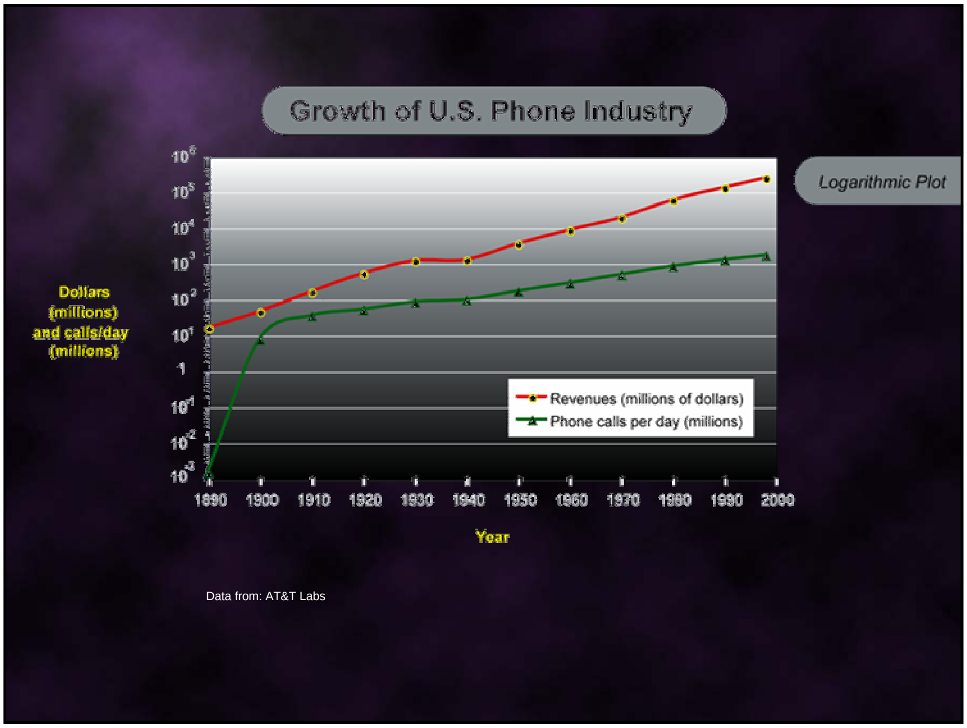
War Fighting in the Early 21st Century: The Remote, Robotic, Robust, Size-Reduced Virtual-Reality Paradigm.

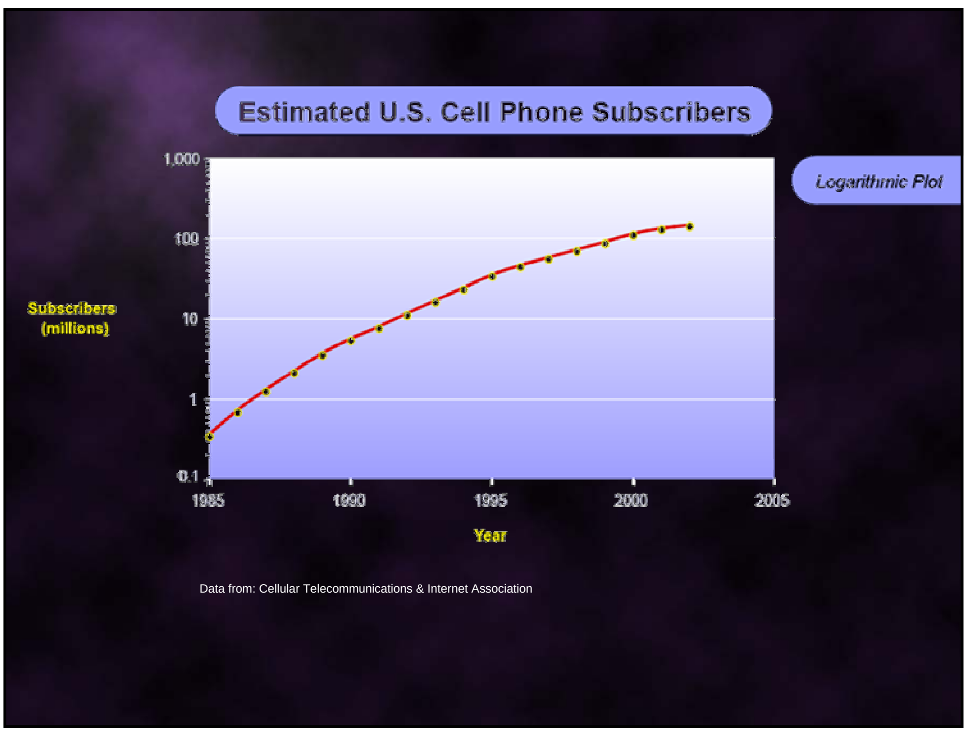
24th Army Science Conference

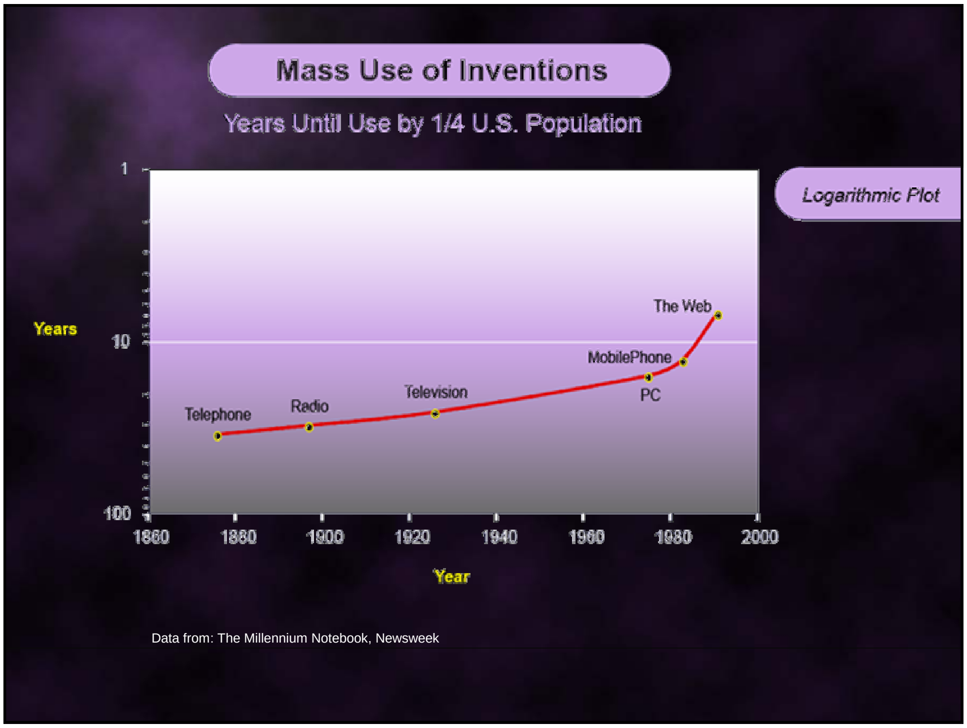
November 29, 2004

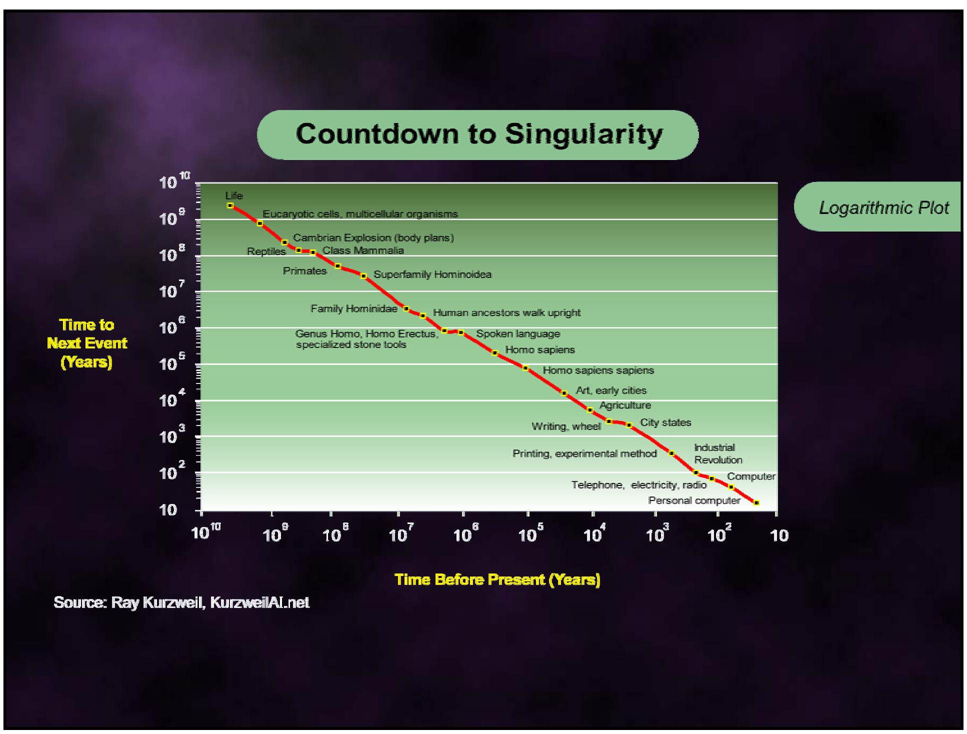
Ray Kurzweil

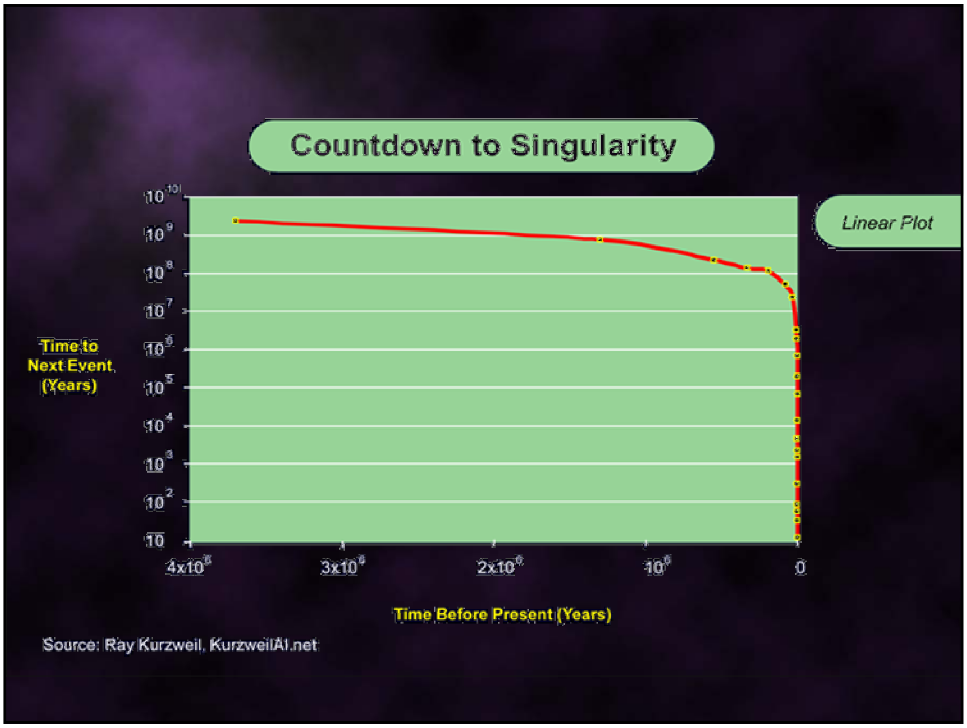
The Paradigm Shift Rate
is now doubling every decade

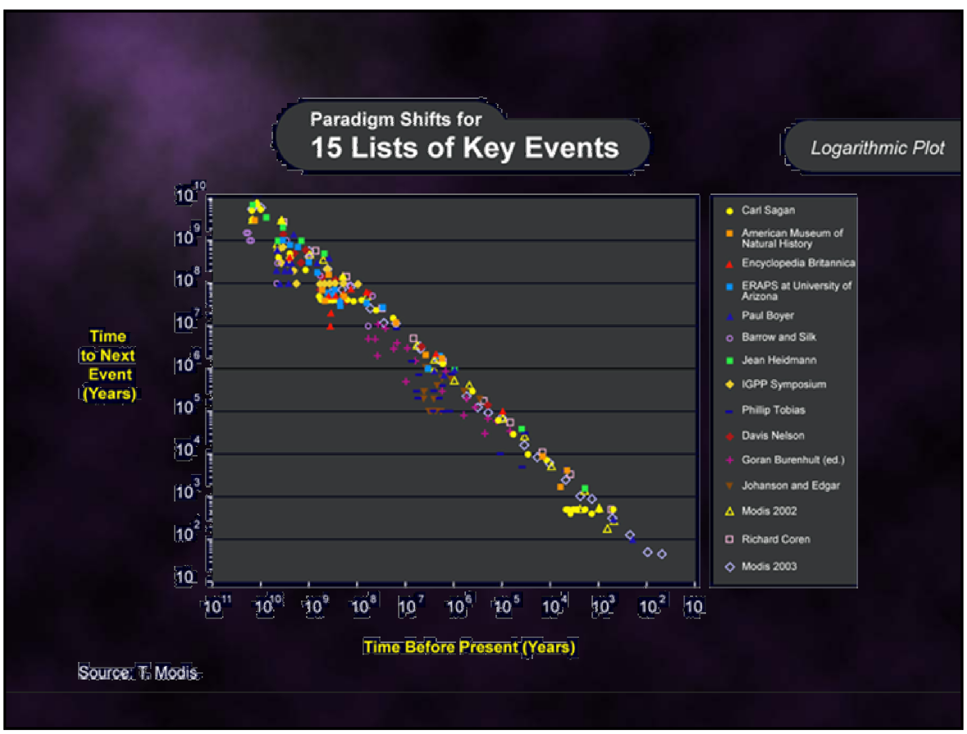

Growth of U.S. Phone Industry
Logarithmic Plot
Dollars (millions) and calls/day (millions)
Revenues (millions of dollars)
Phone calls per day (millions)
Year
Data from: AT&T Labs


Estimated U.S. Cell Phone Subscribers
Logarithmic Plot
Subscribers (millions)
1,000
100
10
1
0.1
1985
1990
1995
2000
2005
Year
Data from: Cellular Telecommunications & Internet Association

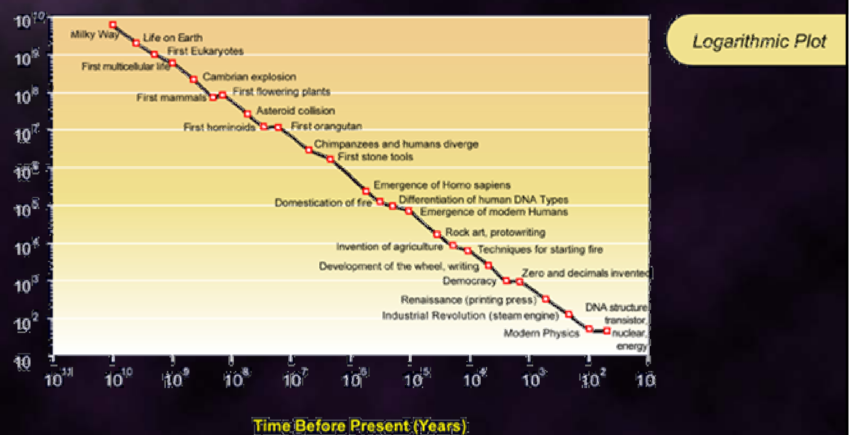

Mass Use of Inventions
Years Until Use by 1/4 U.S. Population
Logarithmic Plot
Years
1
10
100
Telephone
Radio
Television
MobilePhone
PC
The Web
1860
1880
1900
1920
1940
1960
1980
2000
Year
Data from: The Millennium Notebook, Newsweek


Countdown to Singularity
Logarithmic Plot
Time to Next Event (Years)
Life
Eucaryotic cells, multicellular organisms
Cambrian Explosion (body plans)
Reptiles
Class Mammalia
Primates
Superfamily Hominoidea
Family Hominidae
Human ancestors walk upright
Genus Homo, Homo Erectus, specialized stone tools
Spoken language
Homo sapiens
Homo sapiens sapiens
Art, early cities
Agriculture
City states
Writing, wheel
Printing, experimental method
Industrial Revolution
Computer
Telephone, electricity, radio
Personal computer
Time Before Present (Years)
Source: Ray Kurzweil, KurzweilAI.net

