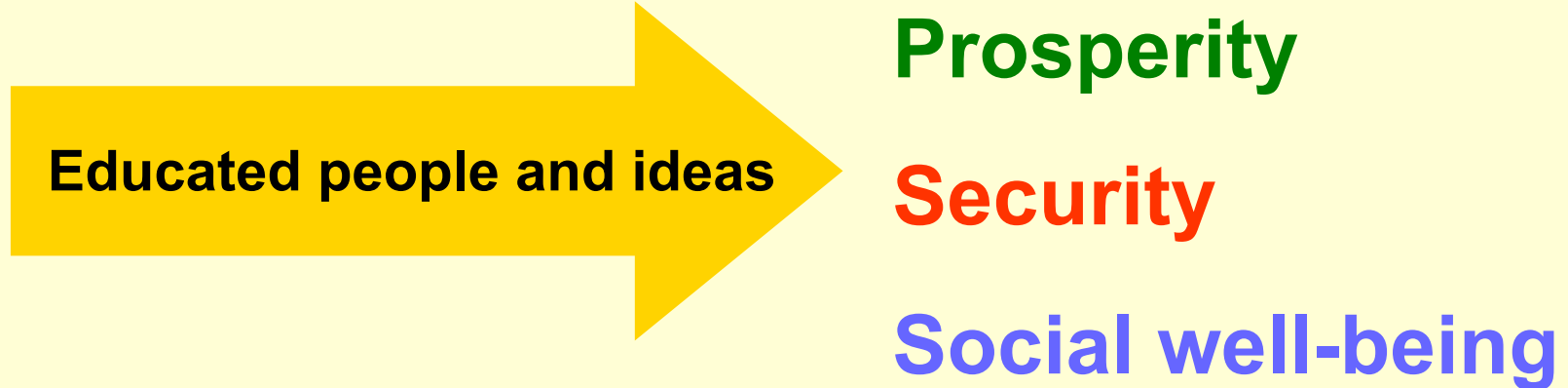


# Information Technology and the Future of the University



# The Age of Knowledge



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

# Forces of Change

## **A Changing World**

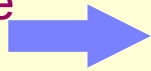
Age of Knowledge

Demographic Change

Globalization

Post-Cold War World

Spaceship Earth



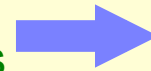
## **Forces on the University**

Economics

Societal Needs

Technology

Markets



**Brave New World?**

**Society of Learning?**

# 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*

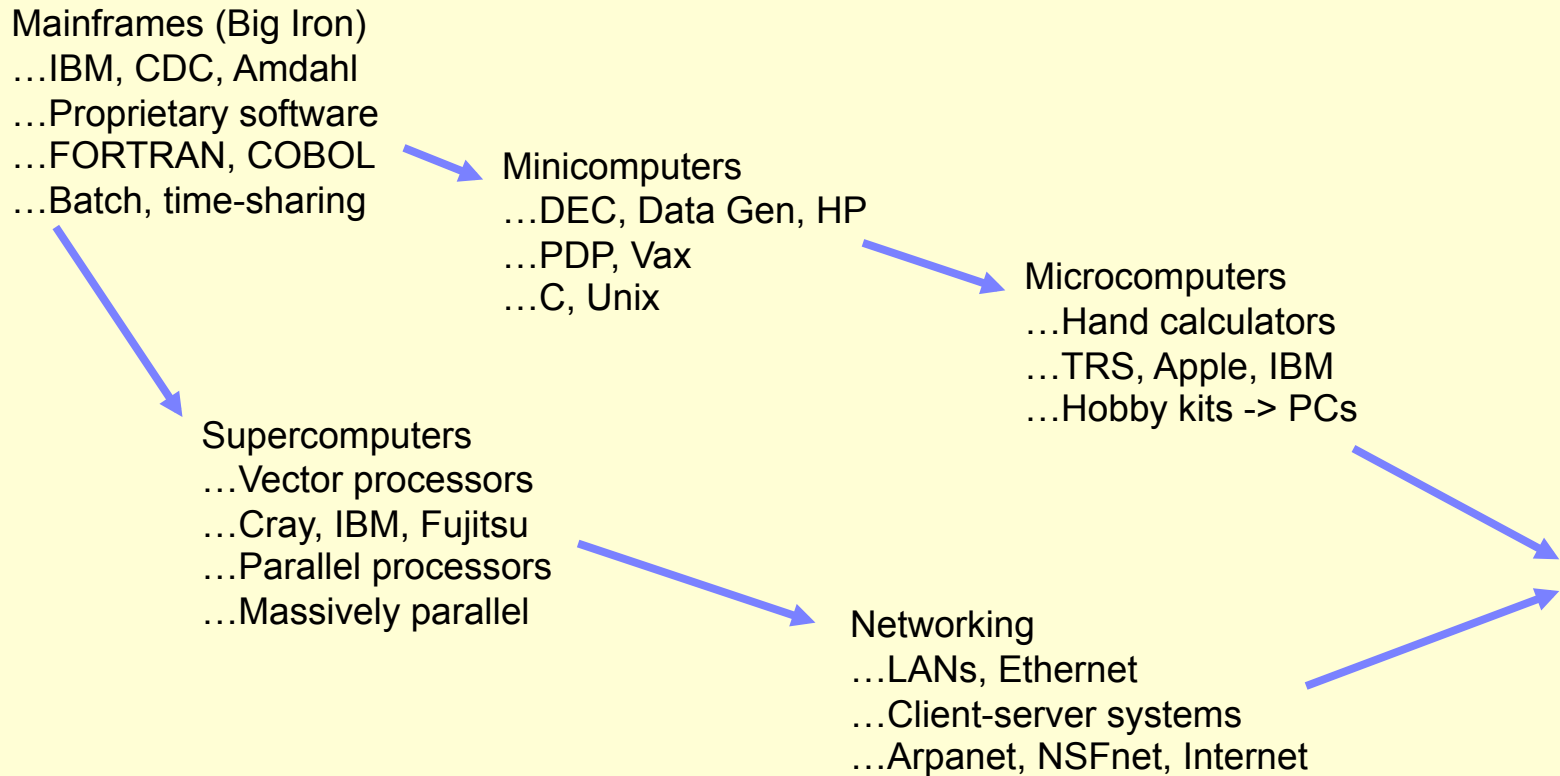
“If you believe that an institution that has survived for a millennium cannot disappear in just a few decades, just ask yourself what has happened to the family farm.”

