# Information Technology and the Future of the University

# The Age of Knowledge

**Educated people and ideas** → 

**Prosperity**

**Security**

**Social well-being**

**Educated people are the most valuable resource for 21st societies and their institutions!!!**

# Forces of Change

**A Changing World**

Age of Knowledge

Demographic Change

Globalization

Post-Cold War World

Spaceship Earth

**Forces on the University**

Economics

Societal Needs

Technology

Markets

**Brave New World?**

**Society of Learning?**

# The Key Themes of the Digital Age

- The exponential pace of the evolution of digital technology.
- The ubiquitous/pervasive character of the Internet.
- The relaxation (or obliteration) of the conventional constraints of space, time, and monopoly.
- The democratizing characterizing of information (universal access to information, education, and research).
- The changing ways we handle digital data, information, and knowledge.
- The growing important of intellectual capital relative to physical or financial capital in the “new economy”.

# Some quotes...

"Thirty years from now the big university campuses will be relics. Universities won't survive.  It is as large a change as when we first got the printed book."

– *Peter Drucker*

"If you believe that an institution that has survived for a millennium cannot disappear in just a few decades, just ask yourself what has happened to the family farm."

– *William Wulf*

"I wonder at times if we are not like the dinosaurs, looking up at the sky at the approaching comet and wondering whether it has an implication for our future."

– *Frank Rhodes*

# A Detour:
# The Evolution of Computers

Mainframes (Big Iron)
…IBM, CDC, Amdahl
…Proprietary software
…FORTRAN, COBOL
…Batch, time-sharing

Minicomputers
…DEC, Data Gen, HP
…PDP, Vax
…C, Unix

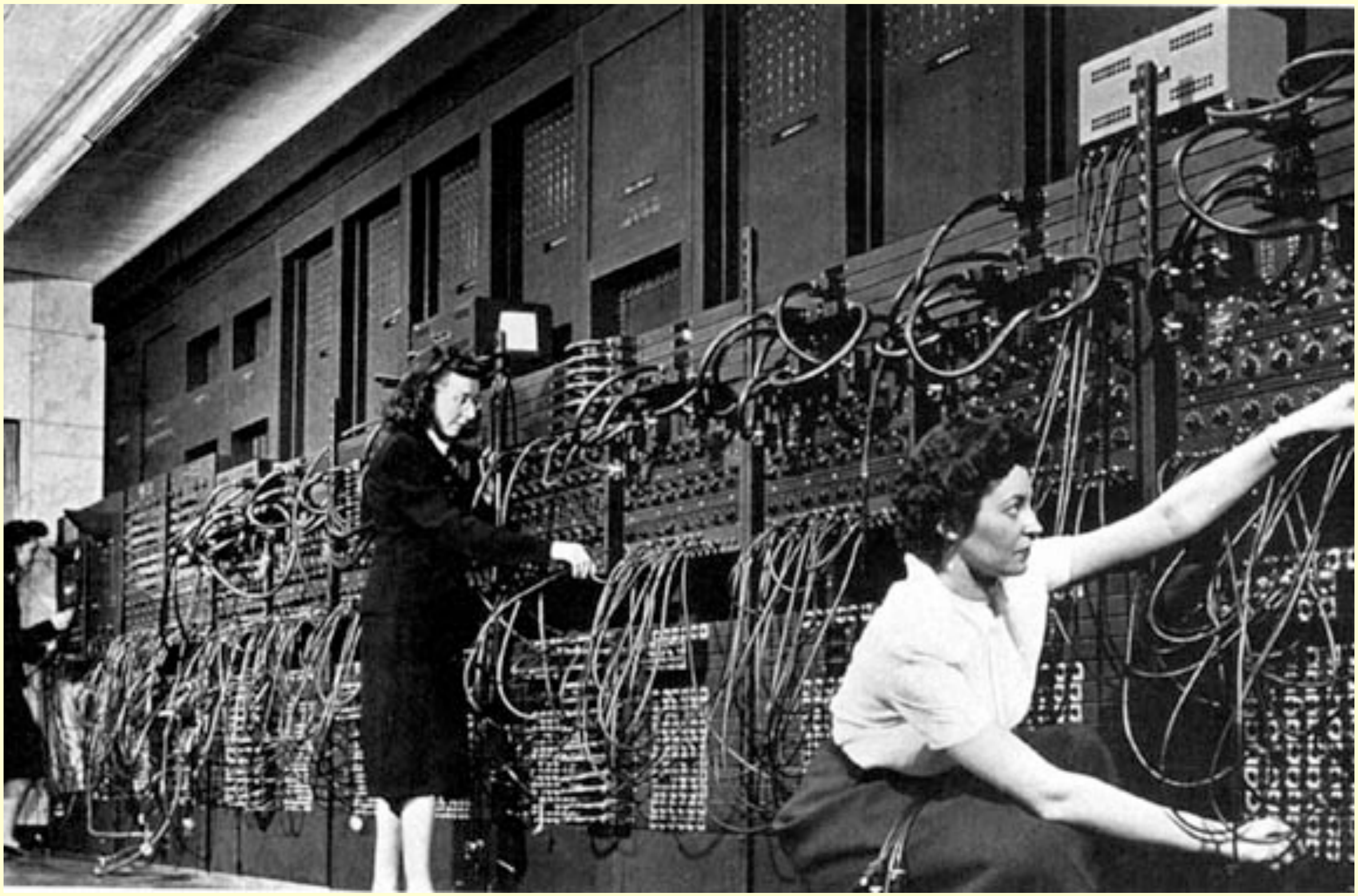
Microcomputers
…Hand calculators
…TRS, Apple, IBM
…Hobby kits -> PCs

Supercomputers
…Vector processors
…Cray, IBM, Fujitsu
…Parallel processors
…Massively parallel

