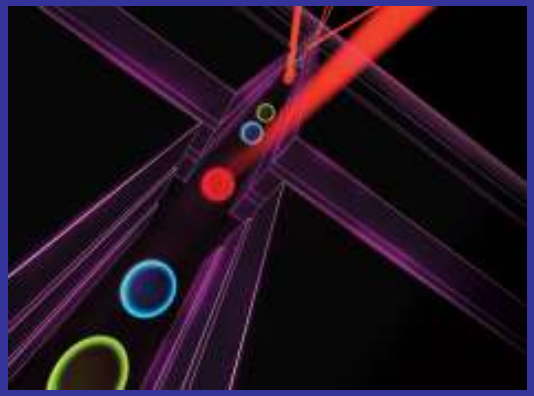
The Future of Technology



October 2007

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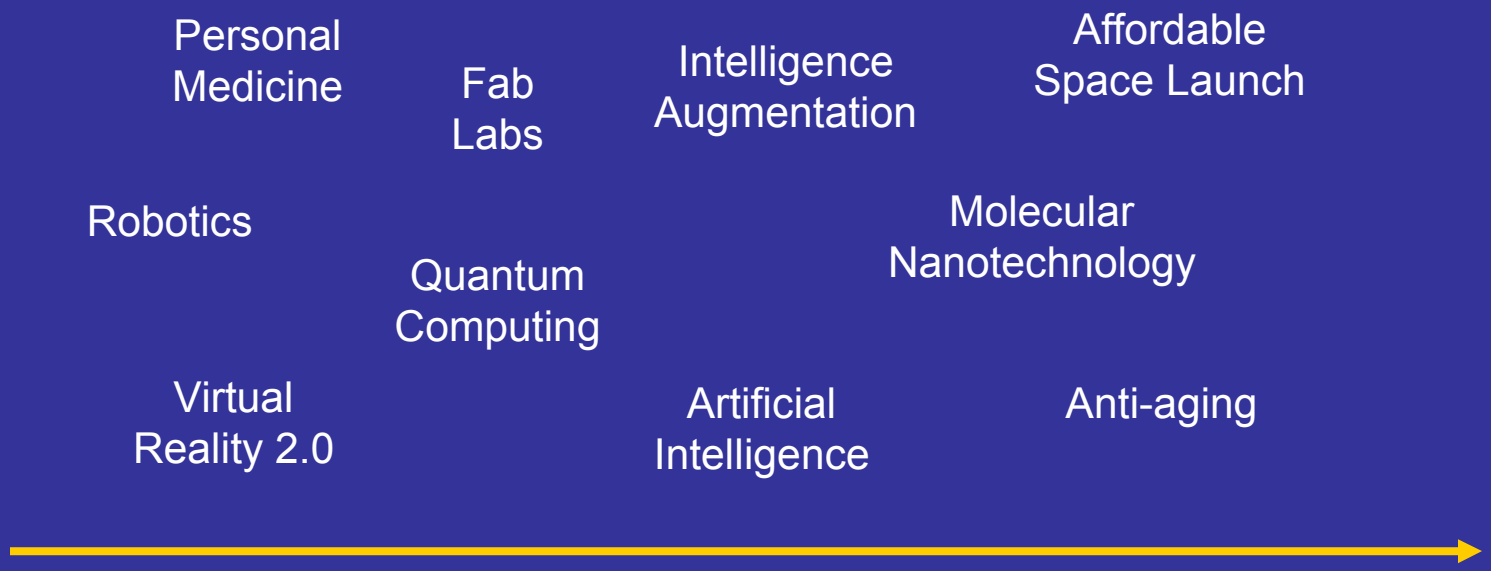
Summary

- We think about growth and change in linear, exponential and discontinuous paradigms, history is a chain of discontinuities
- The realm of technology is no longer discrete, technology is imbuing traditional linear phenomena with exponential and discontinuous change
- Computation (hardware and software) overview: Moore's Law improvements will likely continue unabated in hardware; software however is stuck
- Not only will there be linear and exponential growth in the next 50 years but probably also discontinuous change, possibly a change with greater impact than the Internet in our (current) lifetimes

What will be the next Internet?

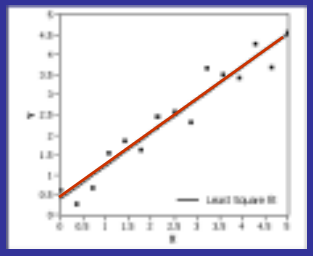
- The future depends on which coming revolution occurs first



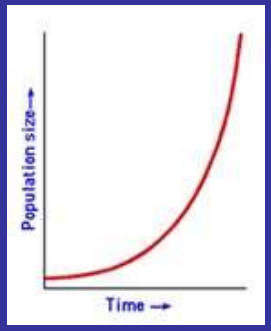
Paradigms of growth and change

- Linear
  - Economic, demographic, biological phenomena
- Exponential
  - Technological phenomena: processors, memory, storage, communications, Internet communities
- Discontinuous
  - Airplane, radio, wars, radar, nuclear weapons, automobile, satellites, Internet, globalization, computers
  - Impossible to predict
    - Evaluate rapid transition time and doubling capability
    - Next possible candidates: molecular manufacturing, artificial intelligence

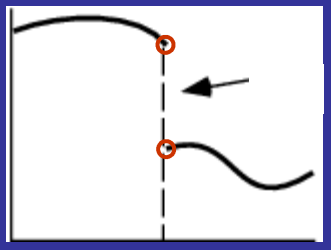
Linear



Exponential



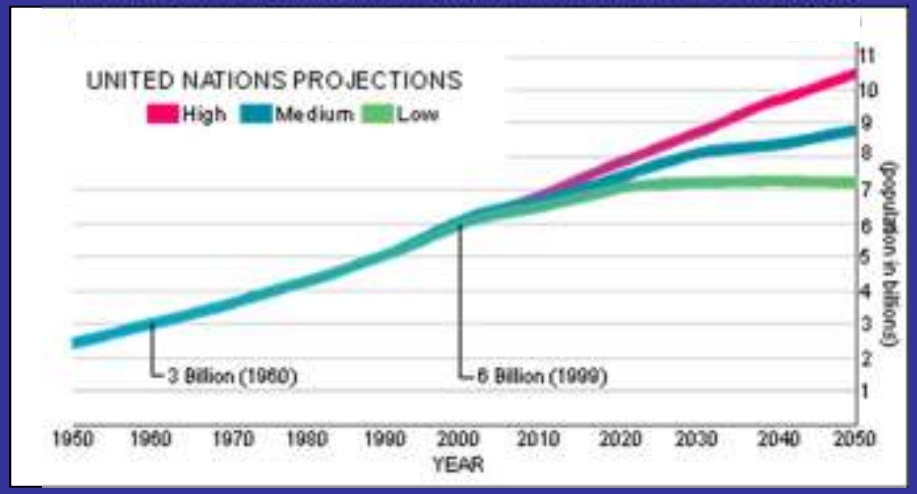
Discontinuous



World population growing at a slowing rate

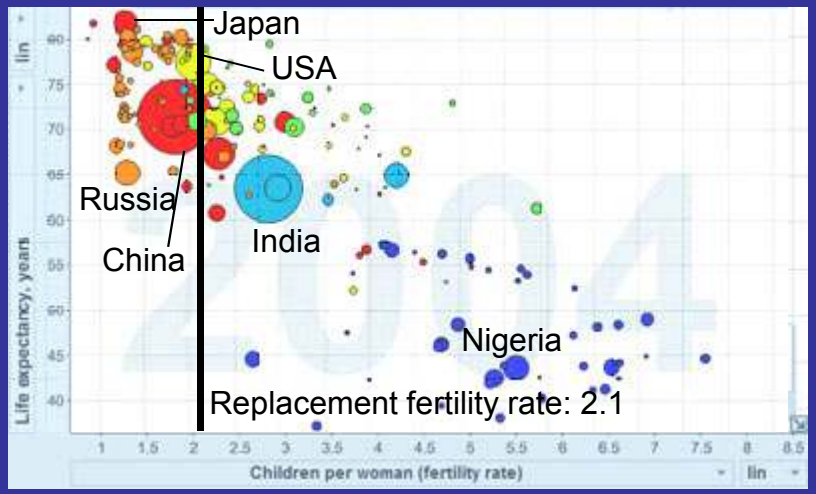
- The UN estimates a population high of 9 billion in 2054
- Populations are already below replacement levels and shrinking, even before considering health advances

