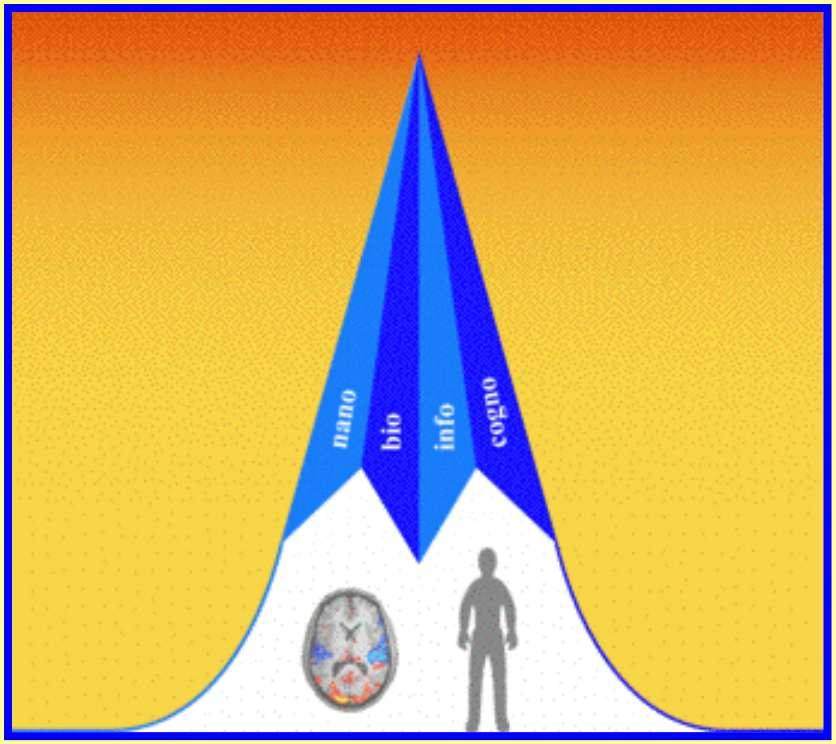
Converging Technologies (NBIC)

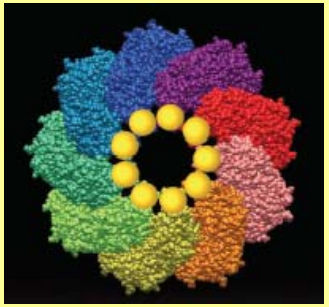
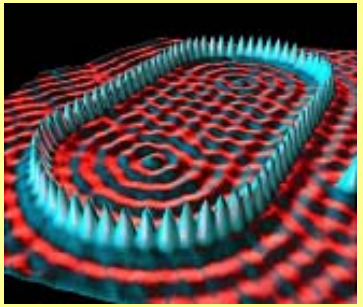


William Sims Bainbridge, Ph.D.
National Science Foundation

NBIC =

- **Nanotechnology**
- **Biotechnology**
- **Information Technology**
- **Cognitive Science - new technologies based on the convergence of computer science, psychology, neuroscience, philosophy, anthropology, economics, sociology, etc.**



The Meaning of NBIC:

- **Based on the unity of nature at the nanoscale**
- **A potential successor to the National Nanotechnology Initiative, and to the Information Technology Research Initiative**
- **Not an official government (or NSF) activity, but an exploratory movement of scientists and engineers**
- **Arising when the unification of science has become possible through the use of transforming tools**
- **A natural extension of work on the societal implications of nanotechnology**

Unification of Technology

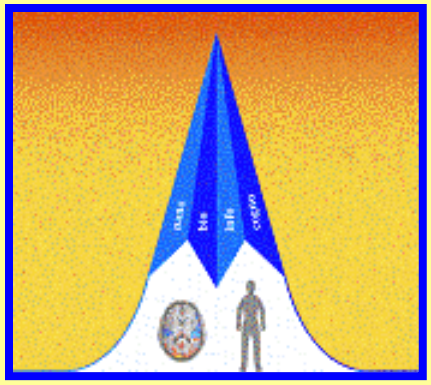
Manuel Castells writes, "Technological convergence increasingly extends to growing interdependence between the biological and micro-electronics revolutions, both materially and methodologically. ... Nanotechnology may allow sending tiny microprocessors into the systems of living organisms, including humans." (Castells, Manuel. 2000. *The Rise of the Network Society*. Oxford: Blackwell, p. 72.)

Unification of Science

In his influential book, *Consilience*, Edward O. Wilson wrote about the rapid unification of scientific knowledge that is taking place today, and he wondered whether the natural sciences would be able to unite with the humanities and religion that traditionally have claimed to understand humanity itself. (Wilson, Edward O. 1998. *Consilience: The Unity of Knowledge*. New York: Knopf.)

