2013. Those figures do not include budget related to infrastructures, ideas, people and international cooperation, which have not yet been spread between the main priorities. Global public and private spending in nanosciences and nanotechnologies in 2005 have been estimated at 9.6 billion dollars, including 850 millions in Europe and 1.7 billion dollars in Asia[12]. US federal spending on nanosciences and nanotechnology for fiscal year 2006 is expected to be of 1.2 billion dollars (not including the military).

Nanotechnology oriented *venture capital* increased to 497 millions dollars in 2005, representing 2 billion dollars in cumulative data). It supported 143 starts-up over the 1500 firms active in the field of nanotechnologies.

Although the areas about to be discussed can certainly be considered separately, their convergence at the nanoscale opens up unsuspected prospects, the beneficial repercussions of which must, however, be considered in light of the disruptions that nanotechnology industries could create due to cumulative effects over an extended period of time (a hundred years or more); or conversely, disruptions that nanotechnologies could limit or even eliminate.

Because these fields produce mainly intermediate goods, they lie upstream of markets for final goods and services which may – or may not – offer benefits to society[13]. Observers agree that *the rate at* which these markets mature will vary greatly from segment to segment, as a result of anticipated contrasts in supply and demand trends.

1.2 The trend in *nanomanufacturing* can be roughly segmented in four generations:

- The first one delivers passive nanostructures designed from atoms assembling and techniques of fragmentation, patterning, lithography, and supplied since 2000.
- The second one is related to the production of active nanostructures involving directed self assembling, templating, the design of new synthetic molecules and requires the control of corresponding technologies of interfaces, field and boundaries control, positioning assembly. The market related to active nanostructures opened in 2005.
- At the third generation, the market to be created in the medium run (2010) relies on systems of nanosystems manufacturing. The techniques necessary to perform such devices are mainly system engineering, device architecture and integration.
- Beyond this stage, the forth generation present in the conventional roadmap is the use of molecular nanosystems and synthetic biology, supported by nanosystems biology and hierarchical integration of emerging systems, to enhance and design devices and related services. Here simulation, computer sciences and artificial intelligence will be of tremendous importance, and constitute a powerful engine for prototyping, test, evaluation and manufacturing activities.

The nanotechnology glossary[14] defines molecular manufacturing as "the automated building of products from the bottom up, molecule by molecule, with atomic precision. This will make products that are extremely lightweight, flexible, durable, and potentially very 'smart'". In its advocacy in favor of the new economics of *abundance*[15], Steve Burgess describes the coupling of molecular manufacturing with appropriate programming tools as a revolution; he goes far beyond the conventional horizon with a suggested vision of 'personal manufacturing' (PN); - a vision in opposition with the huge capitalistic barriers to entry on the nano-empowered markets.

_***The information and communication industries*** *are undergoing two trends,* with application lead times ranging from a few months for the ongoing process of semi-conductor miniaturization, to a few dozen years for the *bottom-up* approach (quantum computing, addressing and communication between infinitely small objects).

A number of industrial giants are already predicting that nanoscale fabrication will become the key to their survival in the global arena, bearing in mind that the market for nanoscale electronics is forecast to reach $300 billion dollars per year by 2010-2015 (to be compared with a 400 billion dollar per year market for mobile telephones).

On April 21, 2003, the Sony group announced that it would invest 1.5 billion euros to build a semiconductor fabrication line for use in developing the 65-nanometer process technology on 300-millimeter wafers. The chips were destined for the group's future worldwide broadband network for video games and entertainment.

Since, **the capitalistic barrier to entry in the nanofabrication** world rose dramatically. Following the tension on the demand side for acquisition on nanostructured flash memories to be included in electronic devices, the major firms of this sector announced in 2006 plans for investing 15 billion dollars : Korean group Samsung electronics, holding 50% of the worldwide market, will invest 11 billions in three industrial facilities, and Toshiba announced 4 billion dollars in the same field, expected to be operated in Texas to produce Nand memories. Nand flash memories manufacturing has been partially prepaid by Apple for its iPod range of products, to Intel and Micron who intended to pledge 5.2 billion $ in a the production of there related memory devices, from 2005 to 2008. The size of this market segment represents one-third of the worldwide dynamic random access memory (DRAM) market.

Concentration is already high but, in the interest of innovation and consumers as well as security of supply, it should not lead to private monopoly in the supply side. Economic viability should be accessible to a variety of suppliers appropriately spread between the major economic regions, which leads us to the conditions required, one of which being innovation protection.

In its 2003 first-half financial disclosure to France's securities regulator (Autorité des Marchés Financiers - AMF), STMicroelectronics stated clearly to shareholders that its business would depend on its ability to protect its technology by patent. The company has teamed up with Motorola Inc. and Philips Semiconductors International BV in an R&D partnership to develop an advanced CMOS process technology to manufacture 90- to 32-nanometer chips on 300-millimeter silicon wafers. The project, based in Crolles (France), represented a first joint investment estimated at $1.5 billion. One step under consideration is the development of 0.13-micron technology on 8-inch wafers in the STMicroelectronics plant in Rousset (near Marseilles).

Moreover, it is noteworthy that Finmeccanica, one of the two founding shareholders of STMicroelectronics, announced on May 23, 2003 that it had signed a strategic agreement with the Carlyle group in the field of European defense aeronautics. Under the agreement, Carlyle acquires 70% of Fiat Avio, a subsidiary of the Italian group that supplies some of the engines and powder boosters for the Ariane rocket. Carlyle Group, an unlisted company, also has investments in nanotechnology. The acquisition makes sense, given that the *market for aerospace products based on nanotechnologies* is forecasted to be worth $70 billion dollars per year by 2010.[16]

Lithography is a key process in the fabrication of integrated circuits and accounts for an increasing share of their production cost. The most significant funding in new-generation lithography research, which focuses on techniques such as extreme ultraviolet (EUV), X-ray lithography, electron beam and ion beam lithography, comes from *public-private partnerships*. EUV is currently drawing the most attention, and could become the dominant technology within about ten years as the 50 and 30 nm nodes are reached.

Trilateral consortia (USA-Asia-Europe) formed as early as 1999 with the aim of producing 157-nm exposure tools, clearly demonstrating their interdependence in these pre-market stages. The Sematech consortium, whose members include AMD, Intel and Motorola, signed a research agreement with State University of New York (SUNY) at Albany to develop EUV lithography infrastructure. The consortium received a $320 million grant from the State of New York, creating 530 jobs. Tokyo Electron Ltd. has teamed up with the consortium to build a fabrication line for electronic components, initially for 45 nm devices.

In France, several clusters in nanoelectronics are being developed, one of the most important being the Minalogic one in Grenoble area (Crolles II). In particular, two projects are relevant for our study: GIN (Growth Initiative for Nanoelectronics) will reinforce the leading position in materials, avanced architectures and design. A strategic point, embedded software, will be the center point of the intensive development program to integrate materials and embedded software onto devices : EmSoC (Embedded Systems on Chip). Total investment there is estimated to 350 million € and could increase up to 710 M€ in the medium run. Investment in supercomputing will be necessary for advanced simulation and modeling of nanoelectronic circuitry and devices. In this domain, the Computational center for nanotechnology innovations (CCNI) in NY State has announced an investment of 100 M$ whose aim is reducing time and costs associated with designing and managing nanoscale materials, devices and systems.[17] The trend in 2006 seems toward customized nanoelectronics obtained by printing electronics. An atomic resolution memory of 10 nanometers has already been demonstrated.

_ ***The market for the category of intermediate goods*** that includes nanocomponents, other than electronic components, is another high-growth area and the focus of an international race for research and development of industrial applications. This segment is geared toward mass markets. One harbinger of future developments is the fact that patents are beginning to appear in Japan for consumer devices and applications (such as cosmetics) in which the inventive aspect is the inclusion of nanocomponents. **Nanomaterials** represent by themselves a potential market estimates at the level of

340 billion US$ in the next ten years. Nanopowders and nanomaterials already are sold on a worldwide basis.

_ ***The chemical and pharmaceutical markets***, which is largely dependent on the patent economy, is estimated to be worth $100 billion for nanotech applications by 2010-2015. It concerns a large field of applications, from nano-enabled textiles with UV protection, automobile painting and tires, displays, augmented solar cells, to nanomedical devices and medicinal products for targeted drug delivery. In the US, more than 120 nano-drugs and devices are waiting for FDA approval, many of which consist in drug delivery devices. One of the strong rationales in favor of a quick and pervasive implementation of nanotechnologies is its potential to saving energy consumption and green gas house effect in the chemical processes of fabrication theselves, as it has been demonstrated already by a firm like Rhodia, who became a powerful actor of the CO_2 quotas market, in the supply side.

Nanostructured polymeric wires, conducting biocompatible, biodegradable and with guidance is one of the most impressive breakthroughs for neuro-vascular central nervous recording and simulating systems. Applications for those nanostructured wires are neuron-to-neuron interaction, simultaneous multiple probes for describing the system, and Parkinson disease[18] treatment. It is envisaged that some of the newly established European technology platforms for nanomedicine and nanoelectronics will be able to assist in the identification of projects where pre-normative research would be required.

Emerging strategic industries in the nanosciences, with sharply contrasted stages of maturity, result not only from the convergence of nanobiology and nano-information technology, but also from the fabrication and integration of non-electronic nanocomponents into conventional industrial processes.

Robotics[19] appears to be at the heart of the nano-IT-bio convergence, with multiple applications, in the civil and military spheres. Nano-enabled devices for medical applications represent a huge market and concentrate public and as well as private R&D fundings. Microrobotics will be increasingly enabled by converging technologies at the nanoscale, including energy provision for lasting autonomy, with huge medical applications in sight, including nano-bio sensors and teleimplants.

Future markets based on ***plant nanotechnology*** lie at the crossroads of chemistry, physics and biology. This field draws on structural biology, which aims to organize a continuum between biosynthesis and catabolism and to understand the behavior of complex molecular systems. Self-assembly and self-organization characterize this science, which needs to be coordinated with cellular biology in order to integrate the concepts of temporal and spatial development of an organ or tissue. [20]

_ The long-term prospects for food safety offered by the **incorporation of nanotechnologies into the food chain** undoubtedly justify a significant commitment of human resources to cover the entire process, from basic research to the day-to-day management of agricultural speculation.

1.3 Issues of the toxicity and pollution potentially caused by nanoproduction warrant a rigorous scientific and ethical approach. Indeed, if such issues are not promptly addressed, public opinion will develop misconceptions about the benefits of nanoscience and the ability of public and private players to establish a regulatory framework, physical precautions and a risk management system with full accountability and transparency. To address this concern, the European Union is developing a new approach for persistent, bioaccumulative and toxic substances produced by the chemical industry. Although not specific to nano elements, the approach does take into consideration the additional costs that industry will incur to ensure environmental protection. In the EU, the 6th R&D framework program delivered three major projects in this field : Nanocare, Nanosafe and Nanoderm. Under EU current consumers protection's regulation, the burden of proof in terms of safety is ultimately carried by the supply side.

One can observe **the growing weight of public subsidies for defence and security on the civil as well as dual technologies level playing field, as strategic issues progressively emerge**. Every observer has in mind the Promethean-like raw figures of market foresight in each set of convergent technologies. But one has to recognise that developed countries, OECD and international bodies (governmental as well as NGOs), lack tools of observations of what is exactly going on when entering the meta convergence.

Classifications, characterization of passive and active nanoparticles and standard test beds are necessary preliminary steps to clearing the way towards safe patenting and, subsequently, to increasing private capital expenditures in nanotechnologies embedded in the CTTs future supply. **Standards, patents and intellectual property rights may be considered as precursors of dominant positions** in the global market of CTTs. Reducing time to market and avoiding unnecessary litigation is related to the amount and quality of work done by the patent offices throughout the world. The European patent office (OEB) should consider the evolutions going on in the short-term, and be fully involved.

1.4 Answers expected from standardization, metrology and certification.

One possible answer of the industrial side could be an active and comprehensive participation in ***international standardization*** process within ISO, including small and medium, innovative undertakings. Standardization has the potential to help addressing the risk issue in nanotechnology production and items life cycle and traceability, through the following cooperative actions[21] :

–Identifying gaps in knowledge.
–Identifying needs for, and encouraging the development of instruments and test methods for use at the nanoscale.
–Development and delivery of test methods to detect and identify nanoparticles, and to characterize nanoscale materials and devices.
–Development and delivery of protocols for bio- and eco-toxicity testing, including protocols to evaluate effects of short term and long term dermal, nasal, oral and pulmonary exposure to, elimination of, and fate determination for nanoparticles and nanoscale devices.
–Development and delivery of protocols for whole life cycle assessment of nanoscale materials, devices and products.
–Development and delivery of risk assessment tools relevant to the field of nanotechnologies.
–Development and delivery of protocols for containment, trapping and destruction of nanoparticles and nanoscale entities.
–Development and delivery of occupational health protocols relevant to nanotechnologies, in particular for industries dealing with nanoparticles and nanoscale devices.
–Support regulation in the area nanotechnologies.
–Support communication of accurate and quantifiable information on nanotechnologies.

One international development of common interest is standardization, in particular for occupational health safety of researchers, workers and consumers. One major participant in the field of international standardization is the People's republic of China who gave its Nanosafety Laboratory[22] the mission to study properties of nanoparticles and hazards to humans and the environment, to recommend regulatory frameworks to the government, to assess the safety of nano-industries and to cooperate with international organizations. China has already published a set of national nano standards including a glossary, four standards for nano products and two methods for test gas absorption and granularity of nanomaterials.[23] This country intends to invest 5MUS$ in nanosafety research for the period 2004-2010, mainly under MOST-project 973 framework.

ISO TC 229 committee for nanotechnology, established in june 2005, has created 3 working groups : terminology and nomenclature, convened by Canada, measurement and characterization (convened by Japan) and Health, safety and environment (USA). Under this last one, will be reviewed nanoparticles of high biocompatibility like oxid nanoparticles (TiO_2, ZNO_2, SiO_2, Fe_20_3), nanoparticles of high reactivity (metallic nanoparticles Cu, Zn), completely manufactured nanoparticles (single and multi-walled particles, fullerenes, metallofullerenes, and nano-complexes for drug delivery and nanomedicine).

The American National Standards Institute announced the formation of the Nanotechnology Standards Panel (ANSI-NSP), whose works began end of September 2004 at the National Institute of Standards and Technology (NIST) by focusing on nomenclature and terminology. Nomenclatures, official statistics, and classifications are difficult to elaborate, especially in an internationally harmonized way. Here is a good opportunity to enter an early inclusive cross co-operation; at the very beginning of the process, for mutual added value. Those works could give scientific support to reliable comparisons, would open the door to trust and, eventually, to common policy recommendations at the global level.

In the European Union, nanostandardization is addressed under CEN/TC 352 established in November 2005, and whose scope was drafted so as to be in close alignment with that of ISO TC 229. Its roadmap includes nanoproducts and processes standardization, which is not scheduled for ISO. A specific role for TC 352 should be to improve coordination between strategic standardization and European public policies concerned by the industrialization of nano-enabled productions.