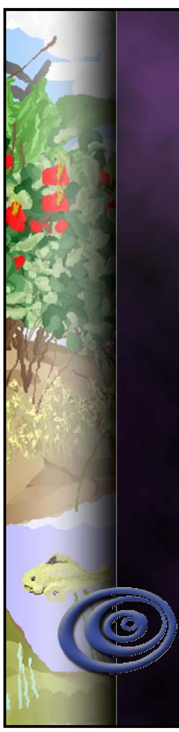

Countdown to Singularity
Linear Plot
Time to Next Event (Years)
Time Before Present (Years)
Source: Ray Kurzweil, KurzweilAI.net


Paradigm Shifts for
15 Lists of Key Events
Logarithmic Plot
Time to Next Event (Years)
Time Before Present (Years)
Carl Sagan
American Museum of Natural History
Encyclopedia Britannica
ERAPS at University of Arizona
Paul Boyer
Barrow and Silk
Jean Heidmann
IGPP Symposium
Phillip Tobias
Davis Nelson
Goran Burenhult (ed.)
Johanson and Edgar
Modis 2002
Richard Coren
Modis 2003
Source: T. Modis

28 Canonical Milestones



Source: T. Modis

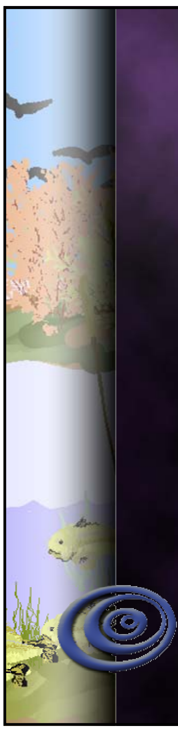


Information Technologies *(of all kinds)* double their power *(price performance, capacity, bandwidth)* every year

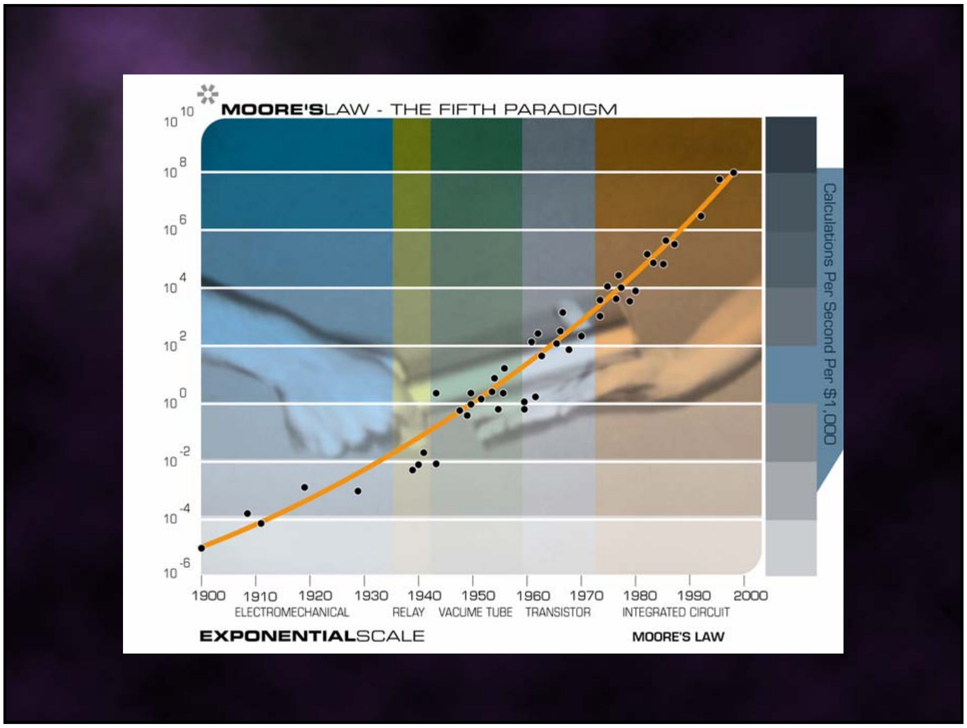
A Personal Experience

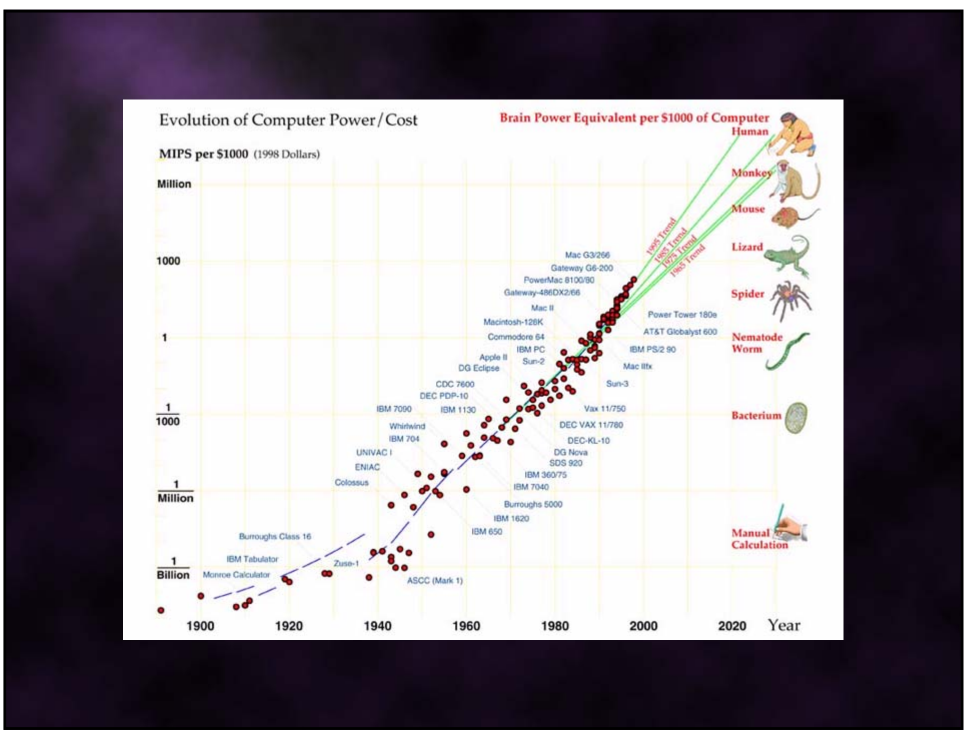
Measure	MIT's IBM 7094	Notebook Circa 2003
Year	1967	2003
Processor Speed (MIPS)	0.25	1,000
Main Memory (K Bytes)	144	256,000
Approximate Cost (2003 $)	$2,000,000	$2,000

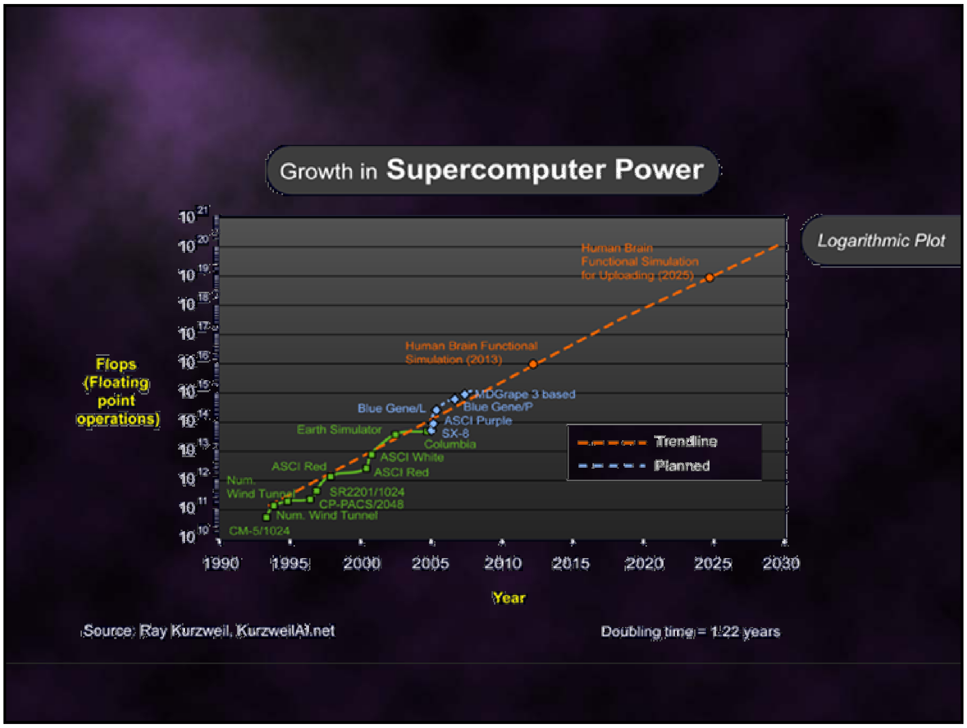
22 Doublings of Price-Performance in 36 years, doubling time: 19 months not including vastly greater RAM memory, disk storage, instruction set, etc.



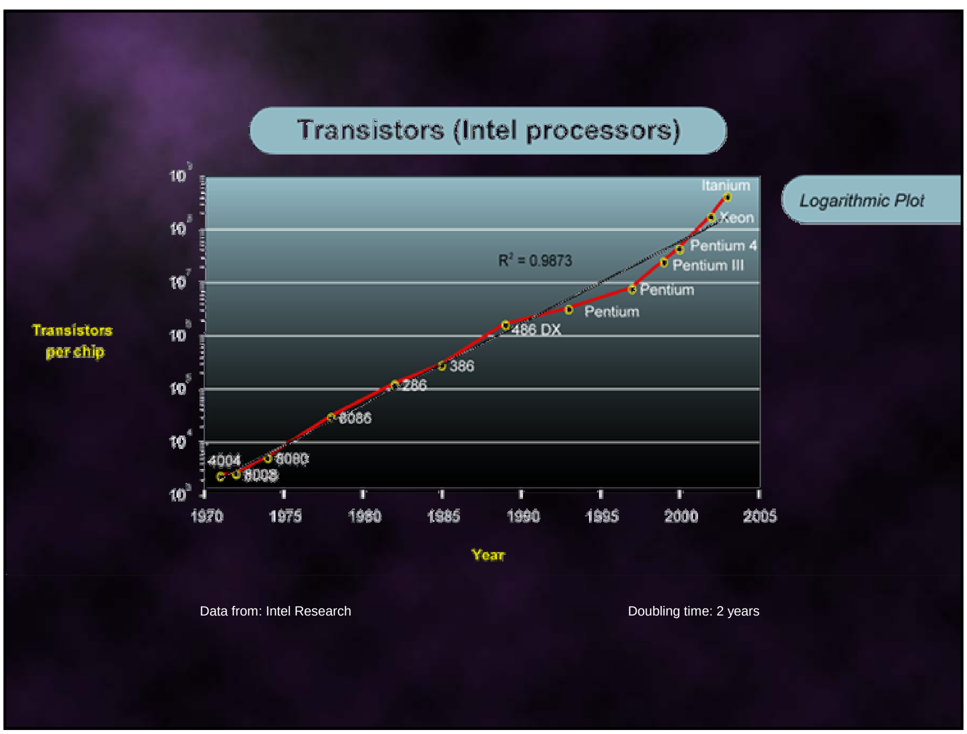
Moore's Law is one example of many….


MOORE'S LAW - THE FIFTH PARADIGM
Calculations Per Second Per $1,000
10^10
10^8
10^6
10^4
10^2
10^0
10^-2
10^-4
10^-6
1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000
ELECTROMECHANICAL
RELAY
VACUUM TUBE
TRANSISTOR
INTEGRATED CIRCUIT
EXPONENTIAL SCALE
MOORE'S LAW

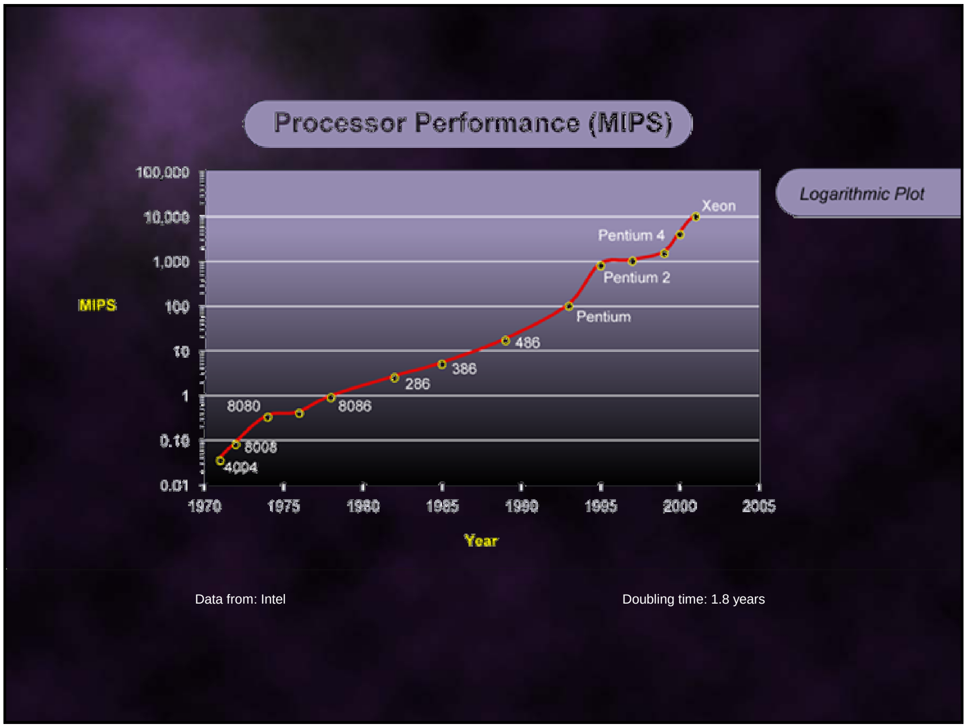

Evolution of Computer Power/Cost
MIPS per $1000 (1998 Dollars)
Brain Power Equivalent per $1000 of Computer
Human
Monkey
Mouse
Lizard
Spider
Nematode Worm
Bacterium
Manual Calculation
Million
1000
1
1/1000
1/Million
1/Billion
1995 Trend
1985 Trend
1975 Trend
1965 Trend
Mac G3/266
Gateway G6-200
PowerMac 8100/80
Gateway-486DX2/66
Mac II
Macintosh-128K
Commodore 64
IBM PC
Apple II
Sun-2
DG Eclipse
CDC 7600
DEC PDP-10
IBM 7090
IBM 1130
Whirlwind
IBM 704
UNIVAC I
ENIAC
Colossus
Burroughs Class 16
IBM Tabulator
Monroe Calculator
Zuse-1
ASCC (Mark 1)
Power Tower 180e
AT&T Globalyst 600
IBM PS/2 90
Mac IIfx
Sun-3
Vax 11/750
DEC VAX 11/780
DEC-KL-10
DG Nova
SDS 920
IBM 360/75
IBM 7040
Burroughs 5000
IBM 1620
IBM 650
1900 1920 1940 1960 1980 2000 2020 Year

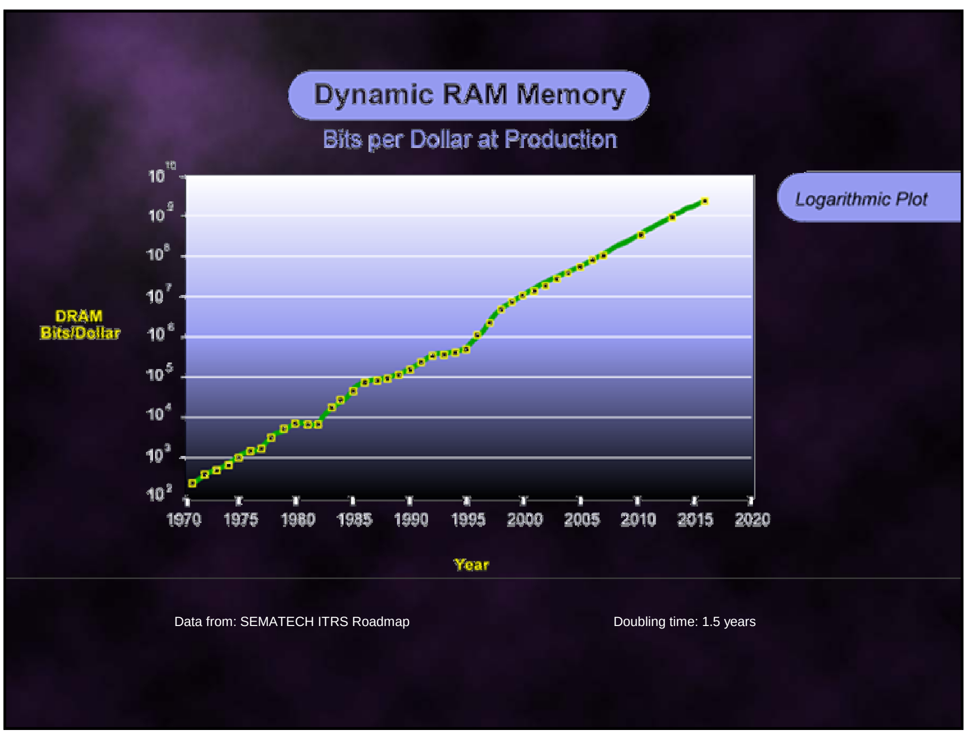


Growth in Supercomputer Power
Logarithmic Plot
Flops (Floating point operations)
10^21
10^20
10^19
10^18
10^17
10^16
10^15
10^14
10^13
10^12
10^11
10^10
Human Brain Functional Simulation for Uploading (2025)
Human Brain Functional Simulation (2013)
MDGrape 3 based
Blue Gene/L
Blue Gene/P
ASCI Purple
SX-8
Columbia
Earth Simulator
ASCI White
ASCI Red
ASCI Red
Num. Wind Tunnel
SR2201/1024
CP-PACS/2048
Num. Wind Tunnel
CM-5/1024
Trendline
Planned
1990
1995
2000
2005
2010
2015
2020
2025
2030
Year
Source: Ray Kurzweil, KurzweilAI.net
Doubling time = 1.22 years

