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!!!

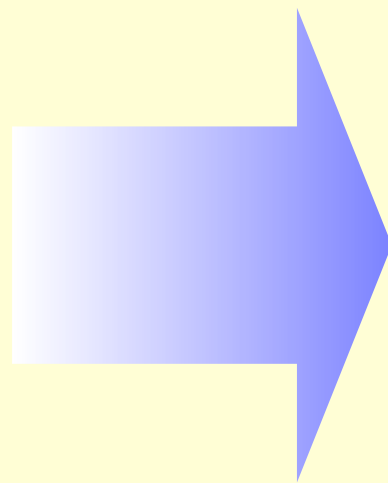# A Social Transformation

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
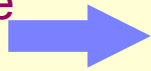
Forces of Change

A Changing World

Age of Knowledge

Demographic Change
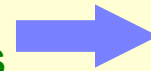
Globalization

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

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
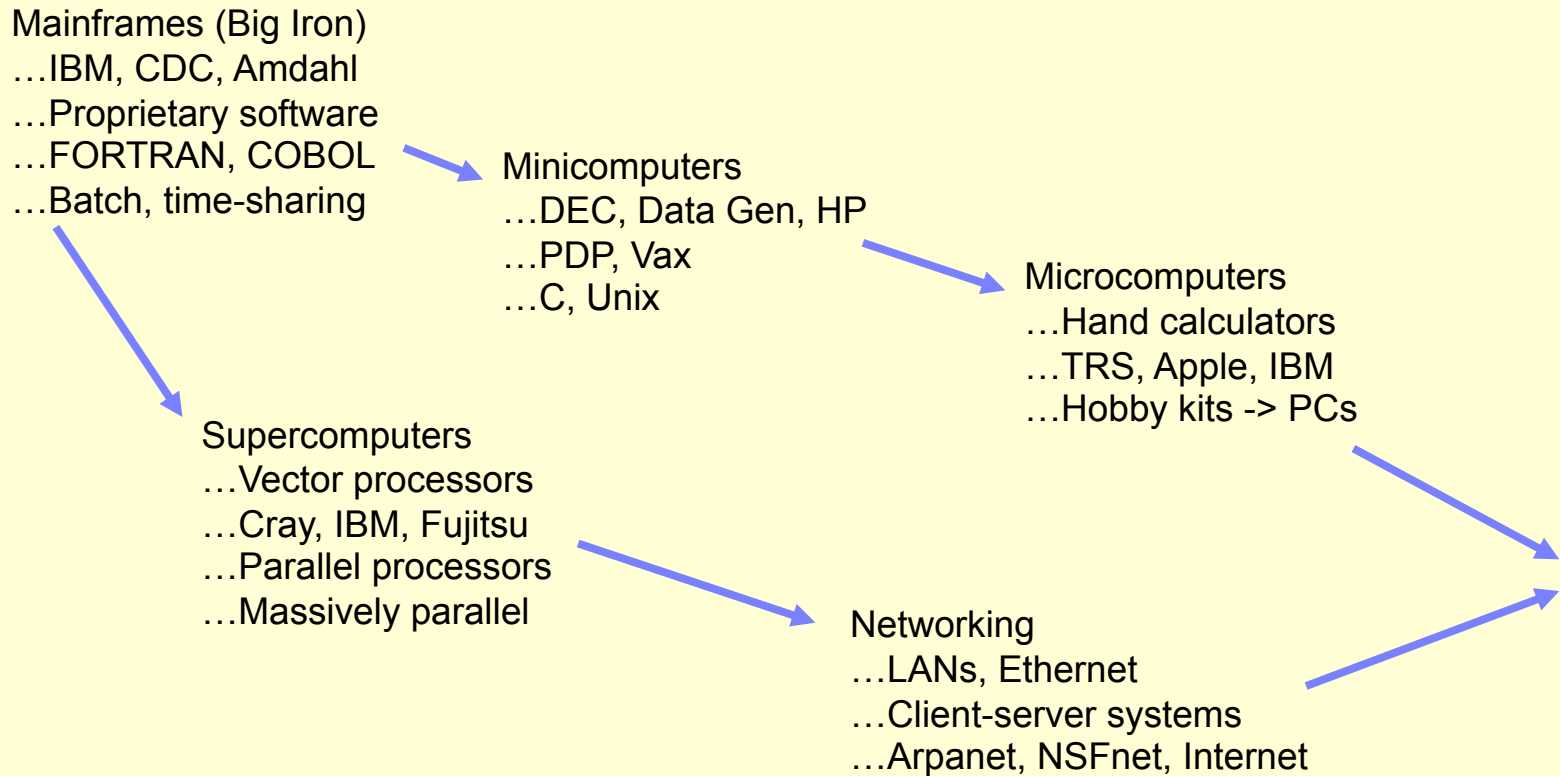
Phase 1