– *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.”

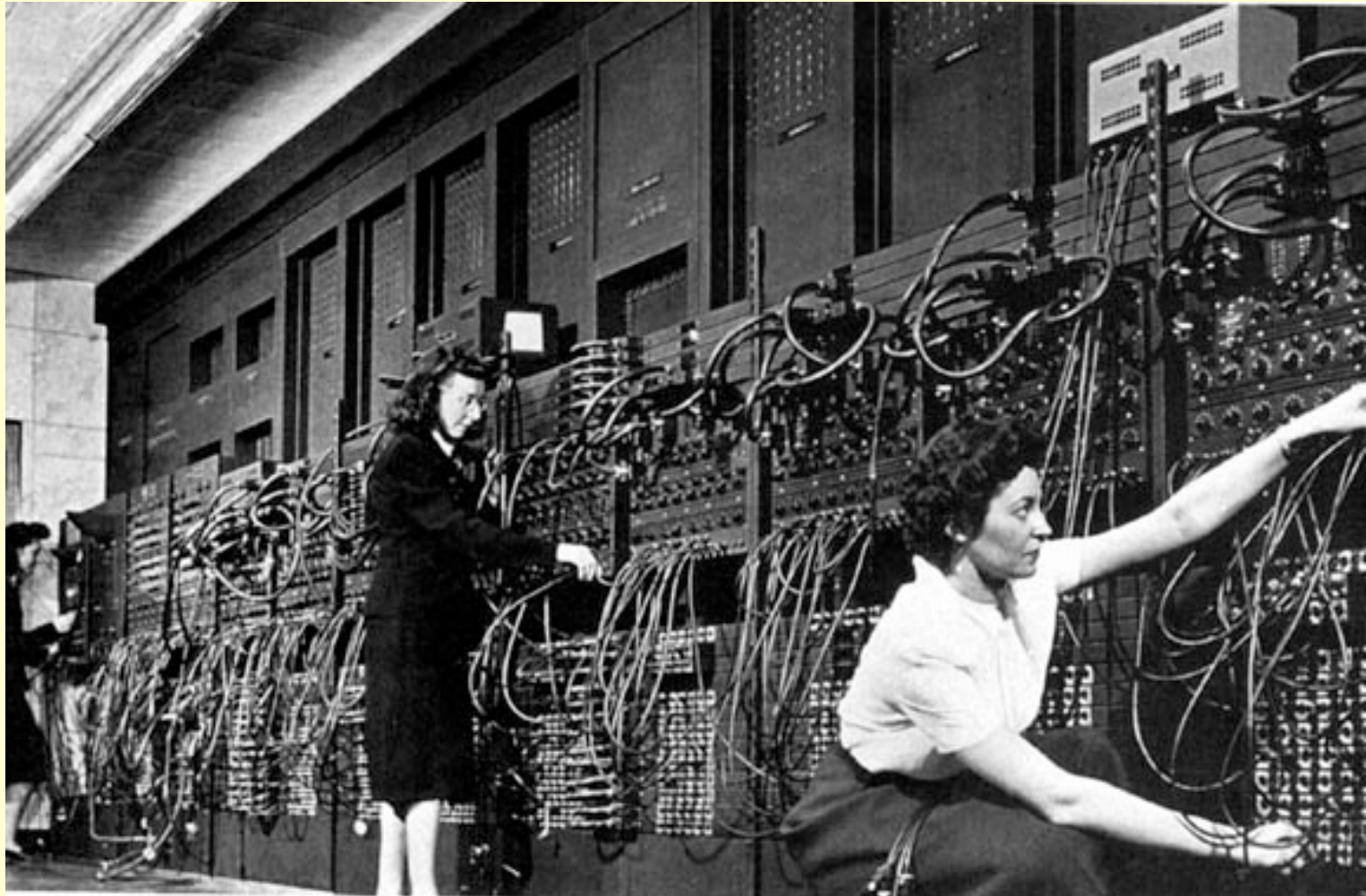
– *Frank Rhodes*

# A Detour: The Evolution of Computers



Batch → Time-sharing → Personal → Collaborative

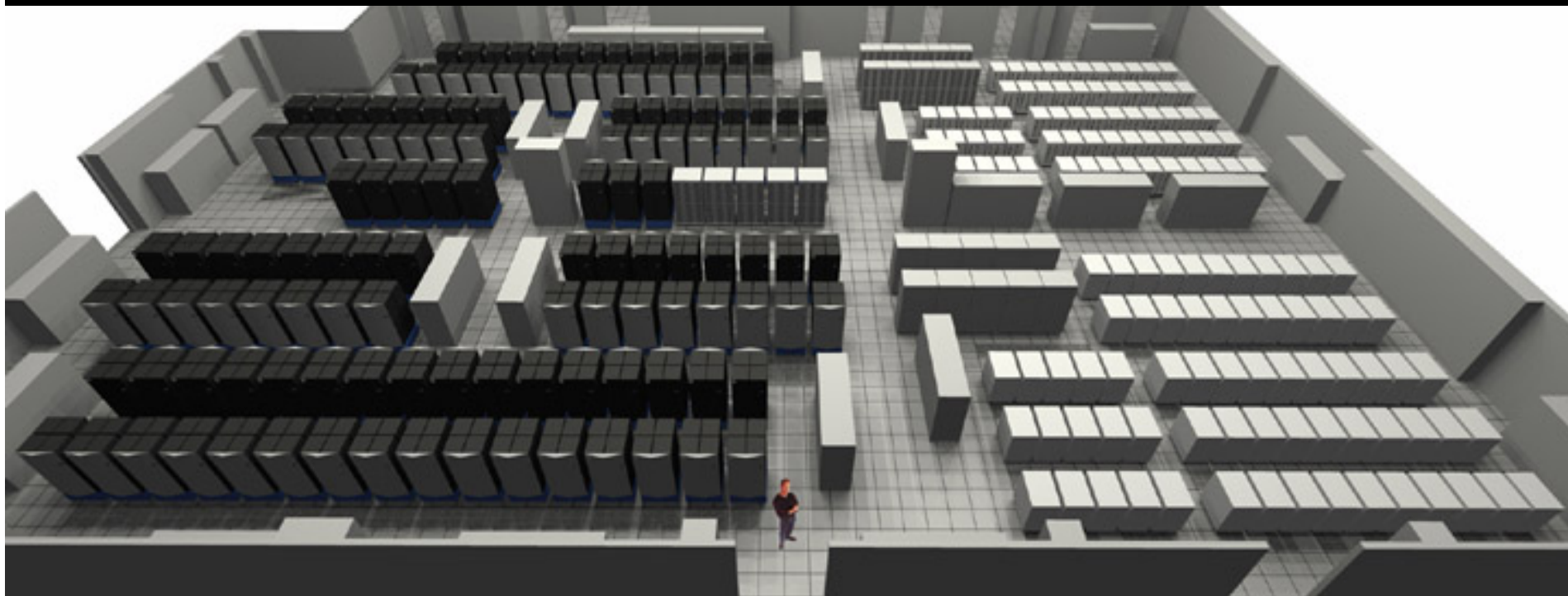