World Population Growth, 1950-2050



Source: http//www.unfpa.org/6billion/facts.htm

2004 Fertility Rate and Life Expectancy by Country

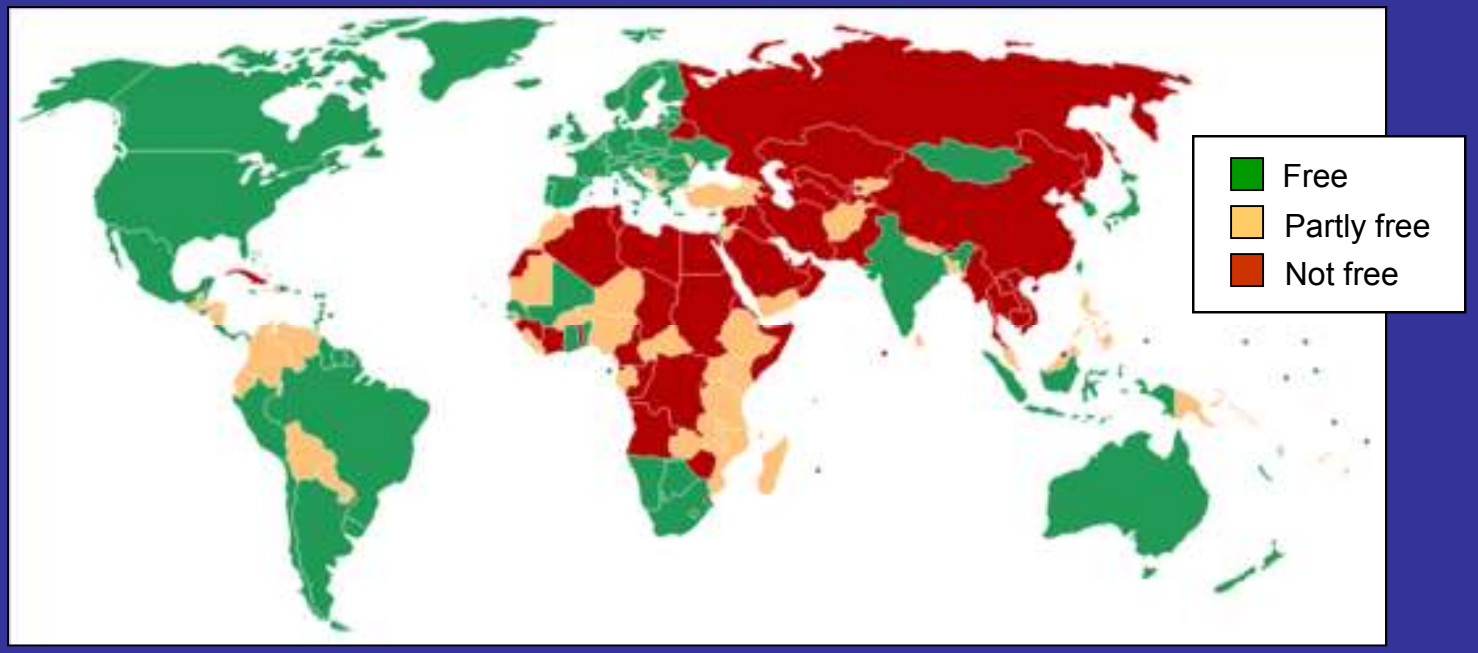


Source: http://tools.google.com/gapminder/

Political enfranchisement room to improve

- Less than half (123) of the world's 245 countries are considered full electoral democracies in 2007

Freedom in the World - Freedom House, 2007
Measures of democracy and freedom

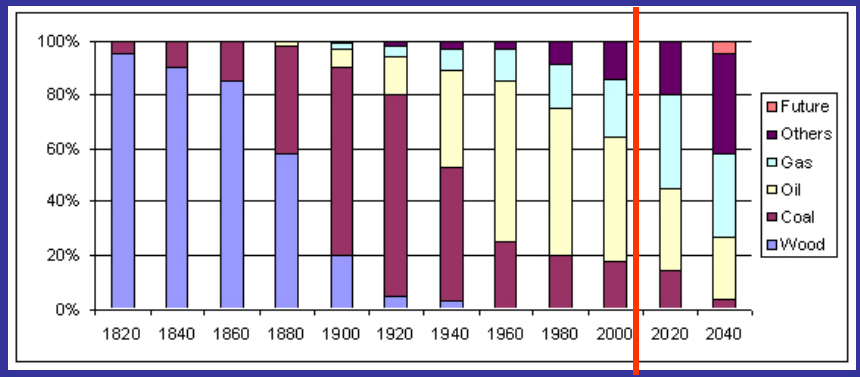


Sources: http://en.wikipedia.org/wiki/Freedom_in_the_World, http://www.freedomhouse.org

Energy demand growing, mix shifting

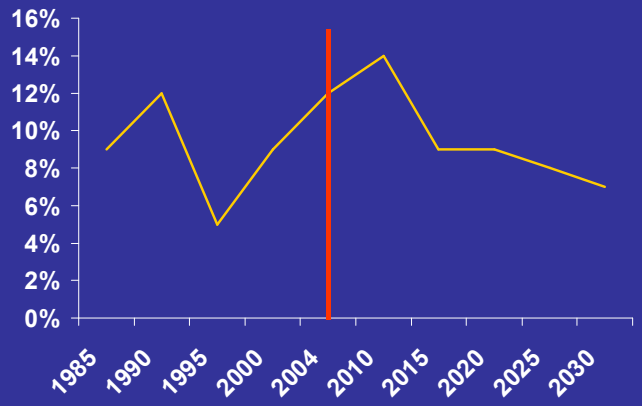
- Rate of growth of energy demand to slow in 2015
- U.S. mix already shifting
- Consumption in perspective

U.S. Energy Consumption by Type, 1820 - 2040



Source: http://lifeboat.com/ex/energy.2020

Global Energy Use Growth Rates 1980 - 2030



Source: http://www.eia.doe.gov/oiaf/ieo/figure_8.html

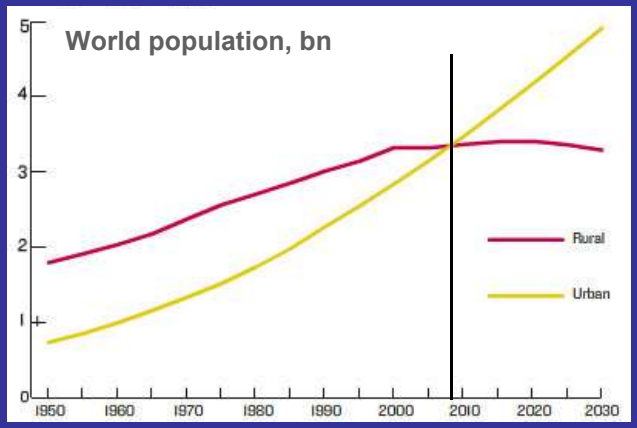
Reference: Energy Scale

Example	Power
U.S. electrical power consumption (2001)	424 GW
World electrical power consumption (2001)	1.7 TW
U.S. total power consumption (2001)	3.3 TW
Global photosynthetic energy production	3.6 - 7.2 TW
World total power consumption (2001)	13.5 TW
Average total heat flux from earth's interior	44 TW
Heat energy released by a hurricane	50 - 200 TW
Estimated heat flux transported by the Gulf Stream	1.4 PW
Total power received by the Earth from the Sun	174 PW

Source: http://lifeboat.com/ex/energy.2020

Urban density increasing

- In 2008, for the first time in history, 50% of the world's population will be urban
- 2030, 60% urban, 4.9 bn people
- In 2005, megacities accounted for 9% of the world's $59.4 trillion GDP



Source: http://www.spectrum.ieee.org/jun07/5148

Top 10 cities and urban areas, 2006 and 2020					
	City/Urban area	2006 (m)	City/Urban area	Growth p.a. 2006-2020	2020 (m)
1	Tokyo, Japan	35.5	Tokyo, Japan	0.34%	37.3
2	Mexico City, Mexico	19.2	Mumbai, India	2.32	26.0
3	Mumbai, India	18.8	Delhi, India	3.48	25.8
4	New York, USA	18.7	Dhaka, Bangladesh	3.79	22.0
5	São Paulo, Brazil	18.6	Mexico City, Mexico	0.90	21.8
6	Delhi, India	16.0	São Paulo, Brazil	1.06	21.6
7	Calcutta, India	14.7	Lagos, Nigeria	4.44	21.5
8	Jakarta, Indonesia	13.7	Jakarta, Indonesia	3.03	20.8
9	Buenos Aires, Argentina	13.5	New York, USA	0.66	20.4
10	Dhaka, Bangladesh	13.1	Karachi, Pakistan	3.19	18.9