Nanometrology represents a major input to standardization as well as an important field for R&D and industrial markets, because precise control of the dimensions of nano-items is a pre-requisite to industrial quality of nanomanufacturing but cannot rely on classical measurement techniques developed for conventional materials. An international specialization of the industrial production of laboratory equipments for nanometrology is already observed, and constitutes a competitive advantage for innovation.

Nano-certification is an other possibility already implemented in Taïwan, under the nanoMark certification initiative. This certification is related to nanoproducts already available in Taïwan. In this perspective, reference test standards have been developed for photo catalyst odorless paints, photo catalyst antibacterial ceramic tiles, and photo catalyst antibacterial light tubes. The application procedure for nanoMark certification includes submission of testing reports, including ISO 9001 certification. In Taiwan, public support for R&D and industrial applications was estimated at $110 million for 2003.

After this brief and non exhaustive description of the spectrum of nanotechnologies markets, those one must be classified according to segment to identify the state of the art as well as their true development potential and time to market delivery.

1.5 Supply and demand related to segmented markets.

In classical economic theory, the characteristics of the *final demand* model depend on the value that consumers assign to goods and services derived from the new technology as a novel or substitute offering, and on price. In the case of nanotechnologies applications, it appears that the demand curve during the period of market emergence must be differentiated according to whether the buyers are public or private.

Demand from the public sector may precede private-sector demand, and may stimulate it by serving as a “trial run” giving initial experience with goods and systems developed in accordance with highly specific technical criteria (particularly for defense and national security markets); this then provides the feedback and experience needed to drive down costs and develop products for consumer markets. This type of demand is characterized by *very low price elasticity*[24]. It can be expressed by specific, **precompetitive public procurement** addressing innovative SME's proposals. Trading rules have been adapted in the USA for this kind of demand and the EU is entering negotiations within the WTO in order to align with western practices without infringing international trade agreements.

On the *supply* side, of the various possible products that could be brought to market, players naturally choose those that offer the best likelihood of generating a return on investments, based on multicriteria segmentations of end-customers. These segmentations guide priorities and choice of distribution territories. The calendar and segmentation of the nanotechnology offering will therefore depend on anticipation of the "places" where their introduction is likely to have the greatest impact on buyer choices.

The sporting goods market is an example of supplier behavior: in the space of two years, a French manufacturer managed to capture more than 5% of the American tennis racket market by including in its range a racket frame reinforced with carbon nanotubes. The French success is one of the arguments put forth by the U.S. Department of Commerce to justify the Bush administration's budget request under the National Nanotechnology Initiative (NNI).

The accessibility of nanotechnology-derived products will naturally depend on their price levels, which in turn depend on production costs.

The *cost of nanoscale production* apparently evolves inversely to Moore's law for the first and second generation of nanotechnologies, pointing to gigantic concentrations in order to garner the promised savings on energy and materials. For example, building a fabrication line for mass memory systems and microprocessors cost somewhere around a billion dollars in the mid-1990s and could cost as much as $5 billion before 2010, taking into account the measures required to eliminate or contain nanoscale imperfections and environmental contaminations (the cost of the Crolles II research center is estimated at €3.5 billion).

Labor costs will depend on the investments earmarked for initial and ongoing training of human resources, and it is important to plan ahead to avoid bottlenecks in this crucial area. Safety equipments used to comply with the precautionary principal in terms of occupational health, accessible for huge groups, nonetheless could raise a capitalistic barrier to the entry of new SMEs into nanomanufacturing.

How is the *industrial fabric* taking shape for the future of nanotechnologies? The Observatory of micro-and nanotechnologies (OMNT) in France estimates that some 200 start-ups have been formed in this sector since 1997, 60% of which in the United States and 30% in Europe, including 7% in France. [25] These ventures coexist with industrial giants from a diversified cross section of the economy. Venture capital funds are now being set up in this sector, from the following sources: $207 million in the United States, $100 million in Israel, £30.1 million in the UK, $12.6 million in Germany[26]. The launch of public initiatives in Asia, particularly in South Korea, will considerably modify these relative figures in the near future.

1.5 **Intellectual property rights deserve a special focus.**

Royalties from *patents* and registered trademarks will be a key factor in the level of return on investments and in the undeniable economic weight of this sector, which will be considered as a strategic industry. However, although it is true that an element in its natural form cannot be protected by patent, the cost of the reproducible creation of a purified form of that element for use in industrial applications can justify the protection afforded by intellectual property rights.

Patents foreshadow the future positioning of companies and nations in the international competitive arena.

In the United States and Europe, statistics published by the USPTO and the European Patent Office (EPO) respectively indicate that the scientific origin of nanotechnology patents is scattered across several scientific disciplines with no single field dominating. The three main sources of patents are physical chemistry (21% of patents), the multidisciplinary category embodying the convergence of disciplines (16%) and applied physics. Other disciplines account for between 2 and 8% of patents, including materials science (4%).[27]. In 2004, US patents accounted for 60% of USPTO patents and 70% of startup companies in nanotechnology worldwide.

In Japan, the number of nanotechnology-related patents (as considered by the *Japan Patent Office*) rose from 3.900 in 1998 to nearly 6000 in 2001, of which 30% were filed by non-Japanese companies (especially L'Oréal, 3M, Procter & Gamble, and IBM) in 2000. A majority of these patents applies to nanostructured materials, nanostructured inorganic devices, carbon and organic-based nanostructured materials, nanostructured macromolecular and inorganic materials, and fundamental nanostructure technologies.

For example, Dow Chemical has patented the metallocenes that are the basis of new nanoscale catalysts used in plastics manufacture. The company has filed fifty patents for interpolymers in the United States and Europe, thereby protecting heretofore unknown material compositions offering unique commercial properties. Exxon Mobil owns 200 patents for the catalysts used in this type of materials.

A dramatic increase is observed in the filling of patent applications for nanotechnology in Asia, North America and Europe, highlighting its growing commercial importance: nanotechnologies as well as synthetic nanomaterials allow innovation in a vide range of industrial domains: materials, mechanical, chemical and pharmaceutical industries, ICT industry, biotechnologies; they have been identified for their strategic importance and drain R&D impressive budgets as well as venture capital ; nanopatent portfolios and related intangible assets values and goodwill are particularly critical to finance the microeconomic growth.

At the crossroad of many scientific disciplines, nanotechnologies represent for patent offices a space where wrong or obsolete knowledge of the state of the art may have led, already, to a non optimal intellectual property protection if we consider the macroeconomic level. Fully aware of those difficulties, the European Parliament, in a motion for a resolution[28] to be taken into account by the nanosciences and nanotechnologies action plan for Europe 2005-2009, expressed regrets on the fact that patenting of nanosciences and nanotechnologiey inventions in Europe is developing slowly, called on the EU to create nanoscience and nanotechnology patent monitoring system governed by the European Patent Office, stressed the need for greater transparency and clear limits to the scope of patent protection, asked the Commission to enhance international cooperation with a view of harmonizing N&N patent application processing between the EU, the USA and Japan and stressed that dialogue should be intensified in compliance with the WTO obligations.

Patents in the field of nanotechnologies will have a macroeconomic impact on international industrial specialisation on wealth distribution. Sectorial distribution of nanotechnologies applications ranks by decreasing order nanomaterials (nanotubes, composites, polymers, films), followed by science and technology for the living, ICTs and optics.

Competition is very strong in all the areas in fundamental research as well as in the applied one (including testing and evaluation. Market segments can be found in electronic communications (equipments and services), health, energy, food, all transportation segments from spatial to submarine ones, weapons, security and safety, building, textile, cosmetics, detergents, identification and traceability in logistics…

The patents covering manufacturing processes at the nanoscale will become in the short run strategic platforms for controlling nanomaterials production, food supply and health, at the crossroad of nanotechnologies, biotechnologies and information technologies. Intellectual

property rights on nanotechnologies are well situated to become the critical tool for value creation, providing a significant market power to their owners and by the strategic technology transfer policy they allow.

The *key figures* available for nano patents and IPR are presented here after.

First of all, patents proposed to patent offices resent two characteristics : their number increase and they tend to concentrate. Since the creation of nomenclature 977 by the USPTO, the number of patents proposed can be identified. It was around 24 000 in 2004 including 6 000 in the USA, 12 000 in Japan, 5000 in the European Union (1300 in Germany and 500 in France).[29] Since 1985, US undertakings have been granted 3 966 patents on nanotechnologies. 1 700 patents are being investigated. 1408 trade marks with the nano prefix have been registered. On 800 firms operating in the US, including 200 in California State, 51 are present in stock exchanges (NYSE, NASDAQ).

Demand of nanotechnology patents registered at the European Patent Office have experienced a 50% increase since 1995, leading to bottlenecks and scarcity in the evaluators availability, equally faced by the USPTO.[30]

Among all patents, *nanoelectronics faces an important patents concentration*. The 30 most important patent holders own more than 50% of the nanoelectronic patents. On those 30 actors, 8% are Europeans, 24% Americans and 51%Japanese. The situation in the nanotechnology patents delivered in the field on nano-energy reveals a comparative European weakness in this field. US firms have fulfilled 398 nanoenergy patent demands between 2000 and 2005, to be compared to 278 by Japan, 77 by South Korea, and 43 by China. Germany obtained 35 patents and France only 10. Are heavily represented in this segment Sony, Samsung, CalTech, Toyota, Hitachi, Hewlett-Packard, Honda, the Chinese Academy of Sciences, Canon and Motorola.

In the field of *nanotechnologies for healthcare and medicine*, China have a better relative position with 147 patent requirements (380 for USA, 41 for Japan, 38 for Germany and 32 for France[31] . Patents owned by American actors represent 33% of the patents delivered in this field, 20% for the Chinese and 13% for the Germans. The key actors for intellectual property rights are L'Oréal, Elan Corp, JSTC, the Chinese Academy of Sciences, Boston Scientific, the Indian Council for scientific and industrial research, Nanosystems Plc, the US federal government, 3M and the Massachusetts's Institute of Technology.

An analysis of the segmentation and the structure of nanopatent portfolios provide an actual panorama of industrial preparedness to the new markets.

Among the basic manufacturing 'nano-bricks' are single-walled and multi-walled carbon nanotubes, quantum dots, dendrimers and fullerenes as well as nanowires since 1999.The most important sub-set is the one of nanotubes. On a worldwide basis, at least 20 firms share the industrial production of carbon nanotubes. The four most important firms in this field are :

- NEC Corporation, owner of a patent on a manufacturing process to be paid by almost all players. For instance, Sumitomo Corporation pays the corresponding royalties for its manufacturing under licence.
- IBM, who sold a licence[32] to Carbon Nanotechnologies Inc. (CNI)
- CNI, created in 2000 Nobel Price Richard Smalley, owns a portfolio of more than 30 patents able, according to ETC Group[33], to lock and control the whole nanotube manufacturing process.
- Hyperion Catalysis (MA, USA).

The Korean firm Samsung obtained 43 nanotube patents at the USPTO, and RICE University, 14.

Patents in the field of nanoelectronics[34] are owned by 30 main stakeholders present first in Asia (18), 10 in the USA and 2 (Philips et Infineon) in Europe. Fujitsu covers the largest part of the nanopatents spectrum, followed by Samsung, Japan Science and Technology Corp and Hitachi, Sony, Toshiba. Hewlett-Packard is equally very well positioned.

Companies who have specialized their activities in nanopatents portfolio management already have entered a structuring stage. For instance, NanoPolaris Inc, subsidiary company of Arrowhead research Corporation, has obtained an exclusive licence on a patents set whose finality is creating value without any industrial commitment. This firm will promote and finance R&D by contracts (with, inter allia, CalTech, CA, USA in key domains like nanosensors), and the University of Tsinghua in Beijing.

This brief overview of the prospects and industrial challenges of nanosciences and their convergence should give non-specialist readers insight into current trends, yet must not be allowed to mask the significant uncertainties which surround policy decisions.

According to M.C. Roco from the NSF[35], about thirty countries had initiated national nanotechnology activities by 2003.

It is therefore important to take a look at the major government-sponsored initiatives that have the potential to structure worldwide development, as well as the enabling processes that will permit the emergence of significant industrial innovations in a global industrial environment.

However, bearing in mind the capitalistic barriers created by a combination of high R&D costs and the increasing cost of production facilities, any national, publicly-funded attempt to capture a competitive position from the starting point of a marginal market position clearly appears doomed to failure. In terms of intellectual property (in the Anglo-American sense), there will be no financially affordable means of catching up in the field of information technology/biotechnology/nanotechnology in the next twenty years. It is therefore crucial to be at the starting gate.

1.7 **Key public initiatives**

The European Union's Sixth Framework Programme reflects the stakes of the nanotechnology race by setting aside 11% of its budget, or €1.3 billion for the period 2002-2006, for this sector, including €700 million for basic research (compared to €150 million under the Fifth Framework Programme). The budget for nano safety has been granted for 25 M€, including the 7.6 M€ NANOCARE project. The launch of European industrial platforms for nanotechnologies aims to bring together all the EU's significant stakeholders in this sector. Under the global 7th framework program, the European union identified nanosciences, nanotechnologies, materials and new production technologies as one of its priorities and a political agreement was reached in july 2006 on a 3.5 billion euros budget for the period 2006-2013.

Newly integrated countries like Poland have contributed to the European research area in the field of nanomaterials under FP6, and developed on an national basis knowledge and research. Poland has initiated in 2000 a project "Metallic, ceramic and organic nanomaterials, followed by two initiatives concerning nano-metallic components produced by plastic forming and polymer modified by nanoparticles.[36]

European Research previous Commissioner Philippe Busquin estimated that public and private R&D efforts in nanosciences and nanotechnologies would require annual funding on the order of €600 to €900 million.[37] Civilian applications targeted by current R&D programs relate to energy storage and distribution, detection, measurements and testing, processors, biological analyses, drug delivery, robotics and prosthetic devices.

The initial call for proposals under the Sixth Framework Programme for R&D encompasses nanotechnologies, nanosciences, knowledge-based multifunctional materials, new production processes and devices to engineer new products and services to become available by 2010. Part of the budget is reserved for small and medium-sized enterprises (SMEs) to support them in efforts to develop new value-added, knowledge-based products and services in industrial sectors which traditionally have a less active commitment to research and technological development.[38]

A few projects are symbolic of the potential of nanosciences. Three of these will be mentioned here:

- **Polymer Micro Sensor Fab** (a disposable chip for low-cost DNA analyses): this pharmacogenomic project entails the identification and extraction of the messenger RNA from a single cell or group of cells.

This project is representative of a broader and fast-growing market for *sensors and detectors* of bacteriological and chemical elements in the environment, based on "lab-on-a-chip" systems organized as a network capable of transmitting information. This field is a prime example of convergence with the development of applications that reproduce human senses by electronic means: electronic nose, bionic eye, replication of haptic data and artificial hands.

- **Measurement of nanocurrents** with the aim of reducing electrical currents to the nanoampere scale needed for miniaturization and reduction of heat generation in electronic nanocircuits. This project calls for cooperation between physicists and metrologists.

More broadly, given the tremendous scientific, industrial and sovereignty challenges involved, the high-level group for measurement and testing recommended that the European Commission devote a significant share of the budget under the Sixth Framework Programme to *nanoscale metrology,* supported by organizations such as Euromet, Eurachem, Eurolab and Euspen, as well as the National Institute of Standards and Technology (NIST) of the United States.[39]

- **Nanorobots**. The Robosem initiative, a partnership of six EU countries including France, is devoted to creating nanoscale tools able to perform the assembly functions vital to industrial production through the use of scanning electron microscope technology to "see" the object and the nanohandling system in real time. The robot will be housed in the vacuum chamber of the microscope. Current processes use conventional optical microscopes with a maximum resolution of 400 nanometers. This project received a €5 million grant under the GROWTH program[40].