Networking
…LANs, Ethernet
…Client-server systems
…Arpanet, NSFnet, Internet

Batch → Time-sharing → Personal → Collaborative

# From Eniac



# To ASCI White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Japan Earth Simulator


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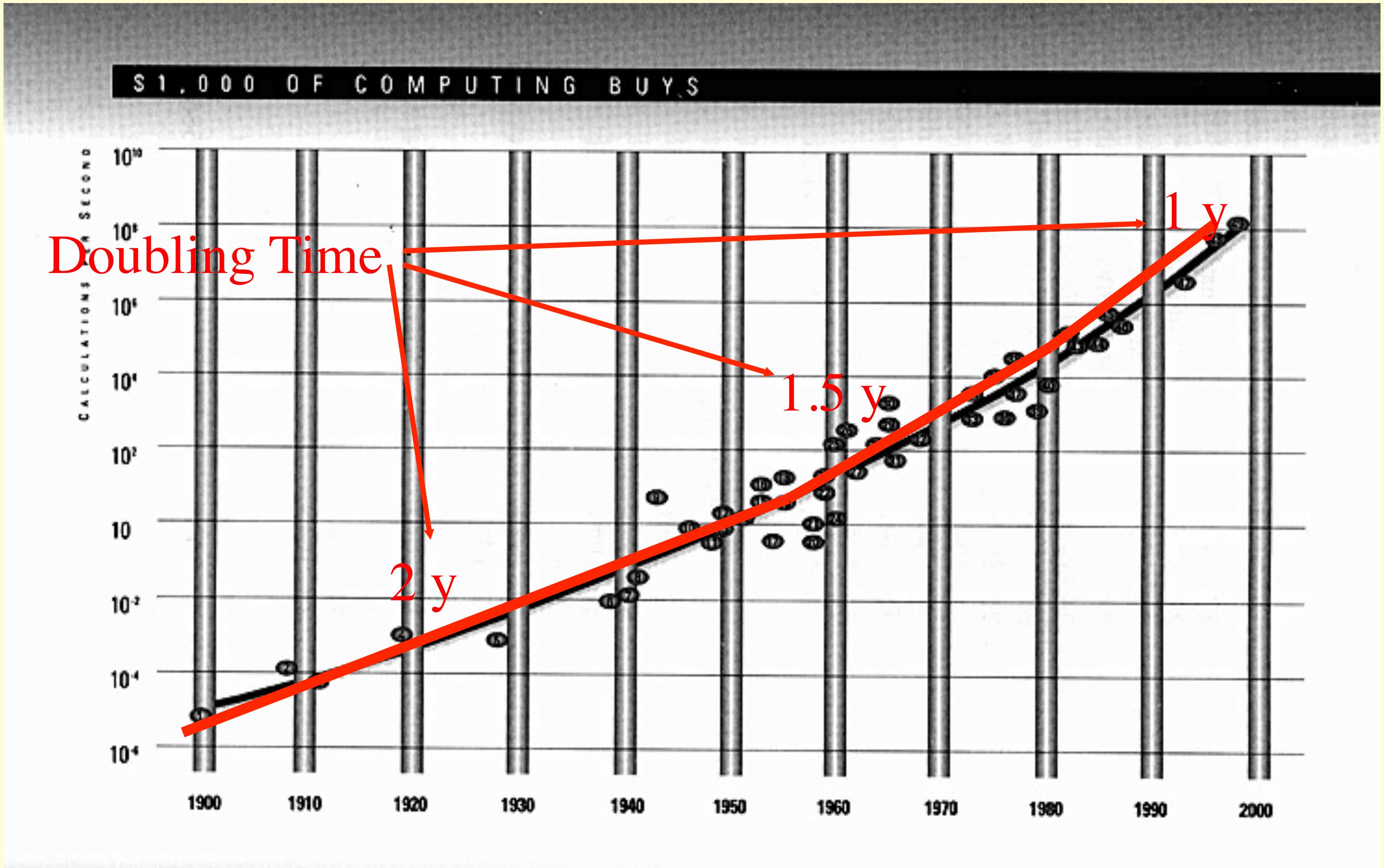
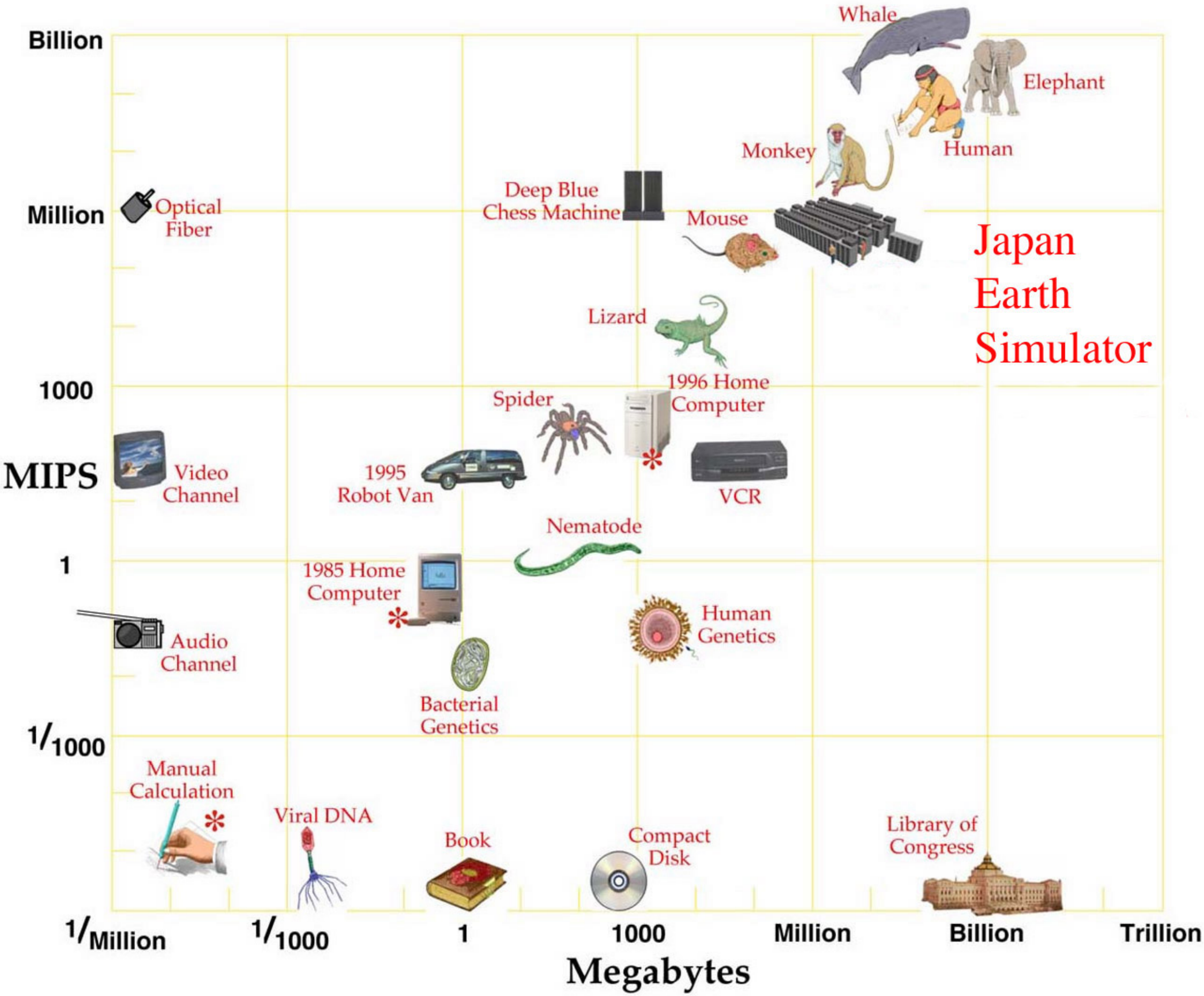
# The Evolution of Computing