# From Eniac







# To ASCII White







2000 / 8/31 7:26AM





# Japan Earth Simulator



PN-07-12/13

PN-08-08/09

PN-09-14/15

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PN-22-14/15

PN-23-14/15

PN-24-14/15

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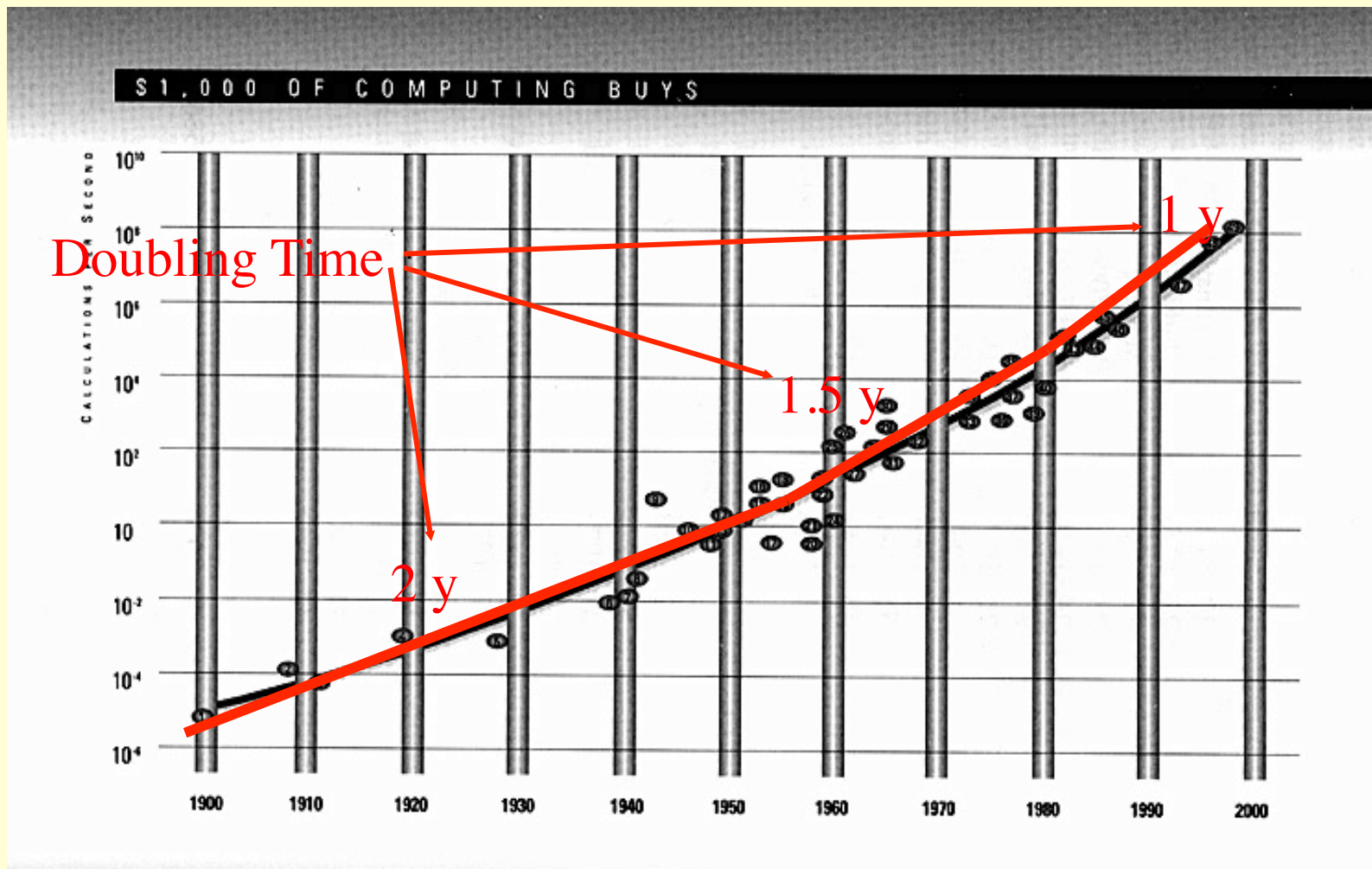
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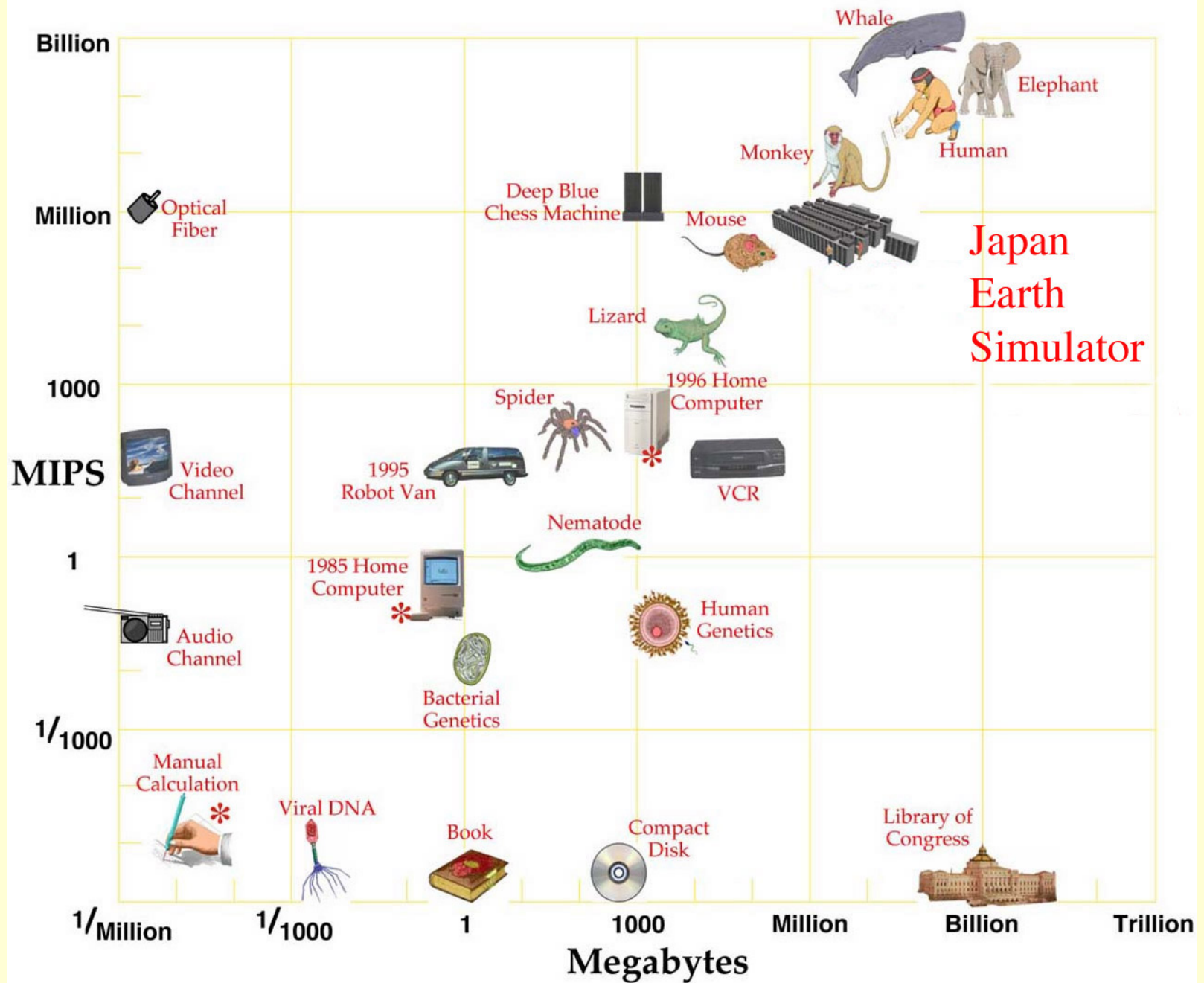
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# The Evolution of Computing