Hatching an Idea

Converging Technologies
for Improving Human Performance:
Nanotechnology, Biotechnology,
Information Technology and Cognitive Science
NSF/DOC-sponsored report



Conference at NSF,
December 3-4, 2001

http://www.wtec.org/ConvergingTechnologies/

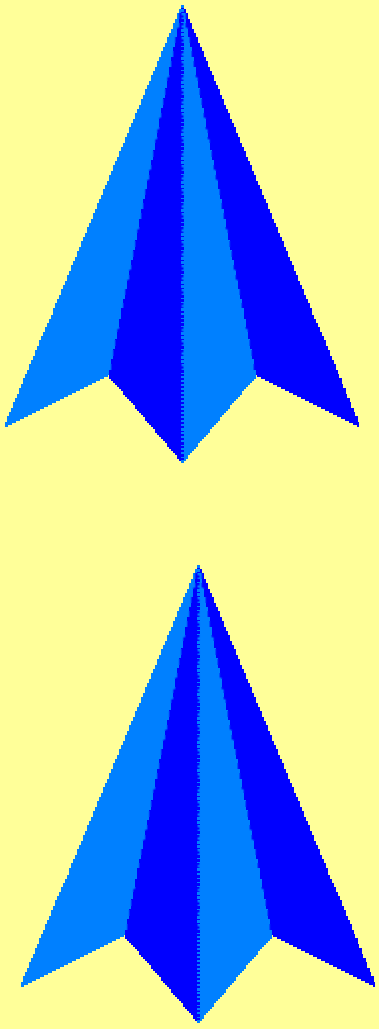
Launching a Movement

First Publications

Mihail C. Roco and William Sims Bainbridge (eds.) 2003. *Converging Technologies for Improving Human Performance*. Dordrecht, Netherlands: Kluwer.

Mihail C. Roco and Carlo D. Montemagno (eds.) 2004. *The Coevolution of Human Potential and Converging Technologies*. New York: New York Academy of Sciences. (Annals of the New York Academy of Sciences, Vol. 1013)

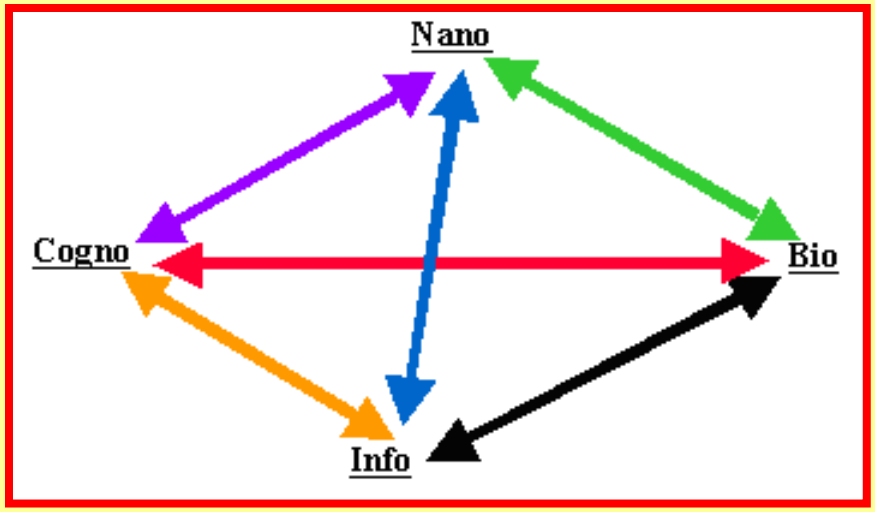
Next Steps



NBIC Convergence, **New York City, February 26-27, 2004 (book in preparation, edited by William Sims Bainbridge and Mihail C. Roco.)**

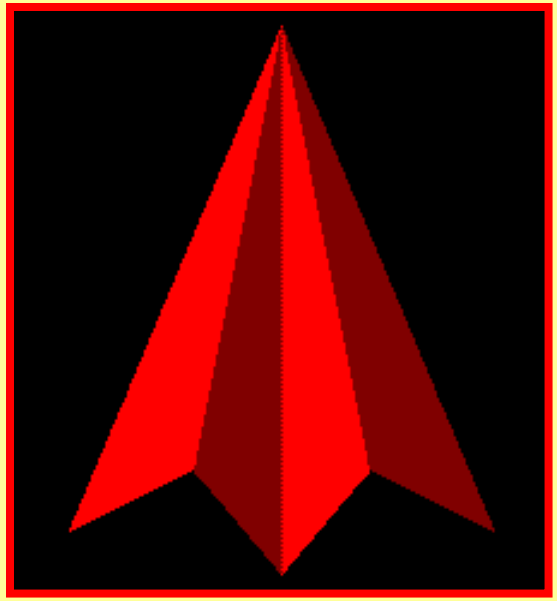
Converging Technologies
Kailua-Kona, Hawaii
February 23-25, 2005
http://www.biztechcomm.com/
(book expected, edited by Bainbridge, Montemagno & Roco)

The NBIC Tetrahedron



Nanotechnology
Biotechnology
Information Technology
Cognitive Science

Principles of Convergence



Convergence is based on:

1. material unity of nature at the nanoscale

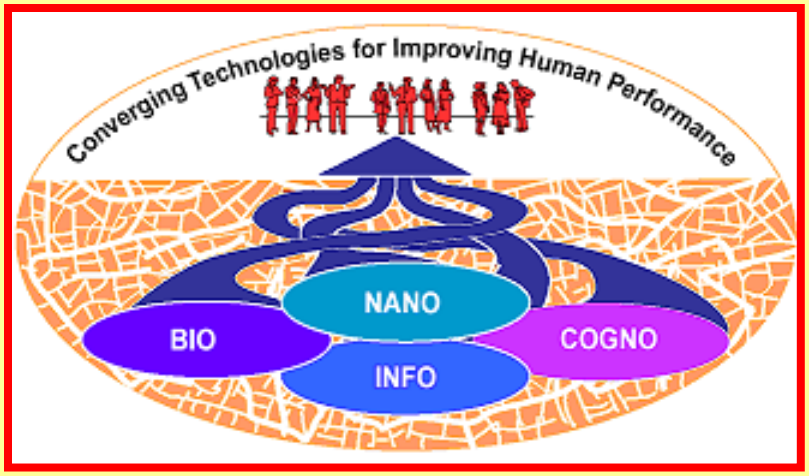
2. technology integration from the nanoscale

3. key transforming tools for NBIC

4. concept of reality as closely coupled complex, hierarchical systems

5. goal to improve human performance

Application Areas



- **Expand Human Cognition & Communication**
- **Improve Human Health & Physical Capabilities**
- **Enhance Group & Societal Outcomes**
- **Strengthen National Security & Competitiveness**
- **Unify Science & Education**

One-way Convergence

Developments in one field are applied to another.

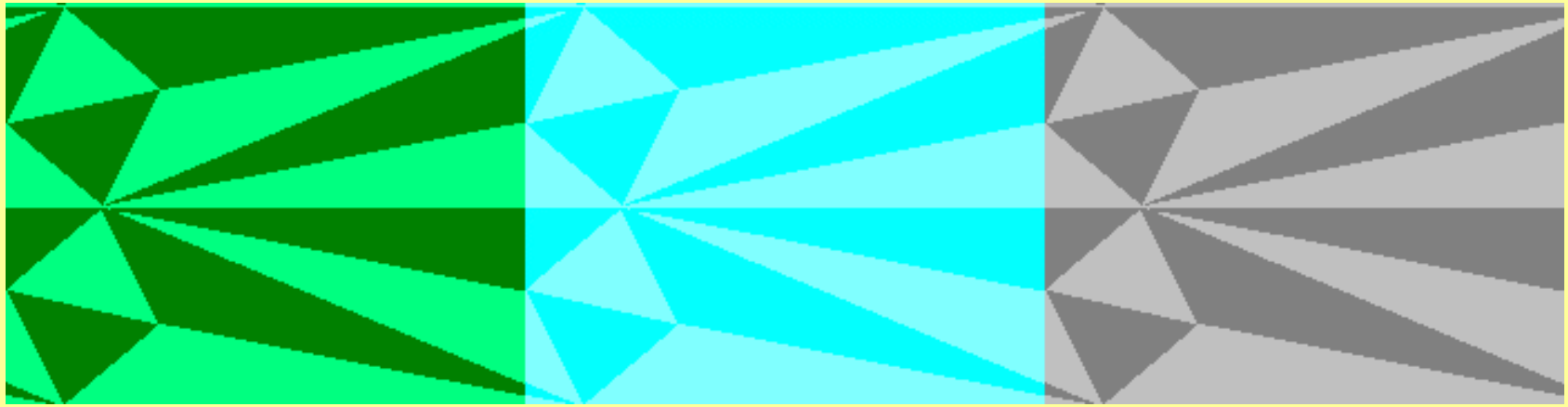
E.g.: Nanotechnology allows Moore's Law to continue in production of ever smaller, faster, and cheaper microelectronic components – enabling continued progress in Information Technology.

An end to Moore's Law could mean a shift to massive parallel computing, but cost and technical challenges have limited the use of parallel systems.

If IC chips become ordinary commodities, nations with low labor costs may mass produce them thereby destroying American (etc.) industries.

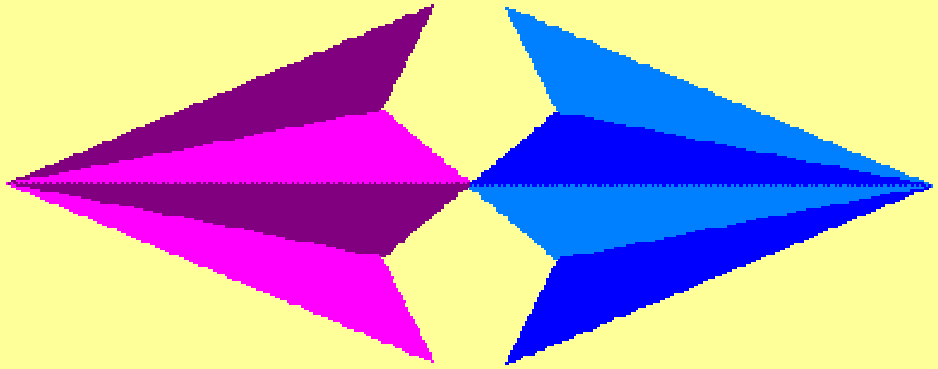
Mutual Convergence

Scientific theories and models are applied across many different fields, facilitating exchange.