# All Thinks, Great and Small



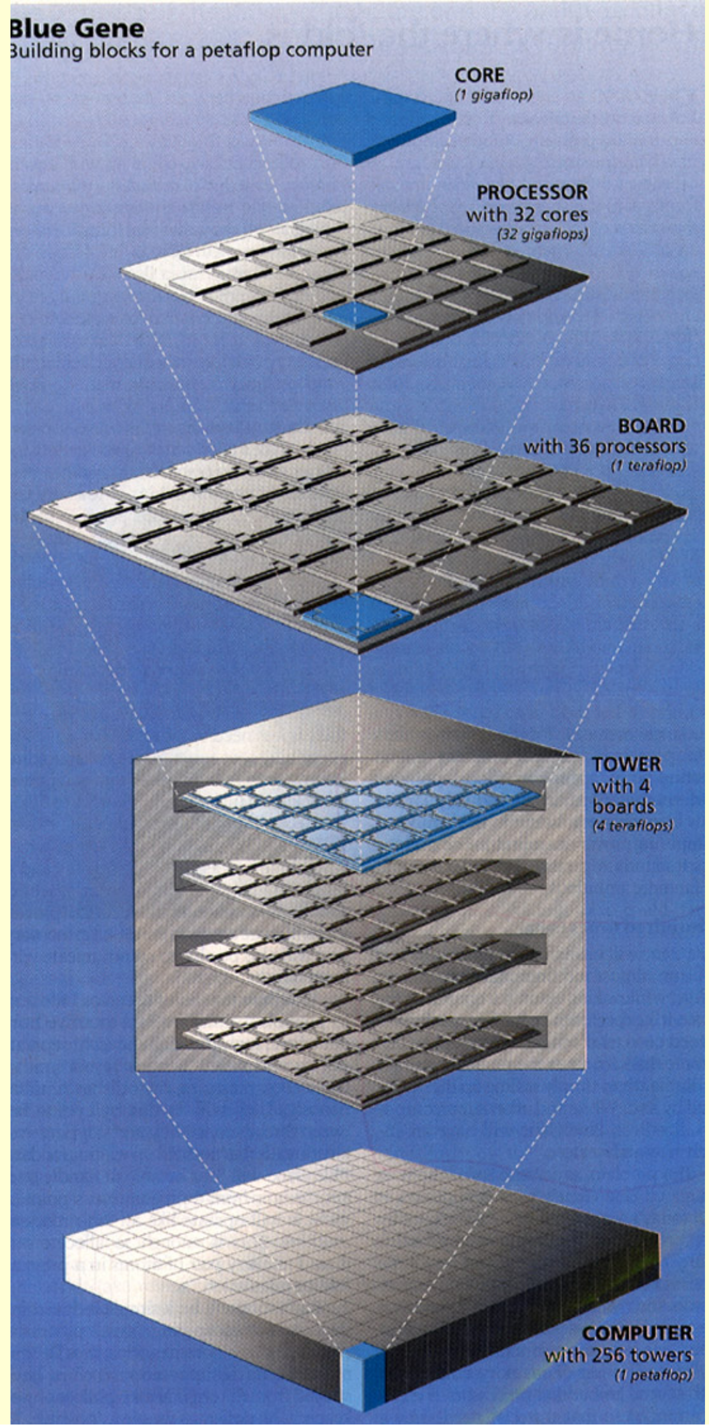
IBM Weather Simulator:

100 TeraFlops

IBM Blue Gene:

1,000 TeraFlops

= 1 PetaFlop



# Some Extrapolation of the PC

| | 2000 | 2010 | 2020 |
|---|---|---|---|
| Speed | $10^9$ | $10^{12}$ | $10^{15}$ |
| RAM | $10^8$ | $10^{11}$ | $10^{14}$ |
| Disk | $10^9$ | $10^{12}$ | $10^{15}$ |
| LAN | $10^8$ | $10^{12}$ | $10^{15}$ |
| Wireless | $10^6$ | $10^9$ | $10^{12}$ |

# Some Examples

- **Speed**
  - MHz to GHz to THz to Peta Hz
- **Memory**
  - MB (RAM) to GB (CD,DVD) to TB (holographic)
- **Bandwidth**
  - Kb/s (modem) to Mb/s (Ethernet) to Gb/s
  - Internet2 (Project Abilene): 10 Gb/s
- **Networks**
  - Copper to fiber to wireless to photonics
  - “Fiber to the forehead…”

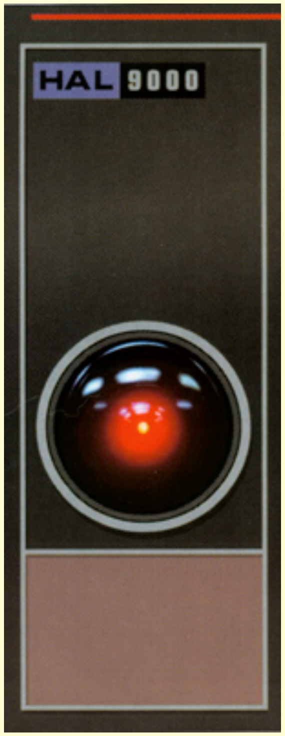
# Computer-Mediated Human Interaction

- **1-D (words)**
  - Text, e-mail, chatrooms, telephony
- **2-D (images)**
  - Graphics, video, WWW, multimedia
- **3-D (environments)**
  - Virtual reality, distributed virtual environments
  - Immersive simulations, avatars
  - Virtual communities and organizations
- **And beyond… (experiences, “sim-stim”)**
  - Telepresence
  - Neural implants