A first **evaluation of the projects supported by the 6th FP** gives some examples of the best outcomes as follows:

- Cornea engineering;

- Emerging nanopatterning methods (NaPa);
- Microsystems and nanotechnology for prenatal diagnosis;
- Anthropogenic aerosols triggering and invigorating severe storms;
- Deliberative citizens debates in European science centers and museums;
- Europe-wide dialogue on benefits, risks and societal, ethical and legal implications of nanotechnologies (Nanologue)
- Enhancing on nanosciences and nanotechnologies in society at the European level (nanodialogue).
- Societal implications of converging technologies (Contecs).

The European Union is also forming scientific partnerships with other countries, namely ***Switzerland*** and the ***Russian Federation***.

In Russia, the government and international organizations were the main sources of funding for nanosciences through 1997, with the involvement of a network of laboratories (including the Ioffe Physico-Technical Institute in St Petersburg, active in the field of electronic and optical properties of nanostructures, the Lebedev Physical Institute and the State University in Moscow, the Institute for Physics of Microstructures in Nizhny Novgorod, the Institute of Semiconductor Physics in Novosibirsk). [41] Materials-related research institutes of the Russian Academy of science include the Institute of microelectronics technology problems an high purity material, in the Moscow region, and the Institute of physico-chemical ceramic materials of Moscow.

Since 1998, the Russian Federation has been careful to "recycle" the results of its own research laboratories by encouraging the creation of *start-ups* and ensuring appropriate remuneration for inventors. The government now also provides them with infrastructure for securing international copyright protection, filing patents, and commercializing innovations, as well as giving them access to the main public research laboratories of the Academy of Sciences. There have been no recent publications detailing the public funding for this area.

Modeled on the practices of American companies or Institutes such as Zyvex or Caltech, a holding company of Russian nanotechnology start-ups [42] was formed with the aim of bringing the first products to market within ten or fifteen years. It is noteworthy that the company holds a patent for *quantum wire* technology, which is destined to replace today's lithography techniques in microprocessor fabrication when the time is ripe, as well as to build tomorrow's quantum computers.

In *Switzerland*, IBM laboratories in Rüschlikon near Zurich played a major role in increasing by imaging the awareness of what could be done by manipulating atoms one by one. Metrology and precision technologies as part of traditional international specialization and excellence, have been pushing innovation in fields like medicine and nano-enabled neurotechnologies (nano, non invasive and biocompatible implants and drugs R&D). Economic and societal aspects have been addressed at an early stage, with the full commitment of insurance stakeholders.

Asia, too, has implemented a number of significant public initiatives to promote nanotechnology.

The highest investment level comes from ***Japan*** ($1.042 billion in 2003, of which $388 million for competitive Research). The main thrusts of its effort are information technology, environmental technology, life sciences and materials. Japan has a technological lead, especially in the fields of nanofabrication and nanostructured materials. By the year 2020, research topics will include quantum cryptography techniques with nanostructures, chemical lab-on-a-chip systems incorporating state-of-the-art silicon treatments, and the development of new nanoscale materials.

The private sector recently took measures to reduce the time-to-market of the results of this research. The Japanese nanotechnology market will be worth an estimated €163 billion by 2010, with magnetic materials for high density memories accounting for the largest share. [43] . The Japanese market size for nanoproducts and technologies was estimated at 3.5 billion dollars in 2004. Nomura research Institute estimates between 43 to 173 billion dollars the Japanese market size in 2015, with a specialization in nanomaterials and nanoelectronics mainly.

Nanosimulation science in on its way to proposing simulation of interactions between molecules or characterization for proteomics and synthetic proteins. Japanese laboratory Riken[44] announced that it raised the Petaflop capacity with a supercomputer called MDGrape-3, including 201 units equipped with 24 chips, operated in Yokohama. The target of nanosimulation enabled by such facilities is to make simulations not only on simple atoms, molecules or solids, but also on complicated systems incorporating nanoscaled structures. The prediction of nanostructures and properties by nanosimulation will be a key element for responsible innovation and informed trust, because it has the potential to clarify and enhance the knowledge of relationships between electronic structures, physical properties and the functions of nanomaterials. According to NIMS researchers, " developments and improvements of the simulation techniques for very large scale simulations, multifunctional analysis (multi-physics), strongly correlated modeling and multiscale techniques is urgently needed".[45]

South Korea, under the nanotechnology Promotion Bill*,* has planned public investments worth $2 billion for the period 2001-2010. Of this budget, 19% is allocated to a national program for the industrialization of nanotechnologies. Over a ten-year period, $100 million is earmarked for the development of mecatronic and nanoscale fabrication technologies. The R&D 'frontier program' consolidates three major projects launched by the Korean government : the center for Tera-level nanodevices, the center for nanostructured materials and the center for nanoscale mechatronics and manufacturing. Five major integrated nanotechnology fabrication facilities are to be opened from 2005 to the end of 2006. A revision version of the Korean initiative is available for 2006-2015, aiming at considering nanotechnology as a future engine of the Korean economy. [46]Nanopowders, nanoparticles, nanocomposites, nanotubes, and photocatalysis are among the avenues being pursued by Korean start-up ventures. Major industrial groups such as Samsung are already investing to reduce the time-to-market of new products that incorporate nanotechnologies.

The People's Republic of China launched its own public initiative within the framework of its 2001-2005 plan, which allocated $300 M$ to nanotechnologies, including world class research on carbon nanotubes, quantum and molecular nano-device research, photocatalytic nanomaterials for water treatment, super-plasticity and extensibility of Cu nanomaterials, super-amphiphobic nanomaaterials and nanopowders. The short-term ambition is to incorporate available applications into the production processes of existing industries. The country's applied research capabilities were expected to converge at a site in Tianjin with the opening of the "Nanotechnology Industry Base." The XIth plan confirms and strengthen public support to nanotechnologies and nanomaterials research as a key to its future competitiveness, in particular in the field of foundries and nanoelectronics. This country, who took the lead in standardization, welcomes foreign investment in strategic domain. For instance, according to a deal announced in 2004, Intel Corp. would transfer manufacturing technology and equipment to Nanotech, once a Chinese start-up based outside Shanghai in Changzhou, Jiangsu Province aiming at producing 15 000, 200-mm wafers per month.

India has announced in Bangalore the set up of an international nanoscience center for material sciences with an investment program of 10 billion Rs for the period 2006-2010. The first nano-laboratory at the Jawaharlal center first advanced scientific research (JNCASR) focuses on the energy sector to develop supercapacitors for batteries and photovoltaic cells. Similar nanolabs will be created to devise applications or sensors to be used in healthcare, agriculture, electronics, hardware and life science. It will be co-steered with the Bangalore's Veeco Instruments Corp. own laboratory for nanotechnologies , opened in 2005[47]. According to the Indian minister of science and technology, India has missed the semiconductor revolution but efforts will be made by the government and the scientific community to tap the potential of nanotechnologies fully in order to develop applications across verticals for the benefit of the common people.

The United States seems ahead of other blocs as regards its preparedness to enter the industrial convergence. It has made digital technologies the spearhead of its international specialization. Underpinning its vision of global economic dominance for the period 2010 to 2020 is NBIC (nanotechnology, biotechnology, information technology and cognitive science) convergence, which is supposed to lead to patterns of human behavior and man-object interaction based on revolutionary processes of self-assembly, replication and system communication. We know virtually nothing of these patterns, quite simply because they lie beyond our powers of imagination or dangerously close to attempts to improve human performance….

A forward-looking vision points to the industrial production of "avatars" with humanized appearance and attitudes in a three-dimensional environment, having the ability to teach and train via a computer monitor or in the form of holograms.[48]

This vision, albeit futuristic, was explained in a call for bids issued by the Defense Advanced Projects Research Agency (DARPA) on June 23, 2003 under the program name *LifeLog*. The corresponding administrative document describes the long-term vision of the agency's Information Processing Technology Office (IPTO), based on a new generation of truly cognitive systems able to perform the duties of a personal, medical, financial or teaching assistant.[49]

In another illustration of the convergence of fields within the nanosciences, the security of biometrical data is at the heart of the biometrics industry, an estimated $2.7 billion market. The launch of the *National Biometrics Security Project* based in the State of Virginia, for instance, has received a $20 million government grant.

In the military arena, aggregate DARPA funding for the development of nanomaterials, nanosciences and related techniques was estimated at $445 million in 2004 with a clear priority on NBIC convergence. The *Institute for Soldier Nanotechnology*[50] was established with an initial budget of $50 million in March 2002, based at the Massachusetts Institute of technology (MIT). In addition to focusing on reducing exposure and improving recovery, a drastic weight reduction and unlimited energy supply for autonomous mobility are two major aims of the target applications. Civil applications of this applied research aiming at increasing energy availability in situations of mobility are part of the nanorace.

Dual and military applications can be found in the following domains:

- information technologies, including space and aeronautics applications
- Nanostructured materials and mechanical systems (MEMS/NEMS)
- Sensors
- Energy and energy management
- New convergint technologies devices and services
- Human performances enhancement and Human-Machine interfaces

- Microrobots and machine-living hybrids
- Defensive as well as offensive nano-enabled weapons in the NNRBC war
- Self-assembly and nanotechnologies, 4^{th} generation
- Selectivity and massive destruction by targeted subsets
- Microweapons and their remote activation

The National Nanotechnology Initiative (NNI) draws its political support from the societal benefits of nanotechnology applications that contribute to sustainable development. The NNI places special emphasis on the potential for reducing CO_2 emissions by 200 million tons per year through more widespread use of nanotechnologies in industrial processes that involve energy production or consumption and considers **nano-enabled energy production as a key market for the future**.

For example, the Nanocrystal Lighting Corporation company near New York has successfully modified phosphorus atoms to increase the amount of visible light they emit. Electric bulbs made using these new nanophosphors would be able to convert nearly 100% of the energy into light (compared to 5% for today's tungsten filament bulbs). The result would be huge energy savings, ranging from 25% of the consumption of American households, to more than 80% in less developed countries.[51]. Altair Nano (Reno, NV), develops new systems based on nanostructured ceramics as Titanium nanostructured components for a cathode instead of graphite, who allows fuel cells to be charges at 80% in a one minute time…[52]

**For FY 2007, budget request under the NNI reaches 1277 M$,** of which 258 M$ would be allocated to the Department of Energy (from 58 M$ for FY2000, and 345M$ to the Department of Defense (including energy nano-enabled military solar-cells applications). In addition to this public support, venture capital investments, reoriented to biotechnologies after the Internet bubble, began investing in nanotechnologies with amounts estimated at $425 million in 2002.[53] Nanosys, NanoSolar and Konarka develop flexible, ultra light solar cells manufactured with semi-conductive nanoparticles. National Institutes of Health received 172 M$ for FY 2006 and the National Institute for Standards and technology was granted 86 M$.

A major potential advantage of the public initiative is that interagency civil research objectives are coordinated by the National Nanotechnology Coordination Office (NNCO) according to an interagency model that has proven effective in the field of information and communication science and technology. Synergies are facilitated by the very way in which the budget resources are voted, that is, as programs, with the endowment for each agency described in detail in a single legislative act.

The impact of the war on terrorism is reflected in the sharp increase in funding for national security applications. Pervasive tracking and tracing of items on motion have been one of the orientations. One representative product is the VeriChip[54] , a device implantable under the skin developed by a subsidiary of Applied Digital Solutions, introduced in February 2002. It entails a ten-dollar-per-month subscription and the device itself, sold for $200. This product is a *forerunner* of other related applications that could be used either voluntarily or without people's knowledge. These could include technologies such as markings designed to prevent counterfeiting through the use of implanted nanotags, or nanocomponents built into physical payment instruments relying upon radioidentification technologies (RFID).

The NNI endowment for the Department of Agriculture increased from one to 5 million dollars from 2003 to 2002006, reflecting recognition of the emergence of agriculture-related nanotech issues.

In the food industry, nanotechnologies constitute a paradox: they may encounter challenges similar to those faced by genetically-modified organisms, but they may also help providing an economical and socially acceptable solution to certain major public health problems related to poor food and water treatment and non efficient solutions for food preserving.

Rutgers University (NJ, USA) hired the first professor of "food nanotechnologies" to develop the field of *nutraceuticals,* foods able to utilize proteins to deliver drugs to targeted areas of the body. This area of research has potential repercussions for neuroscience and related applications, given that combining particles of 65 to 200 nanometers with a drug may augment the effects of the drug on target organs of the body, such as the brain. Already, public opinion has high hopes that this technology will yield great societal benefits by limiting the handicaps of Alzheimer's disease.

Despite the considerable potential offered by the United States' public support for R&D, it is striking that less than $500,000 dollars of the 700 million $ NNI funding in fiscal year 2003 was allocated to studying the environmental impacts of nanotechnologies. Yet these studies are necessary at the international level to provide the basis for risk management regulations. Industry itself has taken the lead in this area: DuPont Corporation took the initiative of starting research into the environmental consequences of disseminating and managing wastes containing industrial nanoelements and is fully involved in international dialogues with Insurance for instance. This company, who previously faced contests from the Environment Protection Agency related to chemical industrial releases, choose a participative approach to designing common frameworks, which have been appreciated by stakeholders and contributed to strengthening an informed trust.

This necessarily brief overview of major public initiatives to promote market developments based on nanosciences and nanotechnologies brings us to the conclusion that research and civilian developments offering clear definite economic and social value are already taking place at the global level, with commercial applications ranging from consumer markets to the fields of safety, security and defense.

Other economies are organizing their own approach by drawing on the characteristics of their existing international specializations. Among the leaders today are ***Brazil, Australia, and Canada*.**. In addition, ***Thailand, Malaysia, Singapore*** and ***South Africa*** have launched their own national programs and announced significant ambitions in these fields. ***Saudi Arabia*** announced in 2006 its ambition to spend 2 billion dollars in nanotechnologies, without providing at this stage a detailed roadmap. A number of official websites are available to provide researchers with useful comparative data. This is also the case in France, although there is as yet no interministerial, integrated portal, which may restrict the ability of a foreign observer to grasp the overall coherence of the country's public initiatives in this area.

All these initiatives are destined for a phase of pre-competitive cooperation, to be followed by intense competition. According to the usual pattern, nations will have to choose among three possible scenarios: dominance, slow growth or downward spiral, depending on the degree of political and social awareness of scientific advances, and the degree of mastery attained in managing the industrial risks created by incorporating nanoparticles and nanomaterials into industrial processes. In the United States, Europe's policy decisions in this area – because they are mostly based on citizens advocacy and a single market of attentive consumers – are viewed as the decisive factor that will tip the world economy into one or the other of these scenarios. Significantly, the economical aspects of nano-enabled industrial production in Chine have been carefully reviewed when this country applied for WTO.