Judith Klein-Seetharaman and Raj Reddy:
“Biological Language Modeling”

William Sims Bainbridge:
“Evolution of Semantic Systems”

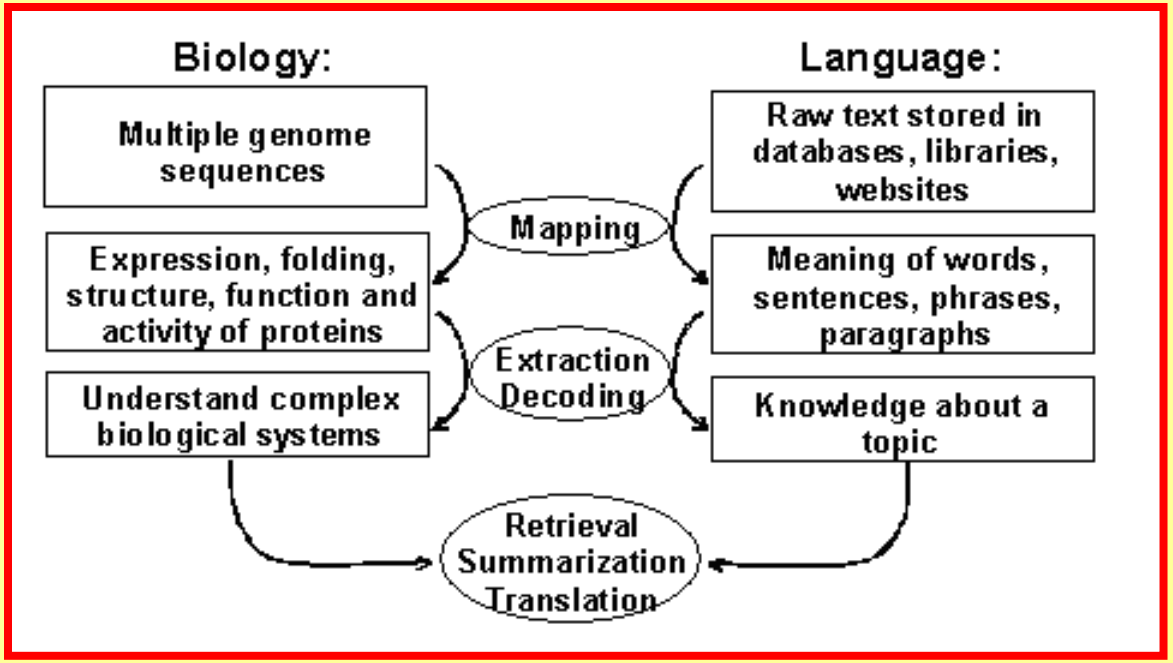


Information Technology Grants

NSF Awards 0225656, 0225636, 0225609, 0225607: "Computational Learning and Discovery in Biological Sequence, Structure and Function Mapping" estimated total: $8,840,267; Carnegie-Mellon, U Pittsburgh, MIT, Boston U

Computer scientists, together with biological chemists will collaborate using statistical and computational tools and methods that the computer scientists have been developing for dealing with human language to better understand the function of proteins.

Evolution

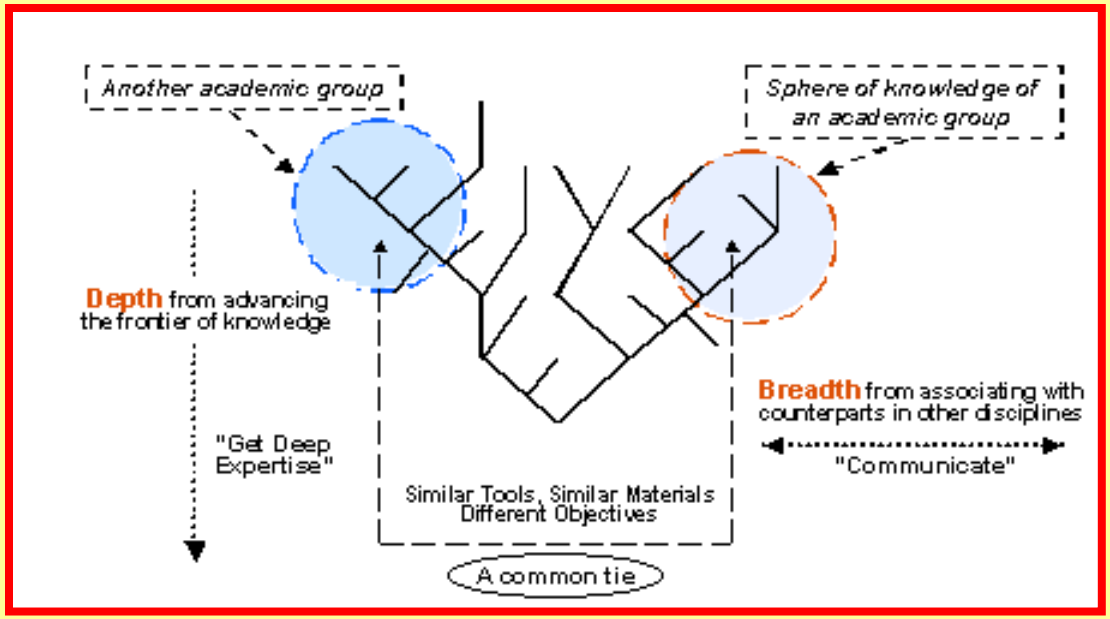


Evolutionary biology to semantic evolution:

Taxonomy: **Linnaean genus-species system, cladistics, numerical taxonomy**

Processes: **Gene, Sexuality, Transduction, Alleles, Natural Selection, Species, Stratigraphy, Catastrophism, Van Valen's Law, Character Displacement, Allopatric Speciation, The Cope-Stanley Law, Exaptation**

Depth with Breadth



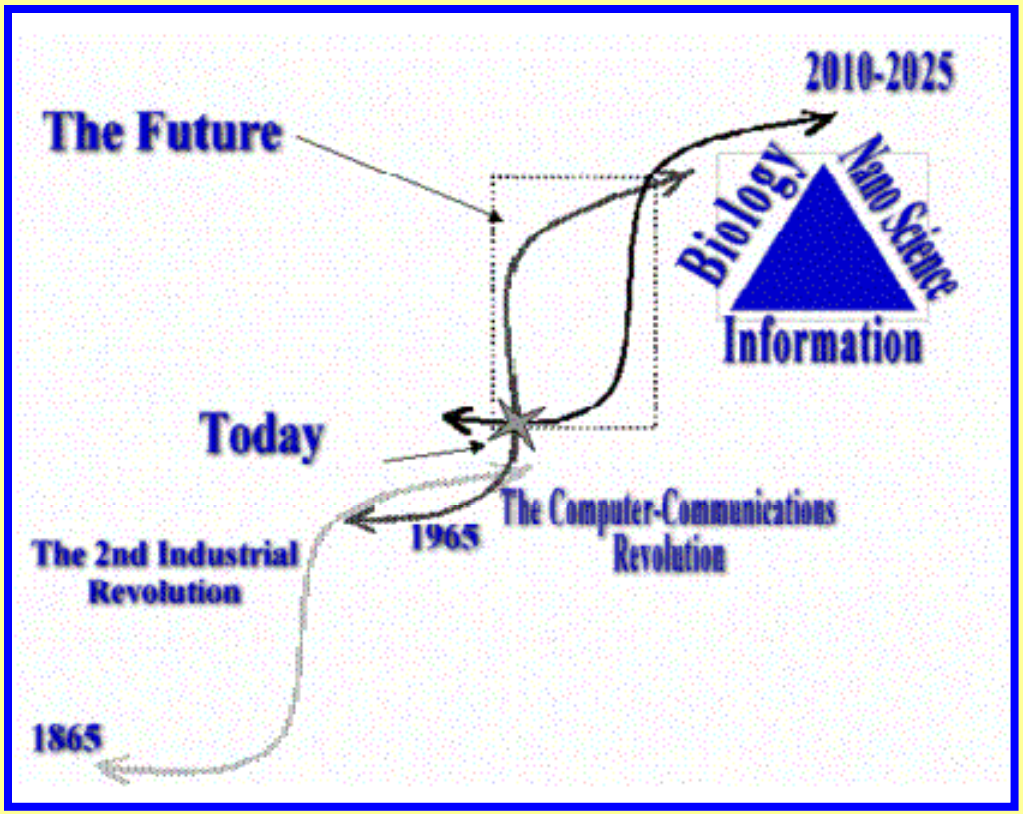
"Combining depth with breadth in NBIC education and research of various groups."

"Nanotechnology offers hope of depth plus breadth"

(W. M. Tolles: "Breadth, Depth, and Academic Nano-Niches" - 1st report)

Sustaining Progress

Has progress stalled in aviation and spaceflight, energy production, artificial intelligence, social and behavioral science, health and longevity?

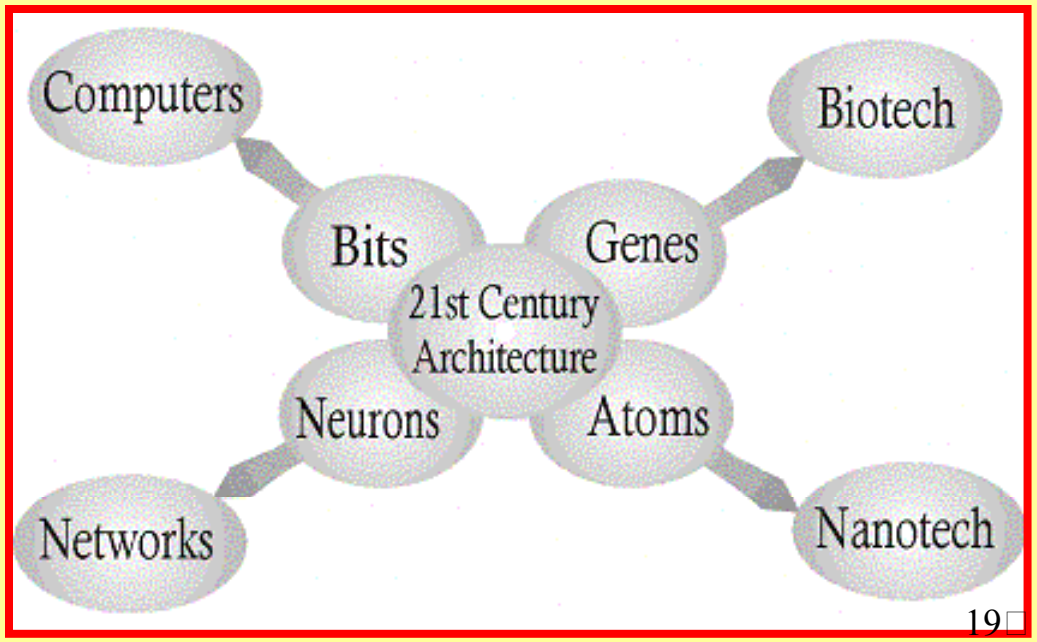


Succession of sigmoid (logistic) curves of progress (Newt Gingerich: "Age of Transitions")

Transforming Tools

Opportunity for science & technology convergence based on shared methodologies (e.g. mathematics, computation, nanoscale observation and experimentation, etc.) & theories (e.g. hierarchical structures, complex systems, evolution, etc.)