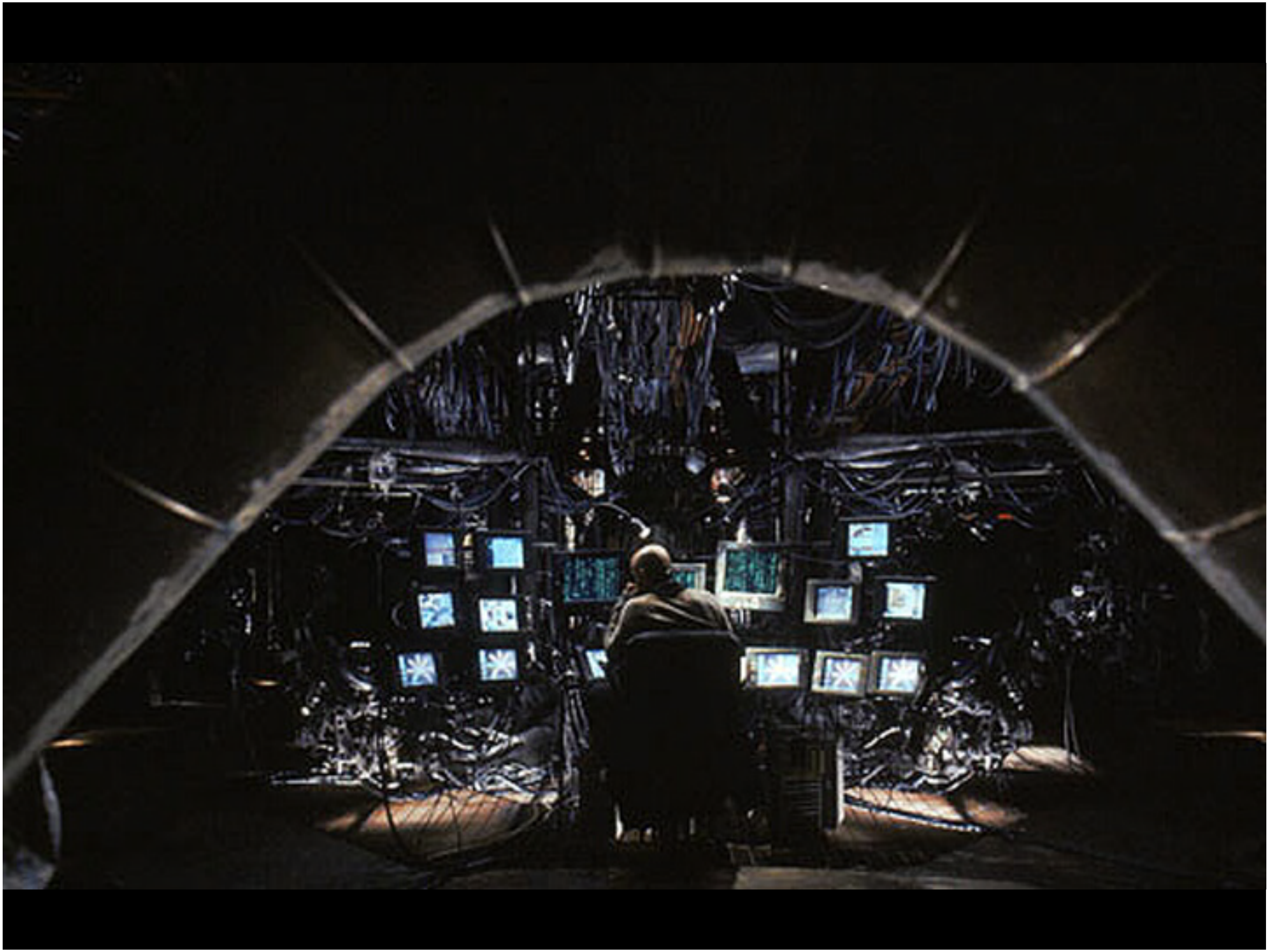
# Evolution of the Net

- Already beyond human comprehension
- Incorporates ideas and mediates interactions among millions of people
- 200 million today; more than 1 billion in 2005
- Internet II, Project Abilene

# Some Other Possibilities




- **Ubiquitous computing?**
  - Computers disappear (just as electricity)
  - Calm technology, bodynets
- **Agents and avatars?**
  - Fusing together physical space and cyberspace
  - Plugging the nervous system into the Net
- **Emergent behavior?**
  - … Self organization
  - … Learning capacity
  - … Consciousness (HAL 9000)



# IT and the University

**Missions**: teaching, research, service?

**Alternative**: Creating, preserving, integrating, transferring, and applying knowledge.

**The University**: A "knowledge server", providing knowledge services in whatever form is needed by society.

**Note**: The fundamental knowledge roles of the university have not changed over time, but their realizations certainly have.

# Research

- Simulating reality
- Collaboratories:  the virtual laboratory
- Changing nature of research
  - Disciplinary to interdisciplinary
  - Individual to team
  - "Small think" to "big think"
- Analysis to creativity
  - Tools:  materials, lifeforms, intelligences
  - Law, business, medicine to art, architecture, engineering

# Libraries

- Books to bytes (atoms to bits)
- Acquiring knowledge to navigating knowledge
- What is a book?
  - A portal to the knowledge of the world.

# Teaching to Learning

- Pedagogy
  - Lecture hall to environment for interactive, collaborative learning
  - Faculty to designer, coach
- Classroom
  - Handicraft to commodity
  - Learning communities
  - Virtual, distributed environments
- Open learning
  - Teacher-centered to learner-centered
- Passive Student to Active Learner to Demanding Consumer
  - Unleashing the power of the marketplace

# The Plug and Play Generation

- Raised in a media-rich environment
  - Sesame Street, Nintendo, MTV,
  - Home computers, WWW, MOOs, virtual reality
- Learn through participation and experimentation
- Learn through collaboration and interaction
- Nonlinear thinking, parallel processing

# Some Interesting Statistics

- Today's entering UM student
  - 90% enter with 3 or more years of computer experience
  - 60% own a computer (90% will own a computer when they graduate
  - Spend 15 to 20 hours a week using computer
- The Global Teenager
  - In year 2000 there are 2 billion teenagers
  - Cellular phones and PDAs are replacing Sony Walkmans
  - They will identify more with their age group than with their ethnicity or nationality, creating a new world culture …

# The Old Paradigm

- Linear, sequential college curriculum
- Based on lectures to passive students
- Students discouraged from interacting with one another (particularly on exams …)
- Student learning activities include reading, writing, and taking exams

# The New Students

- Active learners, building their own knowledge structures and learning through action and collaboration
- Use nonlinear learning (“hyperlearning”)
- Develop peer groups of learning and build sophisticated learning environments
- Faculty will be challenged to shift from development and presentation of content to designing learning environments and mentoring (coaching) active learners

# Some Learning Characteristics of the Digital Generation*

- Multiprocessing
- Multimedia literacy
- Knowledge navigators
- Discovery-based learning that merges with play
- Bricolage
- A bias toward action

*John Seely Brown, Xerox PARC

# Lifelong Learning

- Students increasingly accept that in an era in which knowledge in most fields doubles every few years, lifetime learning will be necessary for survival.
- Today’s graduates expect to change not simply jobs but careers many times during their lives.  At each stage further learning will be necessary.
- A shift from “just in case” to “just in time” to “just for you” learning.