1.7. Where are the talents ?

Available and high-caliber expertise will be decisive in achieving industrial objectives. Skills will be the prize to be won in the battle of influence aimed at attracting the best talent in a multidisciplinary approach. Nanosciences are the natural point of convergence of multidisciplinary expertise, calling for the formation of ad hoc teams of electronics and micromechanics engineers, chemists, biologists, materials scientists, and metrologists. These teams are already in place in some of the California universities, such as Berkeley and Caltech, supported by considerable civilian and military funding. There are differences here between Western and Asian cultures, the former seeming able to evolve more quickly toward a decompartmentalization of academic disciplines…. But how long will this last?

An important challenge here, as part of the global governance relevant issues, will be <u>to fill the educational gap</u> between developed and developing countries, as well as addressing awareness and preparedness by involving the medias at early stages of applied research.

If the research community were to presume that nanotechnologies posed a threat, reflecting ill-informed or misinformed public opinion, there would be problems of lack of motivation for entering the initial training and therefore recruitment of skilled people to supply research laboratories and industry with employable workforce. Availability of talents and labour will condition the choices of localization of R&D, then of nanomanufacturing plants, and consequently influence the mapping of international industrial specialization of the years 2020.

Indeed, even in western societies, the judgment is not unanimous. According to a report by the European Parliament, there is a significant and persistent gap between efforts to promote the scientific disciplines involved in nanotechnology and the fact that the technology itself continues to be perceived as unlikely to affect the daily lives of ordinary people any time in the near future.[55] There is also much more promotion going on in the American scientific community than in the European one, creating the conditions for the emergence of the anticipated *nanometric divide*.

In certain parts of the world, **security regulations and obstacles to sharing scientific knowledge and breakthroughs, can be a threat, by itself, against the countries not included in the closed circle of the ones which whom it is authorised to share this kind of information**. As we know, the classification of scientific knowledge applies, first, to strategic, transformational technologies, in the US since the declaration of war against terrorism, and in other countries too, indeed. The language barrier should not be underestimated here, in particular for publications available only in Chinese, Japanese and Russian.

The international industrial nanotechnology economy, in all its diversity, is already on the march. It is deserving of major intellectual investments in order to first observe, then analyze and finally recommend a public policy in an area in which the nature of the potential applications, the anticipated social benefits, and the progress in understanding the related industrial risks, provide ample justification for public support.

Risk perception from institutional stakeholders has already reached an appropriate level of awareness, and what is more, the risk perception seems not limited to a linear and causal, risk/benefit approach focused on health and environment unwanted impacts. It involves a more dynamic, systemic approach which includes the cognitive, cultural and generally speaking societal impacts to be eventually brought by full and not yet regulated applied nanosciences and nanotechnologies in industry for trade and commerce on a worldwide basis.

The French government expressed his view in favour of the proposal made by the European Commission of a strategic plan for nanosciences and nanotechnologies in September 2004, and in favour of the action plan 2005-2009 released by the EC in may 2005. Its Prime minister has announced in May 2006 the launching of a huge public national debate around nanosciences and nanomanufacturing, taking into account the potential gap between public perception of risks and public knowledge.

In particular, there is a strong support from France to a structured international dialogue between Nations in the field of responsible nanotechnology development, whose characteristics should be transparent, democratic and inclusive, with a special attention paid to societal aspects.

II. THE DEVELOPMENT OF THE NANOMANUFACTURED GOODS DEMAND SIDE, AND THE PREMISES OF SOCIETAL CONCERNS.

Referring again to the proceedings of the special interest group in nano economics of the HLEG 'Foresighting the new technology wave 2020' of the European Commission, we[56] found that we needed to increase our understanding of resistance to new technologies.

21. Resistance to new technology appears to be a constant feature in the history of technology and European society. Three broad points can be made about it.

- These are, first of all, that resistance to new technologies (particularly technologies of external origin) can come from many sources, and should not be seen primarily in terms of a form of 'Luddite' labour resistance to innovation. The perception of negative effects is not something confined to particular groups; on the contrary, there are many potential points of resistance to innovation in business, public administration and politics, which have played important roles in the technological evolution of the European economies.

- Secondly, when resistance is seen in this broad way, it can really only be understood in terms of the interaction between the technology and its social context. It is not simply a matter of specific interests being threatened by new technologies, but a much wider process concerning the ways in which technologies accord or clash with social organisations and cultural values.

- Thirdly, resistance is by no means irrational. While resistance is invariably based on particular social concerns and interests, it can also be seen as a component of the more general processes by which society selects among technological options.

Taken all together, these points raise questions as to what we understand by the term 'resistance' in the face of technological innovation.

Risk assessment beyond the simple causal risk-benefit approach has been analysed in the DUPUY ROURE report [57]as follows :

The first improvement to the simple causal approach consists in opting for a systemic understanding of the risks posed by nanoparticles and nanostructured products, using a methodological procedure that has been well defined in ecotoxicology studies. A synoptic representation of the environments surrounding the emission of nanoparticles, transport, exposure and the effects has been attempted by a working group of the European Commission's Health and Consumer protection Directorate General. It highlighted the usefulness of a systemic approach to risks.

Government policies are increasingly involved in the management of environmental crises, which implies having quantitative and qualitative informations and skilled people for understanding and assessing of the nature of risks and impacts so as to optimise public intervention. Environmental risk assessment is conducted according to the following sequence "identification of the danger – exposure – the dose-effect relation – risk characterisation". The ecotoxicological approach concentrates on nanoparticles and nanostructured materials that are free or bound, manufactured or released by a manufacturing process that is intended for other purposes, with or without a coating, and with a variable lifetime. In terms of safety, the 7th European research program will focus on the characteristics and behaviour of non soluble solid nanoparticles, as a priority.

At this stage there is an expert consensus on the unpredictability of the properties of manufactured nanoparticles, or those occurring naturally in the environment over very long time periods (oxidation of dusts, volcanic eruption dusts, etc.), and nanostructured materials. In these conditions and in the absence of significant progress in this field, it is impossible to pretend to be able make any exhaustive risk assessment by a dose-response type approach or by recording exposure data.

Here again, the systemic approach is not limited to risks in the strict sense of the term, and must take into account the solutions that nanotechnologies are likely to provide for the major challenges facing sustainable development. Nanomaterials, because of their new properties, can lead to a reduction in environmental pollution, not only by improving our understanding of pollutants in the environment, but also by the use of functional filters or of nanoporous ceramics.

ASECO's European consumers protection organisation expressed its opinion as follows: " Radical innovation, especially to face not yet solved problems and to provide enabling solutions that would decrease present unwanted dependencies, is of course welcome. Consumers strongly support nanotechnology applications to preserve the environment (e.g for energy production, especially solar electricity) and for energy savings (e.g. in building materials)".[58]But this support is conditioned under given conditions, including the requirement that the relevant EU regulatory frame is timely revised, with help from consumers, in the light of a proactive approach; that it is progressively adequated in parallel with science and experience; that the case for a specific Authority is taken into consideration"

The short-term requirements for increasing knowledge on the ecotoxicity of nanoparticles are characterisation and classification, the preparation of standards and reliable set of testbeds, investment in nanometrology and instrumentation. But beyond the systemic approach, another qualitative stage must be accomplished, if possible by highly inclusive international cooperation, that of the dynamic approach, which alone can take into account the spatio-temporal dimension, and lead to a *normative methodology for assessing the combination of risks, or meta-risks* posed by nanotechnologies pervasive industrial applications.

The need for such a methodology was considered as urgent in the report cited supra, because in its absence, a rather sterile communications war was expected to raise between the promoters and the critics of nanotechnologies (one should be tempted to qualify the extremists of both parts of nanolatrics versus nanoclasts…). Since, street demonstrations in Grenoble in May 2006 confirmed this prevision.

2.2 Obstacles to market expansion can be highlighted in many ways.

- Nano economic divide is one of them, in particular perspectives of disruptions of international trade of raw materials, particularly for countries in development relying on rare materials mining. Expectation and fear of such disruptions could lead to a fierce contest of any N&N program and public funding, as Friends of the Earth's representatives already warned.
- Lack of proof of safety is another one, addressed by the European Parliament quite clearly : *" the effects of nanoparticles that are not readily soluble or biodegradable should be investigates, in accordance with the precautionary principle, before such particles go into production and are put on the market*"[59]. This means that investments in nano R&D and in industrial manufacturing could be just stranded in absence of parallel, -if not previous- , investment in proof of safety.

Wealth of Nations might not mean Earth's paucity. Technology transfers and appropriate fundings might guaranty equal and undiscriminatory access to the knowledge and products useful to spare scarce resources like energy and contribute to the well being and decent living condition for all. Ethics should regulate what is patentable, opening access to private royalties, and what belongs to public missions and common good. The initiatives taken by the Meridian Institute[60] in favour of nanotechnology for the poor has had the virtue to raise awareness among stakeholders and to promote confrontations, visions sharing and emerging responses, in particular in the field of nanotechnologies contribution to water purification, in a world where more than 2 billion people lack any water treatment infrastructure.

In order to accelerate burden sharing of the proof of safety, a cooperative approach, enhanced and accelerated by grid computing simulations on a large scale, open to all researchers who would wish to participate, should be supported in order to accelerate the dissemination of knowledge on properties of the new 3D artificial nanoparticles and structures, as such and when confronted to a wide range of natural and synthetic environments.

But **there remain forces against cooperation, even amongst public institutions**. Military and security organisations might be given a right/duty to prevent proliferation of offensive technologies and products in the field of nanotechnologies, under democratic instruments to be designed, discussed and eventually implemented on a multilateral basis. Export control has been expanded to nanotechnologies and nano-bio applications.

Intellectual property rights, even if they open information to all about inventions being protected and adds value to the innovation process, could behave as a barrier against innovation itself if improperly managed, and therefore act as an obstacle to a supply meeting the needs of citizens and consumers.

2.3 What are the main evolutions and the expected impacts of the nanopatents race ?

- The first effect of the nanopatent's race in a context of lagging public knowledge about the state of the art is the emergence of what has been called the patent thicket. This situation has been created by acceptance from the patent offices, of too huge invention fields not accurately clear-cut and with a high risk of overlapping with other inventions already protected. This will leave the floor to legal uncertainty and expensive contests.

The main dominant chemical, pharmaceutical and electronics manufacturers organized themselves as IPR's « pace setters » in order to maximizing the return on investment of past innovations. But this economic behaviour will constitute an obstacle to innovation, preventing small businesses from entering the market when it will require protected processes of self assembly, bottom up manufacturing ; the societal value here will therefore not be added, but *withdrawn*, and the consequences should not be underestimated, in particular if it were to leading responsible innovation down to a stage of stranded investment. An evaluation of the societal cost of the nanomanufacturing's IPR locking and controlling could be approached by the global cost of trials and arbitrage as well by decreasing yields of R&D spending.

- The second identifiable effect of the nanopatent's race is <u>the interaction with ethical questions and the diversity of the regulatory framework for applications involving the living</u> (human beings, animals, biosphere…). Here we face the combination and potentially the *confrontation of diverse finalities* emerging from NBIC convergence. For example :

• Curing and restoring deficient body and cognitive functionalities and preserving acceptable conditions for autonomy in active ageing in order to guaranty accessible and sustainable macroeconomic financial equilibriums (e.g by developing cochlear nano-structured implants, remote muscular stimulation …).

• Availability of individual enhancement as new, ultimately non reversible functionalities, providing personal or team competitive advantages, to be compared with a level-playing field as a rule in sports). Here implants for human-machine interfaces, mobile, wearable nanosensors for defensive and offensive applications are at stake. Secrecy problematics may directly challenge patentability because this last one provides information sharing on a basic set of characteristics for the innovation to be protected by IPR's. Nevertheless, protecting innovation or the manufacturing processes themselves is a prerequisite to strengthening a dominant position, creating a guarantied and lasting revenue allowing to remain a pace setter. But this kind of confrontation can create negative effects on the incentives provided for applied researchers working in those fields.

Once a dominant market position is obtained, innovation from other actors can be monitored because it determines the profitability of the market. We can cite a Nanogen Inc. patent related to systems and means of self-assembly based upon the affinity for photonic and nanoelectronic applications derived from nanostructures incorporating synthetic DNA, (e.g : the concept of optical storage on DNA, or nanospheres assembly in octahedrons polymers relying on 3D DNA nanofabrication.)

The specific stakes designed by information technologies and nano-biotechnologies <u>convergence</u> may also, as such, constitute obstacles to the development of the demand side. We refer to the role given to information technologies in the CTEKS/NBIC convergence[61] **wi**th the four following items :'If Cognitive people can think it, Nano people can build it, bio people can implement it, and information technologies people can control and monitor it'.[62] A fifth item might have been added : " *democratic and informed decision-making can authorize or stop it*"…One cannot prevent people asking the question of finality when a project such as GoldenBrain, aiming at conceiving nanogold particles inclusiveness in neurons by phagocytosis, is presented to the public[63], even if an application related to nerve gas detection is offered.

When addressing the convergence between nanoscience and information technology, we, as individuals taking one modest part in a cultural mosaic, we must admit that we are facing the perspective of an increasing *complexity* which, subsequently, opens access to an unlimited universe of *uncertainty*. The hyperchoice brought by potentially unlimited combinations of nanotechnologies and IT from one hand, and, taken together the combinations with biotechnologies and neurotechnologies on the other hand, increases the perception of uncertainty.

And we, as individuals, feel uncomfortable. Unless a clear-cut ethical code enlightens choices, it is unclear whether the decision to, for instance, make an experiment directly involving, or potentially modifying the information system and the " conscience" embedded in the human body, will involve an emotional state of guilt or not.

As a matter of fact, convergence between nanotechnologies and IT brings all together good, productive and useful applications of nanosciences, for example with repairing medical applications, *and* non desirable or even not acceptable intentions and implementations. It raises the question of risk governance and its dilemma for policy makers, torn between opting in favour of the maximum protections, or loosing public trust by a comprehensive *laisser-faire* attitude..

2.4 Here comes the question of limits.

The cultural, professional reaction to this negative feeling is to enter a *routine* attitude, a protective and also professional one, which consists in mapping out and assessing risks related to breakthroughs, by following a formal, once for all established technical guide, designed to prevent from addressing the *normative ambiguity* related to the way by which we interpret the assessment results.

Of which "routine" do we talk about here? The one which is referred to as a reassuring, well known, working instruction : " find ***the right equilibrium between risks and benefits***, let institutions put a green light on it, once and for all, and go ahead consequently." What it means is that, depending on the degree of openness related to the scientific and industrial knowledge, the "norm", here, the "limit" between do's and don't, is to be settled once and for all. The legal norm itself is linked to the society by the **ethics** this society implicitly adopts and implements. In a democracy, there is a consensus to think that intelligent solutions of problems are preferable to what are usually described as "emotional solutions".

One major difficulty comes with the new ways and means of interaction between technological artefacts and human nature created, or to be created by IT and nano convergence, whose impacts are a matter for public deliberation. If we assume that we have not yet fully defined the nature of human species, (here I do refer to the NEST program of DG RDT / European Commission whose title is " what does it mean to be human"), how could we assess "risks" without knowing the whole lanscape. Because of this consideration, one should be tempted to follow Pr. Jan Staman, of the Rathenaus Institute, for whom technology assessment and foresight go hand in hand.