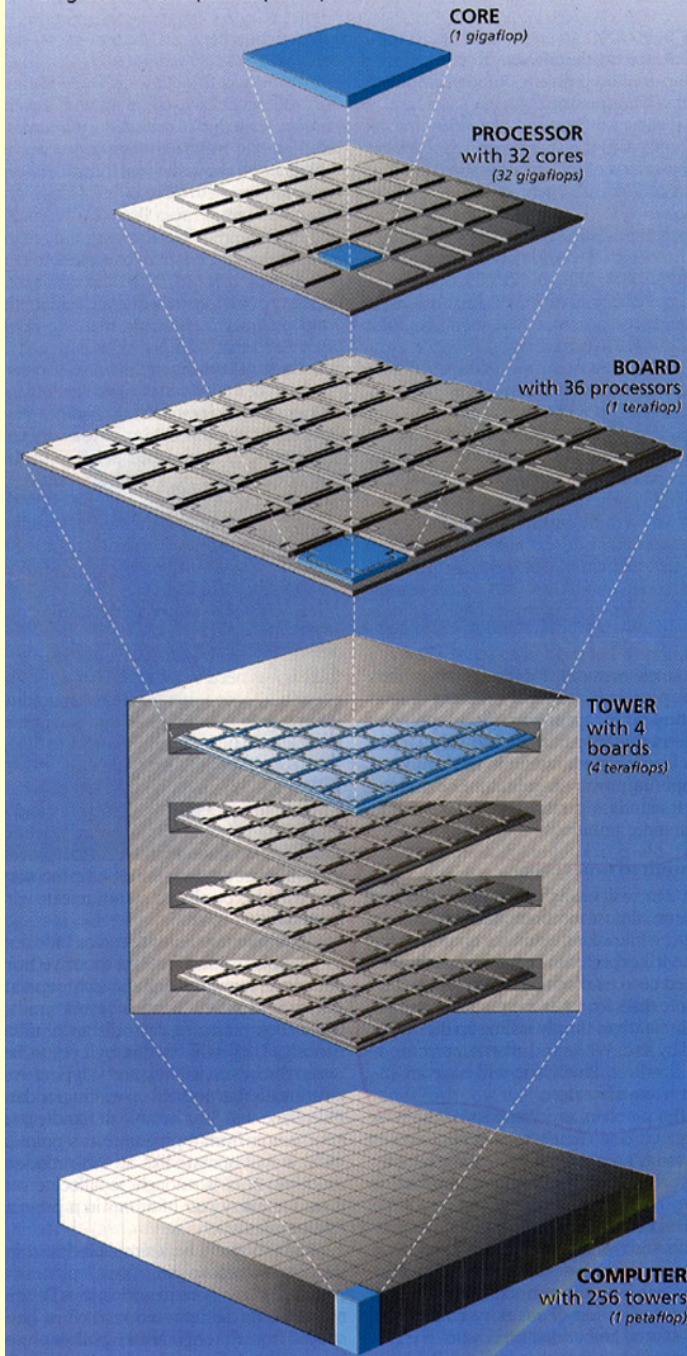
# All Thinks, Great and Small



IBM Weather Simulator:  
100 TeraFlops

IBM Blue Gene:  
1,000 TeraFlops  
= 1 PetaFlop

**Blue Gene**  
Building blocks for a petaflop computer



# Computer-Mediated Human Interaction

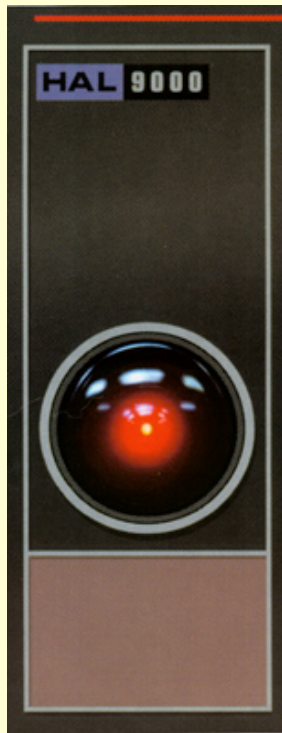
- **1-D (words)**
  - \* Text, e-mail, chatrooms, telephony
- **2-D (images)**
  - \* Graphics, video, WWW, multimedia
- **3-D (environments)**
  - \* Virtual reality, distributed virtual environments
  - \* Immersive simulations, avatars
  - \* Virtual communities and organizations
- **And beyond...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