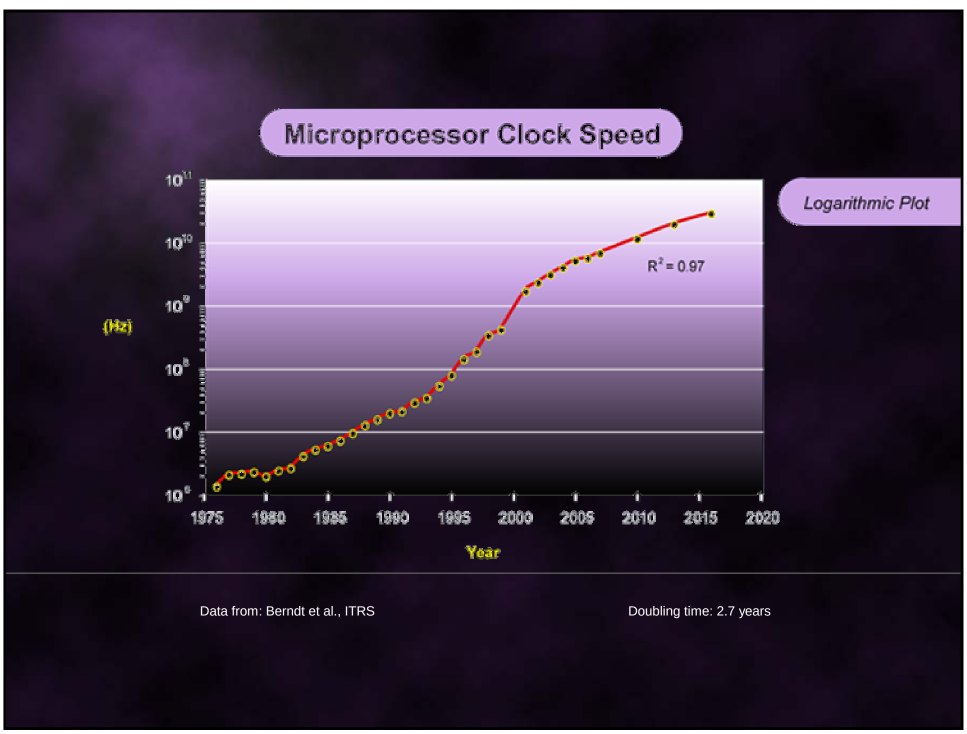


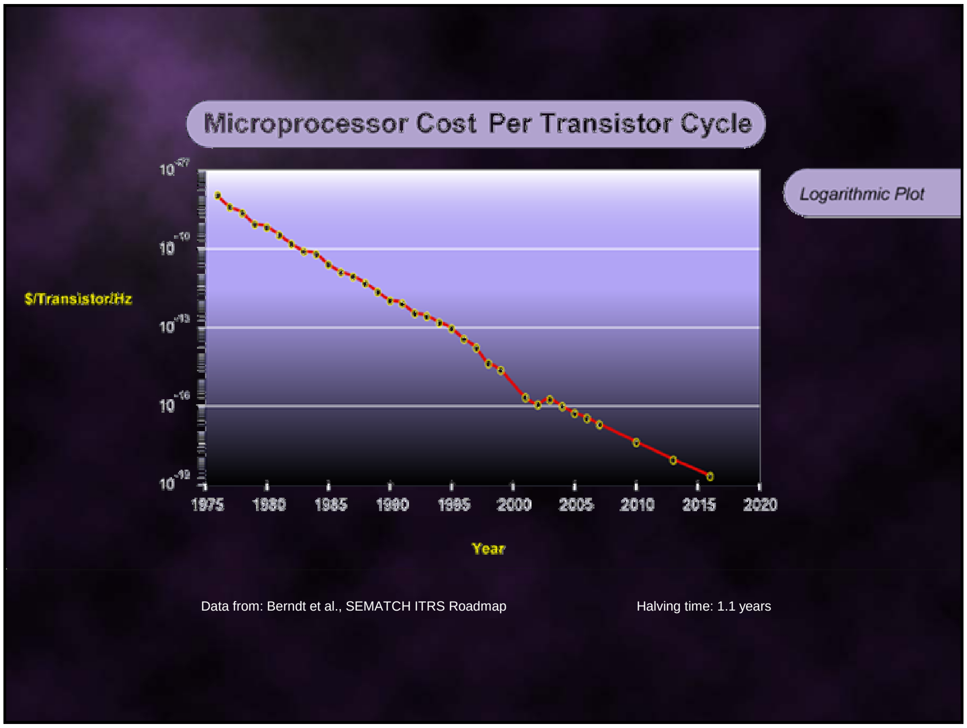
Transistors (Intel processors)
Logarithmic Plot
Transistors per chip
10^9
10^8
10^7
10^6
10^5
10^4
10^3
Itanium
Xeon
Pentium 4
Pentium III
Pentium
Pentium
$R^2 = 0.9873$
486 DX
386
286
8086
8080
4004
8008
1970
1975
1980
1985
1990
1995
2000
2005
Year
Data from: Intel Research
Doubling time: 2 years


Processor Performance (MIPS)
Logarithmic Plot
MIPS
100,000
10,000
1,000
100
10
1
0.10
0.01
1970
1975
1980
1985
1990
1995
2000
2005
Year
4004
8008
8080
8086
286
386
486
Pentium
Pentium 2
Pentium 4
Xeon
Data from: Intel
Doubling time: 1.8 years

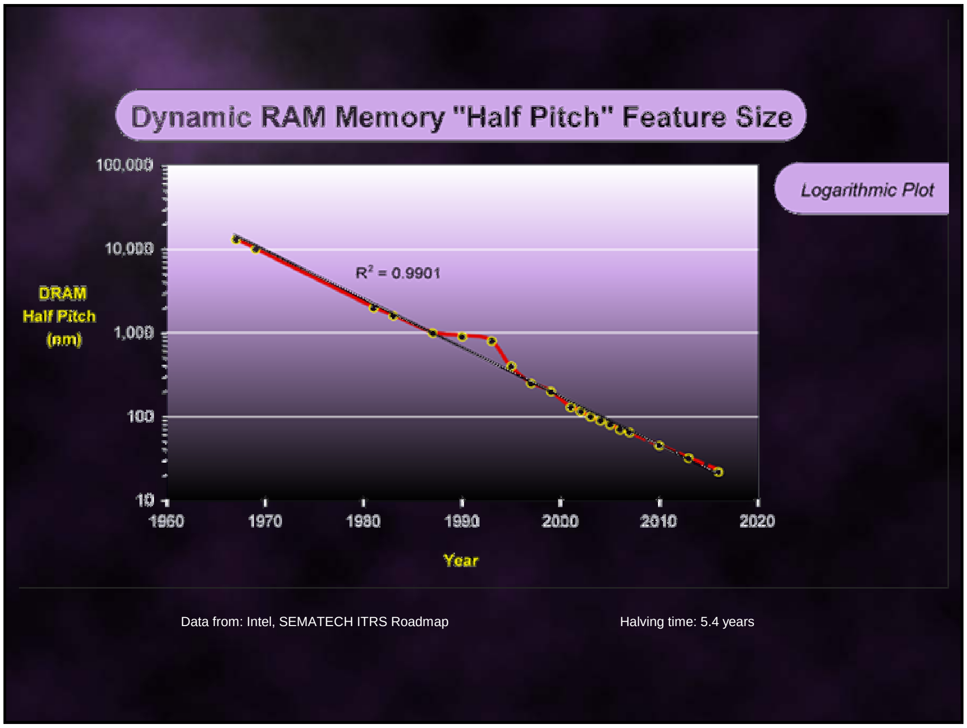

Dynamic RAM Memory
Bits per Dollar at Production
Logarithmic Plot
DRAM
Bits/Dollar
10^{10}
10^9
10^8
10^7
10^6
10^5
10^4
10^3
10^2
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year
Data from: SEMATECH ITRS Roadmap
Doubling time: 1.5 years

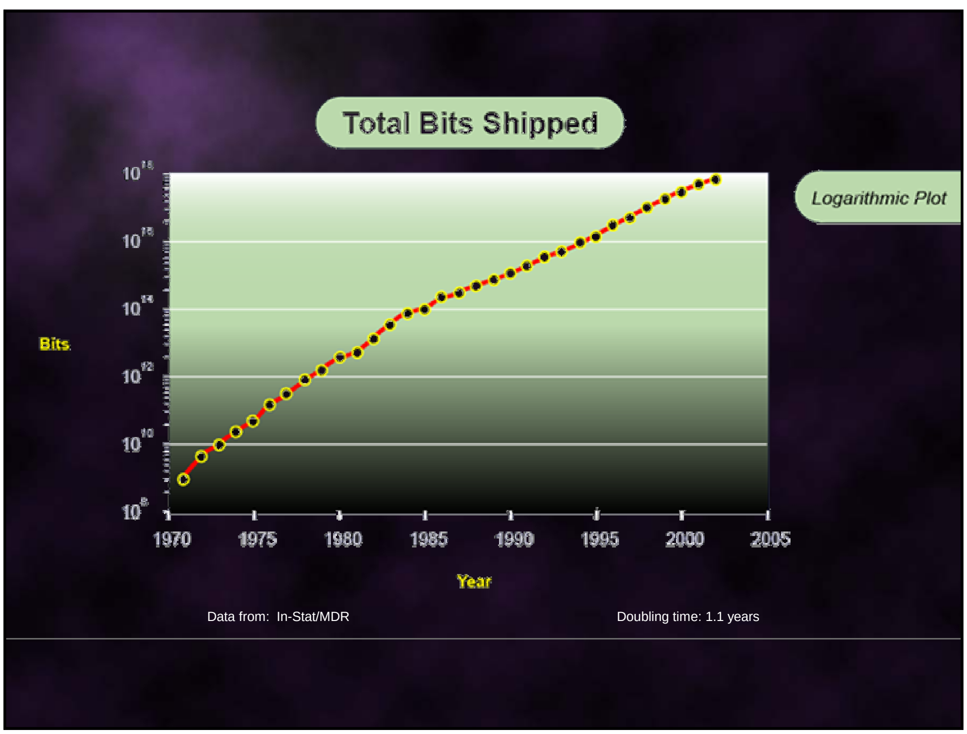

Average Transistor Price
Logarithmic Plot
Dollars
Year
Data from: Dataquest/Intel
Halving time: 1.6 years


Microprocessor Clock Speed
Logarithmic Plot
(Hz)
R^2 = 0.97
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year
Data from: Berndt et al., ITRS
Doubling time: 2.7 years


Microprocessor Cost Per Transistor Cycle
Logarithmic Plot
$/Transistor/Hz
10^-7
10^-10
10^-13
10^-16
10^-19
1975 1980 1985 1990 1995 2000 2005 2010 2015 2020
Year
Data from: Berndt et al., SEMATCH ITRS Roadmap
Halving time: 1.1 years

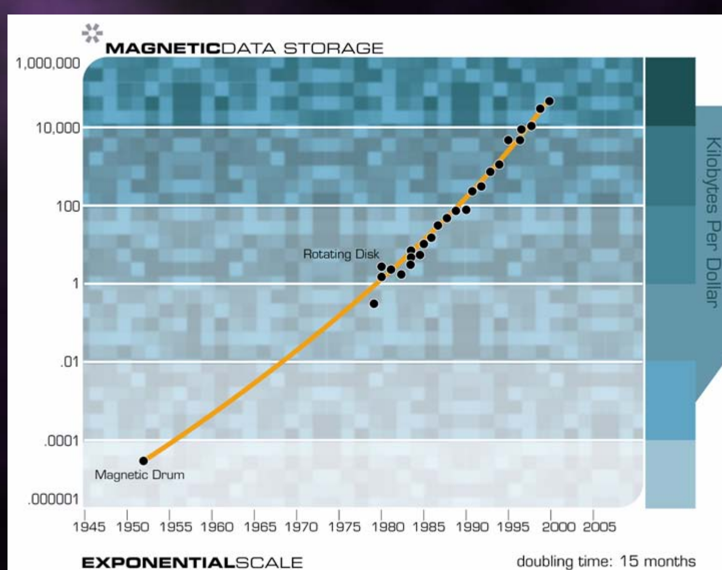

Transistor Manufacturing Costs Falling
Logarithmic Plot
Wafer Cost/
Transistor
(micro-cents)
100
10
1
0.10
0.01
1990 1995 2000 2005 2010
Year
1.0 u
0.7u
0.5u
0.35u
0.25u
0.18u
0.13u
0.09u
0.065u
Data from: SEMATCH ITRS Roadmap


Dynamic RAM Memory "Half Pitch" Feature Size
Logarithmic Plot
DRAM
Half Pitch
(nm)
100,000
10,000
1,000
100
10
R^2 = 0.9901
1960
1970
1980
1990
2000
2010
2020
Year
Data from: Intel, SEMATECH ITRS Roadmap
Halving time: 5.4 years


Total Bits Shipped
Logarithmic Plot
Bits
10^{18}
10^{16}
10^{14}
10^{12}
10^{10}
10^{8}
1970
1975
1980
1985
1990
1995
2000
2005
Year
Data from: In-Stat/MDR
Doubling time: 1.1 years

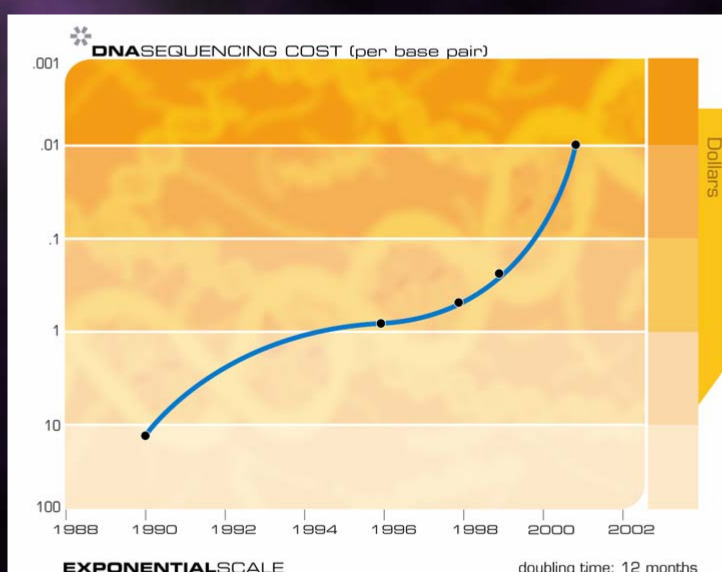
Doubling (or Halving) times

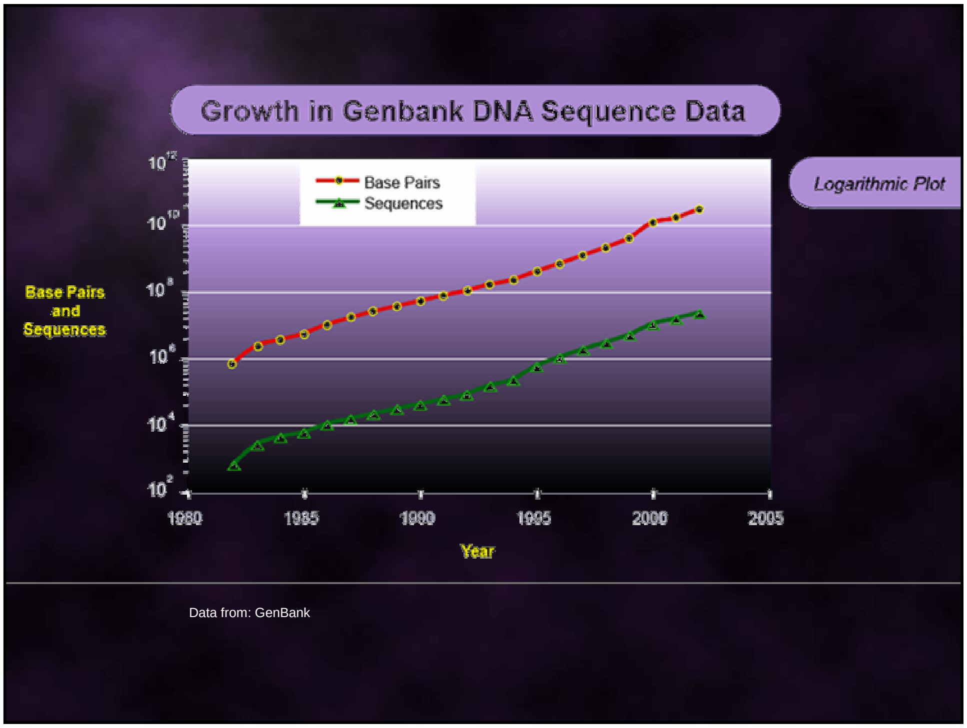
- Dynamic RAM Memory "Half Pitch" Feature Size 5.4 years
- Dynamic RAM Memory (bits per dollar) 1.5 years
- Average Transistor Price 1.6 years
- Microprocessor Cost per Transistor Cycle 1.1 years
- Total Bits Shipped 1.1 years
- Processor Performance in MIPS 1.8 years
- Transistors in Intel Microprocessors 2.0 years
- Microprocessor Clock Speed 2.7 years