Source: http://www.citymayors.com/statistics/urban_2006_1.html, urban_2020_1.html

Economics: sovereigns and MNCs dominate

- Substantial MNC presence in global economics
  - 35% (7) of top 20, 59% (59) of top 100, 66% (132) of top 200

Top Twenty Revenue Generating Entities, 2006

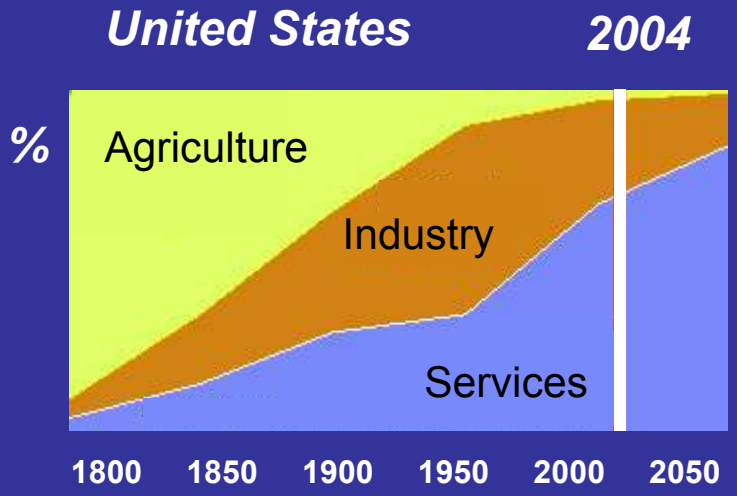
	Entity	$B Revenues (2006)		Entity	$B Revenues (2006)
1	United States	2,409.0	11	Royal Dutch Shell plc	318.8
2	Japan	1,411.0	12	Netherlands	304.3
3	Germany	1,277.0	13	Australia	267.0
4	France	1,150.0	14	BP	265.9
5	United Kingdom	973.0	15	Brazil	244.0
6	Italy	832.9	16	Russia	222.2
7	Spain	488.2	17	Sweden	222.0
8	China	446.6	18	General Motors Corp.	206.5
9	ExxonMobil Corp.	377.6	19	Toyota Motor Corp.	205.0
10	Wal-Mart Stores, Inc.	345.0	20	Chevron Corp.	204.9

Sources: CIA Factbook, http://en.wikipedia.org/wiki/List_of_the_world's_largest_companies

Shift to global service economy

- Fungibility (outsourcing) and globalization

Top Ten Nations by Labor Force Size					
	Nation	% ww labor	% Ag	% Ind	% Svc
1	China	21	50	15	35
2	India	17	60	17	23
3	United States	5	3	27	70
4	Indonesia	4	45	16	39
5	Brazil	3	23	24	53
6	Russia	3	12	23	65
7	Japan	2	5	25	70
8	Nigeria	2	70	10	20
9	Bangladesh	2	63	11	26
10	Germany	1	3	33	64
Total / Weighted Average		**60**	**44**	**18**	**38**

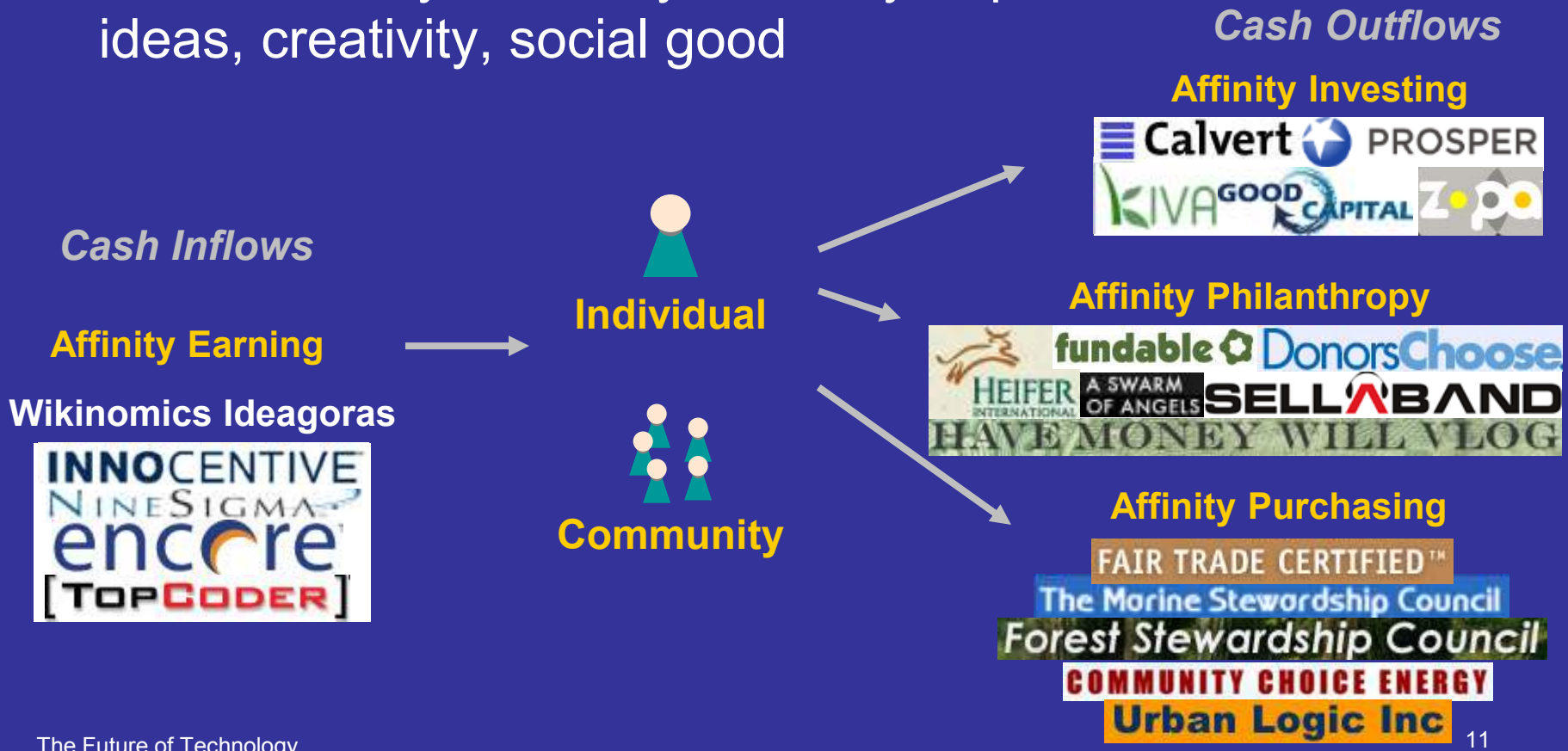


Next wave could be information generation and deployment

Source: Jim Spohrer, Research Director, IBM Almaden, SSME Service Science, Management and Engineering, March 27, 2007, p. 10

Social finance and affinity capital allocation

- Increasingly deep attribute information available
- Multi-currency economy – money, reputation, ideas, creativity, social good



Internet connectivity growth continues

- Only 1.1 billion (17%) people currently on the Internet
- Asia to dominate content and connectivity growth
- Even in high penetration countries 25-33% unconnected
- Mobile device-based connectivity

Top 5 Countries Internet Usage, Jun 2007		
	Country	**% Internet Penetration**
1	Iceland	86%
2	Sweden	76%
3	Portugal	74%
4	Netherlands	73%
5	United States	70%

Source: http://www.internetworldstats.com

Population and Internet Penetration by World Region (Jun 2007)					
Region	**Population % of world**	**% Population Connected**	**% of Worldwide Internet Users**	**Internet users (Mar 2007)**	**Usage growth 2000-2007**
North America	5.1%	69.0%	20.4%	231.0 m	113.7%
Europe	12.3%	39.4%	28.2%	319.1	203.6%
Asia	56.5%	11.0%	**36.0%**	409.4	258.2%
Total World		**17.2%**		**1,133.4 m**	**214.0%**

