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?
“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.
Phase One

- Technology scanning (a decade out)
- Implications for the future of the research university
- Possible roles for federal government and other stakeholders
ITFRU Guidance Committee

- 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
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.

- 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.
From Eniac
To ASCI "Q" … and beyond
Japan Earth Simulator
Defining Extreme Scale Computing: ASCI Purple

*Work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.*
Building BlueGene/L

Compute Chip
- 2 processors
- 2.8/5.6 GF/s
- 4 MiB* eDRAM

FRU (field replaceable unit)
- 25mmx32mm
- 2 nodes (4 CPUs)
- (2x1x1)
- 2.8/5.6 GF/s
- 256/512 MiB* DDR
- 15 W

Compute Card I/O Card
- 16 compute cards
- 0-2 I/O cards
- 32 nodes
- (64 CPUs)
- (4x4x2)
- 90/180 GF/s
- 8 GiB* DDR

Node Card
- SU (scalable unit)
- 16 node boards
- 512 nodes
- (1,024 CPUs)
- (8x8x8)
- 1.4/2.9 TF/s
- 128 GiB* DDR
- 7-10 kW

Midplane
- 2 midplanes
- 1024 nodes
- (2,048 CPUs)
- (8x8x16)
- 2.9/5.7 TF/s
- 256 GiB* DDR
- 15-20 kW

System
- 64 cabinets
- 65,536 nodes
- (131,072 CPUs)
- (32x32x64)
- 180/360 TF/s
- 16 TiB*
- 1.2 MW
- 2500 sq.ft.

Cabinet
- 2 midplanes
- 1024 nodes
- (2,048 CPUs)
- (8x8x16)
- 2.9/5.7 TF/s
- 256 GiB* DDR
- 15-20 kW

(System compare this with a 1988 Cray YMP/8 at 2.7 GF/s)


Salishan 2003 — page 14
ASCI Purple (2004): 100 TeraFlops

IBM Blue Gene L (2004): 360 TeraFlops

The Evolution of Computing
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, l) at 55 Mb/s and beyond
- Displays
  - Full wall projections
  - Resolution much 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 to Grid to National LambdaRail
- **Networks**
  - Copper to fiber to wireless to photonics
  - “Fiber to the forehead…”
Computer-Mediated Human Interaction

- **1-D (words)**
  - Text, e-mail, chatrooms, IM, telephony
- **2-D (images)**
  - Graphics, video, WWW, multimedia
- **3-D (environments)**
  - Virtual reality
  - Virtual worlds
- **And beyond... (experiences, “sim-stim”)**
  - Telepresence
  - Neural implants
An Example: Evolution of the Net

- Already beyond human comprehension
- Incorporates ideas and mediates interactions among millions of people
- 500 million today; more than 1 billion in 2010
- Internet2, National Lambda Rail, TeraGrid
- Semantic Web, Executable Internet, Web Services, Cyberinfrastructure
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.

- Information technology is a **disruptive technology** in higher education that requires strategic attention.
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
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.

- **Procrastination and inaction are the most dangerous courses of all during a time of rapid technological change.**
Because of the profound yet unpredictable impact of this technology, it is important that institutional strategies include:

- the opportunity for experimentation,
- the formation of alliances both with other academic institutions as well as with for-profit and government organizations, and
- the development of sufficient in-house expertise among the faculty and staff to track technological trends and assess various courses of action.