- 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
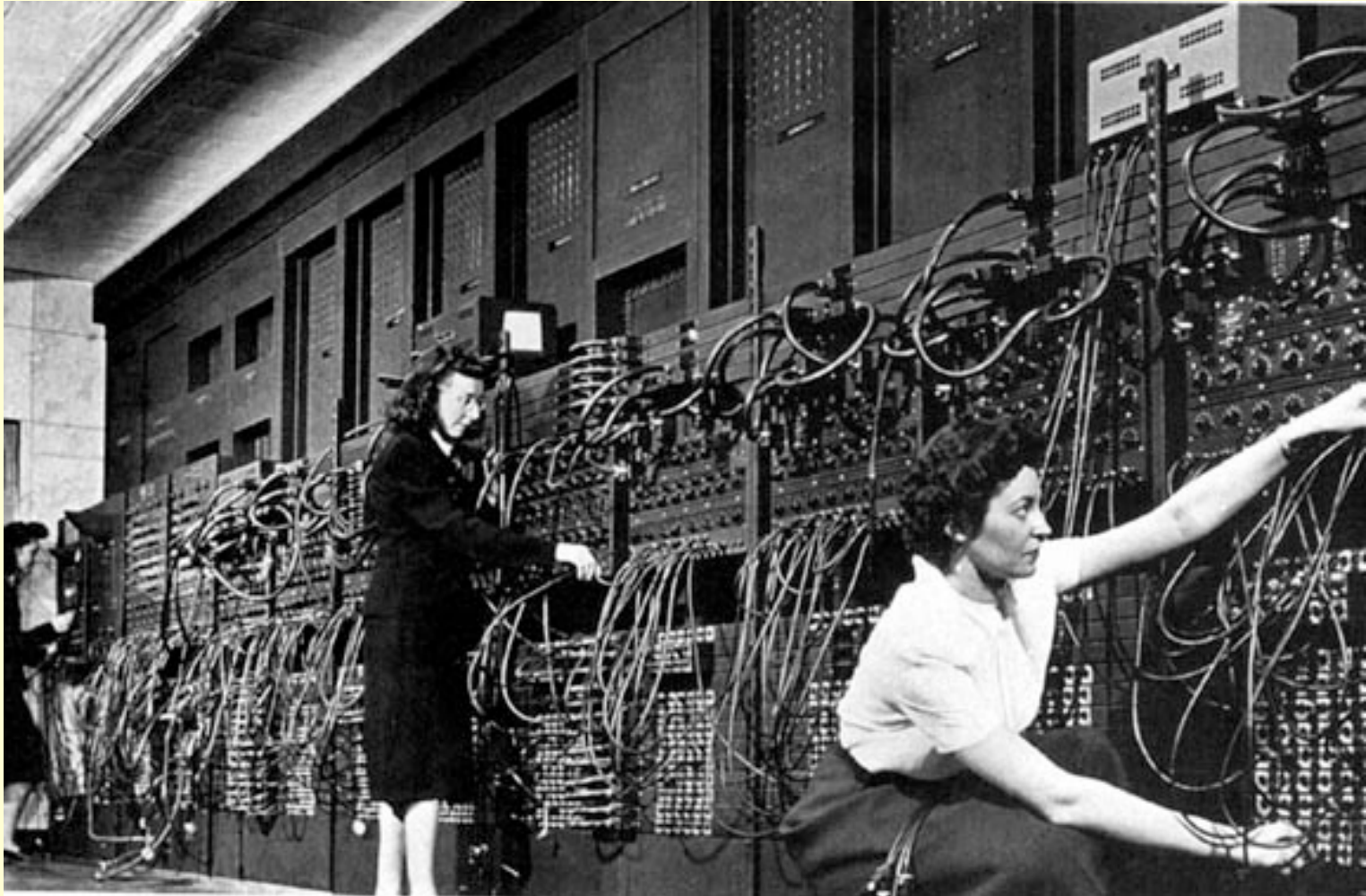
Phase 1: Conclusions

- 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.