Analogous structures in the different fields (James Canton: "Global Futures")



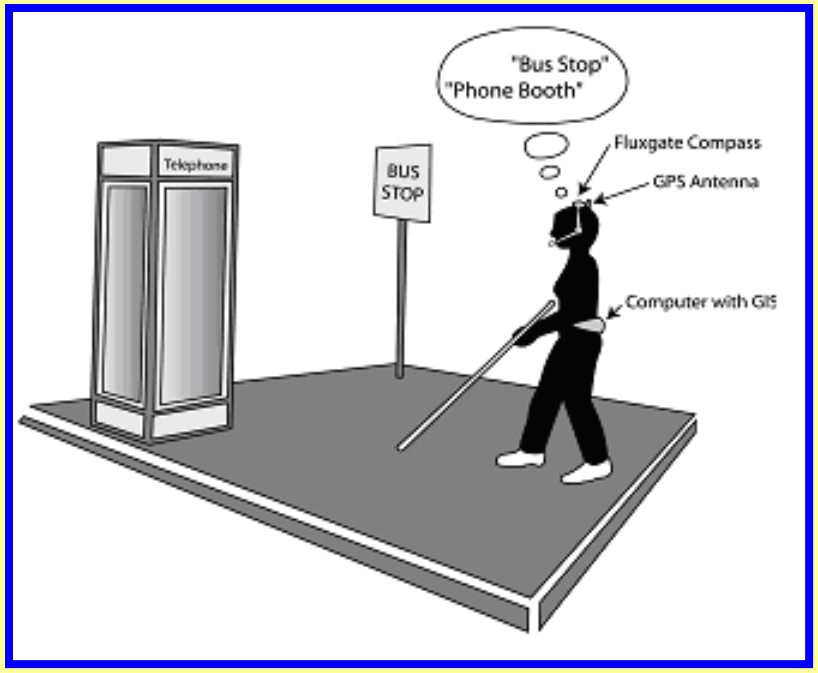
19

Illustrative Application

Comfortable, wearable sensors and computers will enhance every person's awareness of his or her health condition, environment, concerning potential hazards, local businesses, natural resources and chemical pollutants.

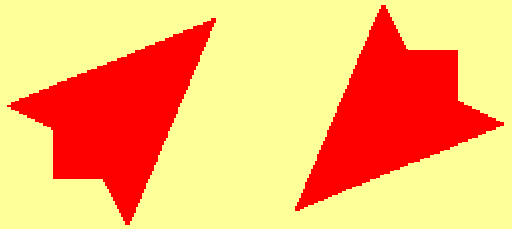
"Spatial Cognition and Converging Technologies"

(Reginald G. Golledge)



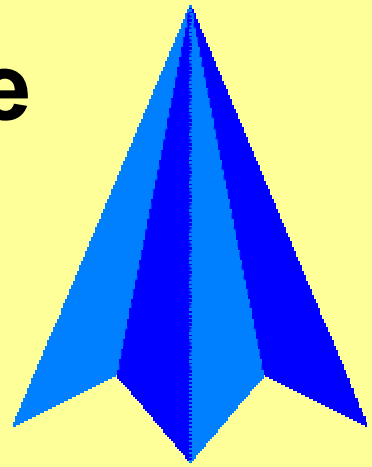
More Applications

National security will be greatly strengthened by light-weight information-rich war fighter systems, capable uninhabited combat vehicles, adaptable smart materials, invulnerable data networks, superior intelligence gathering systems, and effective measures against biological, chemical, radiological, and nuclear attacks.

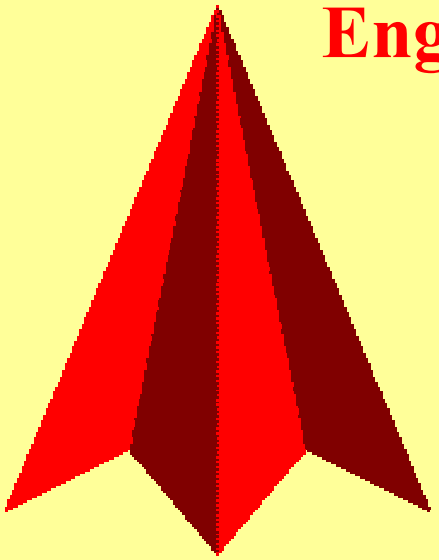


Agriculture and the food industry will greatly increase yields and reduce spoilage through networks of cheap, smart sensors that constantly monitor the condition and needs of plants, animals, and farm products.

Becoming Renaissance People



Formal education will be transformed by a unified but diverse curriculum based on a comprehensive, hierarchical intellectual paradigm for understanding the architecture of the physical world from the nanoscale through the cosmic scale.