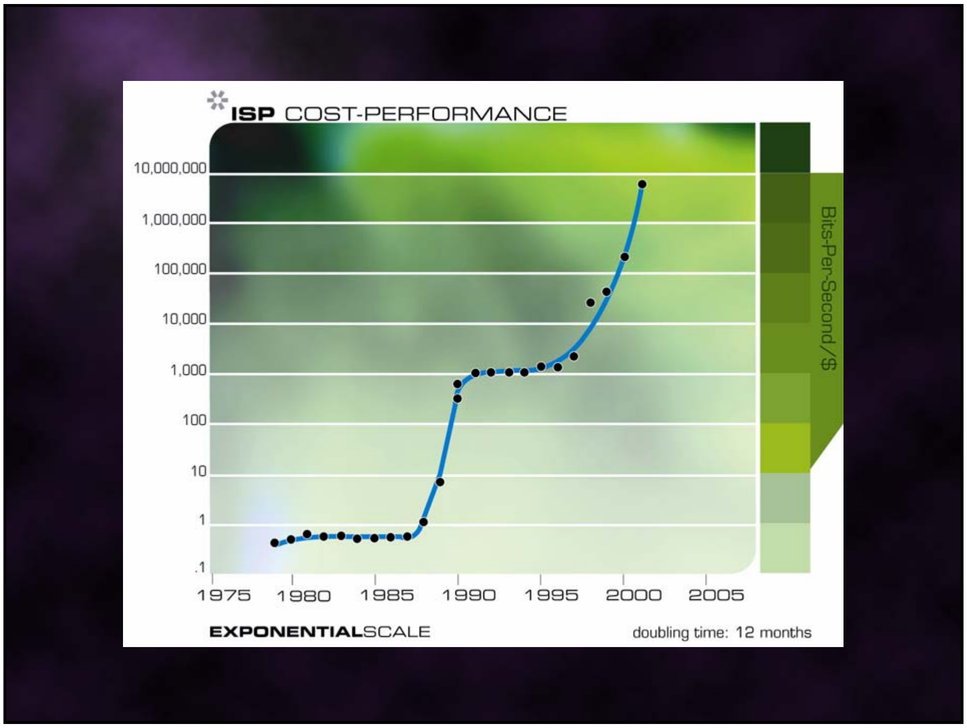
The Biotechnology revolution:

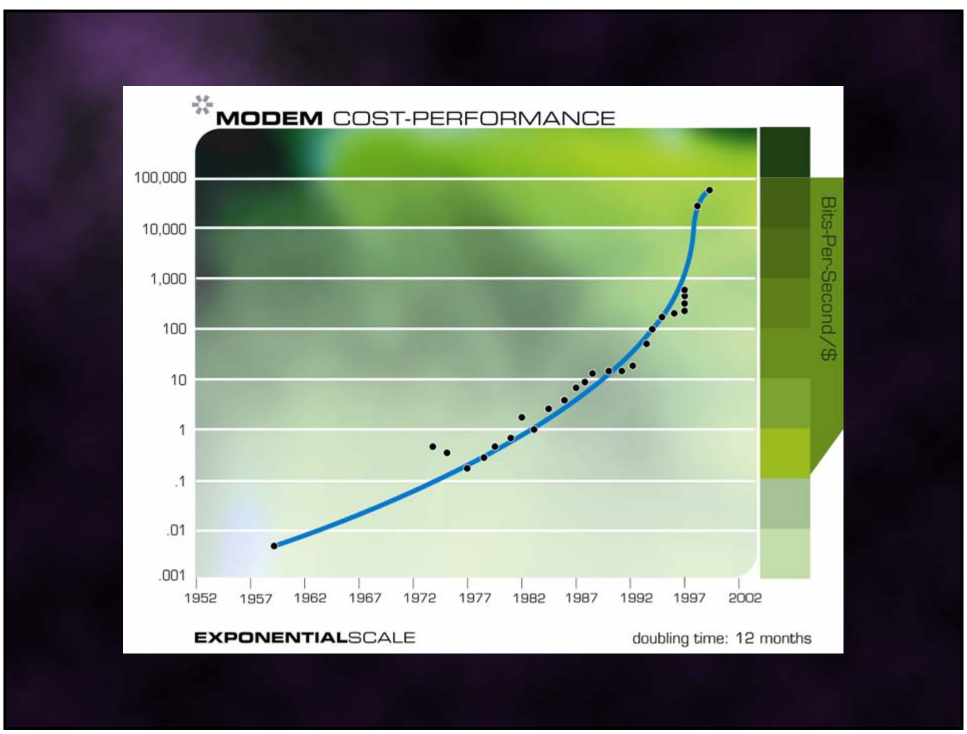
the intersection of biology with information technology

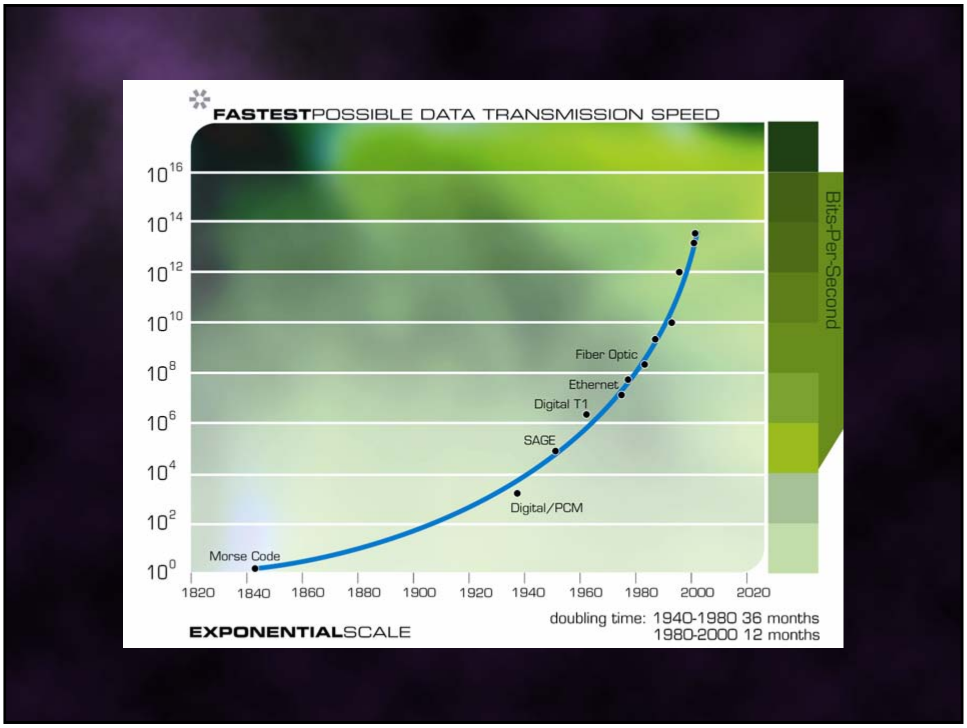


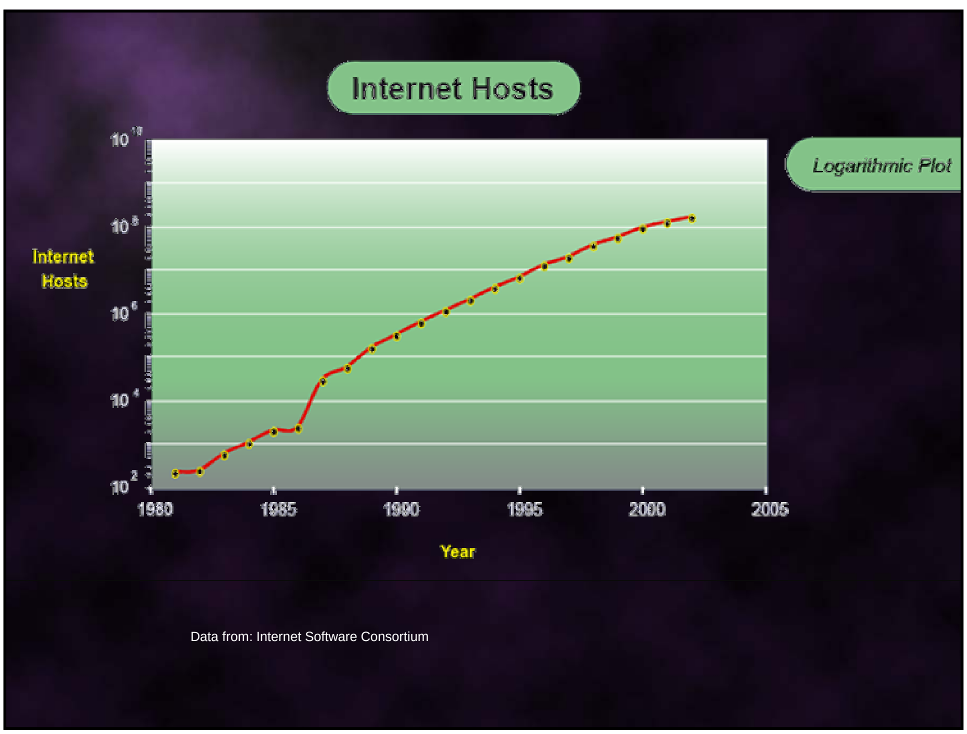

Growth in Genbank DNA Sequence Data
Logarithmic Plot
Base Pairs
Sequences
Base Pairs and Sequences
10^{12}
10^{10}
10^{8}
10^{6}
10^{4}
10^{2}
1980
1985
1990
1995
2000
2005
Year
Data from: GenBank

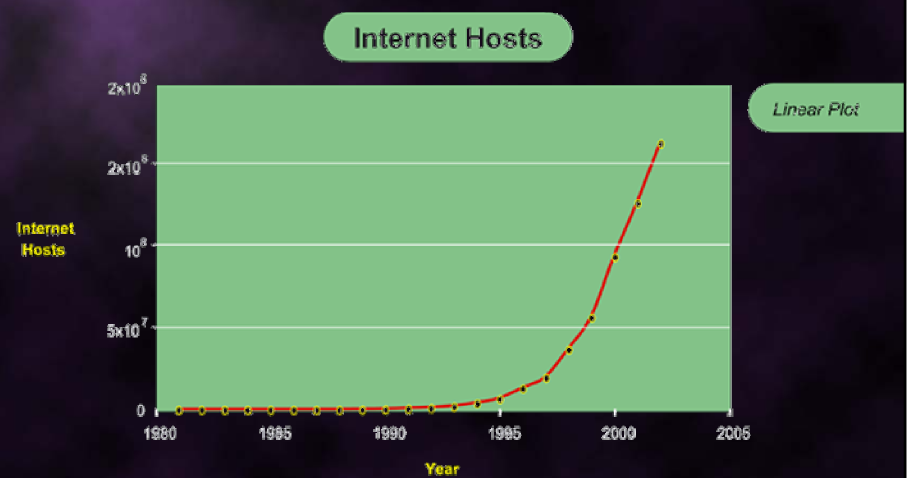

Every form of communications technology is doubling price-performance, bandwidth, capacity every 12 months


ISP COST-PERFORMANCE
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
.1
1975
1980
1985
1990
1995
2000
2005
Bits-Per-Second/$
EXPONENTIALSCALE
doubling time: 12 months


MODEM COST-PERFORMANCE
100,000
10,000
1,000
100
10
1
.1
.01
.001
1952
1957
1962
1967
1972
1977
1982
1987
1992
1997
2002
Bits-Per-Second/$
EXPONENTIALSCALE
doubling time: 12 months


FASTESTPOSSIBLE DATA TRANSMISSION SPEED
Bits-Per-Second
Morse Code
Digital/PCM
SAGE
Digital T1
Ethernet
Fiber Optic
1820 1840 1860 1880 1900 1920 1940 1960 1980 2000 2020
EXPONENTIALSCALE
doubling time: 1940-1980 36 months
1980-2000 12 months

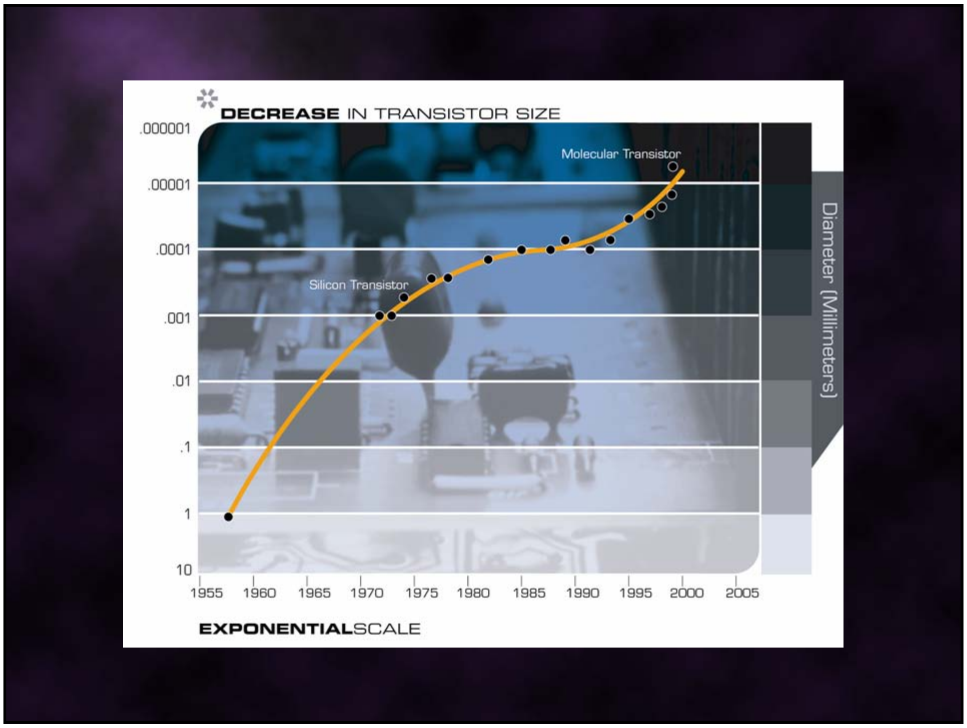

Internet Hosts
Logarithmic Plot
Internet Hosts
1980 1985 1990 1995 2000 2005
Year
Data from: Internet Software Consortium