Illustrations of potential, - if not likely- norms which seem under scrutiny as far as nanotechnologies and meta-convergence are concerned, are the following :

- The precautionary principle opens the door to a moratorium as being the new frontier, and refers to the call made in 2002 by ETC group as regards nanotechnology. Hidden philosophy is : " if you don't know it, just let it drop until you know more". The implementation of this principle implies that "regulators" decide for "no adverse effect level" (NOAL), guaranty reversibility of any action as well as avoidance of irreversible damage. It shifts the burden of the proof to the supply side stakeholders. ETC group called, mid-2002, for a moratorium on the use of synthetic nano-particles in the laboratories, and in any new commercial product, until governments adopt « best practices » for research. On the other hand, the nasty effects of a moratorium are amplified by the brain drain created by early announcements of public support elsewhere. Concerning Chinese, Asian, Russian and European scientists, this trend, once initialised by prohibitions, becomes difficult to reverse because of the gap between researchers' emoluments.

The precautionary principle is often referred too, if not so often included in legally binding texts. At a lower level of constraint comes the "duty of care" concept, used in the chemicals REACH European regulations. The notions of "code of conduct" relying on exchange and voluntary acceptance of recognized best practices, belong to the hortatory level. Each of those notions may help to bring together the people recognizing and willing to face adequately the risks related, directly or indirectly, to convergent transformational technologies.

- The "duty of care" guideline was raised in the context of the European "REACH"[64]directive negociation about chemicals production and trade. It could lead to a combination of a legal , hortatory framework and a code of conduct to be implemented on a voluntary basis by suppliers. This is a more pragmatic approach than the one of a strictly applied principle of precaution, but a heavily challenged one by a western public opinion increasingly aware of environmental and industrial pollutions.

- International legal obligations. For instance, the implementation of the Cartagene Convention on biodiversity, or of the Kyoto convention related to climate change and sustainable development, creates new international legal constraints for those countries who, on a voluntary basis, agreed to cooperate. In an other specific field, the one of nuclear safety, the international convention, including the application of a formal, commonly agreed integrative methodology, opened the door to numerous, mutual and fruitful peers assessments.

- Prohibition on NBC [65] weapons of massive destruction is a last, but not least, example of the characterisation of a " norm", or "limit", at a global level.

As those limits are so painful and slow to be imagined, defined, negotiated and adopted, implementation of the limit between do's and don't comes eventually in an environment which can be stable or , on the contrary, may follow a path of quick changes. But then, it is too late to move the limits: whatever the level of knowledge about voluntary or non intentional impacts on health and environment, and whatever the imagination of human beings for experiments, not to mention for terrorist use and abuse, the limits are fixed.

2.5 The strict application of the balance between risks and benefits, as a routine commonly accepted by risk assessment and management communities, may be challenged on three main points when we come to try and apply it to nanotechnologies at the heart of converging technologies.

- First criticism, it involves a static approach, not a systemic one: it focuses on linear causalities linking one "event" to its impacts (release of engineered free nanoparticules and toxicity/ecotoxicity studies for example); adjustment over time as well as the complexity related to combinations do not fit the risk/benefit approach. Risk here is considered as the "known" uncertainty only. How to fund research on what "we don't know we don't know", without crossing foresight and a systemic, normative risk assessment methodology?

- Second criticism, it carries implicit values which we may want, or may refuse to share as such. In a competition-led approach, the hidden philosophy for action is " if you don't know it, just try it". The stakeholders are under pressure of fulfilling the expected rate of return on investment (RoI) which should be, for instance, no less than x%, within no more than (y) months or years. Unexpected impacts are being considered as externalities to be supported by the whole community . In a more balanced approach combining market efficiency with social welfare, the "norm" could, and should be different.

Other values we may not want to share are, for instance, human performance whatever the ethical consequences might be. Converging technologies for improving human performances is the title of an annual event in the USA. The question here is as follows: when convergence between nanotechnologies, information technologies, cognitive sciences and brain biology gives access to enhanced capacities, how do individuals and groups *consider the freedom/ ability to opt in favour of enhancement when confronted to competition, or opt out* if they are "fed up", to refer to the analysis developed by Pr.Sheila Jasanoff of Harvard University"[66]?

The model suggested by M. William Sims Bainbridge at the NBIC New-York 2004 event was the one of an artificial intelligence personal advisor, for which an AI system provides personal advice to the individual by simulating a human friend or an advisor. This interaction requires *a significant degree of "personal capture" involving the user*. In this example of convergence, cognitive sciences provide design for judgment and decision-making; IT supplies AI information system; the artefact is based on emotional (physiological) responses, and nanotechnology allows nano-enabled *extreme portability*. Appropriation of such " models" is rooted deeply in a societal bet : "if we build it so they will come…"

Confronted to such models *suggested* to scientists by the orientation of R&D funding, one cannot avoid the neuroethics questions raised by Sonia Miller, who created the Converging technologies Bar association (CTBA): " could the possibility to alter an individual's thoughts and actions be used to forcibly control him in the future?" "Who decides and on what basis?" " What are the safeguards for protecting and disclosing the information?"[67]. More fundamental questions will be raised sooner or later around ownership, control and the social ends to which the converging technologies are being directed by those who determine and provide funds for scientific works; who benefits from it/ is potentially harmed by it; who denies or edits out unpredictable and social consequences in the long run; who is allowed to "take the floor".

Pr. Alfred Nordmann, reporter of the high level expert group on "Foresighting the new technology wave" settled by DG R&D of the European Commission, wrote : " the potential and limits of engineering *for* the mind and engineering *of* the mind need to be determined. Also, the effects on cognitive processes by technical environments should be investigated: if the video game culture has altered how students learn, pervasive artificial environments of the future will have a more profound effect".

Pr. Jean-Pierre Dupuy elaborated on the paradox that the triumph of scientific humanism brings with it the obsolescence of man : " in mechanizing the mind, in treating it as an artefact, the mind presumes to exercise power over this artefacts to a degree that no psychology claiming to be scientific has ever dreamed of attaining. The mind can now hope not only to manipulate this mechanized version of itself at will, but even to reproduce and manufacture it in accordance with its own wishes and intentions. Accordingly, the technologies of the mind, present and future, open up a vast continent upon which man now has *to impose norms* if he wishes to give them meaning and purpose. The human subject will therefore need to have recourse to a supplementary endowment of will and conscience in order to determine, not what he can do, but what he ought to do or, rather, what he ought not to do. These new technologies will require a whole ethics to be elaborated…".[68]

- Third criticism: it prevents from recycling immediately the increase in knowledge about effects and impacts. Significant factors who could influence the limits fixed by a given legal framework, such as the classification of scientific informations related to strategic and safety issues, or the impact of patents governance, are not to be questioned in the classic risks/benefits assessment methodology.

International cooperation and information sharing use to a be a powerful tool for the public evaluation of an existing legal framework, and can help strongly adapting the norms at international, national and local levels. "Adapting", here, means to let the limits move, towards harder or softer ones for individuals and entities, when and where appropriate.

In summary, the risk assessment approach based upon the balance between risks and benefits is far too limited to answer adequately the societal questions raised by converging transformational technologies, in particular between IT and the next generation of nano enabled systems. This means that containing risk assessment to this methodology opens the door to disillusions and, unfortunately, to a loosen appointment with the great potentialities of nano and information technologies. Are we rich enough to throw the baby with the bath's water? No, indeed. The ethical consensus will be challenged in a context already characterized by the emergence of a public opinion trend (not already a "wave"), against all technologies *perceived* as privacy/liberty depriving ones.[69]

We, with Pr. Jean-Pierre Dupuy and Dr. Alexei Grinbaum, would suggest to substitute to this traditional approach of a balance between risks and benefits, which is not as neutral as one would like to believe, another one, more appropriate to the very nature of nanotechnologies, nanomaterials and nano-enabled systems.

This new approach is the one of ***an ongoing normative risk assessment methodology***, because this is the only one which allows us to let the limits move, depending of what we actually, gradually know of the state of the art, its speed and foreseen paths. This concept, supporting a renewed approach, was presented at the Alexandria conference in June 2004, whose aim was to addressing the interest of nations for the elaboration of a responsible international dialogue for nanosciences and nanotechnologies. In particular, considering the limits of a linear and causal approach when assessing risks at the nanoscale, has been proposed by the French delegation and endorsed by participants of this conference involving 26 countries representatives as being absolutely relevant to the nanosciences pervasive applications, and explicitly confirmed by the 2nd dialogue in Tokyo in June 2006. This means that the systemic, long term approach of meta-convergence assessment, if allowed to emerge, will be at the heart of the international agenda for designing the first elements of a global governance.

III CREATING THE MARKET : BEYOND THE DILEMMA ?

We need to enter an accountable approach for public private investment in N&N as regards not only the brighters side, but also the darker side of this new « planet ». **Avoiding the moratorium would be acceptable, had all stakeholders accepted entering, together, the age of responsibility**. *What if there were no consensus*, to quote the question raised by one participant of the conference on "Converging technologies for a diverse Europe"? Probably a lose-lose game, and for the long run.

3.1 What will the next technology wave look like in the long run, say to 2020? By communicating on converging technologies for a diverse Europe, the high level expert group constituted by the European Commission (Foresight unit) in 2004 gave a first general outlook upon the main streams already in motion to shape the future European landscape. Our contributions tried to focus on the most powerful levers for change, through the spreading of convergent transformational technologies (CTEKs, including, *inter allia*, info, cogno, bio, nano) in the whole society, as a matter for public policy decisions at the European institutions level.

We, at the global level, have already entered a new race, willy-nilly, enabled by convergent transformational technologies (CTTs). The holistic combination of those technologies provides a mega-trend from one culture to another. Culture of the Future, as a « second nature », to take one of most meaningful expressions of Professor Eleonora Barbieri-Masini, is already with us, as a seed culture. And culture brings to responsibility.

The point is that this new culture is supposed to lead the new technological wave, and subsequently, us, somewhere. But where? For the greatest benefit of whom? **For converging technologies, as we**

are entering an age of quick climate change and the perspective of lasting geographical, demographic and cultural mutations, we, again, face a choice between responsibility and « game », with stakes of paramount importance.

To be responsible may be defined as to accept and suffer the consequences of one's own actions. One possible definition of « game » then is an activity without gravity, or seriousness, with no consequences. Game does refer to " players", be they "smart" ones, to cite Professor J. Encarnacao, chairman of the European Commission's information society technologies advisory group (ISTAG).

There are many ways to choose the path we want to follow when developing converging technologies, provided that we let the debate blossom from business and private spheres, where it already begun, to the public political realm. As a matter of choice, paths may not identical for the Americas, Asia, Africa and the EU as regards the NBIC approach. North America seems more competition led, whereas EU perceives itself as favoring co-operation, in principle.

The case of transatlantic relationships for the genetically modified organisms (GMOs) trade is interesting for our subject. Eventually, the argument between those in favour of a moratorium and those who advocate free trade, could be interpreted as a struggle to win, by law or sometimes by violent actions, the right to put the adverse party under one's own tutelage. Why? Because pro's and anti groups denied each other the capacity and willingness to take one's responsibilities.

When entering the history of convergent transformational technologies, public authorities cannot act just as if the moratorium story of GMOs, and the related European's crisis of confidence in the capacity of European institutions to properly address citizens concerns, had never taken place. Violent events occurred and continue to happen. Debate and law pursuits in the USA at local levels on GMOs exist too, even if this country represents 60% of GMOs world production, Argentina 21% and the rest of the world less than 20%.

How, when coming to converging technologies, to provide **tools for reconciliation**, if not by exploring new possible ways of performing research and development when environment moves fast, in a highly uncertain context, as it is the case in nanobio or nanoelectronics? If we want to grasp the benefits of convergence, we need to bring the responsibilities of each stakeholder into focus, when addressing a global and possibly non reversible evolution. We need to support international cross co-operation and clearly identify the individual or shared responsibility between researchers, civil society, business and the political actors.

Between responsibility and game, one has to consider, from the European viewpoint, the strategic issues of the global agenda. Research for convergent transformational technologies is highly competitive, with a hidden potential of ultimate dominance where industrial and military players are both fully committed.

3.2 Nanoethics emerge as the appropriate way of addressing the questions of finality, respect of human dignity. Its role as a pre-normative dynamic is now well perceived. Publications of great value from UNESCO and dedicated committees begun providing recommendations[70]. One should not forget that Nanotechics have been perceived, at the beginning, as an imbalanced "speech" against CTTs, in the context of GMO's collective trauma. The important, well-balanced contribution of UNESCO in this field has, since, influenced this perception towards a strict legitimacy to guaranty the right of the people to know and decide. Since, we have faced a great deal of trouble in the European inter-institutional dialogue on this topic, the Prodi-led Commission stating that the file "was not mature" for any decision making at this stage. This, strictly following the precautionary principle, could bring to considering that game already is over for CTT's in Europe, as uncertainty seems too high to be correctly addressed, well in advance of potential negative effects.

How to invest safely, find insurance and provide a new supply in the field of CTT's will require, sooner or later, settling an international framework to go beyond the dilemma, at an international level. Communication and transparency will be required in order to highlight the finalities and priorities followed by public policies and business initiatives in the field of converging transformational technologies, as they contribute to orientation and funding of research. Inciting financial and industrial stakeholders to make due diligences, apply self-regulations, define codes of conduct will be an important step towards an improved, reliable and efficient governance.

The European Parliament welcomed the planned reviews of EU 2005-2009 N&N action plan on issues such as non-therapeutic human enhancement and links between N&N and individual privacy. It expected that the reviews would be public and including a thorough analysis of nanomedicine. It is interesting to observe that in Japan, one of the leading public research programmes for nanotechnologies is translated as « Human Body Building », towards industrial use. One should remember that this same country allowed, in August 2004, human cloning limited to research finality, soon followed by Singapore. The question here about the limits to be settled is an ethical one.

Research Centres of excellence, but also coordination functions of disseminated elements of the required multidisciplinary N&N, will be both be promoted within the Infrastructure and People parts of the 7th FP. As the French Academician Michel Serres, wrote in his book « *Le tiers-instruit*", the greatest breakthroughs for converging technologies may find their origins on the border between two or more disciplines, who are used to seeing an interest in entering a dialogue, up to a certain point.

The European Union and its 27 member states should be in a position to impose their own vision of economic and societal progress, to share it with those who would wish to, and to impose respect for their choices by those who would not share the same societal values. Consequently, there is a responsibility of the European institutions not to delay the appropriate decisions in this field, taking on board seriously the US and Asian public prenormative actions.

3.3 The societal aspects should be carefully addressed at the earliest stage possible. As Professor Emilio Fontela expressed very well, « everybody will have to be ready for Cogno ». We need to make research on enhancement of firm's organisations and knowledge, and to assess the strength and nature of resistance to the mechanisms of appropriation of cognitive technologies, as we enter, with the information society, a world of mixed virtual and actual reality. Augmented cognition for instance is a field for R&D for several decades. It aims at expanding the computer user's abilities - via technologies addressing information overload inherent in human- machine interaction - because of the limited number of tasks a person can perform at once. Acceptability by the labour force may be related, for instance, to the reversibility of the process.

Speed and modalities of a comprehensive integration of CTTs in organisations may be key drivers, or obstacles. We should recognise at an early stage, that the powerful combination of nano and neuro-technologies, and also ICTs, opens a cutting-edge area of inquiry, likely to impact the law. Readiness here, for the society taken as a whole, requires a special focus on the relationship among developing convergent technologies, free will and legal responsibility.