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

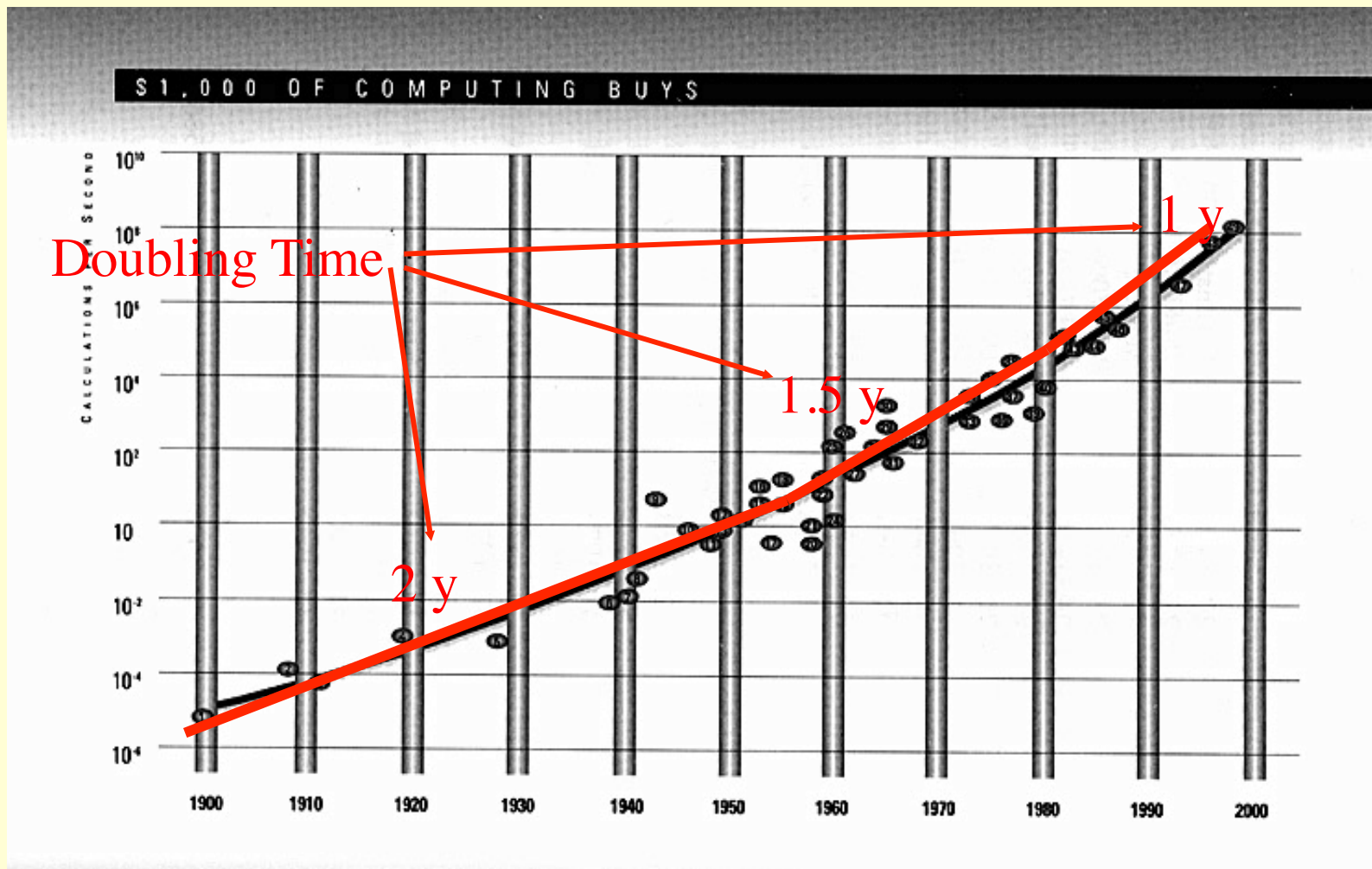# To ASCI "Q" … and beyond