Source: http://www.internetworldstats.com

Video is driving Internet traffic growth

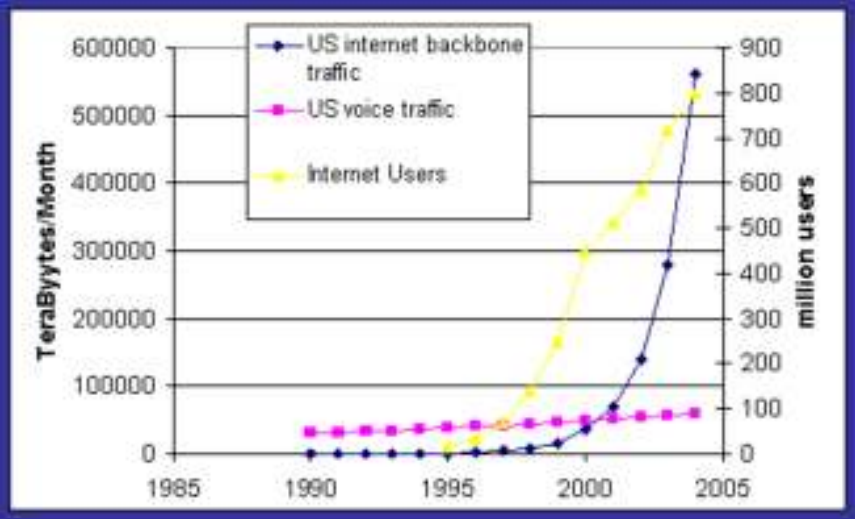
- Internet traffic growth outpacing new bandwidth additions
- YouTube: 6% Comcast traffic
- P2P: 40% Internet traffic
- 127,961,479 websites worldwide (Aug 2007), growing 1.8% / month

Source: http://www.netcraft.com

Global Internet traffic map, 2005

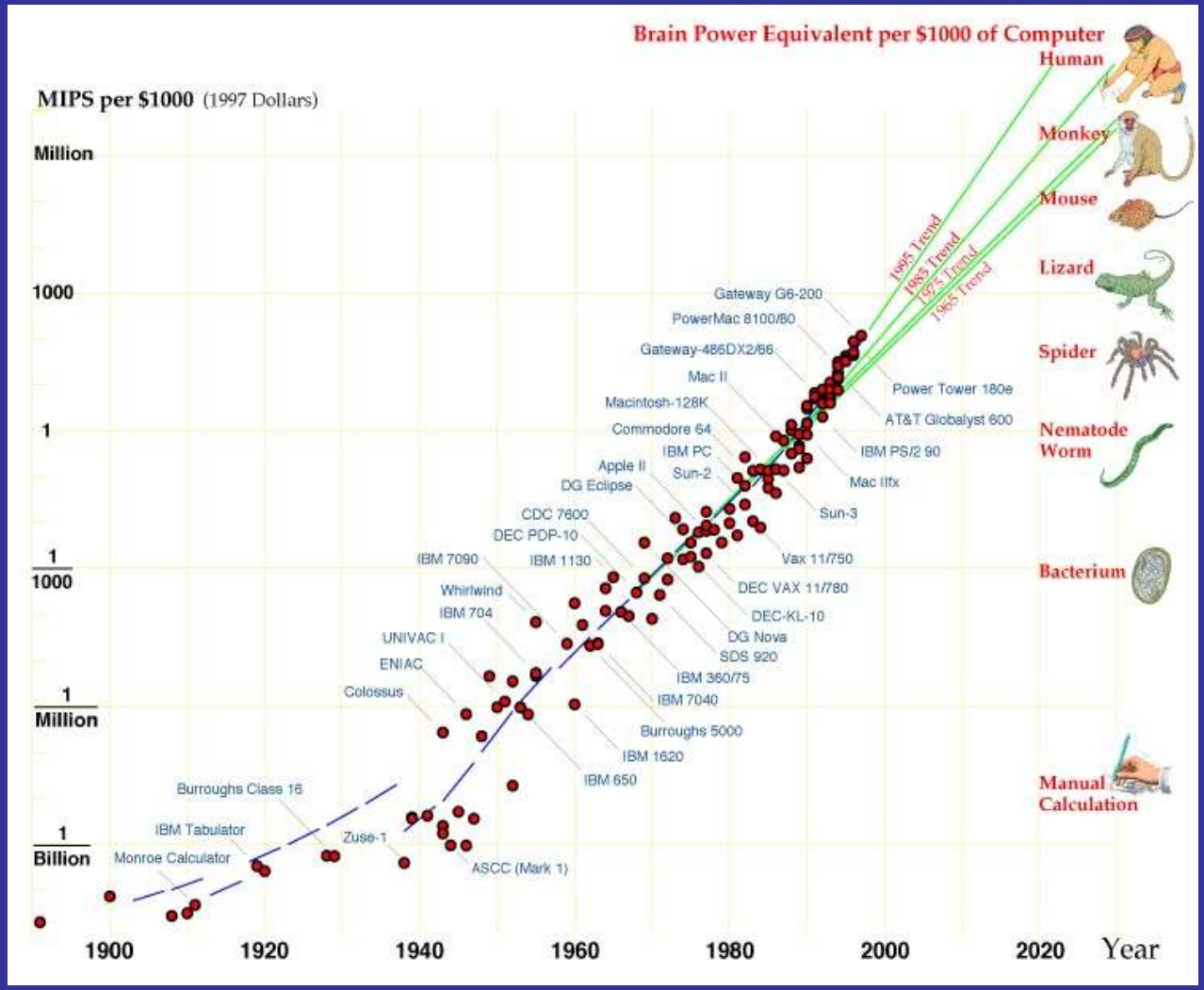
Source: http://www.telegeography.com/ptc/images/traffic_map_05_lrg.gif

U.S. Internet traffic, 1985 - 2005



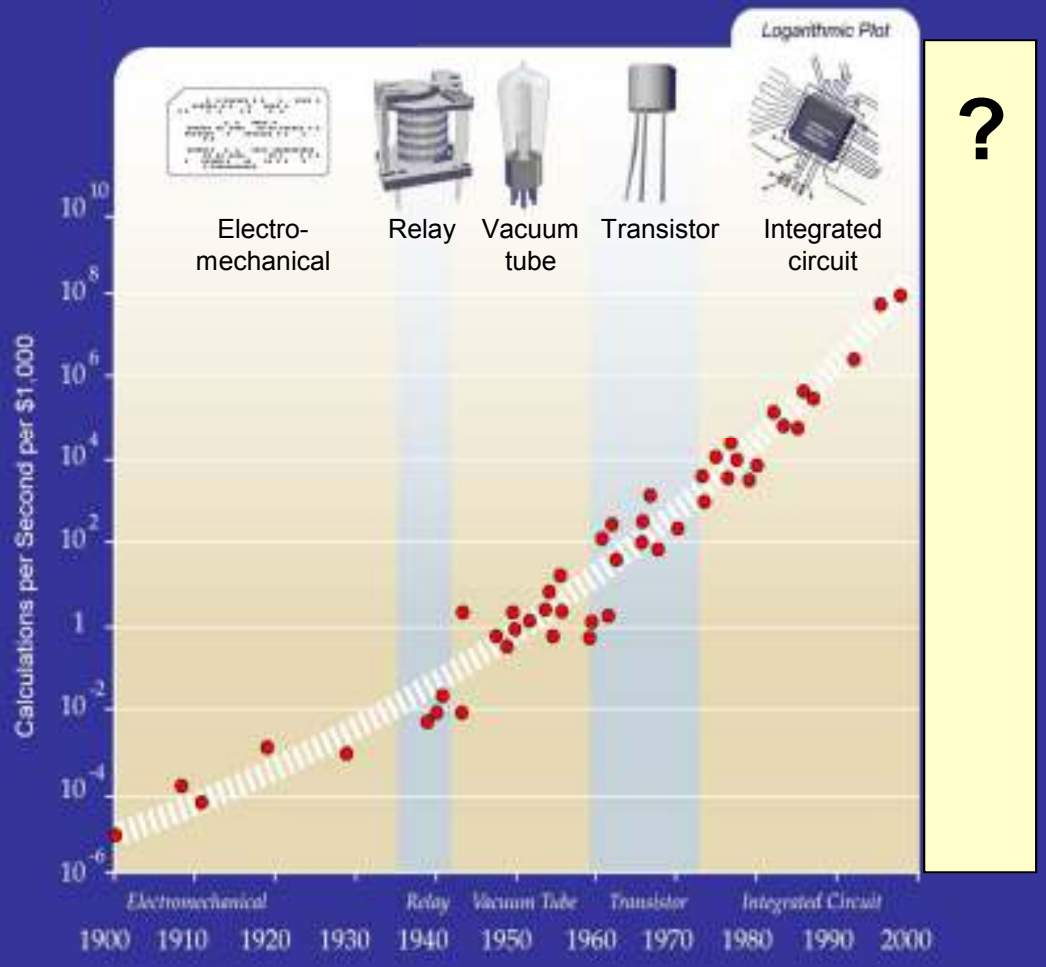
Source: http://www.witbd.org/articles/digital_communications.htm