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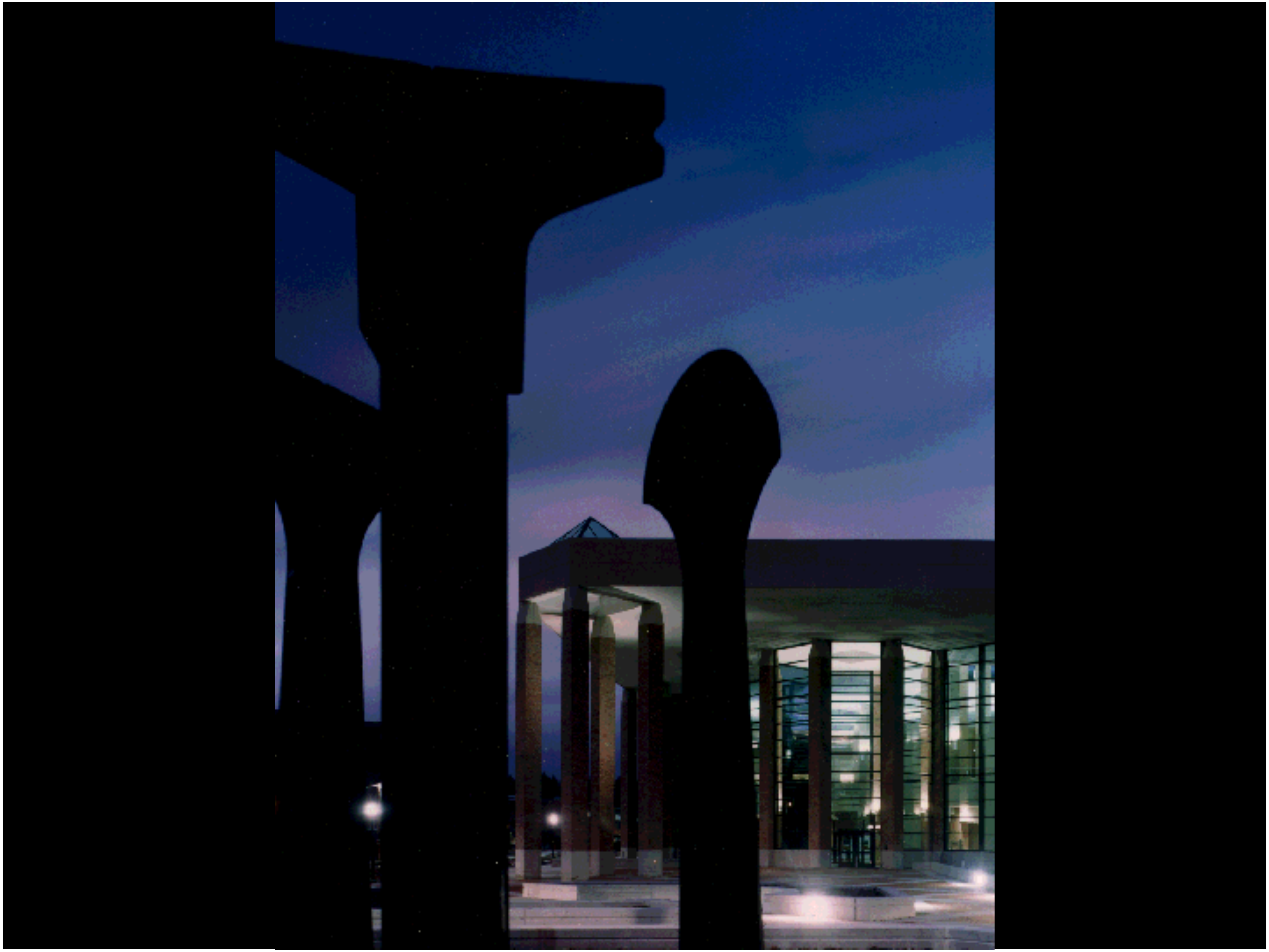
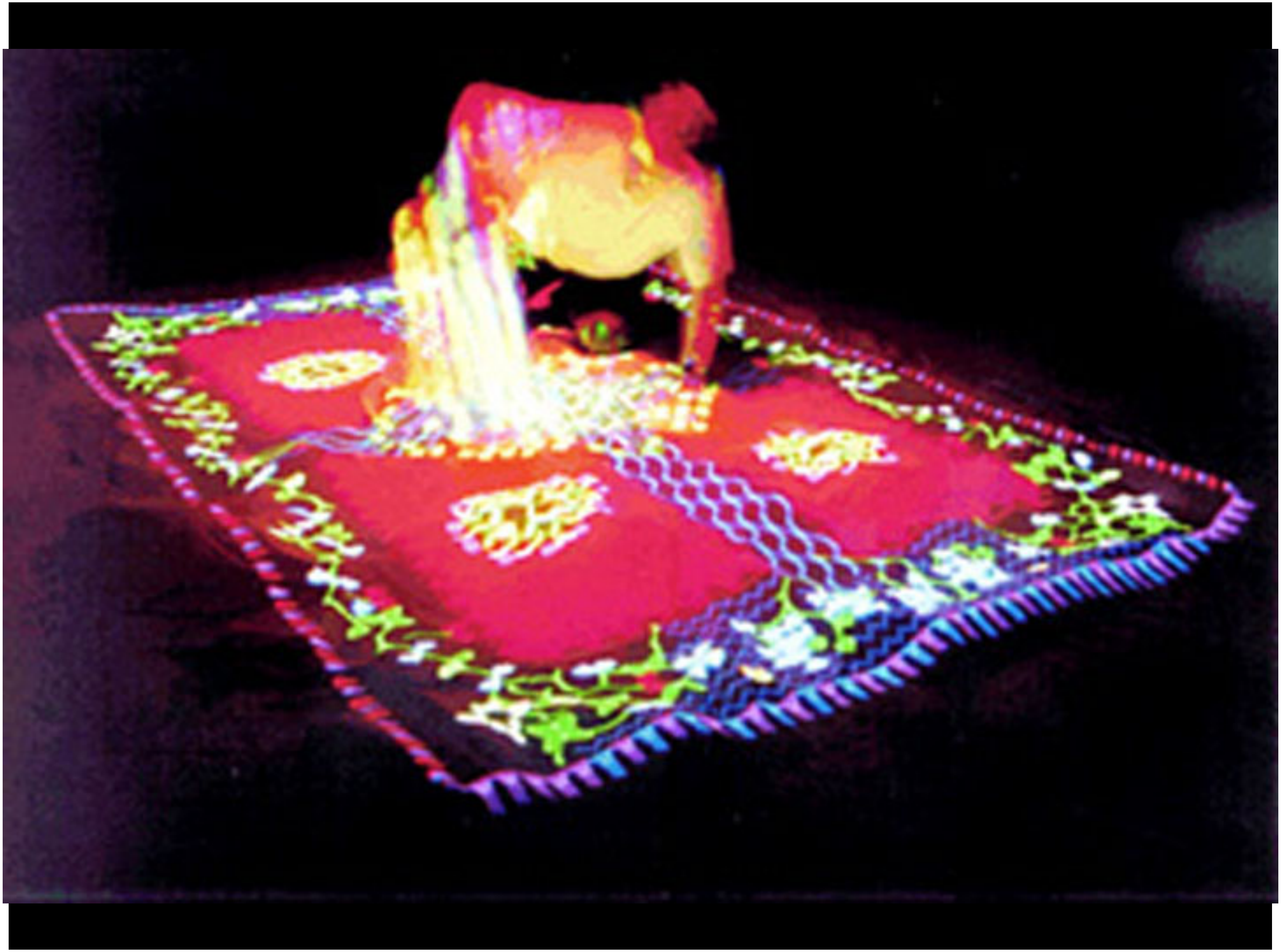



RESERVES



# camp caen

camp caen

The computer exploration camp from The University of Michigan. Summer 2000

# IT-Mediated Distance Learning

The Sloan Foundation has invested over $30 million in the development of Asynchronous Learning Networks. Their conclusions from over 100,000 sponsored course units in thousands of courses:

I) **This stuff works.** You can reproduce the classroom over the Internet with no apparent loss of educational quality (as measured by test scores, etc.).