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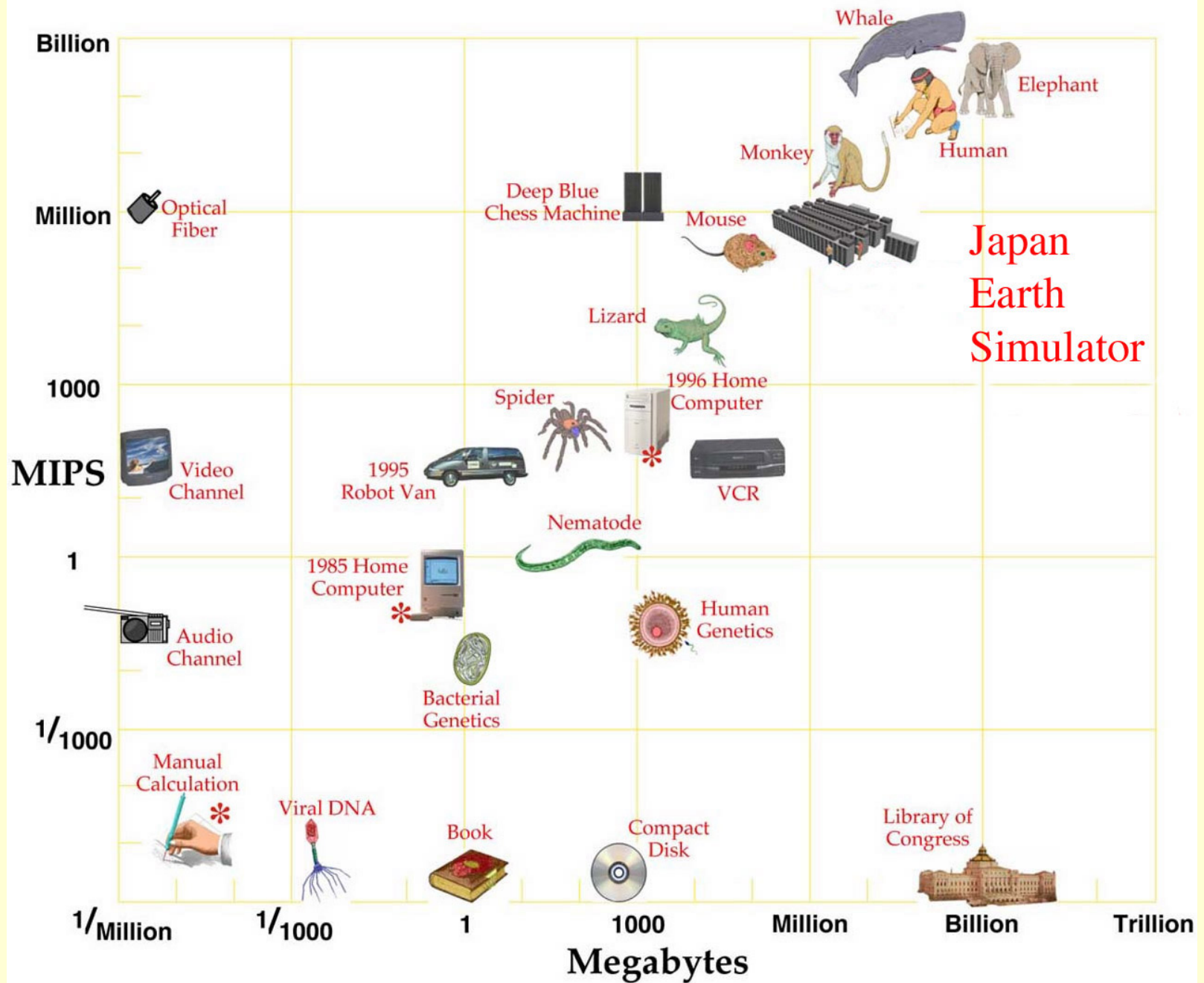
Japan Earth Simulator