Evolution of computing power/cost



Source: Hans Moravec, http://www.transhumanist.com/volume1/moravec.htm

Evolution of computation



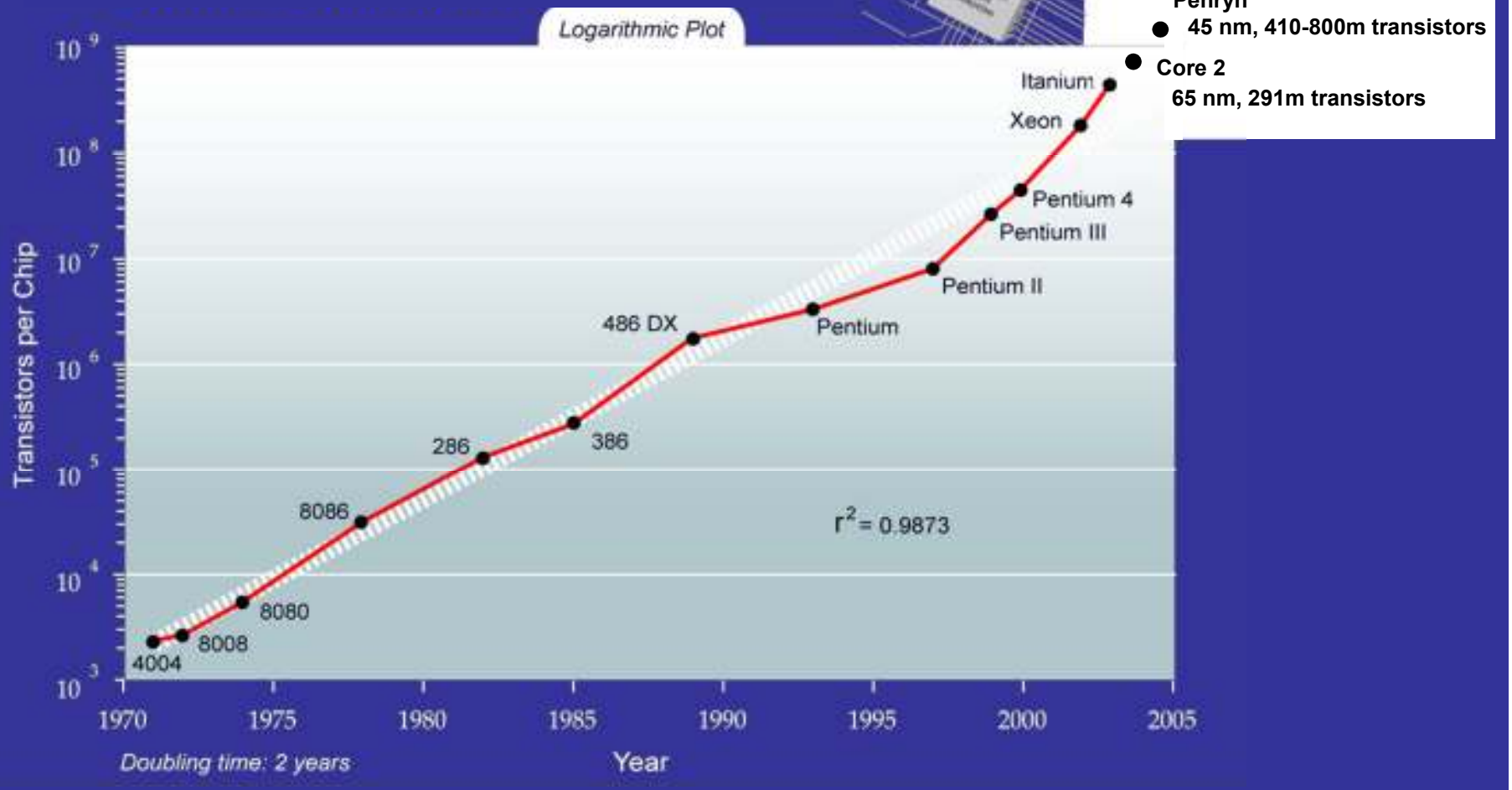
Future of computing

- New materials
- 3d circuits
- Quantum computing
- Molecular electronics
- Optical computing
- DNA computing

