The Ultimate Intelligent Platform:
The American Research 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
The Knowledge Explosion
Globalization
High Performance Workplace
Diversity
Technological Change
Knowledge Transfer

Forces on the University
Economics
Societal Needs
Technology
Markets

Evolution?
Revolution?
Extinction?
The Future of the University?

“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
Outline

- The American Research University, Inc.
- A Restructured Knowledge and Learning Industry
- Possible Strategies
- “Knowledge Management” in the Research University
- The Future of the University
The American Research University
Traditional Roles of the University: The Core

- Educating the Young
- Seeking Truth and Creating New Knowledge
- Sustaining Academic Disciplines and Professions
- Teaching and Scholarship
- Sustaining and Propagating Culture and Values
- Serving as a Social Critic
- Critical Thinking
- Analysis and Problem Solving
- Moral Reasoning and Judgment
The Traditional Roles of the University: The Periphery

- Economic Development (Agriculture, Industry, etc.)
- Technology Transfer
- Health Care
- Teaching and Scholarship
- Entertainment (Arts, Sports)
- National Defense
- International Development
Case Study 1

Higher Education in the United States
The Evolution of U.S. Higher Education

- 1700s…Frontier America  → Colonial Colleges
- 1800s…Industrial Society  → Land-Grant Universities
- 1900s…Rise of Professions  → Technical Colleges
- 1940s…WWII, the Cold War  → Research Universities
- 1950s…Mass Education  → University Systems
- 1990s…Market Forces  → Cyber-U, Global U, For-profit U
The 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 Res U
Res U I, II
Doc U I, II
Comp U I, II
Lib Arts Colleges
Community Colleges
K-12
Cyber U (1,000)
Niche U
New learning lifeforms

Knowledge Infrastructure
(production, distribution, marketing, testing, credentialing)
Some Other Characteristics of the U.S. System of Higher Education

- 65% of high school graduates attend college
  ✴️ (although only 50% of these will receive degrees)
- 15 million students enrolled in 3,595 colleges and universities
  ✴️ (520,000 international students)
- 80% of students enrolled in “public” universities
- $200 billion/year spent on U.S. higher education
  ✴️ $50 billion/y in federal student financial aid
  ✴️ $20 billion/y in federal research grants
  ✴️ $60 billion/y in state (regional) appropriations
  ✴️ $70 billion/y in tuition, gifts, business activities, etc.
The Role of Government in the U.S.

- The Federal Government:
  - No ministry, no national system, no controls…no policy
  - $50 B/y of financial aid for students
  - $15 B/y of research grants to faculty
  - NOTE: The federal government provides funds to people (students, faculty, patients), not universities.

- State Governments:
  - $65 B/y to support operation of public universities
  - Great diversity in state governance, from rigidly controlled systems (New York, Ohio) to strategic master plans (California) to anarchy (Michigan)
Case Study 2

The University of Michigan
University of Michigan

- First truly public university in United States (1817)
- Constitutional autonomy
- One of U.S.’s largest universities
  - People: 50,000 students; 3,500 faculty, 25,000 staff
  - Budget: $3.4 billion/year; ($3.9 billion endowment)
  - Facilities: 3 million m² of facilities
  - Campuses in Europe, Hong Kong, Korea, Brazil, cyberspace
- One of U.S.’s leading research universities (> $700 million/year)
- Some other features:
  - First university hospital (1 million patients a year, $1.4 billion/year)
  - Key role in developing and managing the Internet (now Internet2)
UM Schools and Colleges

- Architecture
- Art and Design
- Business Administration
- Dentistry
- Education
- Engineering
- Graduate programs
- Information
- Kinesiology
- Law
- Humanities
- Medicine
- Music
- Natural Resources
- Nursing
- Pharmacy
- Public Health
- Public Policy
- Sciences
- Social Work
UNIVERSITY of
MICHIGAN
1817
ARTES
SCIENTIA
VERITAS

THIS FLAG CARRIED ABOARD APOLLO 15 DURING THE FIRST EXTENDED SCIENTIFIC EXPLORATION OF THE MOON. JULY 26 – AUGUST 7, 1971
Another way to look at UM

U of M, Inc

- **On campus education**: 50,000 students, $1.2 billion/y
- **National R&D Lab**: $700 million/y
- **UM Hospitals**: 1 million patients/y, $1.3 billion/y
- **UM Health System**: 200,000 “Managed lives”
- **Veritas Insurance Co**: $200 million/y
- **Gobal Knowledge Services**: $200 million/y
- **Entertainment Michigan Wolverines**: $200 million/y
First, a fact of university life: disciplinary silos
But in a research university...
Another way to think of the research university:

- “The contemporary research university is nothing more than a holding company for research entrepreneurs!”
  
  A frustrated junior faculty member

- “Our faculty members can do anything they want—provided they can raise the funds to support what they do…”
  
  A former MIT president
Vannevar Bush Linear Model of Research

Science: The Endless Frontier

Basic, curiosity driven

Application in products and missions.