ASCI Purple RFP

The Purple RFP was issued on February 22, 2002

RFP RESPONSES ARE DUE 4:00 P.M. PDT APRIL 29, 2002

The Evolution of Computing

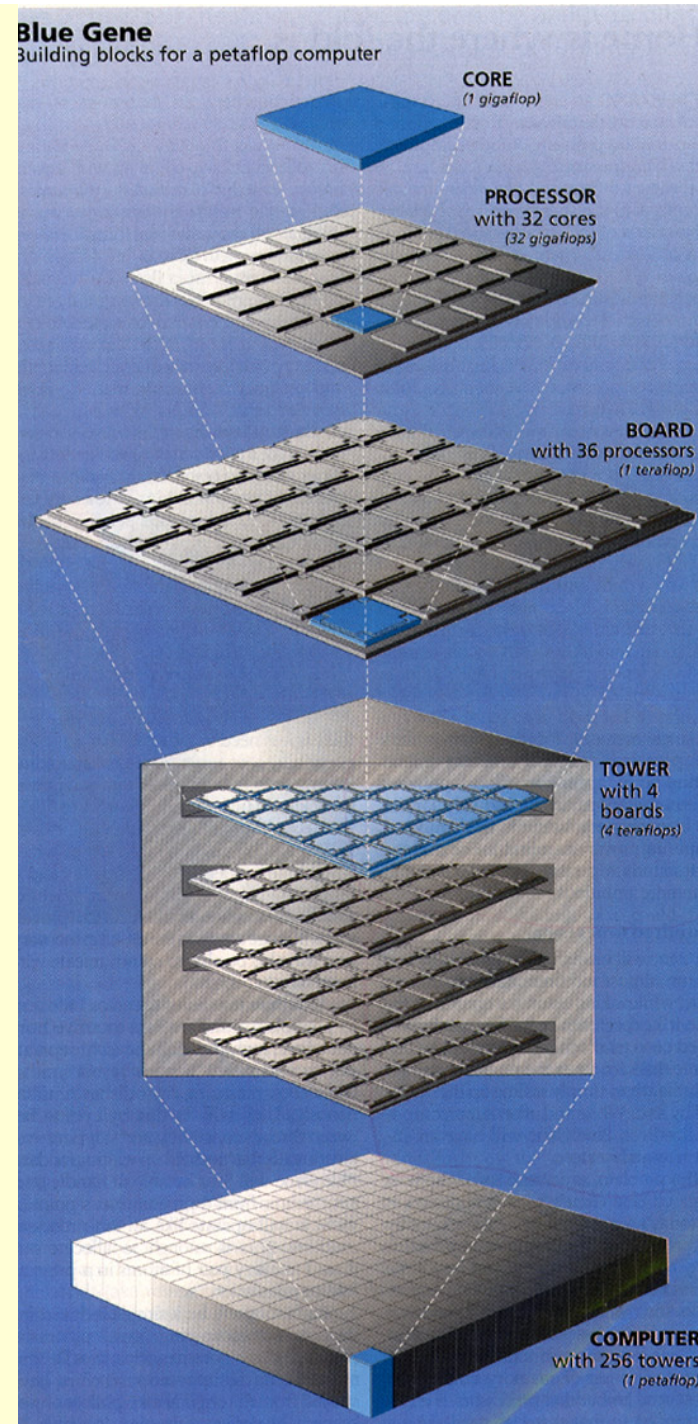# All Thinks, Great and Small

ASCI Purple (2004):

    100 TeraFlops

IBM Blue Gene L (2004):

    360 TeraFlops

IBM Blue Gene P (2006):

    "Several" PetaFlops

Blue Gene
Building blocks for a petaflop computer

CORE
(1 gigaflop)

PROCESSOR
with 32 cores
(32 gigaflops)

BOARD
with 36 processors
(1 teraflop)

TOWER
with 4
boards
(4 teraflops)

COMPUTER
with 256 towers
(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}

Hardware Technology Trends

- Processing (Moore's Law) (increasing 40% per year)
  - Current speed record: 150 GHz chips
- Disk storage (increasing 60% to 100% per year)
  - 3.5 disk can hold 320 Gb
  - Far cheaper than paper or microfilm
- Bandwidth
  - Lab demo on single fiber: 11 Tb/s
  - Real communication at 40 Gb/s
- Mobility
  - 802.11 (a, b, g, I) at 55 Mb/s and beyond
- Displays
  - Full wall projections
  - Resolution must better than paper

Software and System Trends

- Algorithm improvements
- Embodiment of techniques and processes into software
    * Formalization and standardization
    * People are the exception rather than the main line
- Distribution of computing, data, applications, and services
- Grid interconnection of resources
- Services as unit of IT, rather than bare-bones data and processing