Engineers, artists, architects, and designers will experience tremendously expanded creative abilities, both with a variety of new tools and through improved understanding of the wellsprings of human creativity.

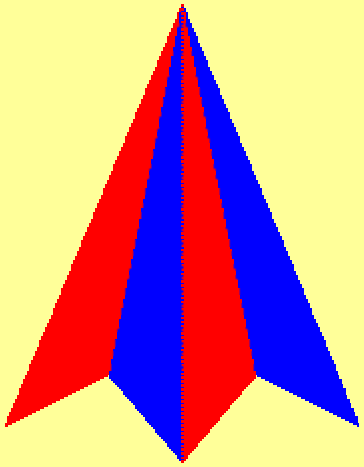
Discovering...

...new categories of materials, devices and systems for use in manufacture, construction, transportation, medicine, emerging technologies and scientific research.

...processes of the living cell, which is the most complex known form of matter - with nanoscale components.

...principles of advanced sensory, computational and communications systems integrating diverse components into a ubiquitous, global network.

...structure, function, and occasional dysfunction of intelligent systems, most importantly the human mind.



Social and Ethical Principles

….evolving socio-cultural context in which convergent research is funded

….societal needs that technology may satisfy

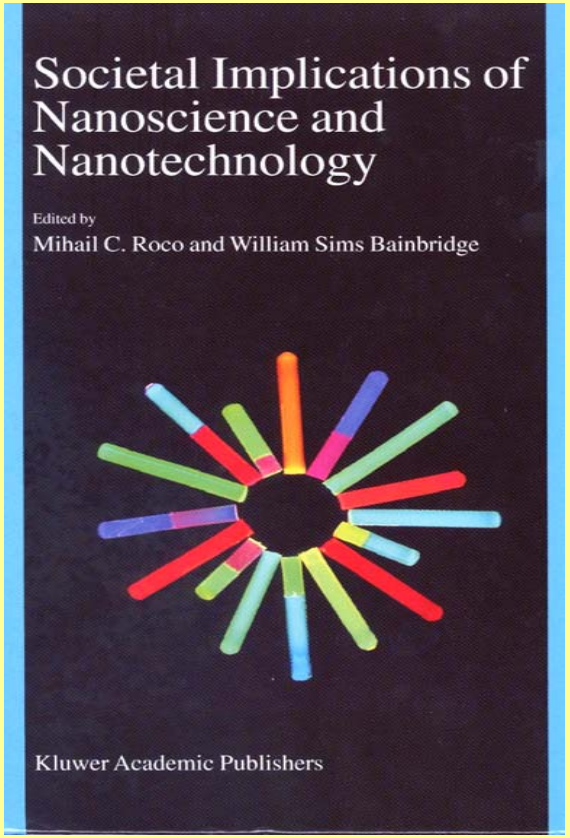
….popular misconceptions that science education will have to overcome

….infection of one field by issues from a different convergent field, e.g.: nano from bio

Oversight I

See:

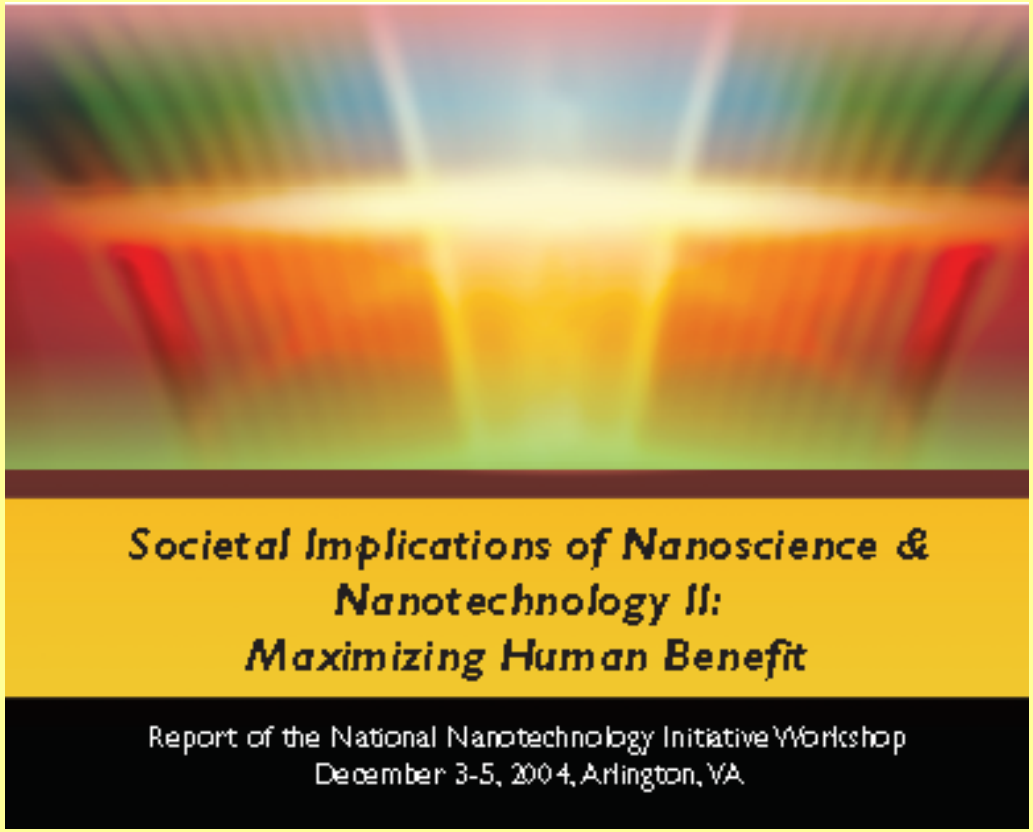
"Societal Implications of Nanoscience and Nanotechnology"