In search of a new model of interaction between research and the public policy agenda, one top recommendation of the Madrid meeting organized by the High level expert group was to determine the aims and modalities of a KEY 2020 campaign for EU (KEY 2020 stands for Knowledge Europe Year 2020). This promotion action would support the European strategy for a knowledge society by showing the course to all the stakeholders. For we believe that the more European stakeholders are involved and give trust to the EU policy as regards CTTs, the easier and the stronger the capacity will be to enter, in the best shape possible, multiple dialogues at the global level.

Among CTTS R&D new models, we found that we needed to give special support to the creation of a **permanent societal observatory** dedicated to assessment, monitoring and management of CTTs dynamics. This entity would be linked to the European Commission R&D Directorate General, working for all the European institutions who would wish so, including the European Parliament

Science and Technology Assessment Office (STOA). More precisely, the roadmap of this observatory would be to create the basis, and provide permanent review of the on-going state of the art in the fields on CTTs in cooperation with the Joint Research Centre and the JRC's IPTS, to combine relevant elements of foresight and, last but not least, to provide valuable information to be used in the international dialogues, in fields of common interest like risk assessment, but not only; appropriate and efficient dissemination of knowledge would be part of the missions, taking into account, at the preliminary stage, all the levels of subsidiary, and the requirements of their related stakeholders. This realisation appears as a condition to enter fruitful talks, on a level playing field, at international level, and to be in a position to explain European choices when the debate comes to R&D public spending, in a context where accountability should be seen as an opportunity to improve the decision-making quality.

3.4 An economic and social observatory of nanotechnologies could be a useful resource for policymakers and the European Executive, in order to assess the impact of scientific progress and the behavior of the parties involved. The quality of business intelligence in this field, as well as the evaluation of public policy, will depend on it. Policy should focus on aspects including enlightened management of technological trends, education of the public and scientific assessment of the risks, as well as on avoiding a regressive macroeconomic process triggered by public opinion founded on fears and misconceptions, rather than on objective factual data available to all.

The ongoing, dynamic and systemic methodology for risk assessment should rely on a new tool to be conceived and implemented quickly from local to global levels , whith the help of new grids. For the European Union, an important step ahead would be the creation of **a societal observatory of converging technologies,** whose ways and means have already been described as follows:

> ***"****The primary mission of this observatory is to study social drivers, economic and social opportunities and effects, ethics and human rights dimensions. It would rely on a standing committee for real-time monitoring and assessment of international converging technologies research. This observatory also serves as a clearing house and platform for public debate. Working groups will deal in multidisciplinarity collaborations with issues of patenting, the definition of commons and the allocation of property rights. The core members in the societal observatory represent policy and ethical perspectives while developing substancial technical and scientific expertise in converging technologies. They serve as intermediaries that bring societal concerns to the research community, and relate research visions to various public constituencies"*[71].

How can formal and informal approaches for research and development be combined and implemented for nanotechnologies? Without a structured, legally binding international agreement, and in order to enter a cooperative process, we should be tempted to suggest the voluntary peers reviews approach. This would be a way to produce a first methodology serving the evaluation process. It requires the coordination and networking of existing observatories dedicated to nanotechnologies , beginning with the EU member states.

I had the opportunity to present this proposal to the European Commission high level expert group dedicated to “Foresighting the new technology wave”. It received full support from this group, and also from participants to the “Converging technologies for a diverse Europe” conference, which is heartening. Indeed, the European Commission is never committed to implementing recommendations from an expert group, but should consider the obvious welcome and election of this societal observatory recommendation among the others. If taken into account in the 7thFP, would allow international networking and may be the creation of a working party dedicated to *sorting out the relevant criteria* for a peers review evaluation methodology. A first presentation has been made at the 3rd Global NanoNetwork Conference in Saarbrücken, may 2005, at the 2nd International dialogue in Tokyo (june 2006) and in OECD’s CSTP working group in Zurich in july 2006.

The best way to legitimize and explain such a program would be to address **the open question of responsibility**, as it eventually was done, but too late, for asbestos production and dissemination. The way by which we usually raise the question of responsibility comes from the cultural perception of risks and the societal response to take them into account.

There is an old French song which sounds like “Who ’s responsible and why did he die? » Nano-powder research laboratories’ workers, unfortunately, appear as one of the exposed pre-cursors to a new kind of risk. No facts, no trials, no responsibilities have been established clearly at this stage, but there are fears growing quickly within this estimable specific research community.

CTTs are increasingly perceived as a risk, sometimes to be dealt with in comparison to the expected benefits, depending on the stakeholders. The official American approach of nano risks, for instance, focus on toxicology research in synthetic nanoparticles and on their direct effects brought by free dispersion. This approach, combined with the willingness to share the scientific knowledge and to enter an overseas cooperation, is a very positive signal.

There is a recent international reconnaissance of emergent new risks related to nanosciences and technologies, as the Alexandria process stressed it (USA June 2004, Tokyo june 2006 meeting of the international dialogue for responsible development of nanotechnology involving 25 countries).. It meets the requirement of insurance companies, now fully aware of unknown and unpredictable risks associated with nanotoxicity or nanopollution. Unfortunately, this focus alone will miss giving the full picture of CTTs risks. Why? A reductionist, causal and linear approach of the nature of CTTs risks, prevents providing a methodology fully adapted to the dynamic potential combinations of nano, bio, info and cognitive technologies.

Beyond the "duty of care" approach, the official Japanese description of *a responsible attitude* is to ensure that the substantial expected benefits of nanotechnology will not adversely affect human integrity and dignity and other ethical issues. Protection of personal digitised data providing physical identification proofs is not of the least concern here.

The context, now, seems characterised by high stakes, slowly emerging political declarations on science, and no perceivable societal reaction. It may be interpreted as a very unstable situation, which opens wide the door to all misunderstandings and even « witchcraft » trials of the worst kind, which we should to try to avoid as part of our collective responsibility. One has to be aware of the first impression given by the media is often indelible. Medias, as stakeholders, have their own part of responsibility when addressing a highly uncertain and complex scientific and industrial field.

3.5 Responsibility? But it can't stop, just relocate...? The raising question of global governance.

This question, which was heard in a discussion group, sounds like a desperate one. It refers to the willingness, or absence of will, to properly assess, address and choose the rules for CTTs development at a global level. We believe that research cross co-operation is necessary to give the global dialogue the best chances to develop, and to avoid tragic environmental and societal dumping in this already highly competitive area. What will happen if gaps widen between, let 's say Europe, who would opt in favour of mandatory regulations, and other parts of the world who would run enthusiastically, without due restrictions, along the fast tracks of CTTs? It cannot stop; just relocate? Is it acceptable for public authorities when public spending and high skilled jobs are at stake? To which kind of disputes would this divide lead to, in the matter of international trade?

Here is a potential different approach in the NBIC report and the High level CTEKs expert group report. The group found that there certainly is a need to try and avoid divergent paths at least in the Transatlantic dialogue and, as quick as possible, with Asia, South America, Africa, and Australia. For without co-operation, there will be no more opt out choice, even when dignity, integrity and sustainable development models eventually come under threat.

The time constant is rather different for Governments, who face a very long run of responsibility at all levels, beginning with local ones (the eventual public support to nuclear power plants decommissioning expenses in the UK remembers that when it comes to very large costs of hazardous activities, the final guarantor remains a public one). The legitimacy of public intervention finds one of its roots here, knowing that lots of the 2020's factors are already, 15 years in advance, predetermined, as explained Norvegian Professor Gill Ringland when presenting the CTEKs scenarios.

Setting rules at the international level for CTTs: beyond good practices?

We had the opportunity to observe that a fully inclusive approach is welcome, but up to a point, by the US Department of Commerce in particular. This kind of approach seems to be perceived by the USA as a weakness, and sometimes as an unacceptable Achille 's heel when considering the need for geopolitical conflict deterrence: the competition economic wargame pulls the vision proposed in the NBIC report. At the same time, a fierce societal debate takes place within the USA, around the rights and limits for each person to opt in favour of human enhancement proposals provided for, or promised by CTTs, like the use of head-up or head-in displays for seamless augmented reality.

The European principles for setting CTTs R&D and, beyond, fabrication rules and regulations at the international level, would be unearthed in the diverse nature of Europe, respectful of other's values, and <u>fully inclusive as an axis of strength</u>. Co-operation (responsibility) pushes the common vision ahead. From our viewpoint, a responsible development of R&D in nano and converging transformational technologies would consider the elaboration of an international framework, if possible built on a commonly agreed methodology for a shared, ongoing, normative assessment of CTTs risks, as well as on a shared observation of the state of the art, and vision of the potential outputs.

To expand, the market itself needs mandatory rules adapted to nano and CTTs in order to find investors and insurers. One has to consider carefully the reasons why the initial public offering (IPO) of Nanosys stopped shortly and abruptly before launch in summer 2004. Considering their use, dual use, and even abuse of CTTs applications, an international framework would help setting clear-cut limits between do's and don't, when and where self-regulation fails to meet the expectations.

A democratic, transparent and multilateral approach, inclusive at an early stage of all stakeholders, could rely on several initiatives. We see two possible, complementary issues to be considered at this stage.

A United Nations, inclusive Task Force dedicated to CTTs international governance would probably help ensure the transition between a decision-making process made by the few, to decision-making process involving more stakeholders; but it is unlikely to meet before the medium range (10 years?) for many forces will oppose this move.

A faster and more pragmatic track could be the elaboration of a methodology for ongoing normative CTTs assessment, beyond the mini/max cost-benefit linear approach. This methodology for evaluation should be supported by the European R&D agenda. It would allow peer-reviews built on criteria for public policy and private practices, operated on a voluntary and regular basis, whose elaboration would involve stakeholders participation, and whose conclusions would be made public. The early designers of the international framework would take the best account of this input to secure responsible public decision making at the global level.

IV. PACIFIC COEXISTENCE ? FINDING THE RIGHT EQUILIBRIUM BETWEEN THE *VISION* OF NANO-STRUCTURED WEAPONS OF MASSIVE DESTRUCTION AND THE MEANS OF MASSIVE NANO-ENABLED FABRICATION.

To give the nanotechnology and converging nanoenabled transformational technologies the best chances to delivering its promises for all, a responsible development of nanotechnology should be ensured at the international level. But above all, it must be ensured at the international level.

As a matter of fact, there is no need to refer to the mass medias hype surrounding the nanotechnologies to understand industrial realities. The patent offices statistics, the amounts invested by venture capitalists, public spending in fundamental as well as applied research, speak for themselves : yes, nanoscience has already left the sheltered confines of the labs to enter the marketplace.

4.1 What does a responsible development means ?

I shall adopt a specific vision of this reality, focusing on the economic and legal matters opened by such a quick evolution, as it expands on a worldwide basis.

Institutional investors, insurances, shareholders and financial authorities have the right and duty to assess the financial risk of their relationships with enterprises involved in the production, or incorporation, or dissemination of nanoelements and structures. They need to act on the basis of financial risk assessment models. Legislation can oblige the chairman of a board to declare on annual basis the potential negative impact of the firm's activities on the environment and the financial risks incurred in case of a legal action to seek redress of a damage occurred at a large scale. The European Parliament adopted a resolution[72] related to corporate governance and supervision of financial services, who supports the European Commission's proposal to tighten up the collective board members responsibilities in the short run, and calls a new proposal in order to create an individual responsibility. But, as far as environmental risk assessments are concerned by financial annual reports, one has to admit that we collectively need a learning process in order to obtain actual implementation of the law...

There is a need to accelerate the risk assessment process initiated at the European level for nanotechnologies and to extend it quickly to converging technologies at the nanoscale, if we want to be in a position to discuss the rules and the price to be payed for, in case they would be broken on a deliberate basis. This point is of a paramount importance, as regards the sincere evaluation of assets in the balance sheets, and the value shareholders would give to firms acting in the field of nanotechnologies. The set of governance rules, ideally, would be settled at the most appropriate level, which is related to the relevant markets and areas of concern.

Multilateral, intergovernmental agreements may provide a helpful framework to nano risks assessment. There are voices expressed in transatlantic relationships whose aims seem to advocate in favour of soft law and self-regulation of the industrial and economic activities related to converging technologies at the nanoscale. The explicit goal here seems to avoid a reluctant approach at the European level, because it would lead to unacceptable trade and investment regional restrictions, based on the precautionary principle, following the GMO's track.

The « cultural » difference between US and UE would be, as ever, the positive « if you don't know it, just try it » American way, versus the negative «first to go, last to know » or in french « *dans le doute abstiens-toi* » European drive. There should be a pragmatic way to bridge the emerging gap, provided that there is a common will to let it happen : a structured, transparent, democratic and multilateral way to address public concerns about the actual knowledge of direct and cumulative impacts of nanoscale productions on the environment and the human beings.

Where there is a clear call for public governance, relevant public authorities should first take the lead.

4.2 **Four questions can be expressed at this stage**.

1<u>) How to avoid environmental dumping</u> by entering, at an early stage, a fruitful dialogue of mutual interest between Asia, Americas, Africa and Europe ?

There are positive signals coming from Japan in this field. The research project on facilitation of public acceptance of nanotechnology issued recommendations for the Japanese government in order to make the societal implications a clear priority topic for collaboration, and to design a policy development framework for a roadmap for implementation of responsible nanotechnology R&D. In particular, this project estimated that a data base is needed, that would incorporate basic knowledge, such as generally accepted scientific opinion on ethical and social dimensions of nanotechnologies and nanomaterials. [73]

2) How to use the specific existing multilateral / intergovernmental tools (hortatory and mandatory ones) and, possibly, amend them to adapt to nano realities :

- for Nano-biotechnology, by the extension of the « Biosecurity Protocole », also known as « *Protocole de Carthagène* » (103 countries signed, but the US) to the nanoscale, including self-assembly (i.e not only new synthetic nanoparticles, but also even classic, known materials with not necessarily well knowned new properties at the nanoscale);
- for Nano-chemistry, by applying the REACH[74] European union regulatory framework on chemistry, to manufactured goods including nano-elements being considered as new substances;
- for Nano-information technologies, by promoting a European union approach through the CEN[75], and participate in ISO TC 229 nanotechnology group.
- last but not least, for Cognitive sciences and NBIC convergence : revisiting the European charter of human rights in order to considering, on a constitutional basis, human dignity and privacy raising concerns due to the progressively strengthening speech in defense of huge, and sometimes unbelievable, human performance enhancements (whatever the ultimate goals) expected from brain/machine and why not brain-to-brain communications...

3) How to promote transparency and citizens commitment to the debate, on an improved and available knowledge basis, through local public governments or consumers associations, amongst other relevant levers of action. Embedded nano-elements or structures should become neither a nightmare nor a dream.

4) Last but not least : how to enter a dialogue with all stakeholders to determine the right burden sharing between public and private responsibilities related to nano risks.

The experience of the multilateral dialogue on the worldwide Internet public/private governance, provides a good basis to understand the difficulties, but nonetheless the social utility, to address seriously, and in due time, this kind of global problem. Under the United Nations Secretary general authority, a group of stakeholders representatives, including governments, NGO's and private sector, has been created by a commonly agreed action plan of the first World Summit on Information Society (WSIS), precisely to define and make proposals to address internet governance issues (either « technical » or public ones) to the second WSIS, and pave the way to further improvements.