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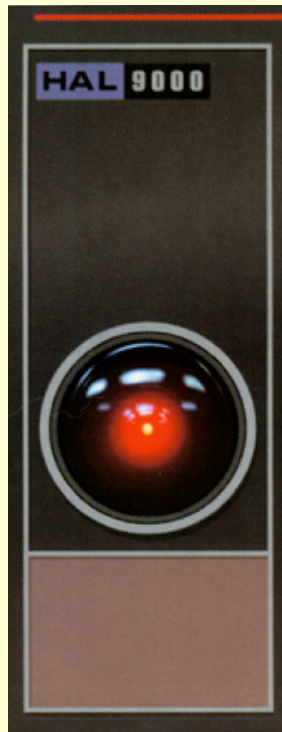
- **Ubiquitous computing?**
  - ∗ Computers disappear (just as electricity)
  - ∗ Calm technology, bodynets
- **Agents and avatars?**
  - ∗ Fusing together physical space and cyberspace
  - ∗ Plugging the nervous system into the Net
- **Emergent behavior?**
  - ∗ … Self organization
  - ∗ … Learning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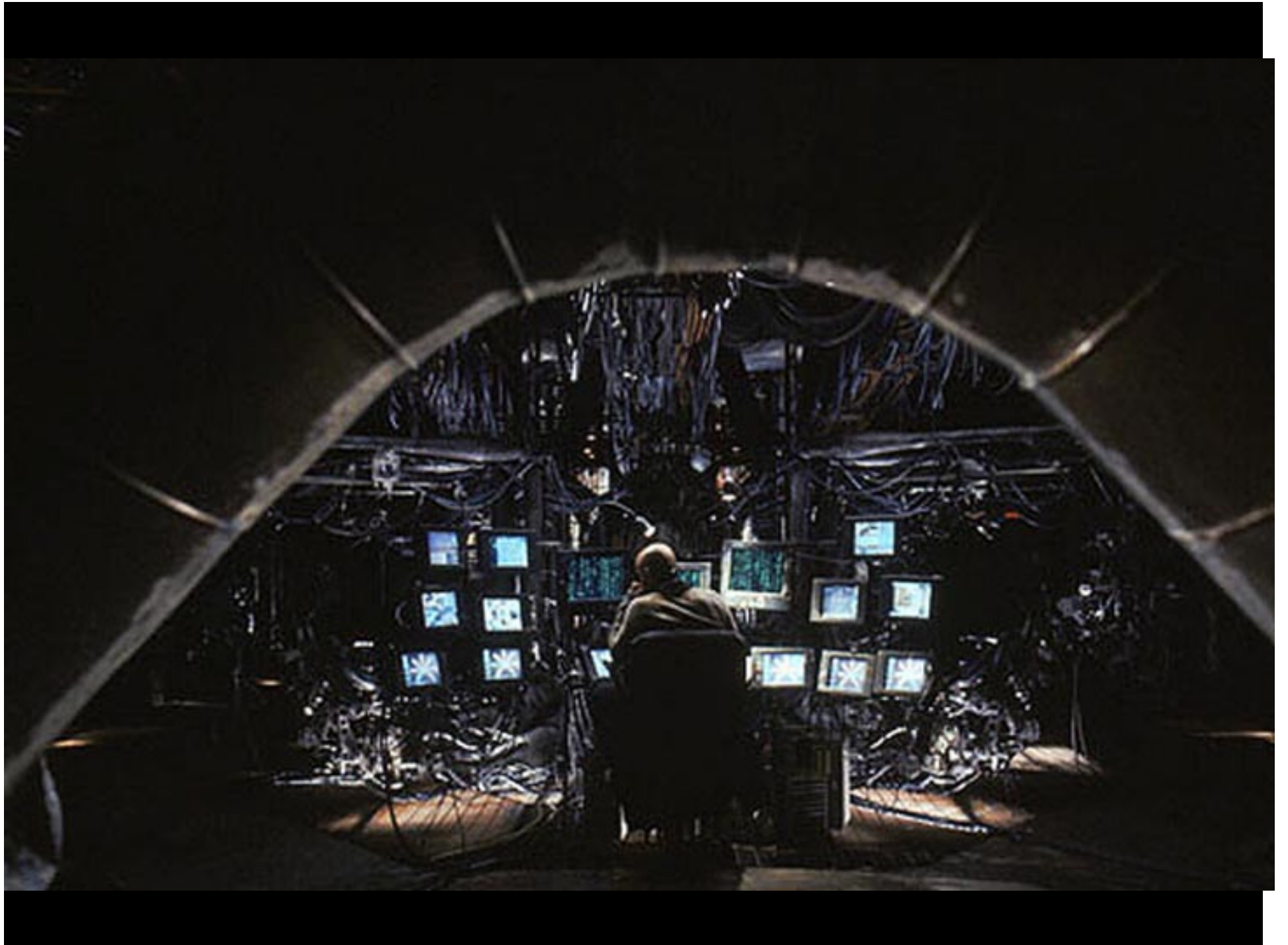
Conclusions (continued)

- 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.