2) **It is not expensive** to convert a course into ALN format (about $10,000 per course), if the aim is interactive rather than automated teaching.

The key: Don't automate the classroom, but break it free from the constraints of space and time!

# A Concern

Although there is a great deal of activity in IT-mediated distance learning (over 1,000 “virtual universities”), as one goes up the learning curve, from community colleges to regional universities to research activities, there is less and less participation.

While there are experiments by research universities such as Unext.com, these are largely hands off, with little participation by the research university faculty. As a result, most research universities are not really learning how to implement this technology like others in the post-secondary education enterprise.

# The Digital Divide

**Concern**: The "digital divide" between those who have access to information and those who do not.

**Another View**: The real divide is not access to technology but rather between those who have access to educational opportunity and those who do not because of economic means, family responsibilities, or job constraints.

As access to IT appliances becomes more ubiquitous (e.g., PDAs) and IT breaks learning free from constraints of space and time, technology may actually narrow the stratification in our society by opening up access to education.

# Implications for Research Universities

**Activities**: teaching, research, outreach

**Organization and structure**: disciplinary structure, faculty roles, financing, leadership

**Enterprise**: markets, competitors, role in evolving national research enterprise, globalization

# Some Examples

- The digital generation will demand interactive, collaborative, nonlinear learning experiences.
- Faculty members will be challenged to become designers of learning experiences, motivators of active learning.
- We are experiencing a transition to open learning environments in which strong market forces will challenge the traditional university monopolies.

# NAS/NAE/IOM/NRC Study

The Impact of Information Technology on the Future of the Research University

# Information Technology and the Future of the Research University

**Premise**:  Rapidly evolving information technology poses great challenges and opportunities to higher education in general and the research university in particular.  Yet many of the key issues do not yet seem to be on the radar scope of either university leaders or federal research agencies.

# Objectives

- To identify those information technologies likely to evolve in the near term (a decade or less) that could ultimately have major impact on the research university.
- To examine the possible implications of these technologies for the research university: its activities (teaching, research, service, outreach); its organization, management, and financing; and the impact on the broader higher education enterprise.
- To determine what role, if any, there was for the federal government and other stakeholders in the development of policies, programs, and investments to protect the valuable role and contributions of the research university during this period of change.

# ITFRU Panel

- James Duderstadt (Chair), President Emeritus, Univesity of Michigan
- Daniel Atkins, Professor of Information and Computer Science, University of Michigan
- John Seely Brown, Chief Scientist, Xerox PARC
- Marye Anne Fox, Chancellor, North Carolina State University
- Ralph Gomory, President, Alfred P. Sloan Foundation
- Nils Hasselmo, President, Association of American Universities
- Paul Horn, Senior Vice President for Research, IBM
- Shirley Ann Jackson, President, Rensselaer Polytechnic Institute
- Frank Rhodes, President Emeritus, Cornell University
- Marshall Smith, Professor of Education, Stanford; Program Officer, Hewlett Foundation
- Lee Sproull, Professor of Business Administration, NYU
- Doug Van Houweling, President and CEO, UCAIC/Internet2
- Robert Weisbuch, President, Woodrow Wilson National Fellowship Foundation
- William Wulf, President, National Academy of Engineering
- Joe B. Wyatt, Chancellor Emeritus, Vanderbilt University
- Raymond E. Fornes (Study staff), Professor of Physics, North Carolina State University

# Phase 1

- Meetings of study panel
- Site visits (Bell Labs, IBM Research Labs)
- National workshop at NAS (100 leaders from industry, higher education, foundations, government)
  - Available on the Research Channel
  - http://www.research.channel.com/programs/na/itfru.html

# Phase 1: Conclusions

- There was a consensus that **the extraordinary evolutionary pace of information technology is likely to continue for the next several decades** and even could accelerate on a superexponential slope. Photonic technology is evolving at twice the rate of silicon chip technology (e.g., Moore's Law), with miniaturization and wireless technology advancing even faster, implying that the rate of growth of network appliances will be incredible. For planning purposes, we can assume that within the decade we will have infinite computer power, infinite bandwidth, and ubiquitous connectivity (at least compared to current capabilities).
- The event horizons for disruptive change are moving ever closer. There are **likely to be major technology surprises**, comparable in significance to the appearance of the personal computer in the 1970s and the Internet browser in 1994, but at more frequent intervals. The future is becoming less certain.

# Conclusions (continued)

- The **impact of information technology on the university will likely be profound, rapid, and discontinuous**–just as it has been and will continue to be for the economy, our society, and our social institutions (e.g., corporations, governments, and learning institutions). It will affect our activities (teaching, research, outreach), our organization (academic structure, faculty culture, financing and management), and the broader higher education enterprise as it evolves into a global knowledge and learning industry.
- Yet, **for at least the near term**, meaning a decade or less, **the university will continue to exist in much its present form**, although meeting the challenge of emerging competitors in the marketplace will demand significant changes in how we teach, how we conduct scholarship, and how our institutions are financed. Universities must anticipate these forces, develop appropriate strategies, and make adequate investments if they are to prosper during this period.
- **Over the longer term, the basic character and structure of the university may be challenged** by the IT-driven forces of aggregation (e.g., new alliances, restructuring of the academic marketplace into a global learning and knowledge industry) and disaggregation (e.g., restructuring of the academic disciplines, detachment of faculty and students from particular universities, decoupling of research and education).

# Conclusions (continued)

- Although information technology will present many complex challenges and opportunities to university leaders, we suggest that **procrastination and inaction are the most dangerous courses of all during a time of rapid technological change**. Just as it has in earlier times, the university will have to transform itself once again to serve a radically changing world if it is to sustain these important values and roles.
- Although we feel confident that information technology will continue its rapid evolution for the foreseeable future, it is far more **difficult to predict the impact of this technology on human behavior and upon social institutions** such as the university. It is important that higher education develop mechanisms to sense the changes that are being driven by information technology and to understand where these forces may drive the university.
- Because of the profound yet unpredictable impact of this technology, it is important that institutional strategies include: 1) the opportunity for **experimentation**, 2) the formation of **alliances** both with other academic institutions as well as with for-profit and government organizations, and 3) the development of sufficient **in-house expertise** among the faculty and staff to track technological trends and assess various courses of action.

