



Designing The Future

NBIC Technologies and Human Performance Enhancement

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Abstract

Never before has any civilization had the unique opportunity to enhance human performance on the scale that we will face in the near future. The convergence of nanotechnology, biotechnology, information technology and cognitive science (NBIC) is creating a set of powerful tools that have the potential to significantly enhance human performance as well as transform society, science, economics and human evolution. As the NBIC convergence becomes more understood the possibility that we may be able to enhance human performance in the three domains of therapy, augmentation and designed evolution will become anticipated and even expected. In addition, NBIC convergence represents entirely new challenges for scientists, policy makers and business leaders who will have, for the first time, vast new power tools to shape future markets, societies and lifestyles. The emergence of NBIC will challenge us in new ways to balance risk and return, threat and opportunity, and social responsibility and competitive advantage as we step into the 21st century.

Welcome to the New Future

We take for granted the speed of innovation that has created the global social context around us. But against the backdrop of fast innovations we see today, over the next fifteen years we will see an acceleration of innovation, change and disruptions on a scale no civilization has ever seen before. Why? The tools of the 21st century are growing exponentially more powerful. The increased capacity for fast innovation and invention--from biotech to nanoscience--will emerge faster than in the past. Increased computing power, high-speed networks, interactive broadband, distributed genomic discovery, and Internet 2 all are bringing future innovations closer. It is the interplay of key technologies, the synergy of technology trends together that will create the most comprehensive impact on society, individuals and the economy.

Human Performance Enhancement

Human Performance Enhancement, (HPE) refers to the augmentation of human skills, attributes or competencies through the use of technology, medicine or therapy designed to replace or increase performance capability [1,2]. Examples of HPE run the gamut from restoring sight or hearing to manipulating genetic material with the goal of promoting or preventing a condition [3,4,5]. Other examples include augmenting normal capabilities such as intelligence, perception or mobility [6].

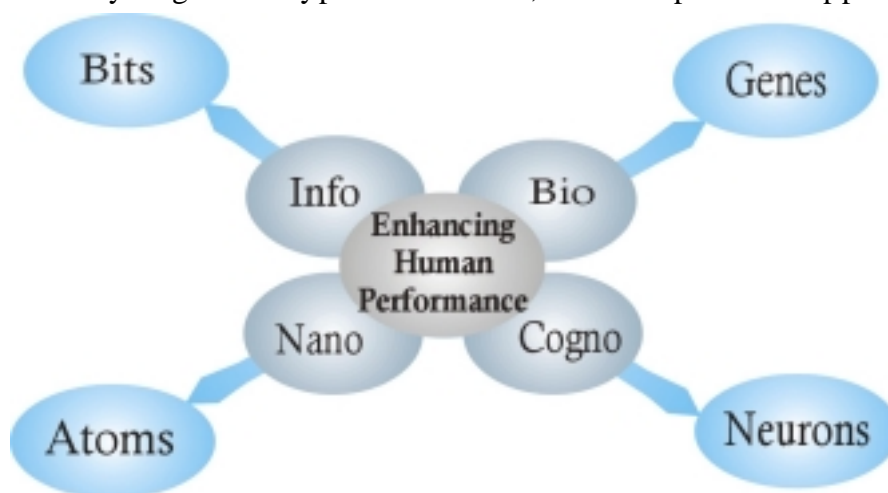
The convergence of nanotechnology, information technology, biotechnology and cognitive science represents the nexus of these power tools that may transform society, markets and the global economy. These statements are not made lightly considering fast moving innovations we see today from cloning to stem cell work. The recent repair of a young boys heart by stem cells being injected into the heart just scratches the surface of what's to come as we move into the future.

Nanotechnology for example, defies the alchemists and Newtonian scientists alike by offering us a radical new tool set to manipulate matter at the atomic level. Nanoscience is disruptively astounding for the potential it may hold to alter much of what we know. What new ways might we design organic or inorganic materials to extend health, to heal, to create new forms of energy? Each of these examples offers an extension of challenges to markets, science and society.

Information technology--having brought the convergence of computing and the Internet--is the accelerator of global knowledge distribution rivaling any information utility. But the combination of NBIC power tools to create social, economic and scientific change represents startling possibilities in the potential for defining, perhaps for the first time, human enhancement.

Re-Thinking Science

We are at the threshold of re-thinking science building towards a more unified and integrated systems approach. Research conducted by the Institute For Global Futures, shows that NBIC could have a more profound and comprehensive impact on people's lifestyles, society and the economy than any other combination of forces if the support from the scientific community were to embrace NBIC research. The potential is that NBIC may forge a new type of innovation, if it is adopted and supported.