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
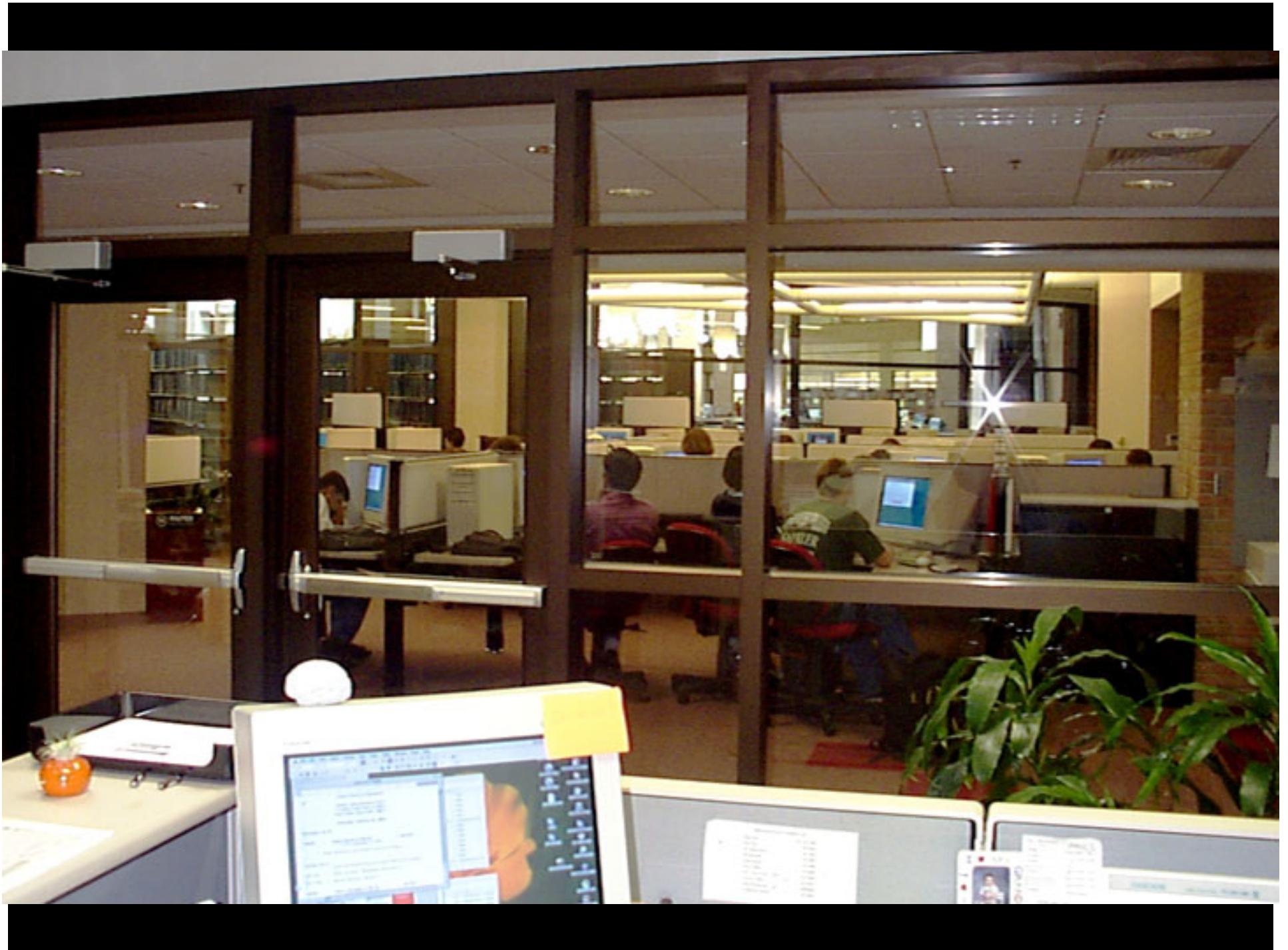
The Old Paradigm