at:

www.wtec.org/loyola/nano/societalimpact/nanosi.pdf

Oversight II



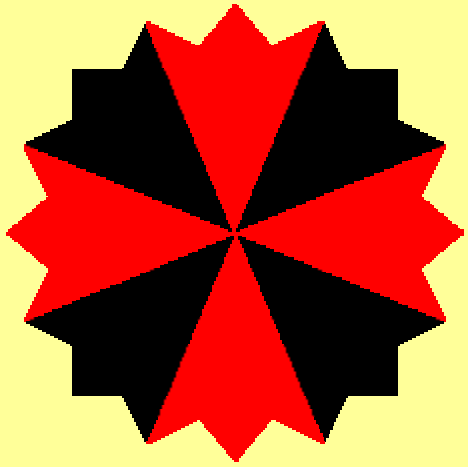
Second Report on Societal Implications to be Published Soon! (Mihail C. Roco & William Sims Bainbridge, editors)

Improving Human Performance

…offering individuals and groups an increased range of attractive choices while preserving such fundamental values as privacy, safety, and moral responsibility

…substantially enhancing human mental, physical, and social abilities

Technological civilization faces the very real danger of stasis or decline unless something can rejuvenate progress.



Unification

Enhancement of human performance should serve the legitimate hopes of human beings, who in return will support the scientific and engineering work required to achieve technological convergence and the unification of science.

Convergence conferences have envisioned the next 20 years, but complete unification of science may require the entire 21st century.

Examples of NSF NBIC Grants

"Active Sensor Networks with Applications in Marine Microorganism Monitoring" (0121141, Requicha, USC). For monitoring microbes in the ocean or in water supplies: distributed network-coordinated nanorobots "to investigate the causal relationships between environmental conditions and micro-organisms."

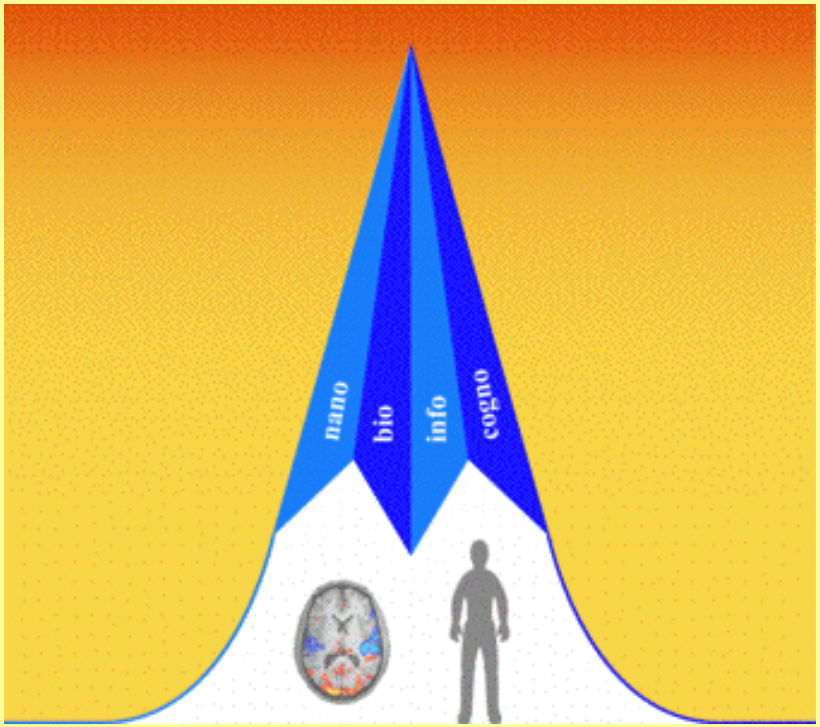
"Pattern Recognition for Ecological Science and Environmental Monitoring" (0326052, Dietterich, Oregon State) Computer vision system designed to recognize and count insects - a new tool for studies of biodiversity & water quality monitoring.

More Examples of Grants

"Interactive Software Systems for Expert-Assisted Image Analysis and Classification of Aquatic Particles" (0325937, Sieracki, Bigelow Lab; 0325167, Riseman, U. Massachusetts; 0325018, Benfield, LSU). Computer vision, machine learning inspired by human cognition, to classify bacteria, plankton in ocean water.

"Sustainable and Generalizable Technologies to Support Collaboration in Science" (0085951, Olson, U Michigan). Studied online research collaboratories in: atmospheric science, behavioral neuroscience, biomedical informatics, computer science, earth science, engineering, genomics, and nanoscience.

Converging



Technologies

W. S Bainbridge: wbainbri@nsf.gov