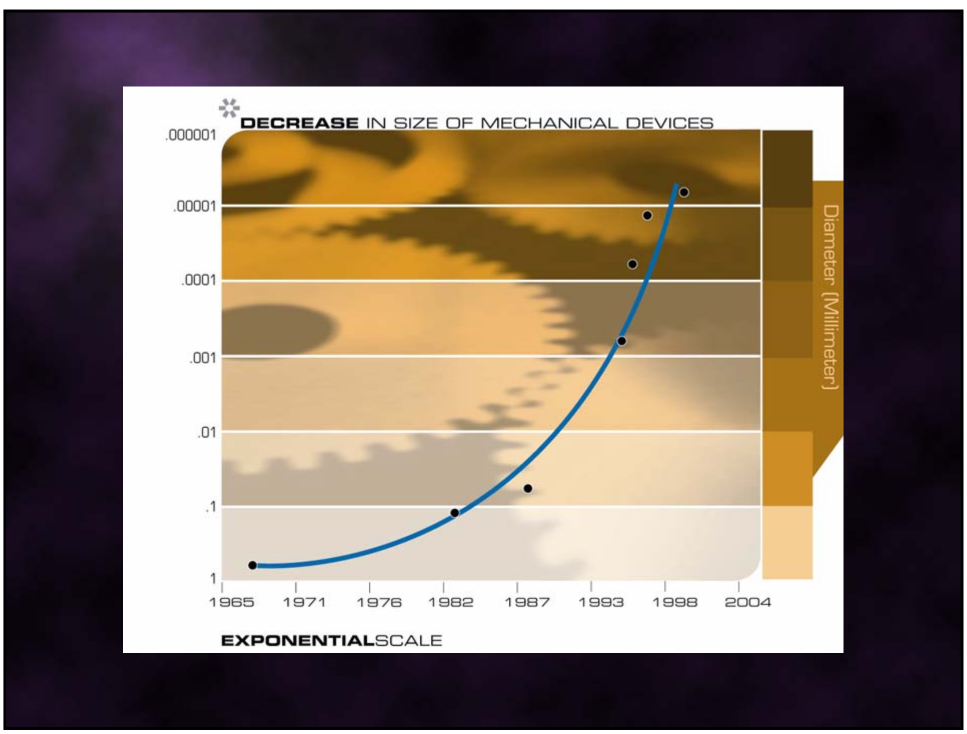


Data from: Internet Software Consortium

Miniaturization:

another exponential trend

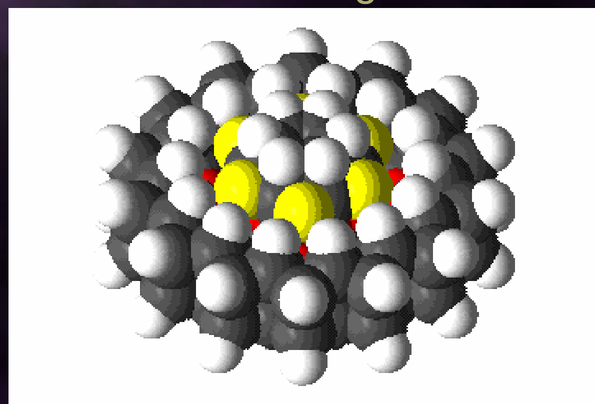

DECREASE IN TRANSISTOR SIZE
.000001
.00001
.0001
.001
.01
.1
1
10
Molecular Transistor
Silicon Transistor
Diameter (Millimeters)
1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005
EXPONENTIALSCALE


DECREASE IN SIZE OF MECHANICAL DEVICES
.000001
.00001
.0001
.001
.01
.1
1
Diameter (Millimeter)
1965 1971 1976 1982 1987 1993 1998 2004
EXPONENTIALSCALE

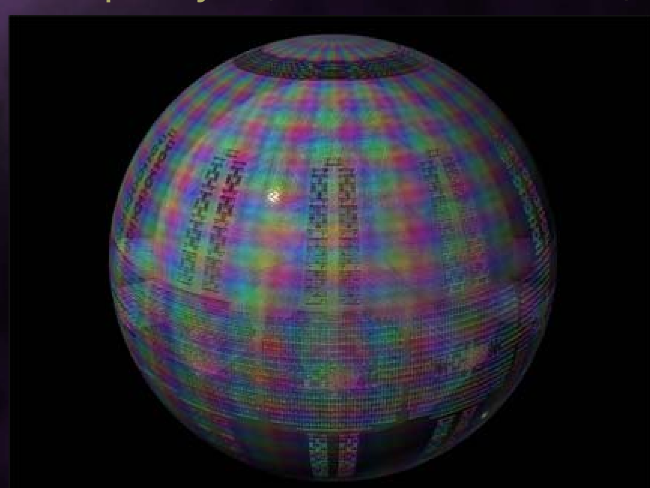
Planetary Gear

Nanosystems bearing

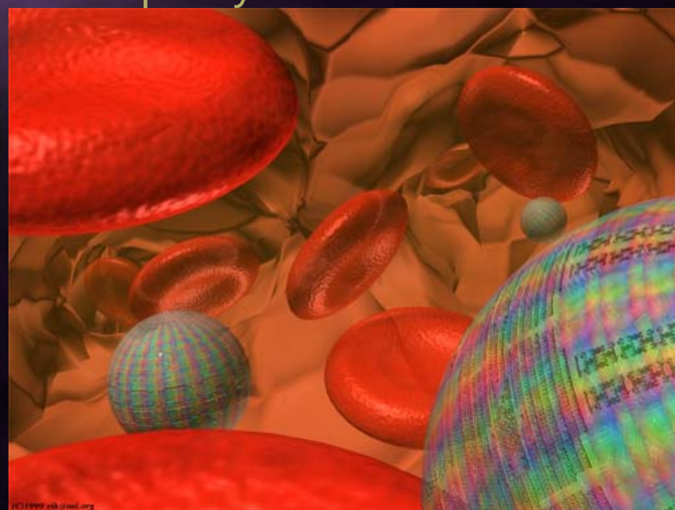
Nanosystems smaller bearing



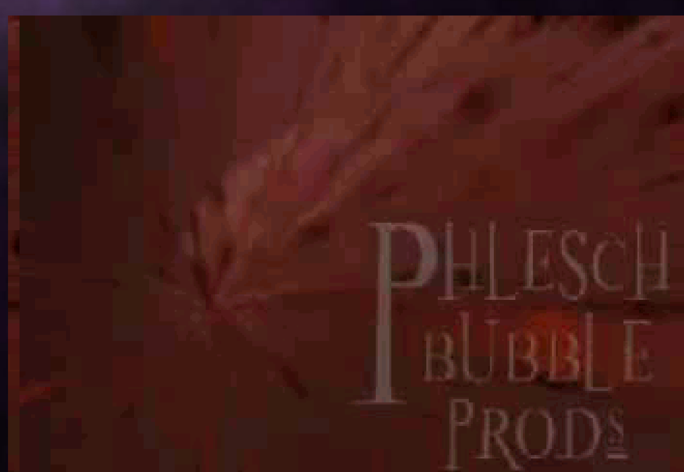
Respirocyte *(an artificial red blood cell)*



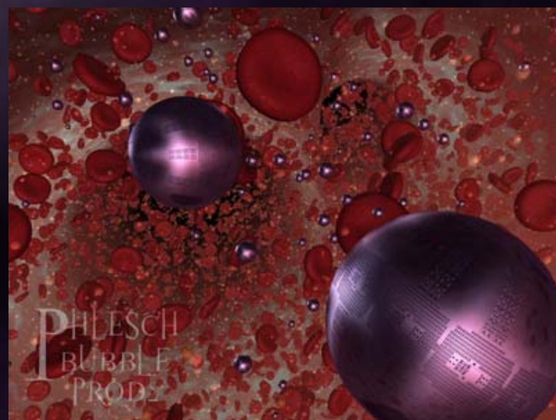
Respirocytes with Red Cells



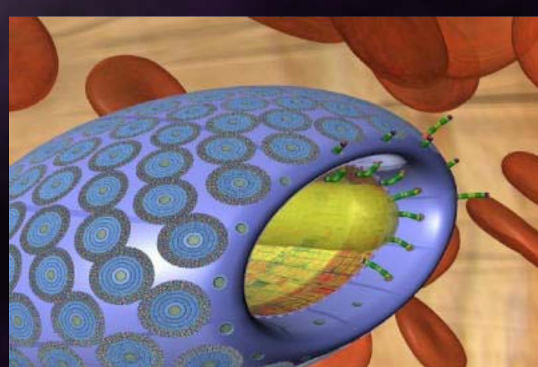
Animation of a respirocyte releasing oxygen in a capillary

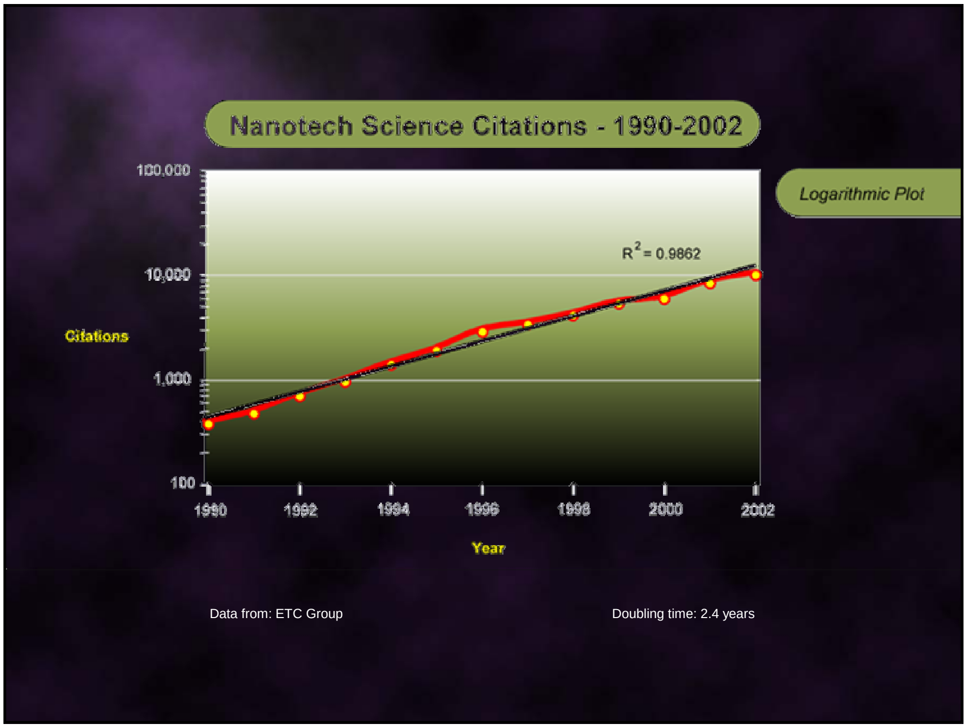


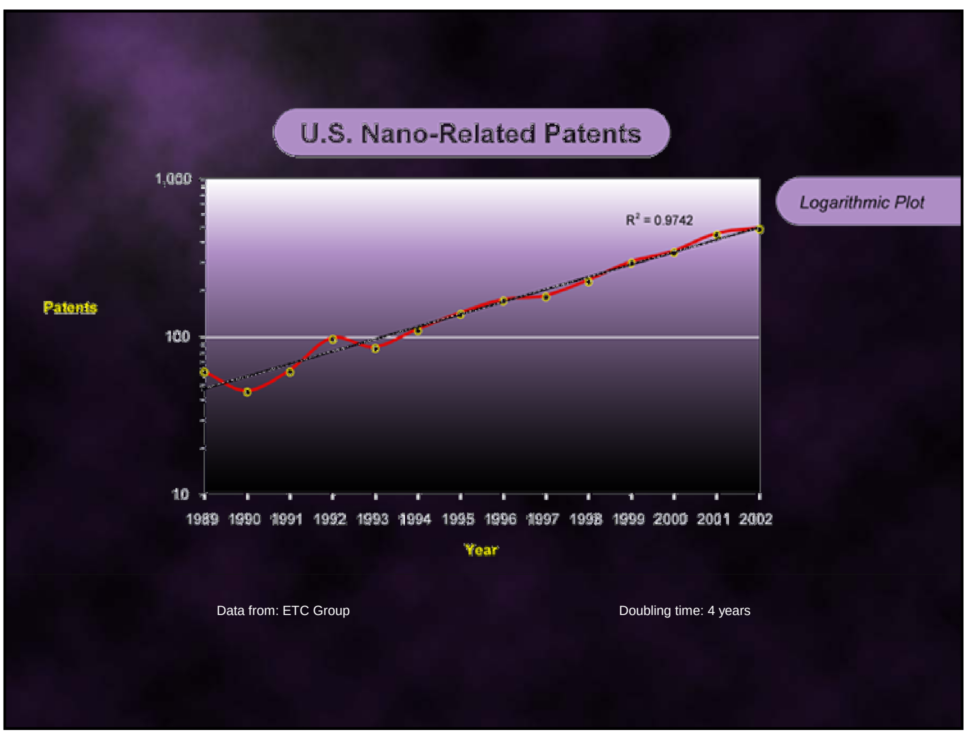
High resolution still from the Animation of a respirocyte

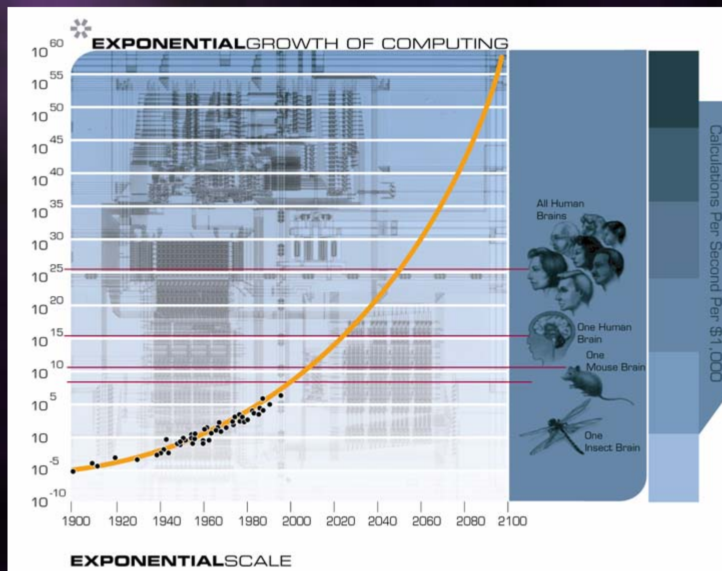


Microbivores II



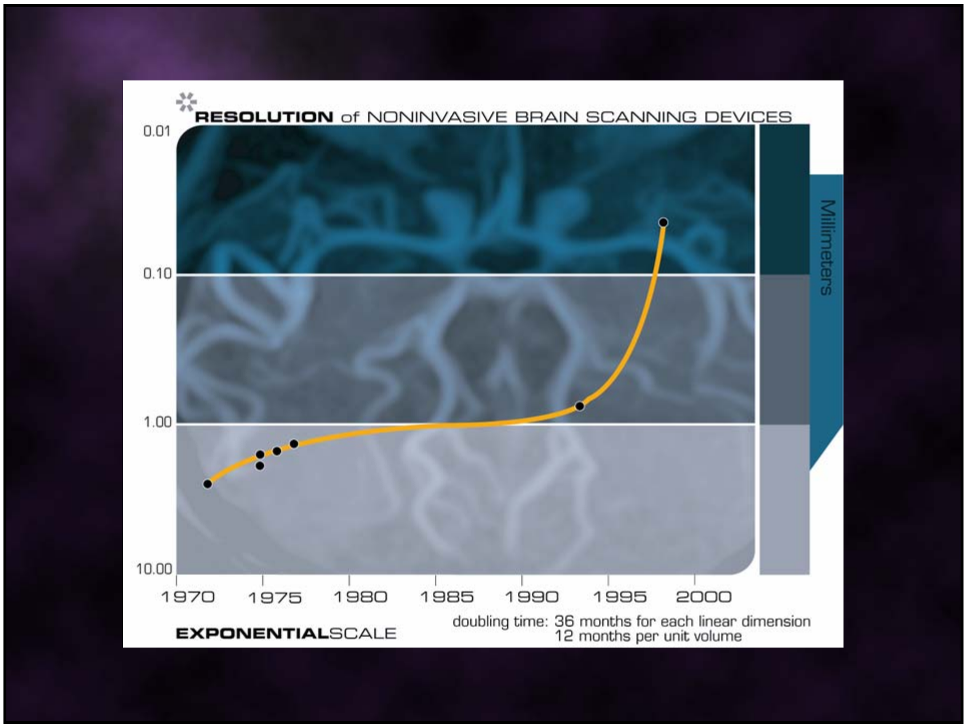

Nanotech Science Citations - 1990-2002
Logarithmic Plot
100,000
10,000
1,000
100
Citations
R² = 0.9862
1990
1992
1994
1996
1998
2000
2002
Year
Data from: ETC Group
Doubling time: 2.4 years