- 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.
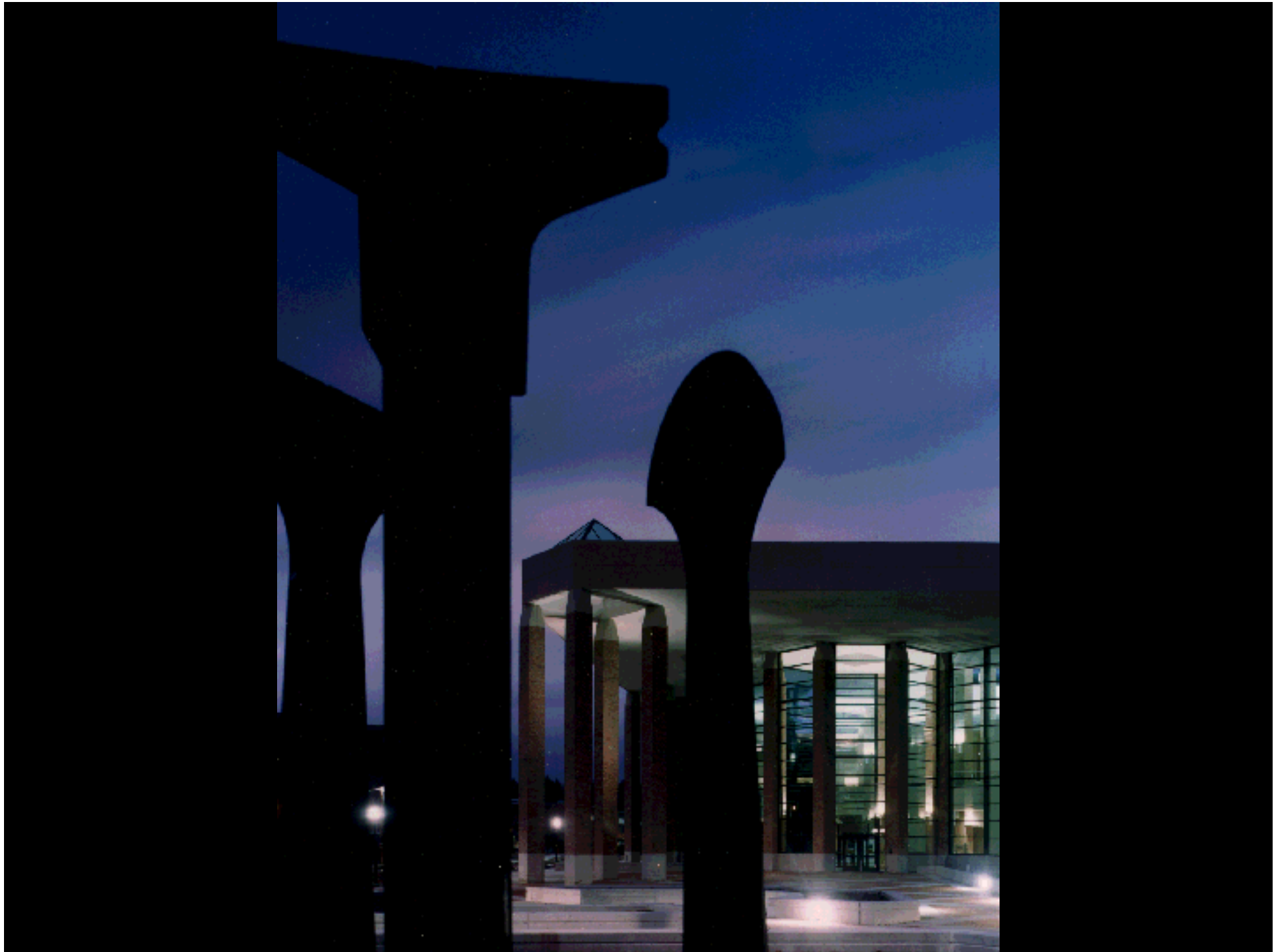
camp caen

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

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 …

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!

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.

Conclusions (continued)

- 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).

Implications for Colleges and 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.

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.

Conclusions (continued)

- 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.

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 Internet.
- 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.

Phase 2

- **NAS IT Forum 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)**

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 comprehensible.

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.

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*