NBIC represents a new type of thinking first for scientists but not in any ways exclusive to scientists. In fact, the systems approach is not really new; witness the large commitment of scientific literature attesting to the validity of this approach. Applying the systems approach towards an integrated view of these NBIC disciplines is new.

There are glimmers of insight appearing at the edge of science that point to the systems approach: Biogerontology is the new discipline concerned with longevity and understanding aging. Nanobiology [7,8] a field just emerging, considers the unification of biotech and nanoscience. Systems biology, looks at redefining the next generation of biotechnology but looking beyond the accepted paradigm to consider the larger systems that intersect with human biology [9,10]. There are other markers as well.

NBIC convergence, as an effort supported and led by the National Science Foundation is the beginning of an examination of the complexity of developments that share common goals, purposes and processes. In other words, this new effort to combine scientific areas is about considering the acceleration of innovation--creating more effective results and a deeper understanding of how convergence may provide better solutions to enhancing human performance-- whether the innovation is a new drug, device, enhancement or treatment. Can we accomplish this faster, with deeper understanding, by unraveling the areas of scientific convergence that might provide new insight? We think so.

NBIC convergence is also a marker for where the future is emerging. Already systems biology recognizes the need for data and expertise outside of biotech alone, to provide a systems approach to gene discovery and personalized medicine. Systems biology is recognition, that given the immense complexities of unraveling the human genome's usefulness, we need new models of thinking about human beings, science and discovery in order to accomplish this daunting task. We cannot get there from here without changing our mental models of how we perceive science.

The NBIC convergence power tools rely on a new generation of building blocks: bits, atoms, neurons and genes. These are the media that NBIC scientists will use to design products and services. We already see the marketplace becoming defined by companies that are gaining a competitive advantage through the manipulation, production, analysis and intellectual property associated with these building blocks. Work in genetic programming at Intel for the next generation of microprocessors, nanoscience-based logic gates for tomorrow's computers at Hewlett Packard and IBM's work on nanodrives for data storage are just some examples of this innovation that may drive tomorrow's competition.

The Human Performance Enhancement Market

The market for human performance enhancement is yet to be defined. This paper attempts to define some parameters and examples. At the risk of raising the specter of eugenics or any other Orwellian scenarios let me first state that human performance enhancement is not a forced manipulation of human beings outside the freedoms and

values of a democratic society. We will not be able to de-link human performance enhancement from the values of social ideology nor the market demands of economics.

No doubt there will be countries and cultures that view HPE (human performance enhancement) as a weapon for overt or covert social manipulation. There will be autocratic nations that view the enhancement of their population's intelligence, mobility or other cognitive and physical capabilities as desirable. Of course there will be abusers of HPE. Planned social evolution based on HPE will be a not-too-distant-future scenario that democratic societies will have to navigate. But at the same time, individual choice will prevail if global social order and democratic values is a desired goal.

Many will shrink from this mixing of science and politics. In a future global economy where the proliferation of weapons is widespread, it would be naive to remain agnostic to the social manipulation of individuals by those governments who thrive on oppression. Science will need to be in balance with the marketplace as well as the ethics in society.

Just as human cloning has been rejected in many countries, there should be debates on what HPE means and what will be available and what will not. We must in all accounts protect the integrity of the human genome from forces that might seek to destabilize it. We want to tread carefully with ethical science, global stewardship and social welfare in mind as we navigate the new domains that human performance enhancement may bring.

There are trends emerging in the current debate about stem cell usage and therapeutic cloning that would suggest the emergence of a global market for HPE. Stem cell research is proceeding unfettered outside the U.S. For the first time in US history a fundamentally new technology with clear value for human health and medicine has met a variety of limiting factors to conducting research.

Due to the globalization of science, the proliferation of power tools such as NBIC, no technology can be restricted for very long if there are clear and certain benefits for enhancing human health, and a market hungry for its products. NBIC sciences, as an indication of consumer demand for human enhancement will play an important role in the emergence of a new global market no government will be able to fully control.

Therapeutic cloning, for organ replacement in the US market will become a reality, even if you acquire your organ offshore. Certainly, you will not allow your wife, son or father die because you cannot get the organ you need in the U.S. when it is available in Europe or Asia. Over sixty thousand Americans will die this year from not having the organ they need. Again, a global market for HPE will emerge and NBIC will help enable it with the power tools of the next economy.