If convergence of technologies at the nanoscale and at the femtosecond timescale were to bring such universal issues as the internet already provided, it would not be so unrealistic to impulse a WSIS-like dynamic to assess nano risks and benefits, and review all opportunities to bridge the emerging « nano » economic divide.

International cooperation and information sharing use to a be a powerful tool for the public evaluation of an existing legal framework, and can help strongly adapting the norms at international, national and local levels. "Adapting", here, means to let the normative limits implemented in regulatory frameworks (including international laws of trade and commerce within the WTO), move towards harder or softer ones for individuals and entities, when and where appropriate.

Since the launching of the Alexandria process in June 2004, the international dialogue gained momentum with the new and full participation of China in the second meeting in Brussels the 14th and 15th of July 2005[76], but lost part of its meaning by the fact that the official position of the USA since mid July 2005 has been to oppose any institutional commitment. This has been understood by the whole institutional community as a step backward we wish will be only temporary. Nevertheless, **responsibility gains momentum with a structured dialogue**. It is a condition of trust and support from the society. We need to find the ways and means of a universally accepted framework for this structured dialogue. Otherwise we will threaten the institutional ability to secure the desirable outputs of nanotechnology.

4.3 Structuring the public debate

Trust also requires transparency, democracy and inclusiveness. One must take into consideration the fact that, on two multilateral agendas, the civil society commitment has been obtained and secured : the WSIS, and ISO TC 26000 for Corporate Social Responsibility. Being given the maturity and readiness of the society when it comes to discussing health impacts of GMOs, pesticides and chemicals, one cannot imagine the society to be left behind, as " *sleeping dogs in the nanofield, not to be awakened prematurely*"…

I suggest three questions in order to promoting public debates on values and the normative process related to nanotechnologies:

- sustainability of progress induced by the nanotechnology toolbox, who may put protection of human beings at stake as well as environment protection ;
- the finality, whose priorities' expression allows to discriminating democratically defined projects from those proceeding with private agendas;
- and the public authorities as well as undertakings' social responsibility, beyond intellectual property stakes.

First question, **what could be the contribution of nanotechnologies to a sustainable development**, in a knowledge society en route towards a digital civilization ?

We have inherited of a world where, for two centuries and without any historical precedent, we have been supplied with abundant fossil fuels available at affordable prices. But, in spite of the prospective warning expressed by the Roma's Club 38 years ago, , the wealth of Nations has brought us to the Earth's paucity, with dramatic effects on climate, public health disturbances, pervasiveness of so-called environmental cancers, and the persistence huge social inequalities.

There is an hope that information and communication technologies and converging technologies bring enough low hanging fruits to accelerate the transition from an energy and heavy materials based industrial economy to another industrial organisation able to implementing solutions to dealing with the worldwide energy deadlock, towards which we collectively hurry, with the development of Chinese and Indian economies. The hydrogen storage capacities, fuel cells, sustainable new materials, remote interaction by virtual reality and tele-presence technologies to save energy spending in physical transport, are determining factors highly dependant of the nanotechnology toolbox, who should not, because of their social utility, suffer from barriers to their development. Likewise, the human performances enhancement *tree*, even if it lies at the root of many ethical questions, should not hide the medical applications *forest,* whose aims are repairing deficient corporeal functionalities (both physical and mental). The economic resilience of our social welfare models is, here, directly at stake in an ageing world.

The questions of individual enhancement, in particular the cognitive ones, will need to be discussed taking into account the new possibilities to increase the dignity with which handicapped people would be treated. Otherwise, we could face emerging (policy) statements in favour of new eugenics progressively replacing a public policy in favour of active ageing, as this last concept is promoted by the European Commission's Joint Research Centre.[77]

The European group of ethics for science and new technologies took into consideration those problems and produced an advice related to the ethical aspects raised by electronic implants within the human body. For this group chaired by the Swedish philosopher Göran Hermerén, such implants do not cause any ethical harm *as such*. The questions come from the finality of those implants and from the availability of a preliminary acceptance of their implementation. He stresses that the use of such electronic, biocompatible implants have an impact on the perception of identity and on the human being dignity. This is the reason why their implementation pursuing a finality of remote control should be prohibited, as well as any surveillance applications, but in the occurrence of justified urgency, and under a judge's control. He called the Commission to take the initiative of a legally binding norm aiming at creating a framework to limit electronic implants applications for the human body to repairing medical finalities.

Second question, **what is the finality of integrating nanotechnologies to the production function**?

Public investment budgets in nanosciences and nanotechnologies increased from 3.850 billion euros in 2004 to 5 billions in 2005, not taking into account private investments in intellectual property rights for water treatment, textiles, nanomaterials, organic tissues…

In this field as well as in many other ones, before the readiness for market of the nano-toolbox, the ethical question exists for applied research. The conditions for implementing new techniques have always been discussed and there will be no exception for nanotechnologies. The ones settled for germ cells for instance continue to fulfil actual public debates throughout the world. In this case, finality may never be hidden. Will competition for a non questionable position, understood as the ultimate leading finality of human enhancement *in occupational activities,* be socially acceptable in a knowledge society ? What would be the societal consequences? Would it increase complexity, social instability and, by and large, conflicts of all natures? What would be the benefits of such an evolution and for whom?

In the specific field of micro and nanoelectronics, the huge investments required seem completely justified by the expectation of Moore's law's end, because of the physical limits of density and heat observed at the critical scale of 10 nanometers. The future of the electronic path relies heavily on breakthroughs in bottom up nanoelectronics techniques and numerous technical and economic challenges can be stressed around the following questions[78]: how to manufacture at an acceptable production cost beyond the physical limits of extreme lithography? How to monitor and control auto-assembly in order to provide guaranteed, desirable properties? How to implement quality controls in a context of high behaviour variability of synthetic 3D active nanoparticles? How to proceed with innovative and responsible nanomanufacturing systems whereas providing a high level of safety for workers, consumers and the environment for very long periods of time ?

Precocity in taking into account risks generally qualified as hypothetical because their very systemic nature prevents them being accurately perceived, is a key idea of radical scope[79]. Philosopher Hans Jonas, used to stress the completely original dilemmas, the increasing complexity and the sophistication of the subtle differences introduced by biotechnology under the reign of morality. For this author, the knowledge here required is both an objective knowledge of physical causes, and the subjective knowledge of human beings ultimate goals. The ethics of the future need this foresight according to a scientific method, of up to which point our today's real acts may lead to a chain of causes and effects, to deal with the future not blindly, but while keeping eyes wide opened.[80]. This proposal adapts quite perfectly to the question of convergence of transformational technologies. It, too, suggests the question of limits faced by the civilizing will, when confronted to new 'continents' (cyberspace, matter-living organisms convergence…)

The artificial life's program already has its international society[81] linking high level scientists around structuring projects. Our generation assists to the simultaneous emergence and to tests of outcomes of mathematical research on relevant algorithms for artificial-living interactions and the corresponding software techniques ; of biocompatible and non invasive synthetic nanomaterials ; of radio-identification techniques; of simulation and measurement for the brain's electric activities with medical applications like Alzheimer disease, nervous breakdowns, obsessive chronic disturbances…).

Third question : how do public authorities and civil society cooperate and share the burden in designing the future?

The citizens have the right to be informed and to challenging the finality of the full integration of nanotechnologies in the investment function. They have the right to define the role those technologies might play in the convergence, as soon as they have the feeling of a potentially significant impact upon values and the living. In a democratic regime, they have the power to accept or influence the proposed equilibriums between, for instance, the two objectives of security and privacy. They must choose the legal framework, provided that they have access to all the relevant knowledge .

Instead of "public acceptance", **informed trust** is difficult to build and requires a commitment of democratic institutions at each relevant level of subsidiarity. Informed trust relies on a strong will to promoting *upstream* dialogues helped by public funding for education, information and citizens groups debates.

The United Kingdom has taken the lead in organizing citizen juries. The Royal Society report puts into light extremist visions of the potential applications of nanotechnologies as the view of consciousness and body separation, which may seem too far, but nevertheless may constitute the rear panorama of the discussions about nanotechnologies' impacts led by non informed, non scientific persons.

Since the lasting GMO's and asbestos crisis, informed trust seems to be the only path between moratorium and *laisser faire*. The European commission has opted in favour of a communication policy calling for public dialogues. Among the divers programs, Nanologue[82] et Nanodialogue[83] , have received respectively 340k€ et de 850 k€ to fulfil this objective. Nonetheless, they do not have by themselves the capability to working in depth on dialogues because they are not supported, at this stage, by an actual work on education and appropriation by the citizens themselves of the key concepts, semantics and evolving environment of nanotechnology. Under those circumstances, how to designing a positive context enabling the emergence of an informed trust for European citizens?

For nanotechnologies, there is no precedent choice in reference to which one may take positions. We enter a stage of quick developments for the integration of passive nanostructures to existing goods or functionalities. Implementation of the firms' social responsibility might be facilitated by a democratic, safety-oriented option.

This leads us to the question of **responsibility's burden sharing** in the application of the precautionary principle. Taking due account of each level of subsidiarity from local to global basis, the ethical, legal and societal criteria upon which an evaluation of the implementation of the precautionary principle can be steered, apply in principle to three sets of decision makers:

- individuals, who can appropriate ethical guidelines, or choose to break the rule ;
- undertakings or organizations following their own goals within the legal framework available ; this framework can be characterized by evolvability and a wise implementation of the precautionary principle leads us to prefer this option[84] ;
- public authorities, bringing the guaranty of full implementation of the public missions of general interest and being accountable for their action.

The question of responsibility in the choices and implementation of the nano toolbox is to be challenged at each level of subsidiarity. With an international dialogue for responsible development of nanotechnology now in good way to structuring itself on an inclusive basis, the very systemic nature of risks, and in particular those designed along with active and complex nanostructures has been accepted in 2006, which is a very positive outcome.[85]

One may observe that the mandate given by the Member states to the European commission and the best efforts it accomplished in order to promote a code of conduct and an action plan to its international institutional partners[86], no practical global outcome emerged. The supranational aspect of responsibility for reseach and manufacturing had been stressed early (2001) by the consultative industrial group NanoSTAG.[87]

Civil society expressed itself, in particular through ETC group, Greenpeace, Friends of the Earth or the Fondation pour les sciences citoyennes were aware of this first step. But one must admit that it has not be possible to elaborate on a joint instrument yet, neither a code of conduct, nor a legally binding text.

All the same, European Union Member states by adopting an action plan, and OECD countries by organizing specialized seminars, and have tried to increase their level of knowledge and of awareness on industrial challenges and societal impacts of nanotechnologies. They do not have underestimated the importance of the relationship between science and society in this field. European and international standardization organisations have focused on those subjects. Asian countries as well have raised publicly their willingness to increase the preparedness of their stakeholders.

But if the social responsibility is to stay for some stakeholders at an indicative non binding stage, for instance in line with the future ISO 26 000 standard being discussed with the participation of the International Labour Organization, on the contrary, the public authorities social responsibility is, by no means, an *option* : it is politically mandatory.

The USA created a research centre dedicated to societal implications of nanotechnologies. The mission of this centre is to design a long term vision of environmental, societal and ethical concerns brought by nanotechnology and the educational gap to be fulfilled in this domain. The NSF contributed to this project with two budgets with 34 M$ granted in October 2005 and 39M$ in 2006.[88] This decision follows a recommendation made by a Conference report[89] from the House of Representatives, directing OSTP to work with agencies receiving funds under the Act for the National Nanotechnology Initiative, to set aside a portion of the funding to analyse and report on the ethical issues generated from the research and development of nanotechnology. The conferees expected OSTP to follow the pattern established for the human genome project, allocating three percent of funding to ethical, legal and social issues research, with a special concern about the possibility of the development of superhuman intelligence.[90]

* * *

In conclusion I would like to stress the fact that our desire of future is probably at stake in the ethical question of impacts of nano-enabled and converging transformational technologies on our values facing the question of individual enhancement of performances. Economic competition has its own virtues as regards innovation and industrial supply at affordable costs, in particular when addressing global and unsolved challenges like shortage of rare raw materials, drinkable water, energy sober in green gas effect emissions and medical, personalized applications .

But citizens, civil society and deliberative assemblies are also called to playing, at each level of subsidiarity, a significant role in shaping the future they want, and in brushing aside the options they will consider against their choices of civilization. Of the equilibrium between cooperation and competition in the field of the new industrial revolution brought by nanofabrication and converging transformational technologies at the nanoscale, depends our future welfare and perpetuation.

Otherwise, the swing in the pendulum might be devastating.