# Conclusions (continued)

- In summary, **for the near term** (meaning a decade or less), we anticipate that information technology will drive **comprehensible if rapid, profound, and discontinuous change** in the university. **For the longer term** (two decades and beyond), **all bets are off**. The implications of a million-fold or billion-fold increase in the power of information technology are difficult to even imagine, much less predict for our world and even more so for our institutions.

# Phase 2

- **Steering Panel Activities (expanded)**
  - Monitoring technology evolution
  - IT Strategy Roadmapping Effort
  - Policy Development
- **National Workshops (2002-2003)**
  - University Presidents and Board Chairs
  - Foundation Presidents and Technology Officers
- **National Workshops (2003-2004)**
  - Presidents, Provosts, Deans, Faculty Governance
  - Impact on education, research, service
- **Regional Workshops (2004-2005)**
- **Campus Workshops (2003-2005)**

# A Social Transformation

| The 20th Century | The 21st Century |
|---|---|
| Transportation | Communications |
| Cars, planes, trains | Computers, networks |
| Energy, materials | Knowledge, bits |
| Prosperity, security | Prosperity, security |
| Social structures | Social structures |

# Another Perspective …

The impact of information technology will be even more radical than the harnessing of steam and electricity in the 19th century. Rather it will be more akin to the discovery of fire by early ancestors, since it will prepare the way for a revolutionary leap into a new age that will profoundly transform human culture.

–Jacques Attali, *Millennium*

# The Restructuring of the Higher Education Enterprise

# Market Forces

Powerful economic forces, changing societal needs, and technology are creating powerful market forces.

# The Role of Markets

- For students (particularly the best)
- For faculty (particularly the best)
- For public funds (research grants, state appropriations)
- For private funds (gifts, commercial)
- For everything and everybody

# Scenario 1

A massive restructuring of the higher education industry

or

Swept away by the tsunami of market forces

# The current monopoly

Universities operate with a monopoly sustained by geography and credentialling authority.

But this is being challenged by

- demand that cannot be met by status quo
- antiquated cost structures
- information technology
- open learning environments

# Restructuring

**Hypothesis**: Higher education today is about where the health care industry was a decade ago, in the early stages of a major restructuring.

However, unlike other industries such as energy, telecommunications, and health care that were restructured by market forces after deregulation, the global knowledge and learning industry is being restructured by emerging information technology, that releases education from the constraints of space, time, and credentialling.

# A Quote from a Venture Capital Prospectus

"As a result, we believe education represents the most fertile new market for investors in many years. It has a combination of large size (approximately the same size as health care), disgruntled users, lower utilization of technology, and the highest strategic importance of any activity in which this country engages . . . . Finally, existing managements are sleepy after years of monopoly."

# United States Higher Education "System"

AAU-Class Research Universities (60)

Research Universities (115)

Doctoral Universities (111)

Comprehensive Universities (529)

Baccalaureate Colleges (637)

Two-Year Colleges (1,471)

**Total U.S. Colleges and Universities: 3,595**

# The Evolving U.S. Education System

For profit U
(650)

Open U

Corporate U
(1,600)

AAU-Class Research Universities
Research Universities
Doctoral Universities
Comrehensive Universities
Baccalaureate Colleges
Two-Year Colleges

Cyber U
(1,000)

Niche U

New learning
lifeforms

**Knowledge Infrastructure**

(production, distribution, marketing, testing, credentialling)

# Contributions of the Research University

**Research Universities** →

| | | |
|---|---|---|
| Teaching | Learning | People |
| Research → | Discovery → | Ideas |
| Service | Engagement | Tools |
| (Classical) | (Kellogg Commission) | (NSF) |

# The Knowledge Industry

| | | |
|---|---|---|
| Hardware → | Boxes, PCs, PDAs → | IBM, HP, Sun, Lucent, Nokia, Erickson |
| Networks → | Backbones, LANs, Wireless → | AT&T, MCI, Telcoms |
| Software → | OS, Middleware, Applications → | Microsoft, IBM, Sun |
| Solutions → | Systems, Integrators → | Anderson, Peoplesoft, EDS, IBM |
| Content → | Data, Knowledge, Entertainment, Learning? → | Time-Warner, Disney, “dot.coms”, **AAU?** |

# Some Implications

- Unbundling
- A commodity marketplace
- Mergers, acquisitions, hostile takeovers
- New learning lifeforms
- An intellectual wasteland???

# A Possible Future

- $300 billion ($3 trillion globally)
- 30 million students
- 200,000 faculty “facilitators”
- 50,000 faculty “content providers”
- 1,000 faculty “celebrity stars”

(compared to 800,000 current faculty serving a $180 billion enterprise with 15 million students …)

# Scenario 2

A Society of Learning

or

Renewing the Social Contract

# A Society of Learning

Since knowledge has become not only the wealth of nations but the key to one's personal prosperity and quality of life, it has become the responsibility of democratic societies to provide their citizens with the education and training they need, throughout their lives, whenever, wherever, and however they desire it, at high quality and at an affordable cost.

# Key Characteristics

- Learner-centered
- Affordable
- Lifelong learning
- A seamless web
- Interactive and collaborative
- Asynchronous and ubiquitous
- Diverse
- Intelligent and adaptive

# Evolution or Revolution?

Many within the academy believe that “this too shall pass”.

Others acknowledge that change will occur, but within the current paradigm, i.e., evolutionary.

Some believe that both the dramatic nature and compressed time scales characterizing the changes of our times will drive not evolution but revolution.

Some even suggest that long before reform of the education system comes to any conclusion, the system itself will have collapsed.

# Some Quotes…

"Thirty years from now the big university campuses will be relics. Universities won't survive. It is as large a change as when we first got the printed book."

*–Peter Drucker*

"If you believe that an institution that has survived for a millennium cannot disappear in just a few decades, just ask yourself what has happened to the family farm."

*–William Wulf*

"I wonder at times if we are not like the dinosaurs, looking up at the sky at the approaching comet and wondering whether it has an implication for our future."

*–Frank Rhodes*

# The Key Policy Question

How do we balance the roles of market forces and public purpose in determining the future of higher education in America. Can we control market forces through public policy and public investment so that the most valuable traditions and values of the university are preserved?

Or will the competitive and commercial pressures of the marketplace sweep over our institutions, leaving behind a higher education enterprise characterized by mediocrity?

**Which of the two scenarios will be our future?**

# Institutional Strategies

# Some Assumptions

- Information and communications technology will continue to evolve exponentially (Moore's Law) for the foreseeable future.
- Ubiquitous, high speed, and economically accessible network capacity will exist nationally and to a great extent globally.
- Affordable, multimedia-capable computers (including network appliances) will be commonplace and most college will expect student ownership of such devices.
- Most colleges will deliver some portion of their instructional missions both on campus and beyond via the I
- nternet.
- Nontraditional sources of university-caliber instruction such as software developers and publishers are likely to become increasingly important suppliers of course content and materials.