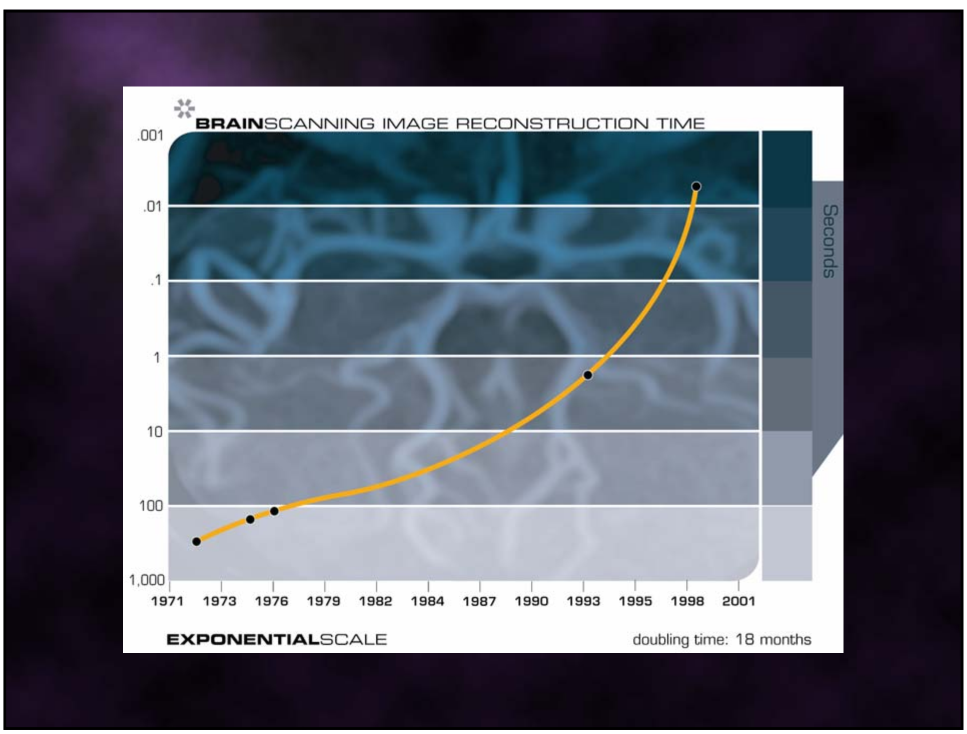

U.S. Nano-Related Patents
Logarithmic Plot
1,000
100
10
Patents
R² = 0.9742
1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002
Year
Data from: ETC Group
Doubling time: 4 years



Reverse Engineering the Brain:

the ultimate source of the templates of intelligence


RESOLUTION of NONINVASIVE BRAIN SCANNING DEVICES
0.01
0.10
1.00
10.00
Millimeters
1970
1975
1980
1985
1990
1995
2000
EXPONENTIALSCALE
doubling time: 36 months for each linear dimension
12 months per unit volume


BRAINSCANNING IMAGE RECONSTRUCTION TIME
.001
.01
.1
1
10
100
1,000
Seconds
1971
1973
1976
1979
1982
1984
1987
1990
1993
1995
1998
2001
EXPONENTIALSCALE
doubling time: 18 months

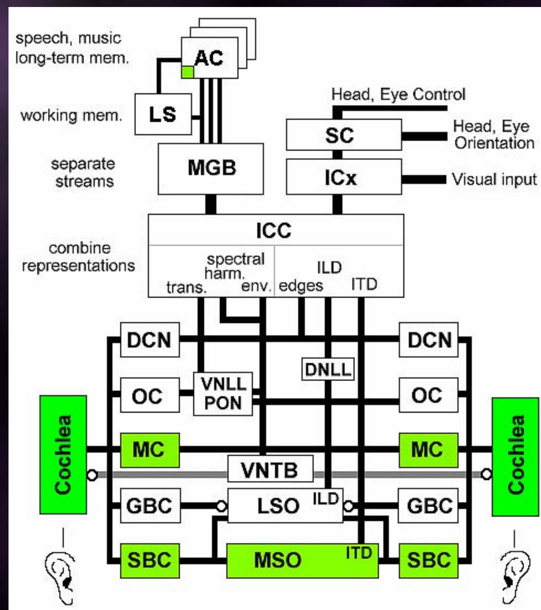


Chart by Lloyd Watts

"Now, for the first time, we are observing the brain at work in a global manner with such clarity that we should be able to discover the overall programs behind its magnificent powers."

-- J.G. Taylor, B. Horwitz, K.J. Friston

Ways that the brain differs from a conventional computer:

- Very few cycles available to make decisions
- Massively parallel: 100 trillion interneuronal connections
- Combines digital & analog phenomena at every level
  - Nonlinear dynamics can be modeled using digital computation to any desired degree of accuracy
  - Benefits of modeling using transistors in their analog native mode

Ways that the brain differs from a conventional computer:

- The brain is self-organizing at every level
- Great deal of stochastic (random within controlled constraints) process in every aspect
  - Self-organizing, stochastic techniques are routinely used in pattern recognition
- Information storage is holographic in its properties

The Brain's Design is a level of complexity we can manage

- Only about 20 megabytes of compressed design information about the brain in the genome
  - A brain has ~ billion times more information than the genome that describes its design
- We've already created simulations of ~ 20 regions (out of several hundred) of the brain

Models often get simpler at a higher level, not more complex

- Consider an analogy with a computer
  - We do need to understand the detailed physics of semiconductors to model a transistor, and the equations underlying a single real transistor are complex.
  - A digital circuit that multiplies two numbers, however, although involving hundreds of transistors, can be modeled far more simply.

Modeling Systems at the Right Level

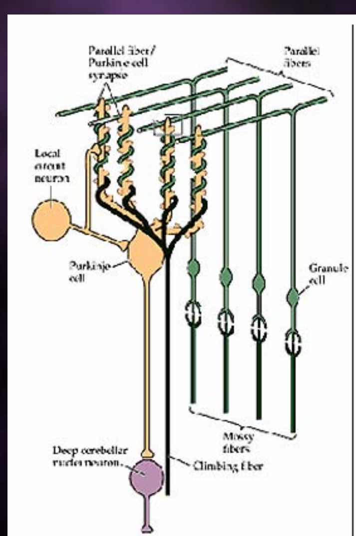
- Although chemistry is theoretically based on physics, and could be derived entirely from physics, this would be unwieldy and infeasible in practice.
- So chemistry uses its own rules and models.
- We should be able to deduce the laws of thermodynamics from physics, but this is far from straightforward. Once we have a sufficient number of particles to call it a gas rather than a bunch of particles, solving equations for each particle interaction becomes hopeless, whereas the laws of thermodynamics work quite well.

Modeling Systems at the Right Level

- The same issue applies to the levels of modeling and understanding in the brain – from the physics of synaptic reactions up to the transformations of information by neural clusters.
- Often, the lower level is more complex.
- A pancreatic islet cell is enormously complicated, in terms of all its biochemical functions, most of which apply to all human cells, some to all biological cells. Yet modeling what a pancreas does in terms of regulating levels of insulin and digestive enzymes, although not simple, is considerably less complex than a detailed model of a single islet cell.

The Cerebellum

- The basic wiring method of the cerebellum is repeated billions of times. It is clear that the genome does not provide specific information about each repetition of this cerebellar structure, but rather specifies certain constraints as to how this structure is repeated (just as the genome does not specify the exact location of cells in other organs, such the location of each pancreatic Islet cell in the pancreas).



The Cerebellum

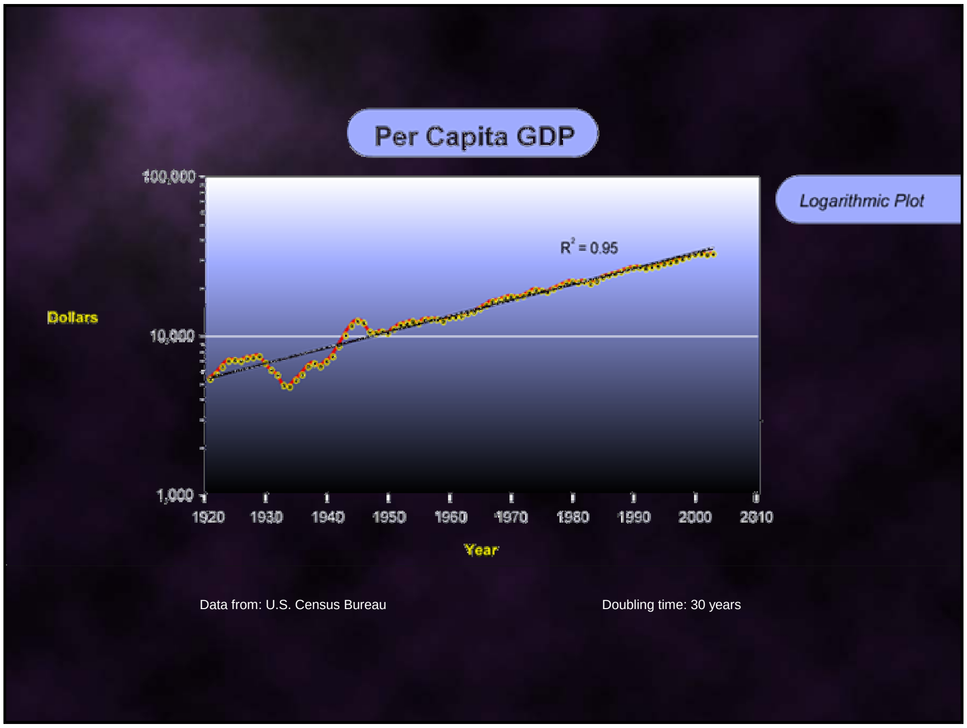
Gathering data from multiple studies, Javier F. Medina, Michael D. Mauk, and their colleagues at the University of Texas Medical School devised a detailed bottom-up simulation of the cerebellum.

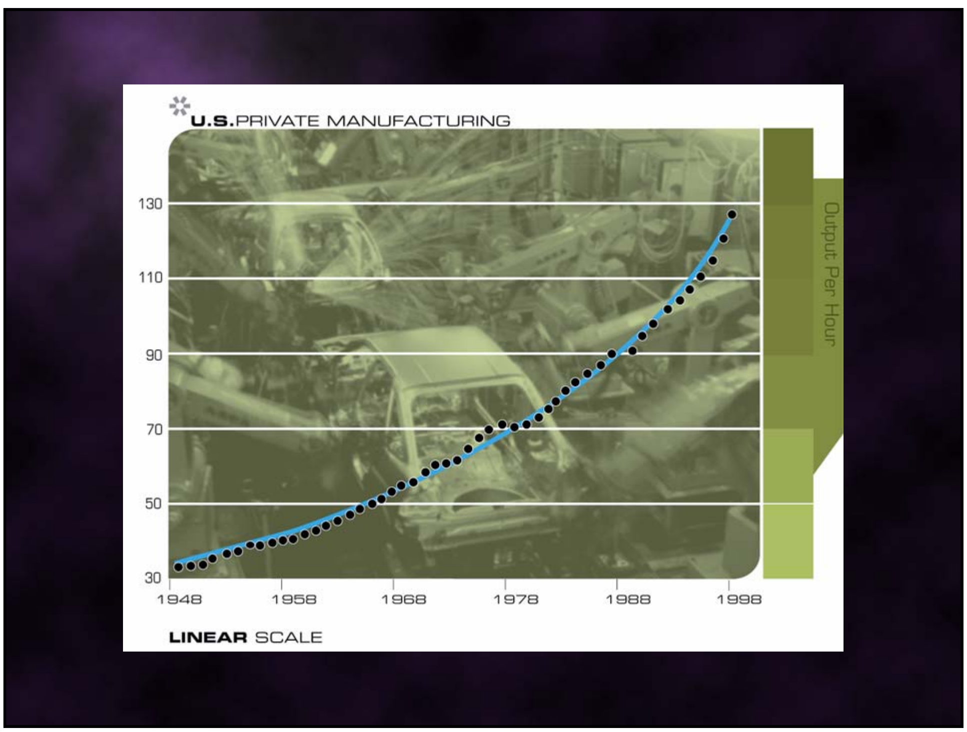
Their simulation includes over 10,000 simulated neurons and 300,000 synapses, and includes all of the principal types of cerebellum cells.

The Law of Accelerating Returns is driving economic growth

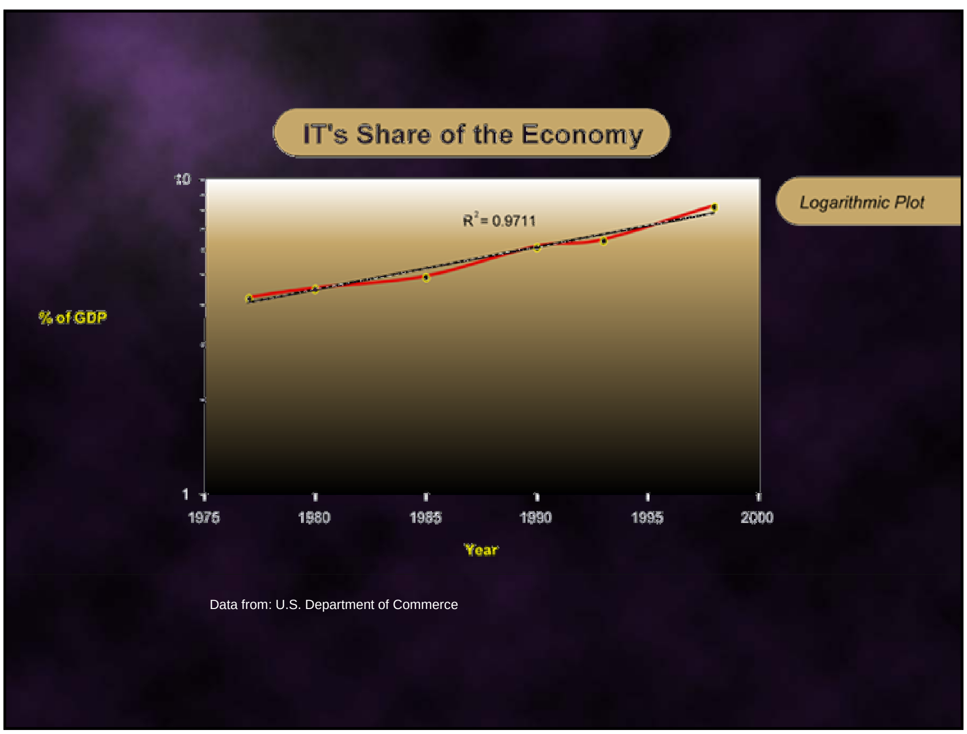
- The portion of a product or service's value comprised of information is asymptoting to 100%
- The cost of information at every level incurs deflation at ~ 50% per year
- This is a powerful deflationary force
  - Completely different from the deflation in the 1929 Depression (collapse of consumer confidence & money supply)

Data from: Bureau of Economic Analysis

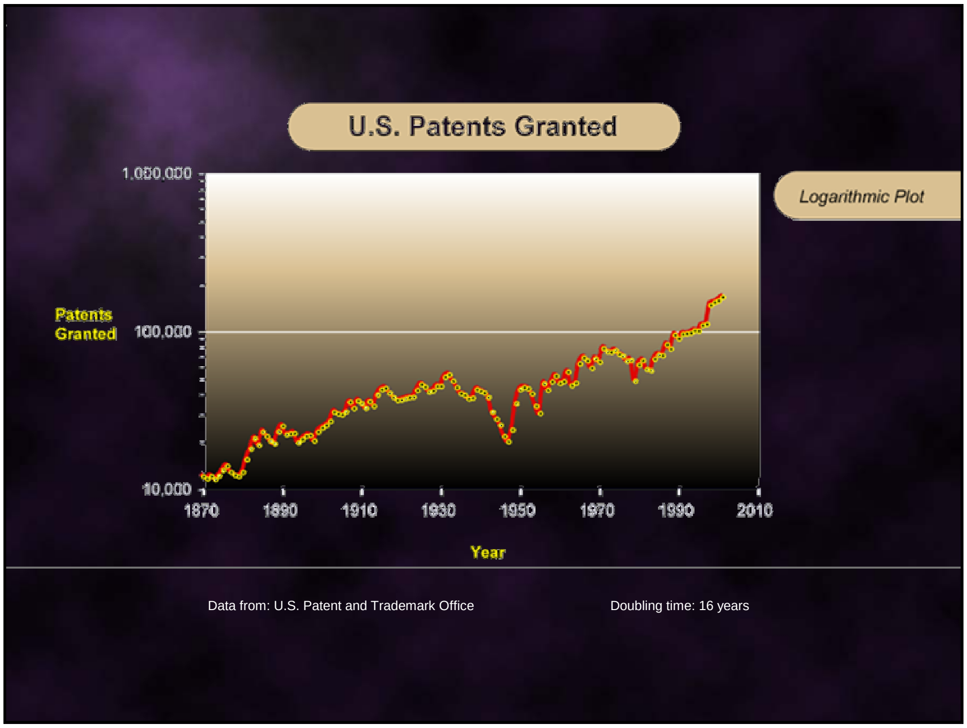

Per Capita GDP
Logarithmic Plot
Dollars
100,000
10,000
1,000
$R^2 = 0.95$
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Year
Data from: U.S. Census Bureau
Doubling time: 30 years


U.S. PRIVATE MANUFACTURING
Output Per Hour
130
110
90
70
50
30
1948
1958
1968
1978
1988
1998
LINEAR SCALE