Tables

Table 1

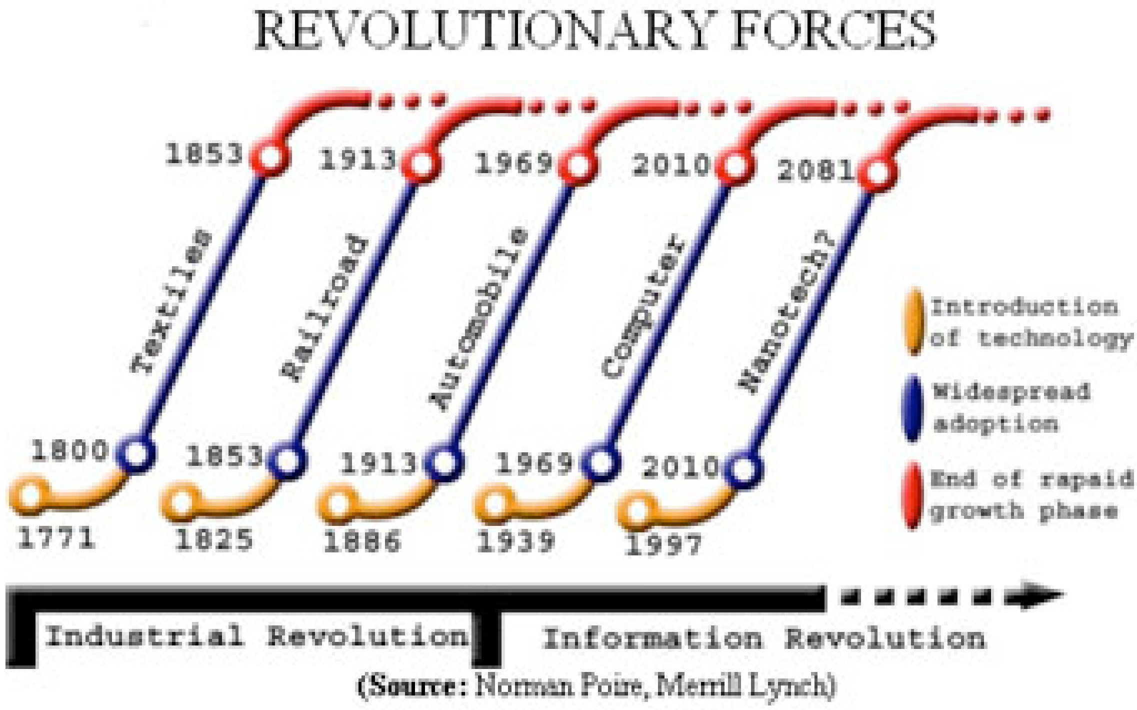
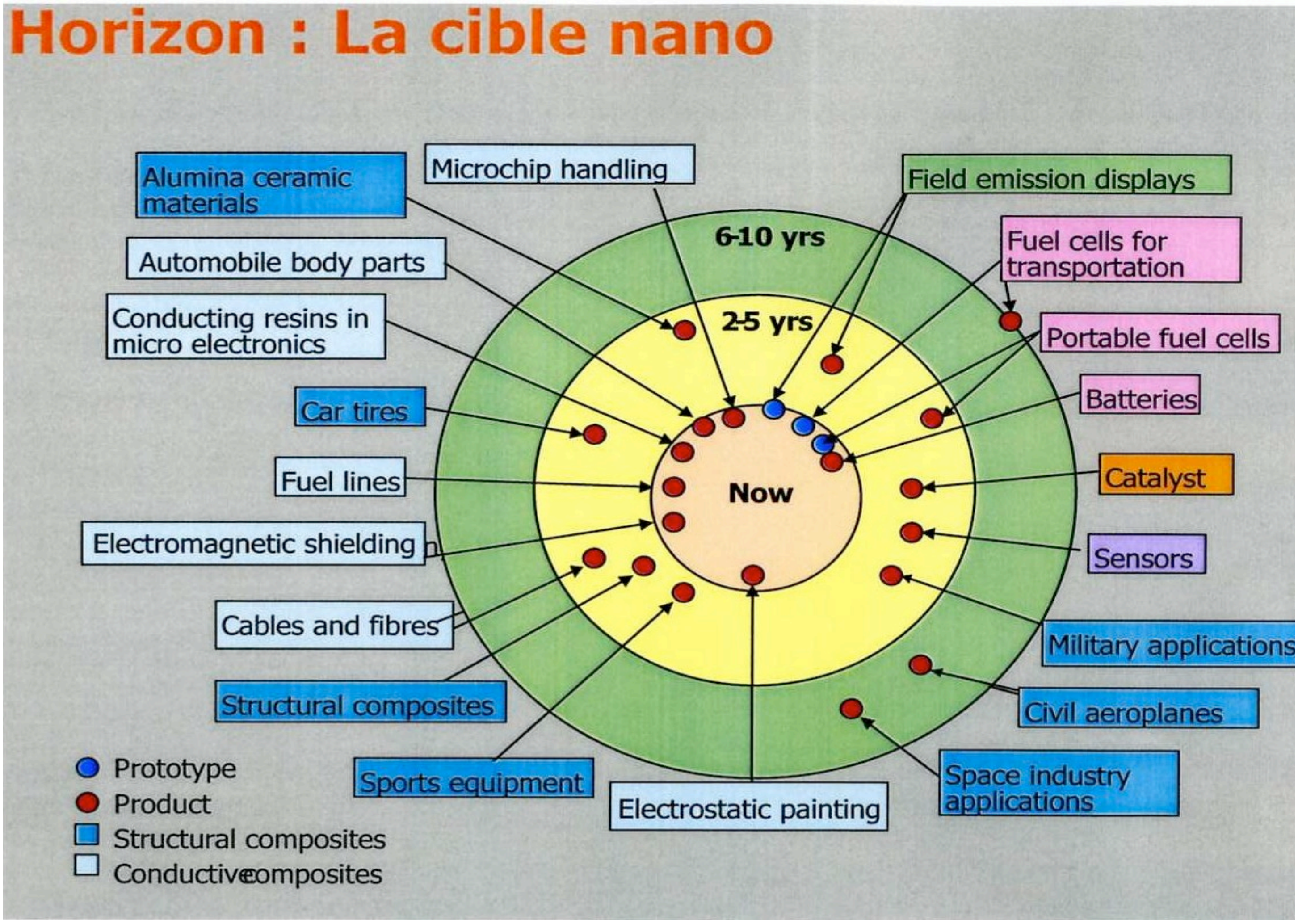

REVOLUTIONARY FORCES
1853
1913
1969
2010
2081
Textiles
Railroad
Automobile
Computer
Nanotech?
Introduction of technology
Widespread adoption
End of rapaid growth phase
1800
1853
1913
1969
2010
1771
1825
1886
1939
1997
Industrial Revolution
Information Revolution
(Source: Norman Poire, Merrill Lynch)

Table 2



Source : Hervé Durand, Cientifica, Observatoire des micro et nanotechnologies (OMNT) january 2005, 27th

Table 3

COMBINING IPv6, RFID, Micro nano Robots and Life?
(human beings and other Living organisms)

ROBOTICS as a synthesis of convergence:

- AIRBORNE Robots and miniaturization
- TERRESTRIAL Robots : a *holonomic* future ?
- SUBMARINE Robots : surveillance and action
- WEARABLE Robots for civilians and the Army
- COOPERATIVE smart teams of Robots
- Networks of remote controlled/ autonomous/ embedded Robots?

Where control problematics emerges……in a brave new world of complexity and uncertainty.

TECHNOLOGY v/s FINALITY

Table 4

Source : Canada DEF

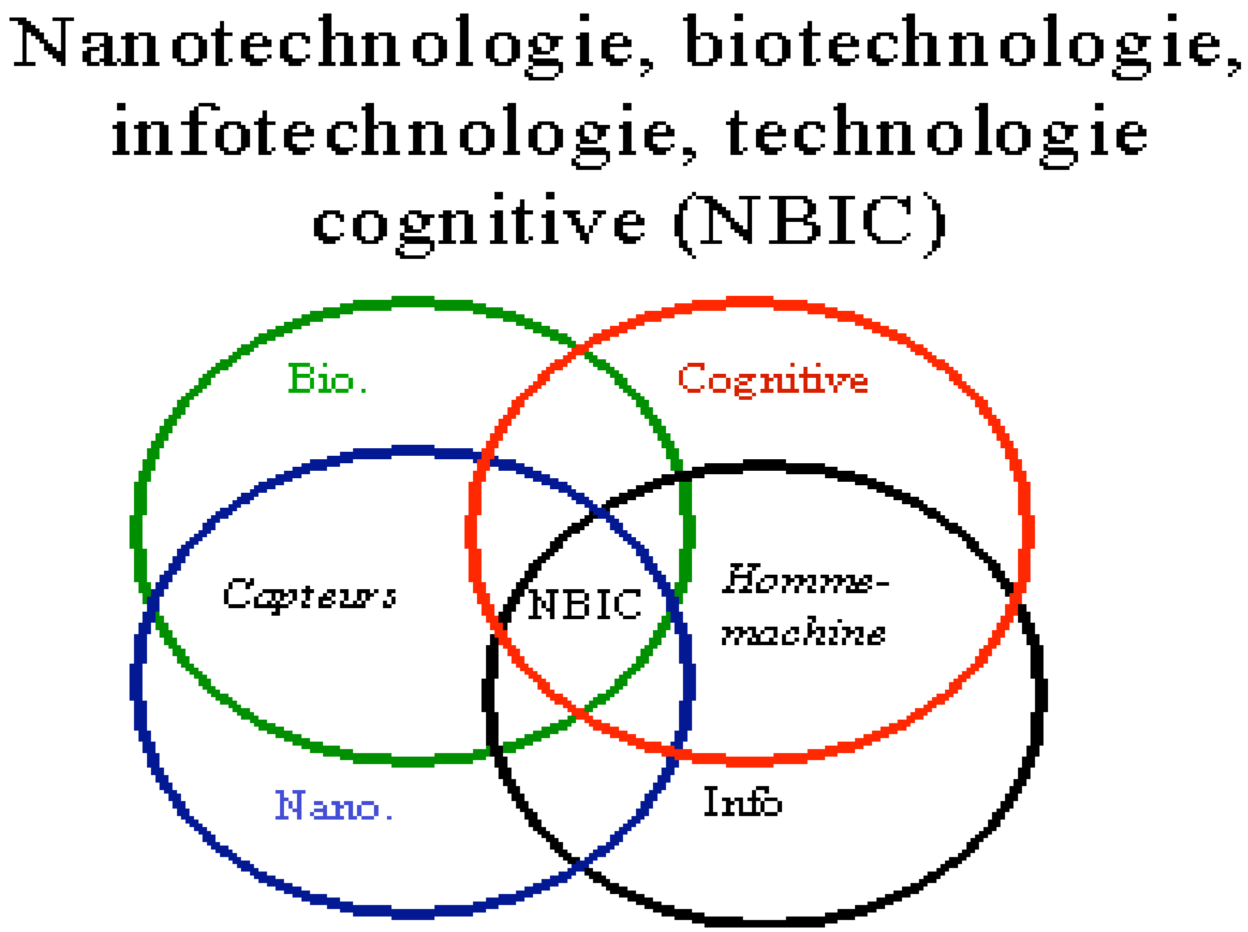
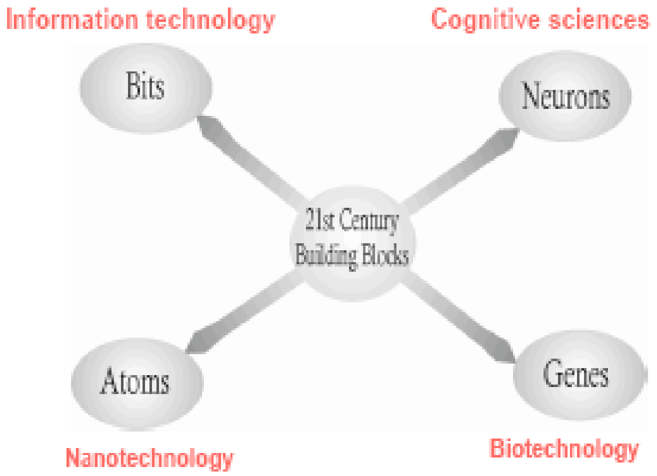


Table 5

Convergence



If the *Cognitive Scientists* can think it
the *Nano* people can build it
the *Bio* people can implement it, and
the *IT* people can monitor and control it

From a workshop participant (W.A.W.) MC Roco, 4/22/04

Table 6

How should we understand the nature of 'resistance'?

An important point is that, from one perspective, resistance is simply part of the selection process through which new technologies are adopted or rejected. Modern market economies tend to generate many technological opportunities, but relatively few are diffused into widespread application; resistance can be seen as simply one of the ways (failure in the market is another) in which technologies fail to achieve acceptance.

Recent theories of technological change tend to follow an evolutionary perspective, in which the dynamics of technological change are based on some process which generates variety and diversity among technologies, and some mechanism which selects among the new varieties. It is important to note that in the evolutionary perspective the selection mechanism is not simply the market: it involves the whole complex of non-market decision processes, and there are many ways in which technology can be accepted or rejected by relevant actors. These non-market decision processes may involve, for example, public or semi-public procurement decisions, or political decisions to regulate, control or promote a technology. When there is continuous generation of technological variety, selection among alternative lines of technical advance is always necessary, and this selection process can easily be pictured as 'resistance'; but we should not see this as resistance to technological advance as such.

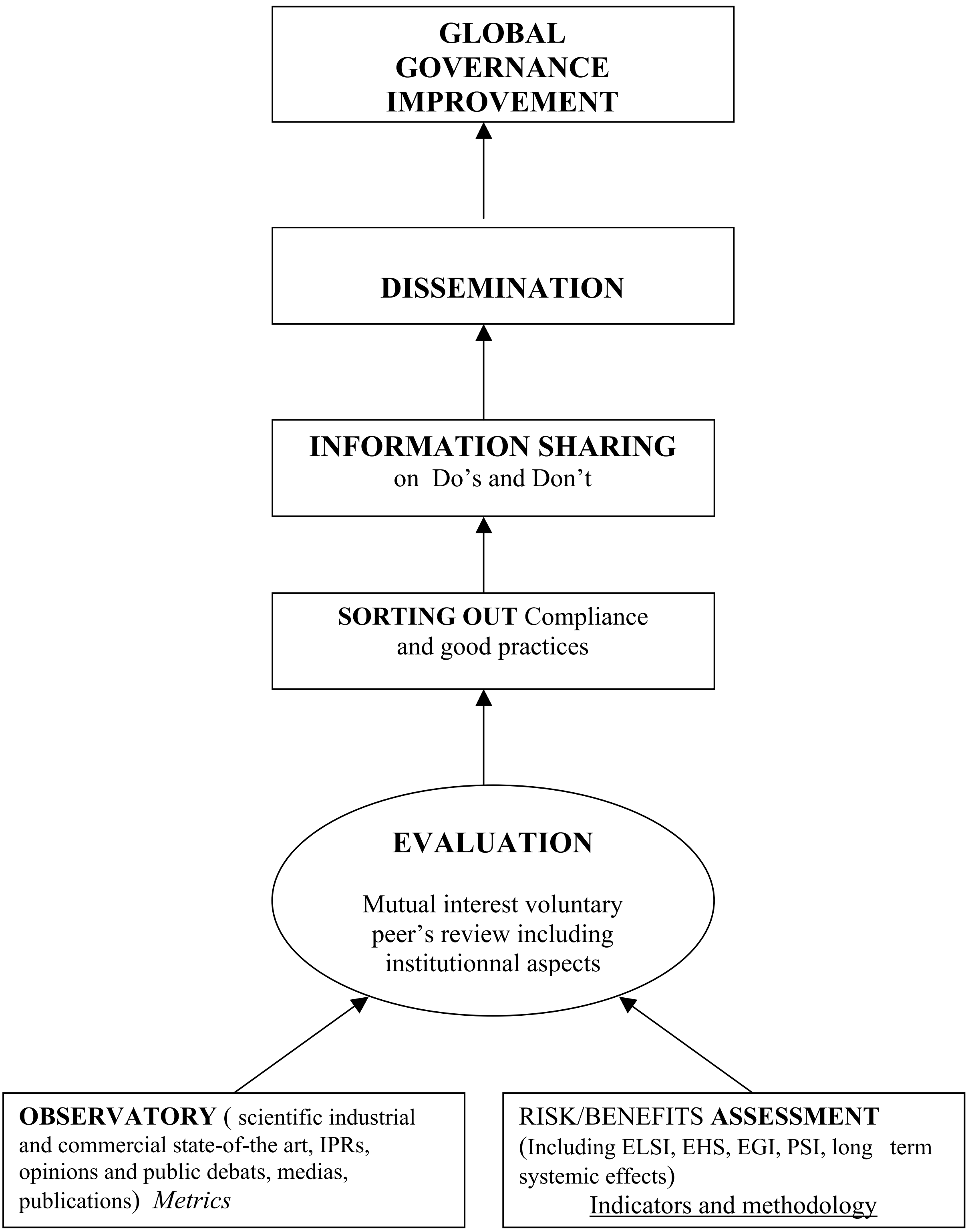
The necessity of selection is integral to the technological change process as a whole. Many modern technologies, in particular biotechnology, genetic modification and nanotechnology, are encountering severe resistance in Europe, and a deeper understanding of the character of this resistance is necessary if these technologies are to become genuinely useful in our society.

Source : HLEG Foresighting the new technology wave 2020. SIG Nano economics, Madrid meeting, May 2004

Table 7

TOWARDS AN INTEGRATIVE EVALUATION OF NANOTECHNOLOGIES

Suggested "upstream" roadmap



End notes and bibliography

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