# Evolution of the Net

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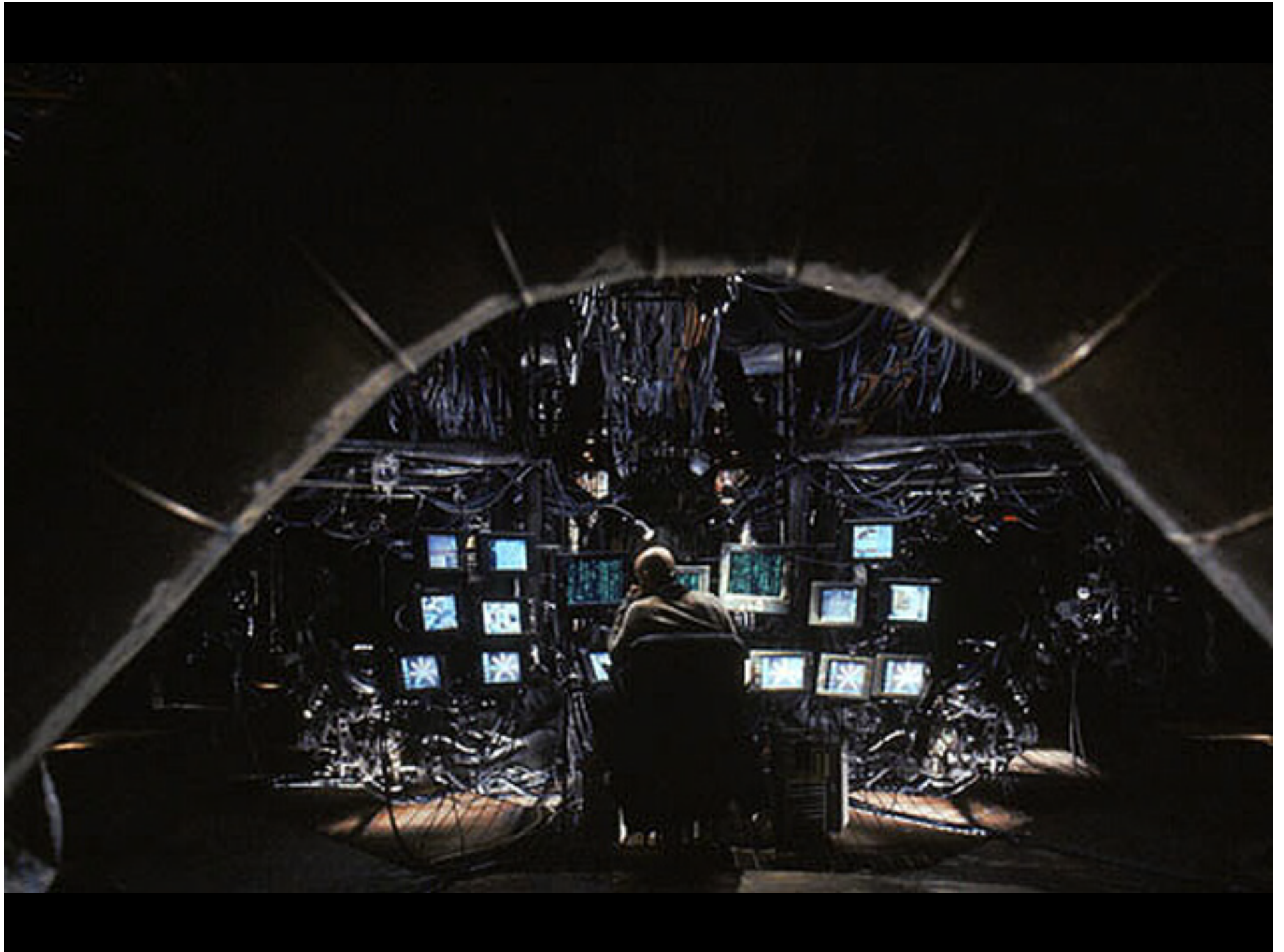
- Already beyond human comprehension
- Incorporates ideas and mediates interactions among millions of people
- 200 million today; more than 1 billion in 2005
- Internet II, Project Abilene

# 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

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**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