Source: Ray Kurzweil, http://www.KurzweilAI.net/pps/ACC2005/

Extensibility of Moore's Law

Transistors per microprocessor

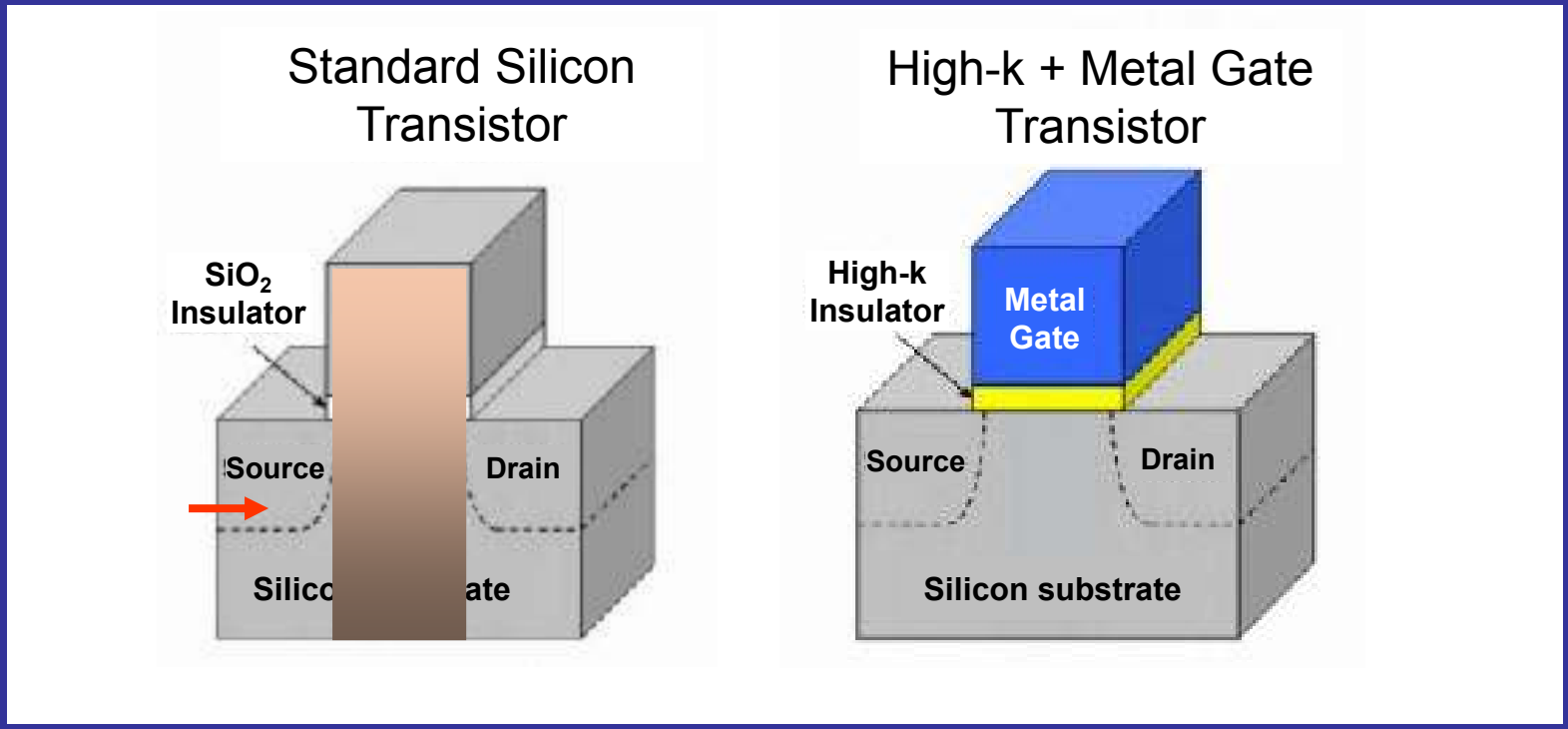


Source: Ray Kurzweil, http://www.KurzweilAI.net/pps/ACC2005/

Semiconductor advancements

Historical semiconductors
65nm+

Intel Penryn 45nm chip,
shipping fall 2007



Source: http://www.siliconvalleysleuth.com/2007/01/a_look_inside_i.html

Software remains challenging

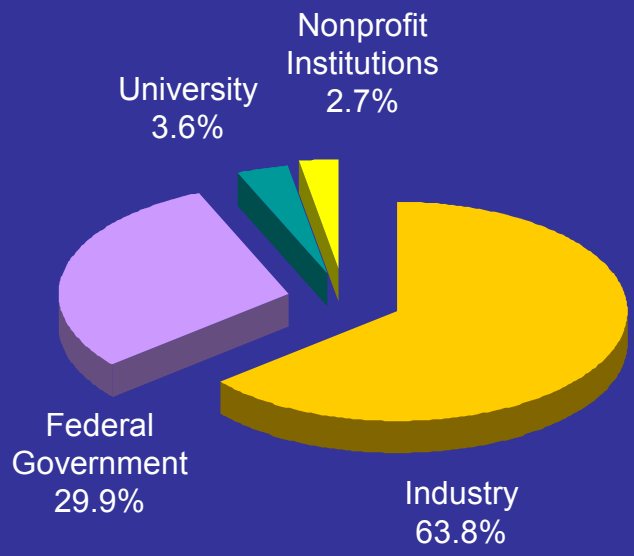
- Abstract, difficult to measure
  - Doubling each 6-10 years
  - Wirth's law: "Software gets slower faster than hardware gets faster"
- Large complex projects (FAA, CIA) failure
- 19 m programmers worldwide in 2010[1]
- Solutions?
  - Distributed ecologies of software programmers
  - Open source vs. proprietary systems
  - Standards, reusable modules
  - Web-based software
    - Aggregating collective intelligence (tagging, RSS, presence), community platforms as the back end (FB, LinkedIn, MySpace)
  - Software that programs software

Lady Ada Lovelace

[1]*Source: http://www.itfacts.biz/index.php?id=P8481*

Rate of human innovation: research funding

- $312.1 billion total US R&D spending 2004
  - Industry R&D spend is 2/3 of the total
- Increasing roughly 5% p.a. since 1998
- 20% Basic Research, 20% Applied Research, 60% Development
- Science innovation process improvement
  - Incentive reorientation, performance metrics, management skills
  - Patent reform, example Beth Noveck, peer to patent
  - Granularity sharing: SciVee, Useful Chemistry blog/wiki
  - Discover unused IP: yet2.com

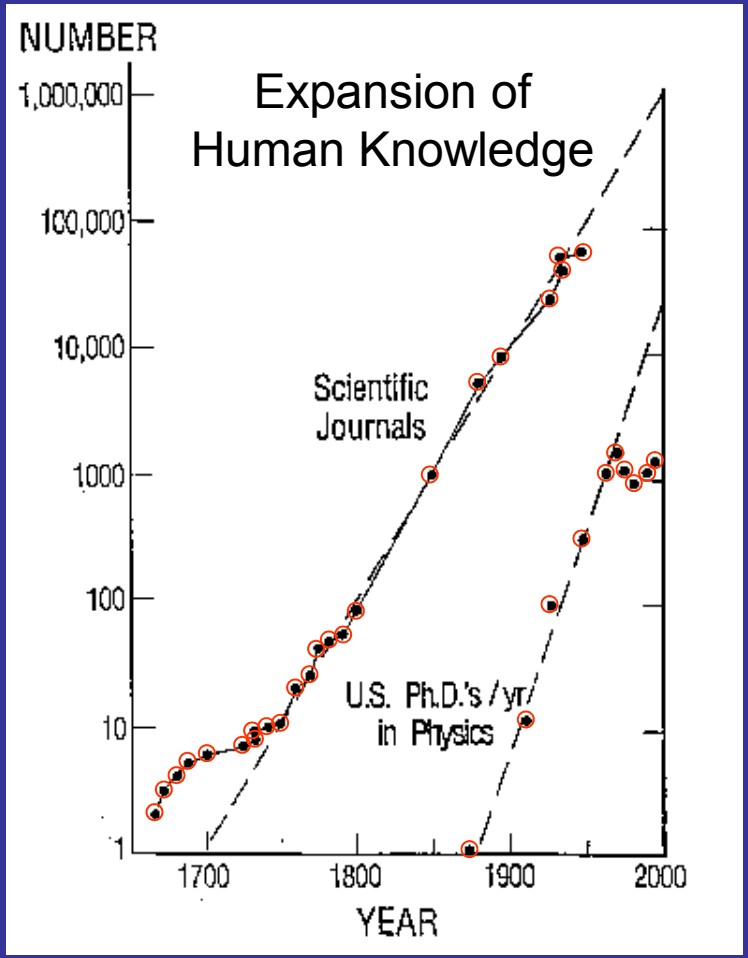


Source: http://www.nsf.gov/statistics/

Doubling rate of human knowledge

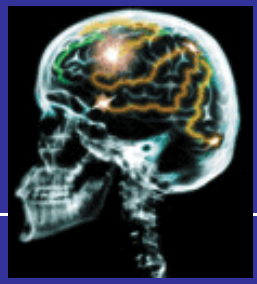
- U.S. role as science and engineering leader slipping
- U.S. comprised 40% global PhDs in 1970 vs. 20% in 2000
- U.S. 17th in worldwide BAs in science and engineering
- In 2002, 17% U.S. BA degrees were in science and engineering, vs. 53% in China

Source: Laura Tyson Commonwealth Club, May 3, 2007, http://odeo.com/audio/13503603/view



Source: David Goodstein, http://www.its.caltech.edu/~dg/crunch_art.html

Arms race for the future of intelligence



Machine	Human
▪ Blue Gene/L 360 teraFLOPS (≈.36+ trillion IPS) and 32 TiB memory[1] ▪ Unlimited operational/build knowledge ▪ Quick upgrade cycles: performance capability doubling every 18 months ▪ Linear, Von Neumann architecture ▪ Understands rigid language ▪ Special purpose solving (Deep Blue, Chinook, ATMs, fraud detection) ▪ Metal chassis, easy to backup	▪ Estimated 2,000 trillion IPS and 1000 TB memory[2] ▪ Limited operational/build knowledge ▪ Slow upgrade cycles: 10,000 yr evolutionary adaptations ▪ Massively parallel architecture ▪ Understands flexible, fuzzy language ▪ General purpose problem solving, works fine in new situations ▪ Nucleotide chassis, no backup possible

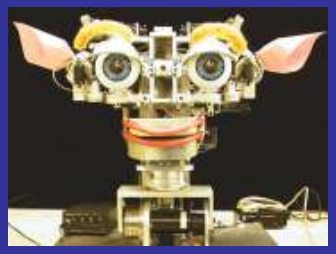
[1]*Source: Fastest Supercomputer, June 2007, http://www.top500.org/system/7747*

[2]*Source: http://paula.univ.gda.pl/~dokgrk/bre01.html*

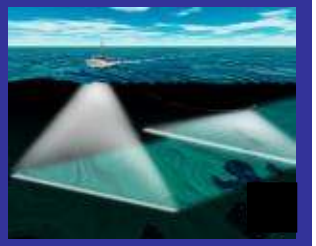
Artificial intelligence: current status

- Approaches
  - Symbolic, statistical, learning algorithms, physical/mechanistic, hybrid
- Current initiatives
  - Narrow AI: DARPA, corporate
  - Strong AI: startup efforts
- Near-term applications
  - Auditory applications: speech recognition
  - Visual applications: security camera (crowbar/gift)
  - Transportation applications: truly smart car
- Format
  - Robotic (Roomba, mower, vehicles)
  - Distributed physical presence
  - Non-corporeal