# Some Recommendations

1. University leaders should recognize that the rapid evolution of information and communications technologies will stimulate–indeed, demand–a process of strategic transformation in their institutions.
2. It is our belief that universities should begin the development of their strategies for technology-driven change with a firm understanding of those key values, missions, and roles that should be protected and preserved during a time of transformation.
3. It is essential to develop an integrated, coordinated strategy for the institution in a systemic and ecological fashion.
4. Universities need to understand the unique features of digital technologies and how these affect people and their activities.

# Recommendations (cont)

5. Universities should aim to build layered organizational and management structures, based upon broadly accepted values, strategies, heuristics,a nd protocols at the highest levels, but encouraging diversity, flexibility, and innovation at the level of execution.

6.One should recognize that the investment in technology infrastructure necessary for higher education in the digital age will not only be compatible in expense to physical and human capital, but it will be pervasive and continually evolving throughout the institution.

7. Getting from here to there requires a well-defined set of operational strategies and tactics at institutional transformation.

# Some Conclusions

# For the Near Term

For the near term, meaning a decade or less, it is likely that most colleges and universities will retain their current form, albeit with some evolution and pedagogical and scholarly activities and in organization and financing.

While change will occur, and while it is likely to be both profound and unpredictable, it will be at least be understandable.

# For the Longer Term

If the past dictated by Moore's Law continues to characterize the evolution of information technology, over the next several decades we would see the power of this technology (and related technologies such as biotechnology and nanotechnology) increase by factors of one-thousand, one-million, one-billion, and so on, likely reshaping our society and most social institutions into unrecognizable forms.

# Assumptions for the Longer Term

- Digital technology will continue to evolve exponentially over the next several decades (perhaps even superexponentially), evolving from giga to tera to peta to exo to yetta and beyond.
- Digital technology will become the primary interface for human interaction with one another, with our environment and with our various activities such as learning,work, and play.
- The human-machine interface will evolve rapidly, with immersive telepresence, artificial intelligence, and neutral implants.
- Knowledge media will change the relationship between people and knowledge.
- Education will become the key strategic issue for a knowledge-based society.

# Some Further Speculation

The Age of Spiritual Machines:

When Computers Exceed Human Intelligence

*–Ray Kurzweil*

# 2009

- A $1,000 PC delivers Terahertz speeds
- PCs with high resolution visual displays come in a range of sizes, from those small enough to be embedded in clothing and jewelry up to the size of a thin book.
- Cables are disappearing. Communication between components uses wireless technology, as does access to the Web.
- The majority of text is crated using continuous speech recognition. Also ubiquitous are language user interfaces.
- Most routine business transactions (purchases, travel, etc.) take place between a human and a virtual personality. Often the virtual personality includes an animated visual presence that looks like a human face.

# 2009 (continued)

- Although traditional classroom organization is still common, intelligent courseware has emerged as a common means of learning.
- Translating telephones (speech-to-speech language translation) are commonly used.
- Accelerating returns from the advance of computer technology have resulted in a continued economic expansion.
- The neo-Luddite movement is growing.

# 2019

- A $1,000 PC is now approximately equal to the computational ability of the human brain.
- Computers are now largely invisible and are embedded everywhere–in walls, tables, chairs, desks, clothing, jewelry, and bodies.
- 3-D virtual reality displays, embedded in glasses and contact lenses, as well as auditory “lenses”, are used routinely as primary interfaces for communication with other persons, computers, the Web, and virtual reality.
- Most interaction with computing is through gestures and two-way natural-language spoken communication.

# 2019 (continued)

- Nanoengineered machines are beginning to be applied to manufacturing and process control.
- High-resolution, 3-D visual and auditory virtual reality and realistic all-encompassing tactile environments enable people to do virtually anything with anybody, regardless of physical proximity.
- Paper books or documents are rarely used and most learning is conducted through intelligent, simulated software-based teachers.
- The vast majority of transactions include a simulated person.
- Automated driving systems are now installed in most roads.

# 2019 (continued)

- People are beginning to have relationships with automated personalities and use them as companions, teachers, caretakers, and lovers.
- There are widespread reports of computers passing the Turing Test, although these tests do not meet the criteria established by knowledgeable observers.

# 2029

- A $1,000 unit of computation now has the computation capacity of roughly 1,000 human brains.
- Permanent removable implants for the eyes and ears are now used to provide input and output between the human user and the worldwide computing network.
- Direct neural pathways have been perfected for high-bandwidth connection to the human brain.  A range of neural implants is becoming available to enhance visual and auditory perception and interpretation, memory, and reasoning.
- Automated agents are now learning on their own, and significant knowledge is being crated by machines with little or no human intervention.

# 2029 (continued)

- Computers have read all available human- and machine-generated literature and multimedia material.
- There is widespread use of all-encompassing visual, auditory, and tactile communication using direct neural connections, allowing virtual reality to take place ("sim-stim")
- The majority of communication does not involve a human; rather it is between a human and a machine.
- There is almost no human employment in production, agriculture, or transportation.  Basic life needs are available for the vast majority of the human race.

# 2029 (continued)

- There is a growing discussion about the legal rights of computers and what constitutes being "human". Although computers routinely pass apparently valid forms of the Turing Test, controversy persists about whether or not machine intelligence equals human intelligence in all of its diversity.
- Machines claim to be conscious. These claims are largely accepted.

# 2049

- The common use of nanoproduced food, which has the correct nutritional composition and the same taset and texture of organically produced food, means that the availability of food is no longer affected by limited resources, bad weather, or spoilage.
- Nanobot swarm projections are used to create visual-auditory-tactile projections of people and objects in real reality.
- Picoengineering begins to become practical.

# By 2099

- There is a strong trend toward a merger of human thinking with the world of machine intelligence that the human species initially created.
- There is no longer any clear distinction between humans and computers.
- Most conscious entities do not have a permanent physical presence.
- Machine-based intelligences derived from extended models of human intelligence claim to be human, although their brains are not based on carbon-based cellular process, but rather electronic and photonic equivalents. Most of these intelligences are not tied to a specific computational process unit. The number of software-based humans vastly exceeds those still using native neuron-cell-based computation.

# By 2099 (continued)

- Even among those human intelligences still using carbon-based neutrons, there is ubiquitous use of neural-implant technology, which provides enormous augmentation of human perceptual and cognitive abilities. Humans who do not utilize such implants are unable to meaningfully participate in dialogues with those who do.
- Because most information is published using standard assimilated knowledge protocols, information can be instantly understood. The goal of education, and of intelligent beings, is discovering new knowledge to learn.
- Life expectancy is no longer a viable term in relation to intelligence beings.

# Many Milleniums Hence …

Intelligent beings consider the fate of the Universe …