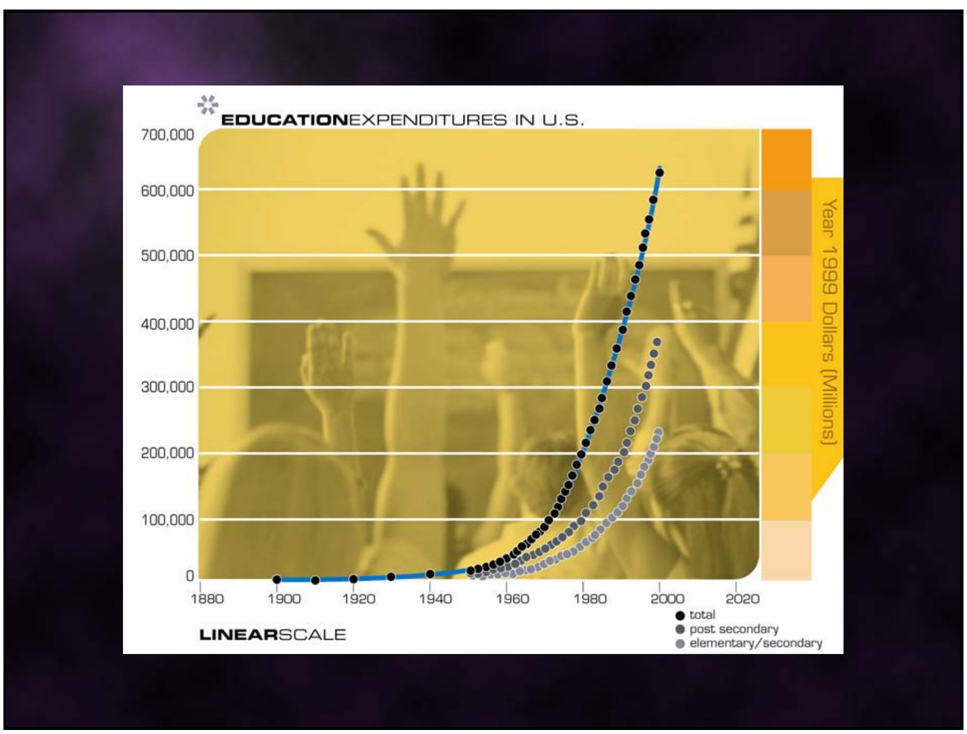
E-Commerce Revenues in U.S.
Logarithmic Plot
B2C (Business to Consumer)
B2B (Business to Business)
10,000
1,000
100
10
1
Billions of dollars
1997
1998
1999
2000
2001
2002
2003
2004
2005
Year
Data from: eMarketer



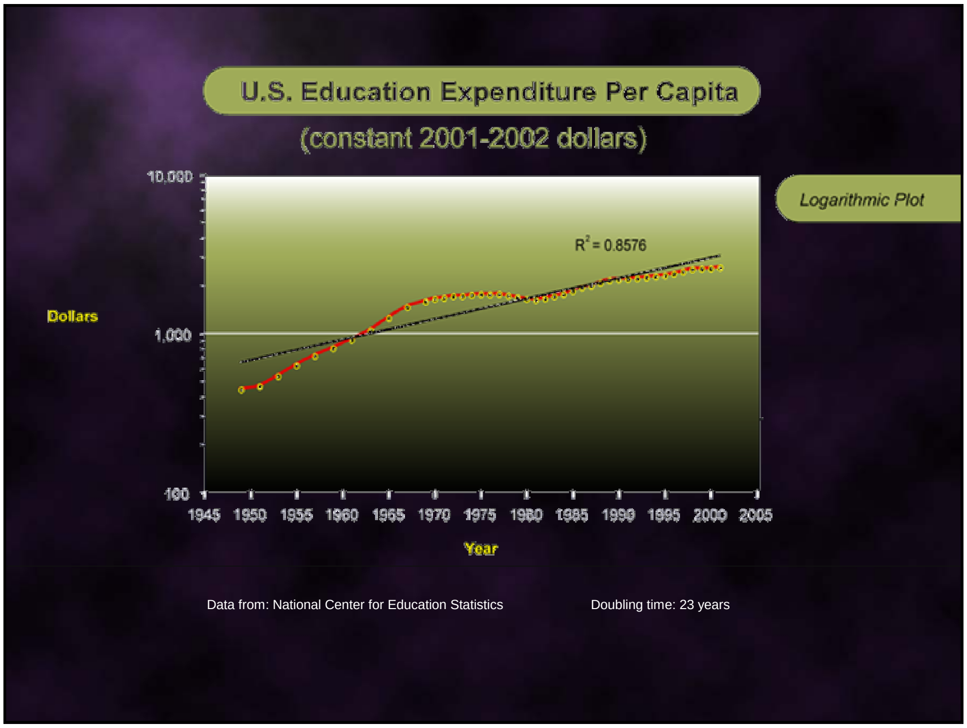
IT's Share of the Economy
Logarithmic Plot
10
1
% of GDP
R² = 0.9711
1975
1980
1985
1990
1995
2000
Year
Data from: U.S. Department of Commerce



U.S. Patents Granted
Logarithmic Plot
1,000,000
100,000
10,000
Patents Granted
1870
1890
1910
1930
1950
1970
1990
2010
Year
Data from: U.S. Patent and Trademark Office
Doubling time: 16 years



EDUCATION EXPENDITURES IN U.S.
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1880
1900
1920
1940
1960
1980
2000
2020
Year 1999 Dollars (Millions)
LINEAR SCALE
total
post secondary
elementary/secondary



Contemporary Examples of Self-organizing systems

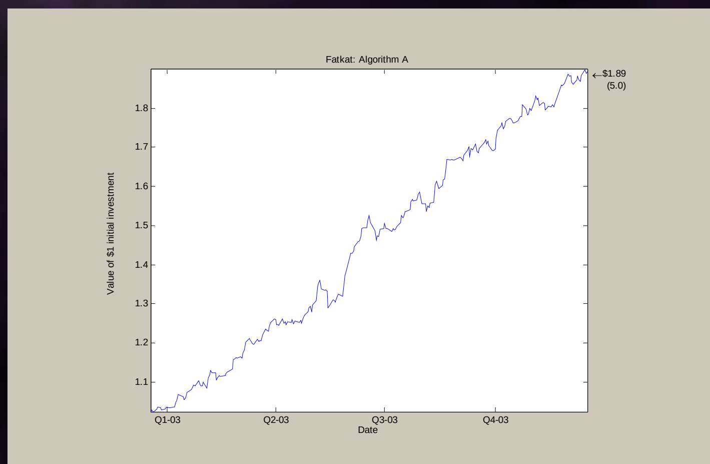
- The bulk of human intelligence is based on **pattern recognition**: the quintessential example of self-organization

Contemporary Examples of Self-organizing systems

- Machines are rapidly improving in pattern recognition
- Progress will be accelerated now that we have the tools to reverse engineer the brain
- Human pattern recognition is limited to certain types of patterns (faces, speech sounds, etc.)
- Machines can apply pattern recognition to any type of pattern
- Humans are limited to a couple dozen variables, machines can consider thousands simultaneously

FatKat *(Financial Accelerating Transactions from Kurzweil Adaptive Technologies):* applying pattern recognition with thousands of variables to short-term stock movements

FatKat *(Financial Accelerating Transactions from Kurzweil Adaptive Technologies):* applying pattern recognition with thousands of variables to short-term stock movements



2010: Computers disappear

- Images written directly to our retinas
- Ubiquitous high bandwidth connection to the Internet at all times
- Electronics so tiny it's embedded in the environment, our clothing, our eyeglasses
- Full immersion visual-auditory virtual reality
- Augmented real reality
- Interaction with virtual personalities as a primary interface
- Effective language technologies

2029: An intimate merger

- $1,000 of computation = 1,000 times the human brain
- Reverse engineering of the human brain completed
- Computers pass the Turing test
- Nonbiological intelligence combines
  - the subtlety and pattern recognition strength of human intelligence, with
  - the speed, memory, and knowledge sharing of machine intelligence
- Nonbiological intelligence will continue to grow exponentially whereas biological intelligence is effectively fixed

Nanobots provide…

- Neural implants that are:
  - Noninvasive, surgery-free
  - Distributed to millions or billions of points in the brain
- Full-immersion virtual reality incorporating all of the senses
  - You can be someone else
  - "Experience Beamers"
- Expansion of human intelligence
  - Multiply our 100 trillion connections many fold
  - Intimate connection to diverse forms of nonbiological intelligence

Implications of the Law of Accelerating Returns on Army Science and Technology Priorities ast improvements in:

- Reduce development cycle time for new weapons systems
  - Increase use of simulation
- Develop the "remote-robotic-robust-size-reduced-virtual reality" paradigm

Move personnel away from combat to the extent possible:

- Remotely guided systems
- Increase level of autonomous control
- Miniaturized systems
- Robotic systems
- Self-organizing, secure communications

Virtual Reality Systems

- Put human controllers virtually "inside" combat systems (e.g., armed predator)
- Soldiers inside weapons (e.g., tanks) also need virtual reality environments
- For training

Miniaturization: top-down

- Start with concept of conventional tanks, planes
- Take human out, eliminate human support
- Then make them smaller to be more maneuverable
- Perform higher-risk missions

Miniaturization: bottom-up

- Smart Dust
  - Power from movement, wind, thermal currents, nano fuel-cells
  - Go beyond today's passive smart dust prototypes
- Insect and golf ball size devices
- Smart bullets
- Harness swarm intelligence

Capabilities of swarms of tiny devices

- Reconnaissance on movement of people and machinery
- Locate specific persons (thermal and electromagnetic fields)
- Ultimately combat missions

Highly secure and self-organizing command and control

- Information flows in from many sources:
  - Every person at every level of command
  - Every device
  - Software agents processing information

Information needs to be presented:

- To each person:
  - Effective display environments
  - Highlighting of the most important information
  - Immersive environments
  - Take into account mission and capabilities of each combatant and commander
- To each device

Communications must be self-organizing

- World wide mesh
- Each node can both send and receive its own and other messages
- No centralized points of control that would be vulnerable
- Highly distributed
- Scalable
- Secure

Bioterrorism

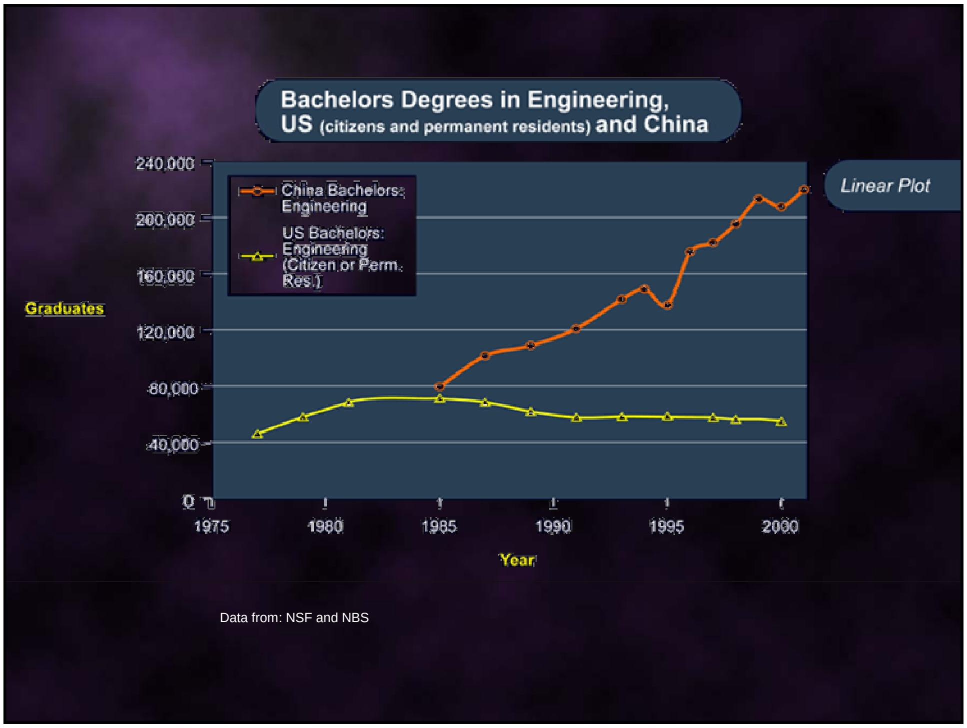
- The primary existential threat is from bioengineered biological viral agents.
- We need to greatly increase the priority of developing broad spectrum anti-viral technologies.
- Idea: Rapid response through RNA interference.

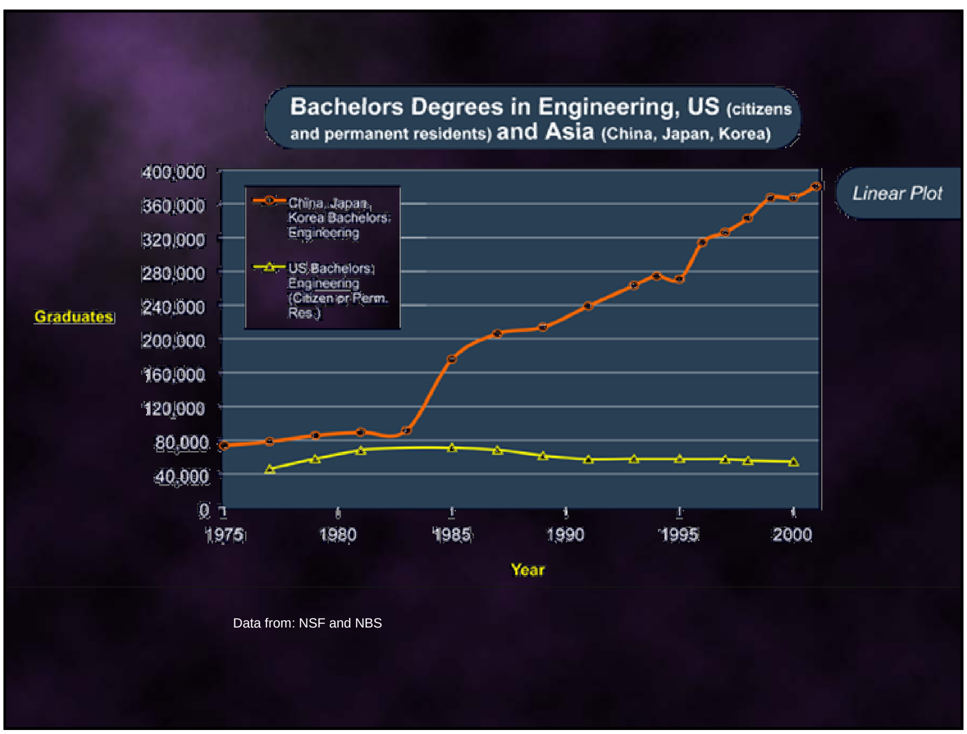
Other Key Areas

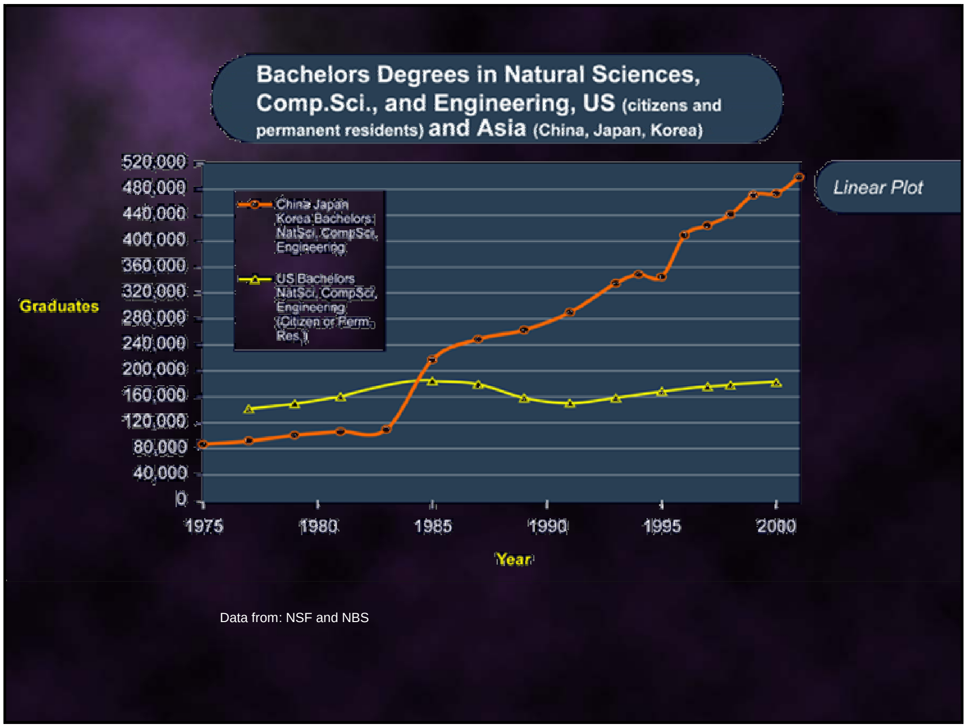
- Simulation for development testing, and training
- Lightweight, intelligent armor (nanocoatings)
- Automated diagnosis and treatment built into the armor
- Extending human capability
  - Robotic extension of human motion
  - Perceptual and cognitive
- Space-based weapons