Stanley

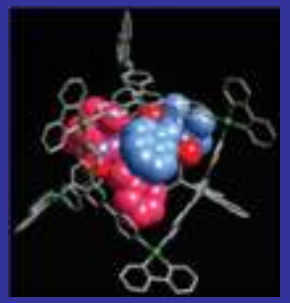


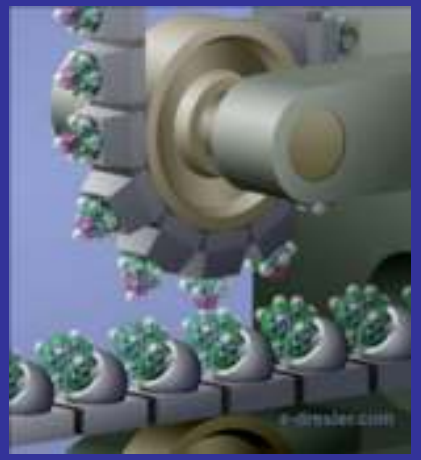
Kismet

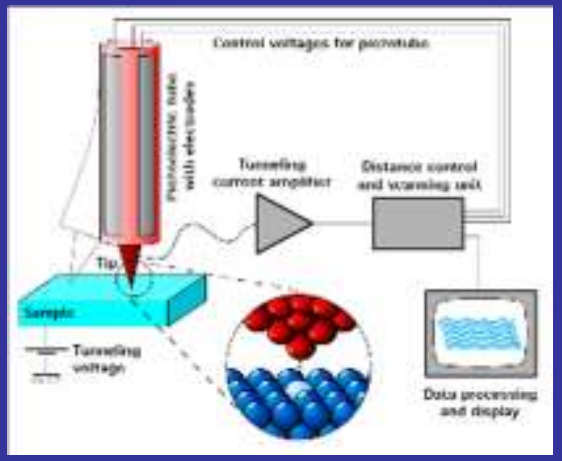


Molecular nanotechnology

- Definition: not work at the nano scale or with atoms in 2D but 3D molecular/atomic specific placement
- Scale
  - Human hair: 80,000 nm
  - Limit of human vision: 10,000 nm
  - Virus: 50 nm, DNA: 2 nm
- Microscopy tools







Sources: http://www.imm.org, http://www.foresight.org, http://www.e-drexler.org, http://www.rfreitas.com

Personal fab labs and 3D printing

- Community fabs, o/s designs
  - MIT Fab Labs
  - Make, TechShop (Menlo Park)
- 3d printing
  - Fab@Home, RepRap, Evil
- Personal manufacturing
  - Ponoko (platform)
  - Fabjectory

RepRap
http://reprap.org

MIT Fab Labs
http://fab.cba.mit.edu/about

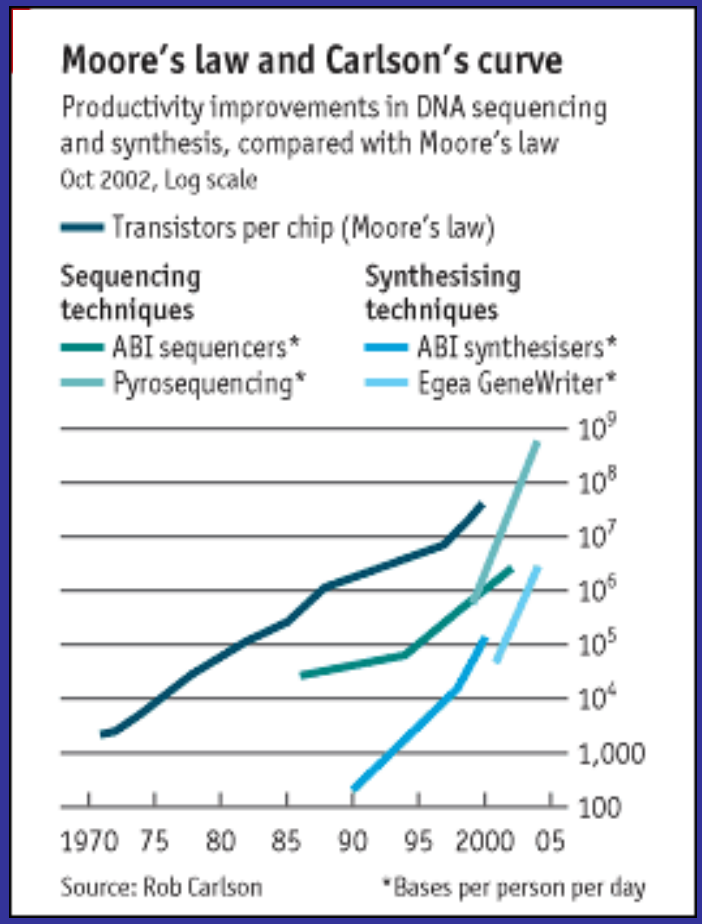
Evil Labs
http://www.evilmadscientist.com/

Fab@Home
http://www.fabathome.org

3D printed plastic avatars

Biology and Genetics

- Biology: an information science
- Personalized medicine
- Faster than Moore's Law
  - Sequencing
  - Synthesizing
- Cure vs. augmentation
- Archon X Prize for Genomics
  - $10M to sequence 100 human genomes in 10 days
- The Omics: genomics, proteomics, metabolomics
- 90% genome not understood



Sources: http://www.economist.com/background/displaystory.cfm?story_id=7854314, http://www.molsci.org/%7Ercarlson/Carlson_Pace_and_Prolif.pdf

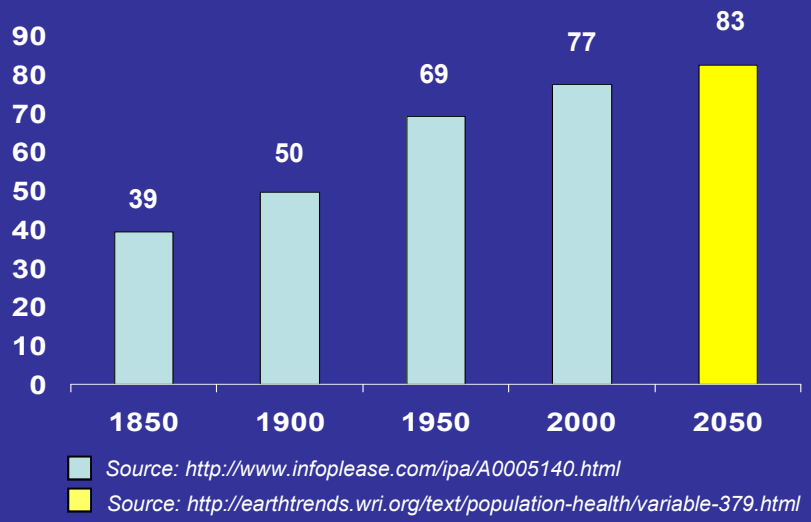
Anti-aging, life extension and immortality

- Aging is a pathology
  - Immortality is not hubristic and unnatural
- Aubrey de Grey
  - Strategies for Engineered Negligible Senescence (SENS) and escape velocity
  1. Cancer-causing nuclear mutations
  2. Mitochondrial mutations
  3. Intracellular junk
  4. Extracellular junk
  5. Cell loss
  6. Cell senescence
  7. Extracellular crosslinks
- Life expectancy test
  http://gosset.wharton.upenn.edu/mortality/perl/CalcForm.html

The Methuselah Foundation

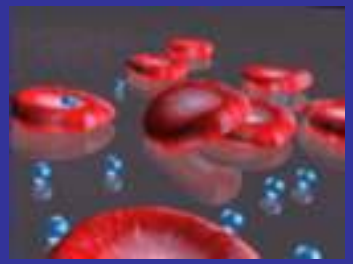
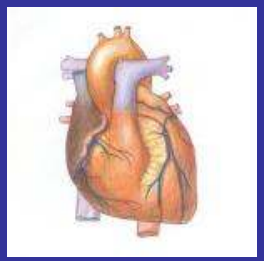
Research to repair and reverse the damage of aging

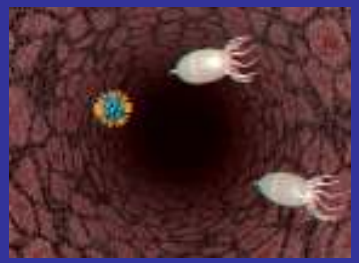
http://www.methuselahmouse.org/



Human body 2.0, 3.0

- Redesign: the digestive system is rebuilt
  - Auto-nourishment via clothing
  - Nanobots go in and out of the skin cycling nutrients and waste
  - Digestive system and blood based nanobots supply precise nutrients
  - Eating becomes like sex, no biological impact, just for fun
- Redesign: the heart is optional
  - Obsolete organs, heart, lungs, blood; nanobots delivering oxygen to the cells, don't require liquid-based medium
- Two systems left
  - Upper esophagus, mouth and brain
  - Skin, muscle, skeleton and their parts of the nervous system