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

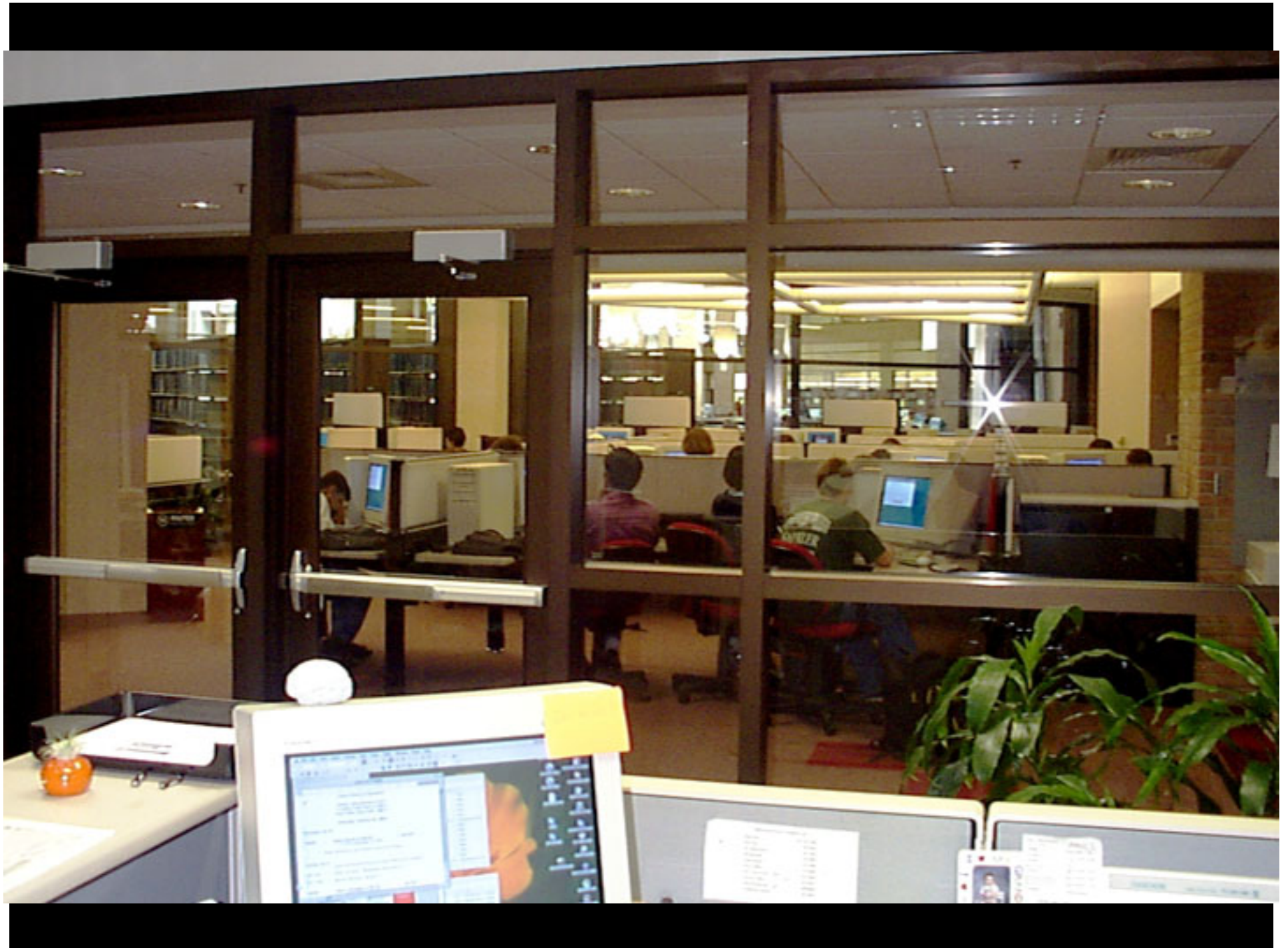
# Teaching to Learning

- 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

















# The Old Paradigm

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- 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.

# 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 will be 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 ...



# 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:

1) **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

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**Activities:** teaching, research, outreach

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

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

# Some Deeper Issues

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- The New Literacy
- Constructionist Learning
- Ripping learning out of the classroom and placing it into the environments of research and professional practice
- The Creative University

# The New Literacy

- Elizabeth Daley's "The Screen is the New Vernacular"
- Evolution from the oral tradition to the written word to film and video to the compute and multimedia
- From "read-only" to "composition"
- What about art, poetry, mathematics, science itself?



# The New Media

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- Active, not passive
- Not just learning, but creating knowledge
- Play becomes important
- Collaborative
- Multitasking
- Bricolage

# Constructionist Learning

- From John Dewey to Marie Montessori to Jean Piaget to Seymour Papert
- “Constructionist learning”
- Discovery (inquiry) based learning
- Work becomes play
- And learning becomes research!

# A Chinese Proverb

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- I hear, and I forget.
- I see, and I remember.
- I do, and I understand

# Some Implications for the University

- From the “3 R’s” to the “3 X’s” (eXploration, eXpression, eXchange)
- Students learn best by doing
- Difficult to differentiate between teachers and students...both are learners.
- Who “controls” the learning?



# An Idea

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- Shift paradigm of undergraduate education from the lecture format of the classroom to the discovery environment of the laboratory, or
- The problem solving environment of professional practice.
- (Note this aligns better with real interests of the faculty of the research university.)