On an individual basis, HPE is already in demand. Today elective enhancements from fertility science, to plastic surgery to prosthetic limbs, and wonder drugs like Prozac and Viagra are all designed to enhance human performance. This impact on lifestyle gives us some indication what the market, the interest and customer demand might be in the future.

Based on our studies at the Institute For Global Futures, global demand will be high and demand will drive research investment parameters. Just as the current markets for plastic surgery, mood altering drugs, and even beauty and fitness aids total in the billions of dollars spent by consumers today, tomorrow this market will be multiplied many times over in a world where longevity and health enhancement become the most valued assets.

Some HPE procedures are restorative others augment or even transform. These are small examples that point to a future in which NBIC moves into delivering mature procedures or treatments. NBIC may translate into genetic vaccines, neural implants, in vitro genetic management, even physical, biochemical and behavioral enhancements that prolong life. Given choices for enhancing intelligence, mobility, and physical attributes—who could resist prolonging life or health? Our research shows there are significant factors that will drive the emergence of the human enhancement market making it robust, desirable and inevitable.

Market Drivers for Human Performance Enhancement

78 Million Baby Boomers will shape and drive the market for human performance and health enhancements. Boomers control the largest concentration of wealth of any demographic population on the planet. The Baby Boomer marketplace will set the standard for future generations They will want just what the boomers want in terms of human performance enhancement: longevity, personalized medicine, sensory enhancement, improved intelligence, mobility and memory.

Not only will Boomers be living longer, they will demand human performance enhancement as their right. Enhancement will be the key lifestyle trend of the future.

Generations that follow will not settle for less than their Boomer parents, they will want more enhancement at better prices. They will want all the upgrades. Their collective sense of entitlement of enhancement will be a decisive force that will win political elections, will set government and private sector scientific research agendas and will fuel a trillion dollar global enhancement marketplace.

Three Domains of NBIC Human Performance Enhancement

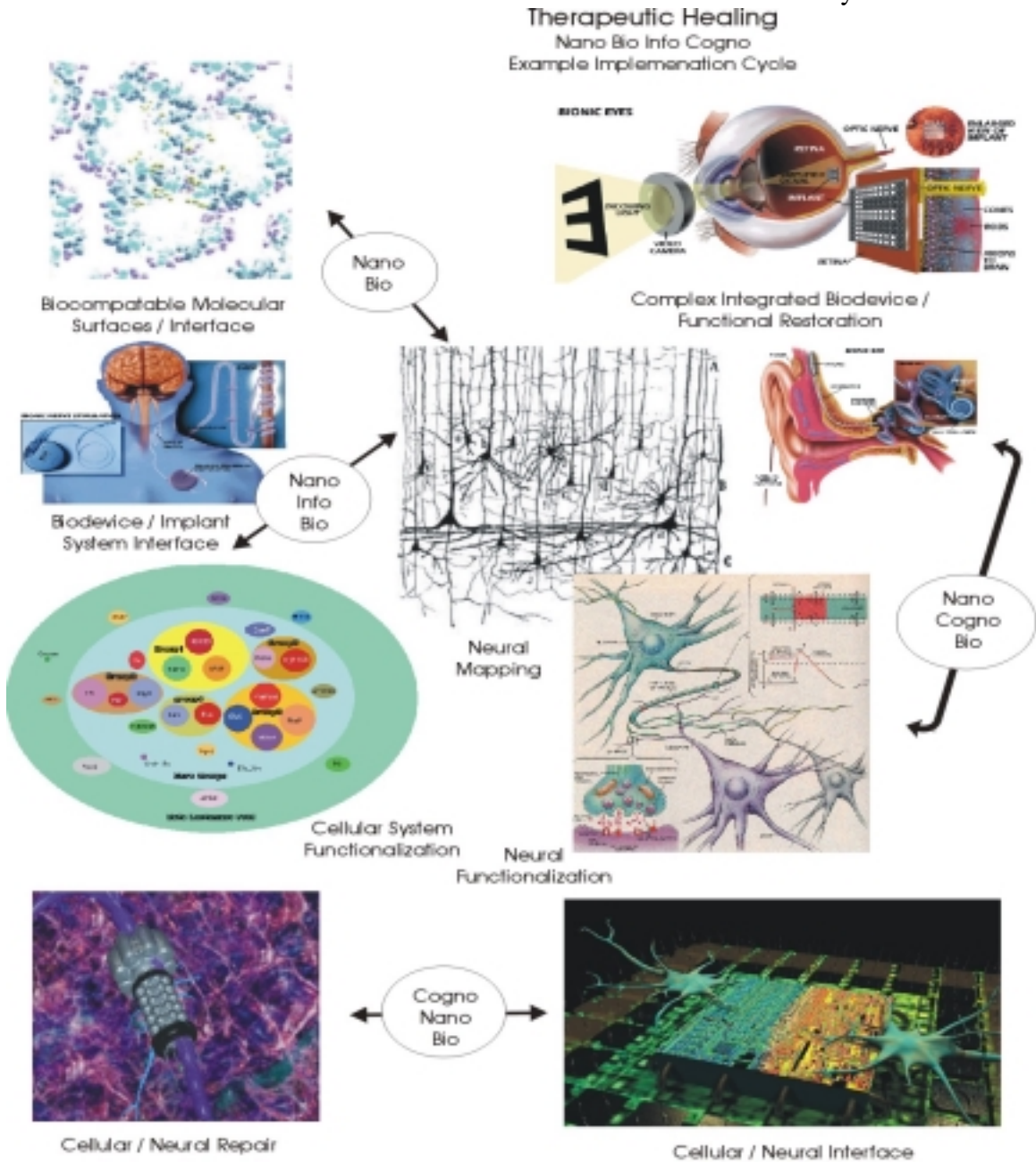
The Three Domains of NBIC human enhancement performance are:

1. Therapeutic
2. Augmentation
3. Designed Evolution

1. Therapeutic

Therapeutic refers to the enhancement of human performance to restore normal human capabilities to the disabled or dysfunctional [11,12,13]. Conditions resulting from disease, birth defects, or accidents would fall into this category. This domain has already emerged and will be accelerated by NBIC. Examples of Therapeutic enhancements include:

- Restoring sight
- Restoring hearing
- Prosthetics for limbs
- Genetic vaccines
- Depression Management
- Personalized Medicine
- Organ Cloning
- Memory Restoration
- Mobility Restoration



2. Augmentation

Augmentation refers to the enhancement of human performance to superhuman levels. Anyone who is a candidate for therapeutic human performance enhancement will want augmentation as well. Augmentation will begin to appear in the next 5-8 years. The augmentation of cognitive, physical and other capabilities could have a broad degree of customization based on career, age and interests [14,15]. Some examples include:

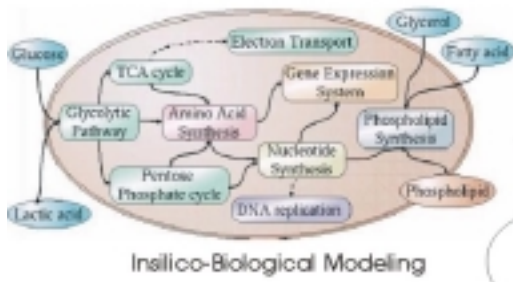
- Enhanced Memory (total recall)
- Infra-red Night Vision (security workers)
- Wide Spectrum Hearing
- Long-range vision
- Specialized Tool Augmentation and Cybernetics (doctors, engineers)
- Embedded Wireless Communications (knowledge workers)
- High Velocity Robotic Limbs (athletes)
- On-Demand Strength Augmentation
- Preventive Medicine and Enhanced Genomic Health Promotion
- Cognitive Multi-Tasking (project managers)
- Personal Genomic Optimized Analysis
- Visual Cognitive High Capacity Storage (transaction agents)
- Real-time Visual and Voice Data Mining, Search and Discovery
- Synaptic Knowledge Access Port (direct Internet link)
- Haptic Virtual Communications Interface (simultaneous language translation on-demand)

Extended Sensory Capacity
Intellectual / Cognitive Capacity
Strength, Endurance Attributes
Extended Longevity



Augmentation

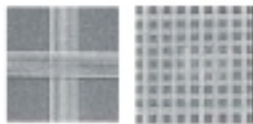
Nano Bio Info Cogno
Example Implementation Cycle



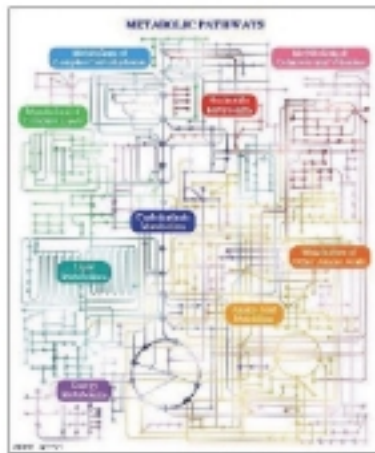
Insilico-Biological Modeling



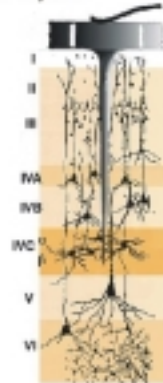
Extreme Supercomputing



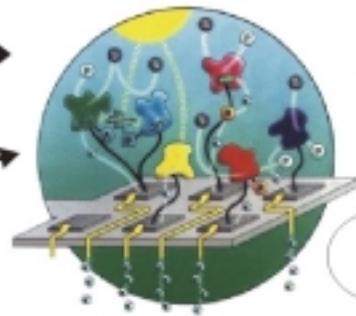
Nanoelectronics / reconfigurable architecture enabled Next Generation Supercomputing