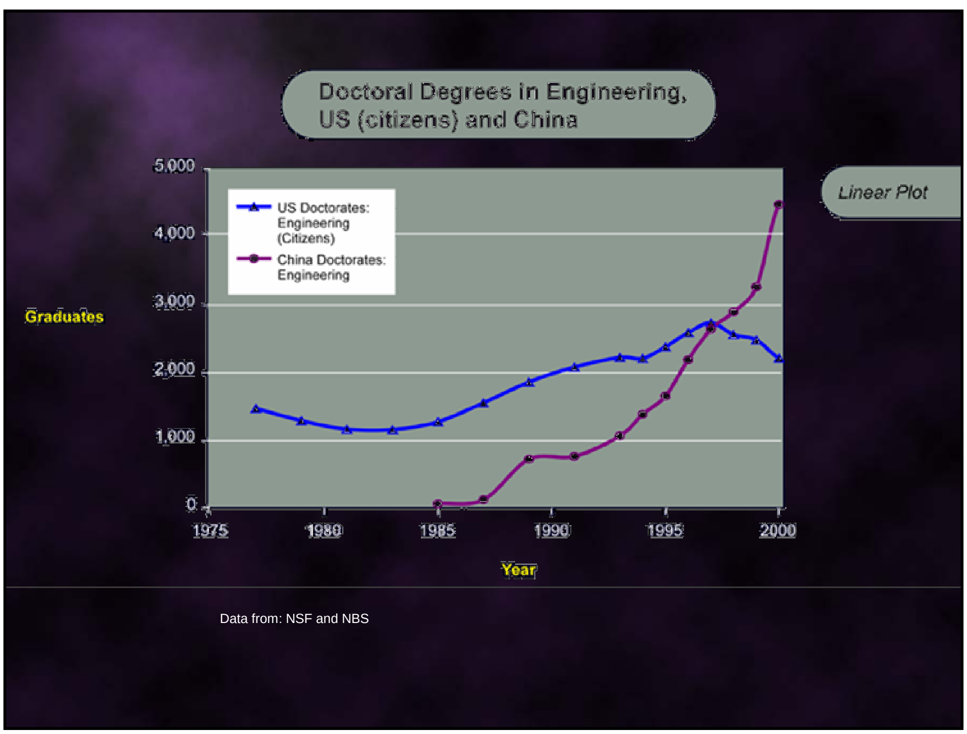
Cyberwarfare

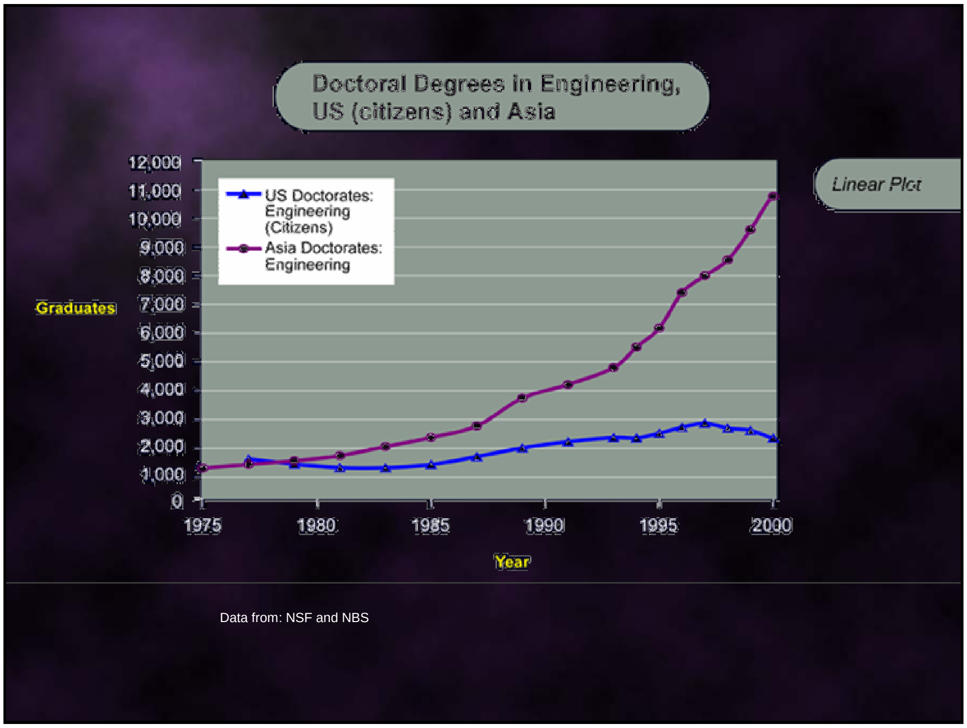
- Security of our own self-organizing communications
- Ability to infiltrate, disrupt, confuse and/or destroy enemy communications
- Encryption and decryption

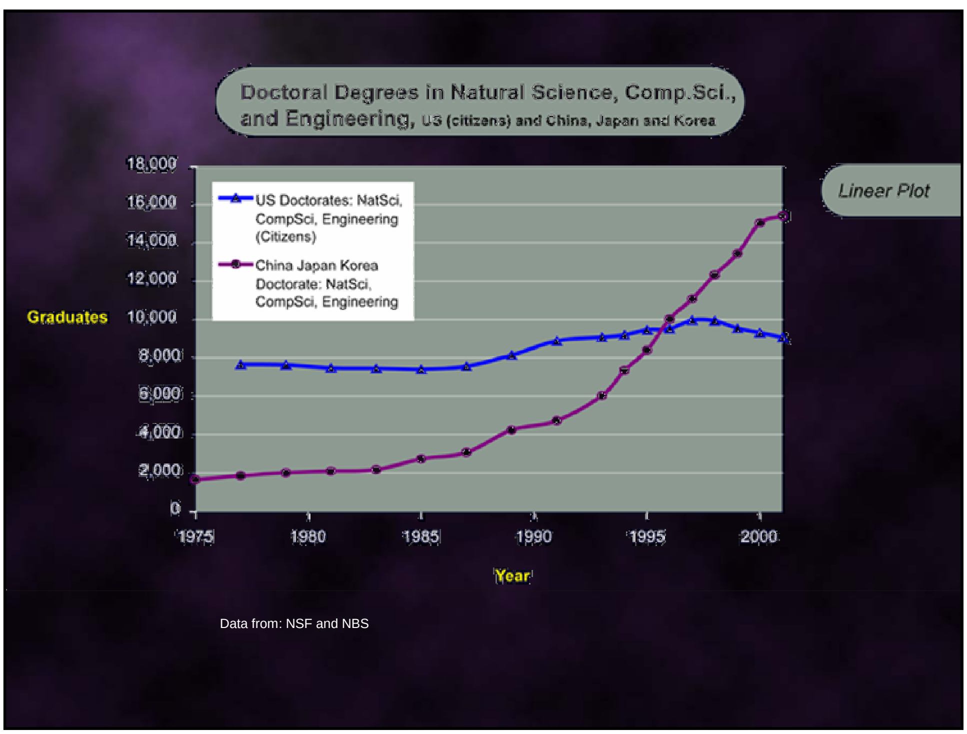

Bachelors Degrees in Engineering,
US (citizens and permanent residents) and China
Linear Plot
Graduates
240,000
200,000
160,000
120,000
80,000
40,000
0
1975
1980
1985
1990
1995
2000
Year
China Bachelors: Engineering
US Bachelors: Engineering (Citizen or Perm. Res.)
Data from: NSF and NBS

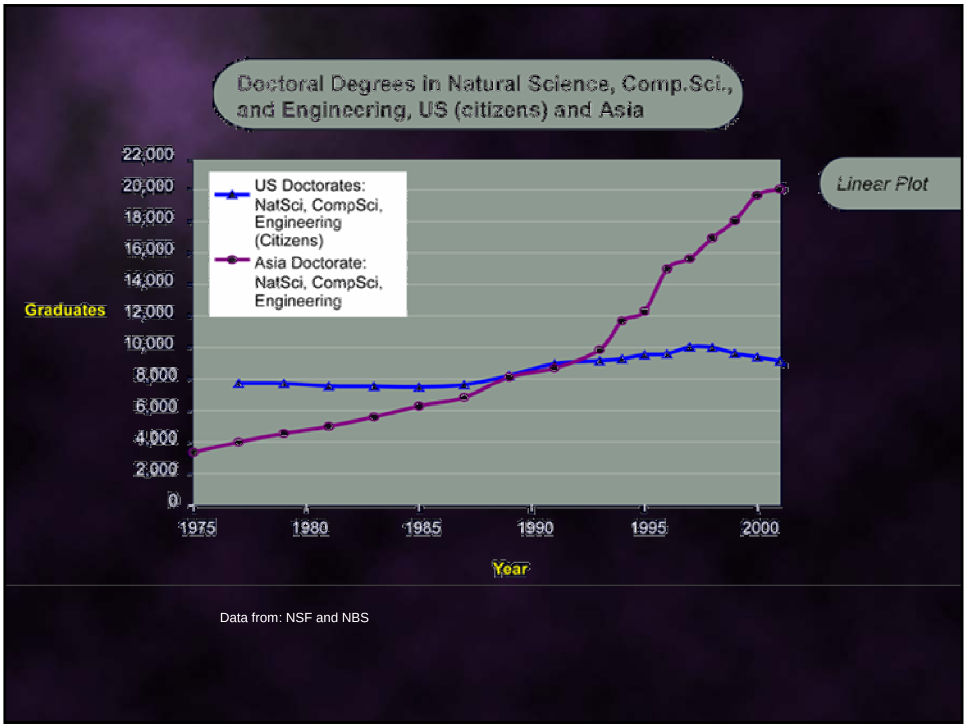

Bachelors Degrees in Engineering, US (citizens and permanent residents) and Asia (China, Japan, Korea)
Linear Plot
Graduates
400,000
360,000
320,000
280,000
240,000
200,000
160,000
120,000
80,000
40,000
0
1975
1980
1985
1990
1995
2000
Year
China, Japan, Korea Bachelors: Engineering
US Bachelors: Engineering (Citizen or Perm. Res.)
Data from: NSF and NBS

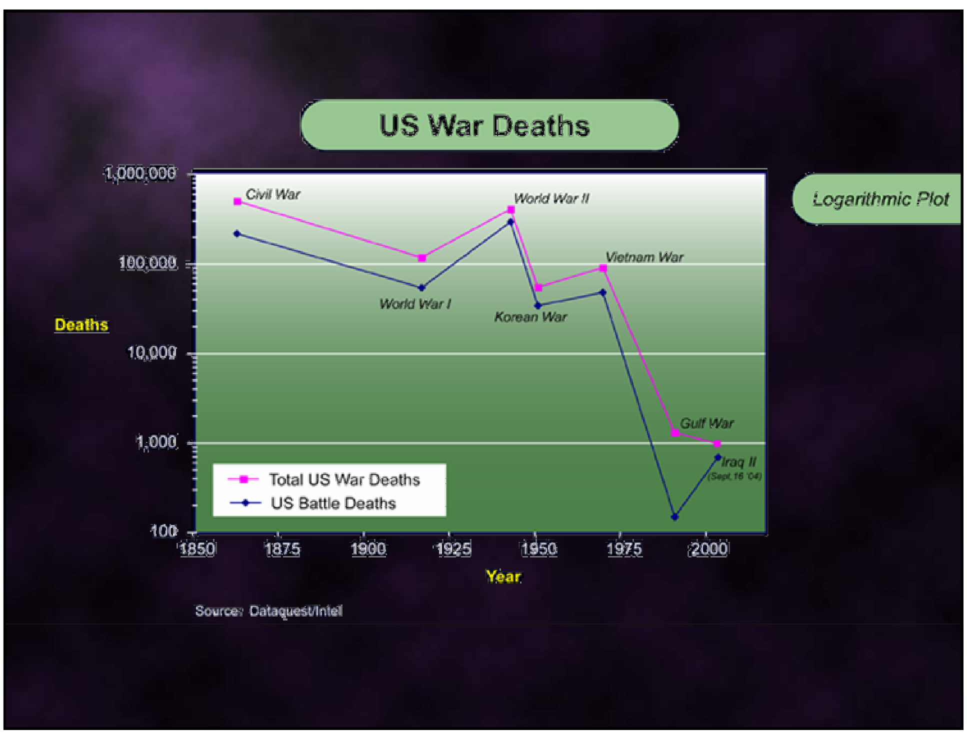

Bachelors Degrees in Natural Sciences, Comp.Sci., and Engineering, US (citizens and permanent residents) and Asia (China, Japan, Korea)
Linear Plot
China Japan Korea Bachelors: NatSci, CompSci, Engineering
US Bachelors NatSci, CompSci, Engineering (Citizen or Perm. Res.)
Graduates
520,000
480,000
440,000
400,000
360,000
320,000
280,000
240,000
200,000
160,000
120,000
80,000
40,000
0
1975
1980
1985
1990
1995
2000
Year
Data from: NSF and NBS


Doctoral Degrees in Engineering, US (citizens) and China
Linear Plot
US Doctorates: Engineering (Citizens)
China Doctorates: Engineering
Graduates
5,000
4,000
3,000
2,000
1,000
0
1975
1980
1985
1990
1995
2000
Year
Data from: NSF and NBS


Doctoral Degrees in Engineering, US (citizens) and Asia
Linear Plot
US Doctorates: Engineering (Citizens)
Asia Doctorates: Engineering
Graduates
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1975
1980
1985
1990
1995
2000
Year
Data from: NSF and NBS

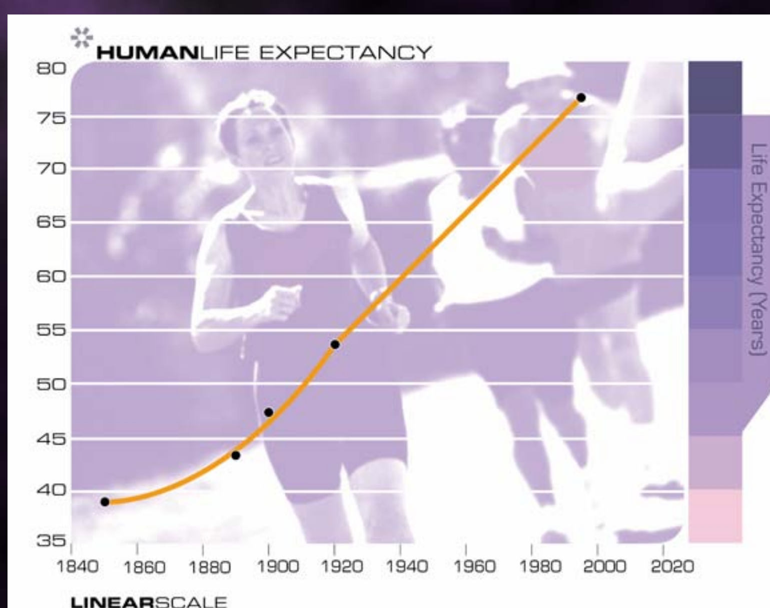

Doctoral Degrees in Natural Science, Comp.Sci., and Engineering, US (citizens) and China, Japan and Korea
Linear Plot
US Doctorates: NatSci, CompSci, Engineering (Citizens)
China Japan Korea Doctorate: NatSci, CompSci, Engineering
Graduates
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1975
1980
1985
1990
1995
2000
Year
Data from: NSF and NBS


Doctoral Degrees in Natural Science, Comp.Sci., and Engineering, US (citizens) and Asia
Linear Plot
US Doctorates: NatSci, CompSci, Engineering (Citizens)
Asia Doctorate: NatSci, CompSci, Engineering
Graduates
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1975
1980
1985
1990
1995
2000
Year
Data from: NSF and NBS


US War Deaths
Logarithmic Plot
Deaths
1,000,000
100,000
10,000
1,000
100
Civil War
World War II
World War I
Korean War
Vietnam War
Gulf War
Iraq II
(Sept 16 '04)
Total US War Deaths
US Battle Deaths
1850
1875
1900
1925
1950
1975
2000
Year
Source: Dataquest/Intel

Average Life Expectancy (Years)

Cro Magnon	18
Ancient Egypt	25
1400 Europe	30
1800 Europe & U.S.	37
1900 U.S.	48
2002 U.S.	78



Reference URLs:

Graphs available at:

www.KurzweilAI.net/pps/Army/

Home of the Big Thinkers:

www.KurzweilAI.net