Sources: Ray Kurzweil, The Singularity is Near, http://lifeboat.com/ex/human.body.version.2.0

Physical human interface with technology

- Nanobots in close proximity to every sensory interneuronal connection
- In-brain nanobots
  - Regulate physical functions
  - Serve as personal assistants (download new skills)
  - Provide continuous high-bandwidth connectivity and VR
  - Virtual reality overlays
- Physical human interface with technology
  - Biologic human thinking is too limited to persist
  - Non-biological intelligence will predominate

Source: Ray Kurzweil, The Singularity is Near and http://lifeboat.com/ex/human.body.version.2.0

Virtual worlds, 3D and simulation

- Increasing demand for streaming video, data visualization and 3D data display: learning, work and play
  - Simulation and augmented reality

- Increasingly detailed capture of reality
  - Geospatialization: Google Earth, Nasa World Wind
  - Life capture, life logging

- Virtual worlds explosion
  - MMORPG video games and interactive worlds
  - Participants: enterprise, education, government
  - Activities: interacting, collaborating, prototyping

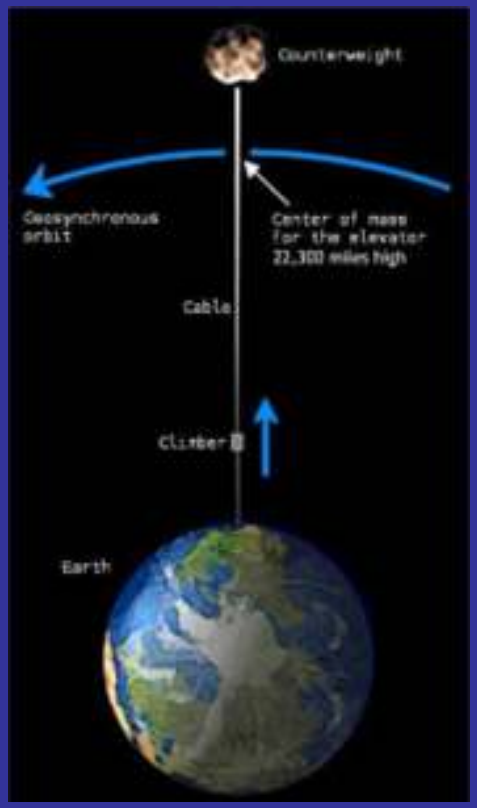
- Virtual reality 2.0: biofeedback, touch, taste, smell

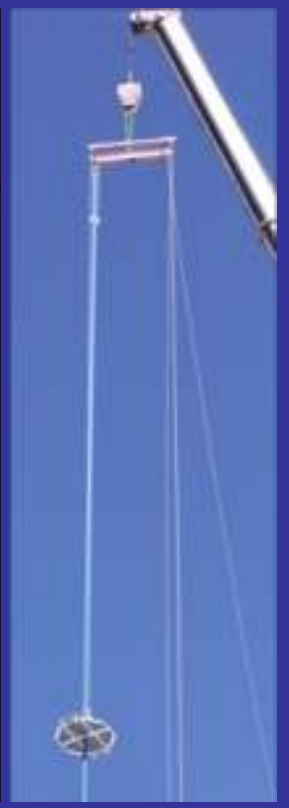
Wild Divine

Affordable space launch

- Commercial payload launch
- Space elevator
- Sub-orbital human flight
  - Spaceport development
- Extra-orbital robotic missions
- Planetary manned missions

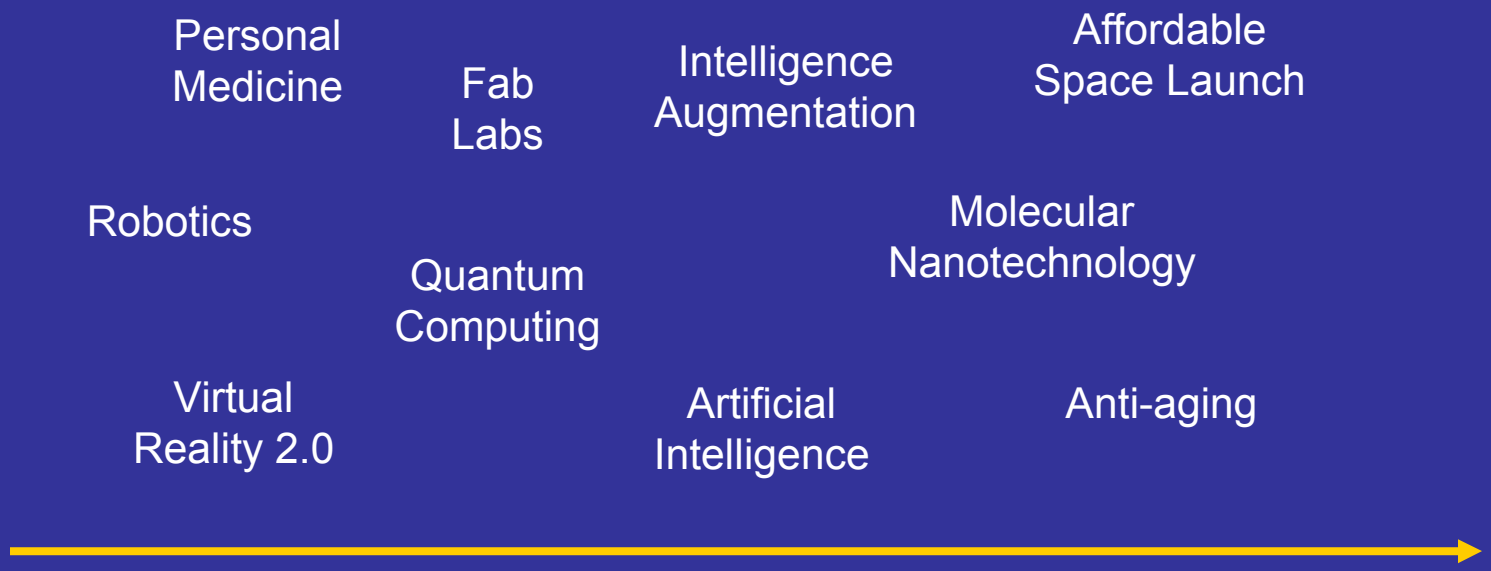
- International participation
- NASA/ESA complement
- Prizes stimulate development



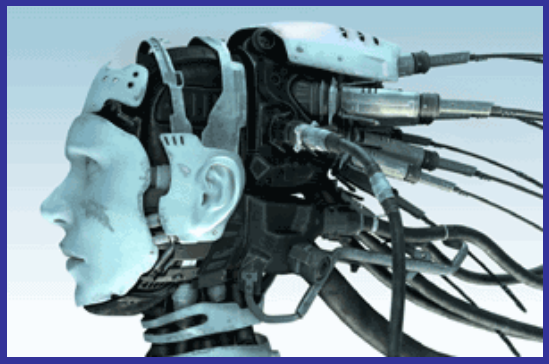


What will be the next Internet?

- The future depends on which coming revolution occurs first

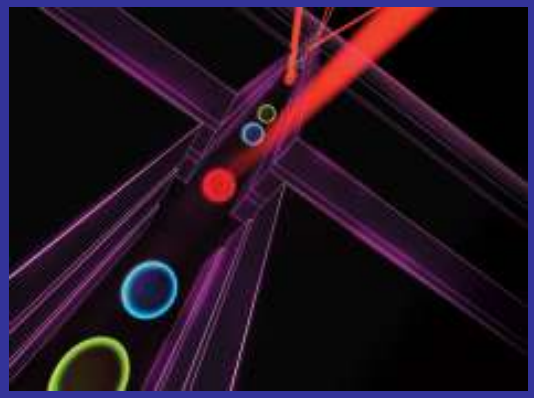


Summary



Source: Fausto de Martini

- We think about growth and change in linear, exponential and discontinuous paradigms, history is a chain of discontinuities
- The realm of technology is no longer discrete, technology is imbuing traditional linear phenomena with exponential and discontinuous change
- Computation (hardware and software) overview: Moore's Law improvements will likely continue unabated in hardware; software however is stuck
- Not only will there be linear and exponential growth in the next 50 years but probably also discontinuous change, possibly a change with greater impact than the Internet in our (current) lifetimes



Thank you

Slides:
http//www.melanieswan.com/presentations

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