Complex Insilico-Biological System Modeling



Direct Neural Interfacing
Sensory / Cognitive Enhancement



Biocompatible Molecular Interfacing
Micro / Nano Integrated BioDevices



Complex Cellular / Subcellular System Interfacing

Info Bio

Cogno
Nano
Bio

Nano
Bio
Info

Nano
Bio

Nano
Bio
Info

3. Designed Evolution

Designed Evolution refers to human enhancements that we might choose to make in vitro, prior to conception and after birth, involving the human genome that as individuals and as a society we have ethically and scientifically chosen. This could include in vitro enhancement of memory, intelligence, speed, agility, and certain behavioral and physical attributes.

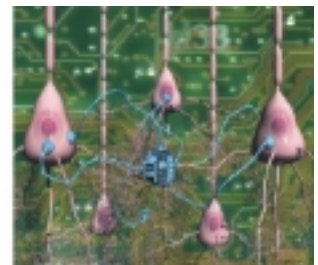
The largest area will be the in vitro identification of undesired genes that might be precursors for dysfunction or disease such as cancer or alcoholism. Although this domain of human enhancement is 8 to 15 years away, decisions and choices will be made in the near future that will set the stage for the future.

Different cultures will choose different paths, some in direct conflict with their citizens and other cultures. Ideology, politics and religion will collide with science as experiments driven by the brazen and bold, unfettered by social responsibilities and ethics will create a higher degree of geopolitical risks. Some examples include:

- Longevity Enhancement
- Optimized Immuno-Defense
- Co-Evolutionary Man/Machine Cyborgs
- Digitally Engineered Personalities
- Human Clones
- Anti-atrophy muscles that resist degeneration
- Bones that replenish through self-assembly
- Intracellular disease scavengers that search and destroy on-demand

It is entirely possible that the scenarios that will shape our future are already underway. Cisco's routers operate like neural networks fed by their own language human's don't speak. Motorola talks of digital DNA and IBM's work with furthering autonomic computing seeks to model itself on the human autonomic system. Already all gene discoveries are optimized by IT. In fact BioIT is the new model where in-silico efficiencies have replaced wet labs. This work and others demonstrates that the NBIC models are emerging.

Co-Evolution with Emergent Intelligences
Genetic / Biophysical Enhancement
Accelerated Environmental Adaptation
Extended Longevity & Functionality



Concluding remarks

We need new models of scientific discovery to solve the many mysteries that are so fundamental to our reality today. We know little about the brain and cognitive science and both are essential to understanding our universe. Doctors lack a deep understanding of the personalized genetic interactions and are forced to treat disease as a molecular event.

Just a few short years ago scientists took the first steps to decoding the human genome--yet we still refer to parts we don't understand as junk DNA. We need perhaps new models to accelerate discovery. That's what makes the work around NBIC so interesting—not for what we think it may uncover today but for the new models of discovery it may create tomorrow.

We need to invent another way to unlock the concepts, strategies and problems that will lead to solutions [16,17,18]. The mysteries that keep AIDS, cardiovascular disease and cancer prevalent may one day be solved with systems approaches such as NBIC.

We need to proceed carefully with an eye towards social responsibility and with the democratic rights of individuals squarely in view. We do not want NBIC or human performance enhancement to be subverted by rogue interests, corporations or governments that might misuse or oppress individuals. Human enhancement should be an individual choice protected by the state but not mandated or used as a tool of oppression or an attack on freedom of choice. Not all cultures will embrace these values, but science and society's values will need to navigate a complimentary vision of the future.

NBIC is not a silver bullet. It is a metaphor that recognizes that greater efficiencies may emerge from thinking about new models such as a systems approach to science. The combination of innovations, strategies and solutions offered by NBIC can be catalysts for human performance enhancement.

No doubt, we are at the threshold of this work and should invite other voices to the conversation. There is much ground to cover in search of the miraculous. But NBIC may point the way to designing a more preferred future, one in which we can provide individuals through the freedom of choice, a more productive and higher quality existence.

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