# From analysis to creation

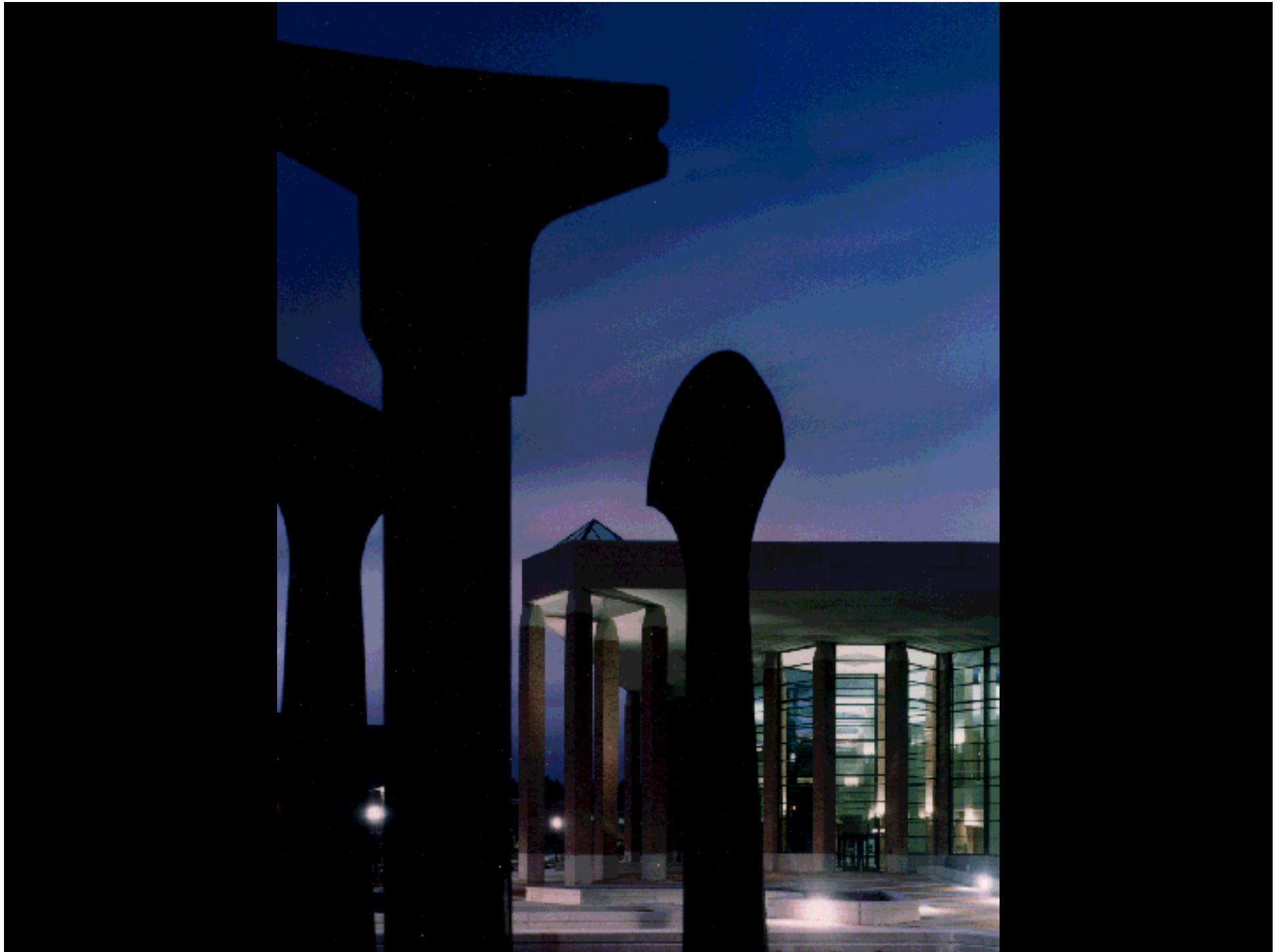
“The winners of this new era will be creators, and it is to them that power and wealth will flow. The need to shape, to invent, and to create will blur the border between production and consumption. Creation will not be a form of consumption anymore, but will become work itself, work that will be rewarded handsomely. The creator who turns dreams into reality will be considered as workers who deserve prestige and society’s gratitude and remuneration.”

Jacques Attali, *Millennium*

# A transition

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- |                        |   |                      |
|------------------------|---|----------------------|
| ● Business             |   | ● Art                |
| ● Law                  |   | ● Architecture       |
| ● Health Professions   |   | ● Music              |
| ● Social Sciences      | → | ● ...Engineering...  |
| ● (the Central Campus) |   | ● (the North Campus) |



























# 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

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**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

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- 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, University 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



# Objectives

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- To determine what role, if any, there is 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.

# Early Conclusions

- The extraordinary evolutionary pace of information technology is likely to continue for the next several decades.
- The impact of information technology on the university will likely be profound, rapid, and discontinuous—affecting all of its activities (teaching, research, service), organization (academic structure, faculty culture, financing and management), and the broader higher education enterprise.

# Conclusions (continued)

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- Yet, for at least the near term, the university will continue to exist in essentially 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.
- 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.

# 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. **It is a disruptive technology.**
- For the longer term (two decades and beyond), the future is less clear. 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.

# A Social Transformation

The 20th Century

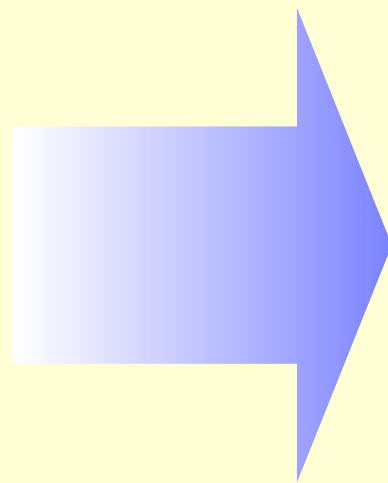
Transportation

Cars, planes, trains

Energy, materials

Prosperity, security

Social structures



The 21st Century

Communications

Computers, networks

Knowledge, bits

Prosperity, security

Social structures



# Another Perspective ...

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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*

# Some Conclusions



## For the Near Term

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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 neural 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

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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.
- 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.

# 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.
- The vast majority of transactions include a simulated person.

# 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 created 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 (“simstim”)
- 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.
- Machines claim to be conscious. These claims are largely accepted.



# 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 neurons, 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 ...