Transfer
Pasteur’s Quadrant

PASTEUR’S QUADRANT

Basic Science and Technological Innovation

Donald E. Stokes
Pasteur’s Quadrant Research Model (from Donald Stokes)

Extent of Focus on New Knowledge Creation?

Extent of Focus on Application/Product
Pasteur’s Quadrant Research Model
(from Donald Stokes)

Focus on New Knowledge Creation?  

Yes  

No

Focus on Application?  

Yes  

No

Bohr  

Pasteur  

Edison
The Forces of Change
Forces of Change

A Changing World

The Knowledge Explosion
Globalization
High Performance Workplace
Diversity
Technological Change
Knowledge Transfer

Forces on the University
Societal Needs
Economics
Technology
Markets

Brave New World?
Society of Learning?
Changing Societal Needs

- Increasing population of “traditional” students
- The “plug and play” generation
- Education needs of adults in the high-performance workplace (lifelong learning)
- Passive student to active learner to demanding consumer
- “Just-in-case” to “just-in-time” to “just-for-you” learning
- Diversity (gender, race, nationality, socioeconomic,...)
- Global needs for higher education

Concern: There are many signs that the current paradigms are no longer adequate for meeting growing and changing societal needs.
Half of the world’s population is under 20 years old.

Today, there are over 30 million people who are fully qualified to enter a university, but there is no place available. This number will grow to over 100 million during the next decade.

To meet the staggering global demand for advanced education, a major university would need to be created every week.

“In most of the world, higher education is mired in a crisis of access, cost, and flexibility. The dominant forms of higher education in developed nations—campus based, high cost, limited use of technology—seem ill-suited to addressing global education needs of the billions of young people who will require it in the decades ahead.”

Sir John Daniels, British Open University
Financial Imperatives

- Increasing societal demand for university services (education, research, service)
- Increasing costs of educational activities
- Declining priority for public support
- Public resistance to increasing prices (tuition, fees)
- Inability to re-engineering cost structures

Concern: The current paradigms for conducting, distributing, and financing higher education may not be able to adapt to the demands and realities of our times
Since universities are knowledge-driven organizations, it is logical that they would be greatly affected by the rapid advances in information and communications technologies. We have already seen this in administration and research.

But the most profound impact could be on education, as technology removes the constraints of space, time, reality (and perhaps monopoly ... )

**Concern:** The current paradigm of the university may not be capable of responding to the opportunities or the challenges of the digital age.
Market Forces

Changing societal needs, economic realities, and rapidly evolving technology are creating powerful market forces in the higher education enterprise. The traditional monopolies of the university, sustained in the past by geography and certification, are breaking apart. We may be seeing the early signs of a restructuring of the higher education enterprise into a global knowledge and learning industry.

Concern: The current faculty-centered, monopoly-sustained university paradigm is ill suited to the intensely competitive, technology-driven, global marketplace.
The Restructuring of the Higher Education Enterprise into a Global Knowledge and Learning Industry
Market Forces

- Changing Social Needs
- Financial Imperatives
- Evolving Technology

Powerful Market Forces
The Role of Markets

The U.S. higher education enterprise is highly competitive!

- For students (particularly the best)
- For faculty (particularly the best)
- For public funds (research grants, state appropriations)
- For private funds (gifts, commercial)
- For winning athletics programs
- For everything and everybody…
The Role of Markets

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- For winning athletics programs
- For everything and everybody…

In a sense, Michigan competes not only with UC-Berkeley, Harvard, and MIT, but also with Oxford and Cambridge, not to mention IBM and Microsoft!
A Restructured Industry?

There are signs that higher education may be in the early stages of a major restructuring like other economic sectors such as energy, banking, and transportation that underwent restructuring following deregulation.

The restructuring of the higher education enterprise is being driven by changing social needs, financial pressures, rapidly evolving technology, and most significantly, emerging market forces. These are also driving a convergence of education with other knowledge-intensive industries such as information technology, telecommunications, information services, and entertainment into what might be regarded as:

A Global Knowledge and Learning Industry
“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.”
Scenario 1

The Brave, New World of Commercial Higher Education
Contributions of the Research University
The Knowledge Industry

- **Hardware**: Boxes, PCs, PDAs
- **Networks**: Backbones, LANs, Wireless
- **Software**: OS, Middleware, Applications
- **Solutions**: Systems, Integrators
- **Content**: Data, Knowledge, Entertainment, Learning?

**Companies**:
- IBM, HP, Sun, Lucent, Nokia, Ericsson
- AT&T, MCI, Telcos
- Microsoft, IBM, Sun
- Accenture, EDS, IBM, Unisys
- Time-Warner, Disney, “dot.coms”, AAU?
The Core Competencies of the University

Educated people

Content

Services

Learning

Research

Faculty and Staff expertise

Culture
A Possible Future for the U.S. Higher Education Enterprise

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

Supported by a commercial industry handling the production and packaging of learning ware, the distribution and delivery of educational services to learners, and the assessment and certification of learning outcomes.

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

- Unbundling
- A commodity marketplace
- Mergers, acquisitions, hostile takeovers
- New learning lifeforms
- An intellectual wasteland???
Scenario 2

A Society of Learning
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 of Education in a Society of Learning

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

How do we balance the roles of market forces and public purpose in determining the future of higher education. 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?
Strategies
Challenges to Change

- The complexity of the contemporary university
- The unrelenting pace of change
- Resistance to change (from within and without)
- Mission creep
- Antiquated governance of universities
Begin with the basics: mission and values

- What are our most important roles? Educating the young? Preserving and transmitting culture? Basic research and scholarship? Sustaining the academic disciplines and professions? A responsible critic of society?

- What are our most important values? Academic freedom? An openness to new ideas? Rigorous study? Faculty governance? Faculty tenure?
The Importance of Diversity

- Diverse institutions to serve diverse societal need (diversity in every human characteristics...race, gender, nationality, socioeconomic background, ...)
- Importance of stratified systems, tiered to both achieve excellence and serve mass education needs (e.g., the California master plan)
- Focus on missions that reflect not only tradition and unique roles but also core competencies where institutions can attempt to be world-class
- Avoid the “Harvardization” syndrome
Achieving balance

- Among missions (teaching, research, service)
- Among disciplines (liberal education, academic disciplines, professions)
- Undergraduate vs. graduate vs. professional education (e.g., education vs. training)
- Sciences vs. humanities
- Life sciences vs. everything else (U.S. dilemma)
Governments and Governance

- Public policy that views the university as
  - A “public good” or an individual benefit?
  - A public investment or an expenditure?
  - A government agency or a social institution?
- Increasing government demands for accountability and performance
- Shared governance (rigor mortis or anarchy?)
Financing the University

- Tax policy that stimulates private donations (charitable contributions)
- Ownership of intellectual property (Bayh-Dole Act)
- The entrepreneurial university
- The “privately-supported but publicly-committed” university
As universities become more specialized and differentiated, alliances become more important among different types of institutions (research universities, polytechnics, liberal arts colleges). International alliances (e.g., Erasmus-Socrates, Bologna Declaration) and symbiotic relationships (industry, government) are also important.
Change is accelerating. The future is becoming less certain.

One possible approach to uncertainty is explore possible futures through experimentation and discovery.

To encourage a higher-risk culture in which occasional failure is tolerated

To encourage grass-root engagement of faculty and students (to ban the word “No” from the vocabulary of administrators and bureaucrats)
An Example: the University of Michigan

During the 1990s we explored an array of new paradigms

- A *privately-supported, public university* (restructuring financing by increasing tuition, federal R&D support, private gifts, endowments, reserves, and moving to more efficient management styles)
- A *diverse university* with respect to race, gender, nationality, socioeconomic background, etc.
- A *world university* with programs in Asia, Europe, Latin America, and Africa
- A *cyberspace university*, with leadership through the Internet (and now Internet2)
“Knowledge Management” in the Research University
IT and the University

Technologies to operate the university as an enterprise

- Information management and collaboration
- Integration of back end, auditing, etc.
- Governance (board, faculty senate, etc.)
- Employee relations (unions, academic staff, etc.)
- Procurement (products, students, etc.)
- Customer relationship management (counseling, careers, scholarships, alumni)
- Marketing (products, services, students)
The University as a Vendor

- Education-traditional (course materials, lectures, classes, credentials)
- Education-nontraditional (part-time, distant, executive)
- Hotel (room, board, parking, telecom, )
- Student and staff services (counseling, content distribution)
- Products and services (publications, intellectual property, entertainment, )
- Consulting and contract research
IT and Knowledge Management

- Knowledge creation
  - Traditional models (single investigators)
  - Multidisciplinary, multi-institution
- Knowledge college and integration
  - Libraries
  - New forms, sources, collections
- Knowledge dissemination
  - Students and disciples
  - Publications
Indicators of Change in Scholarly Publication

- Public-domain models
- Knowledge conservancies
- Institutional publishing
- Bypass publishing
- For-profit universities
- Open Courseware (MIT)
The “Digital Library” Environments: Dependencies Between

- Content
- Creators & Users
- Economic & IP Principles
- Values in the Academy
Digital Library Environment

Mediating Metadata Authentication Interface

Licensed content

Local digital library

“Free” content
Electronic Journals
2,202 e-titles
>1.5M e-articles

Web interface
Full text retrieval

Science Databases
47M records

Preprints
100k papers

Distributed Collections
DOE, DoD, NASA
Universities consortia

Euro-science agencies

29,200
Technical Reports
2.355 million images
PubMed Central is a web-based archive of journal literature for all of the life sciences. It is being developed by the National Center for Biotechnology Information (NCBI) at the U.S. National Library of Medicine (NLM). With PubMed Central, NCBI is taking the lead in preserving and maintaining open access to the literature in electronic form, just as NLM has done for decades with the printed biomedical literature. We may not have all the answers to this grand challenge, but we invite all journals to join those that have already committed to creating this resource for people all over the world.

PubMed Central aims to fill the role of a world class library in the digital age. It is not, and has no intention of ever becoming, a journal publisher. Access to PubMed Central is free and unrestricted.

Learn more about the benefits of participating in PubMed Central or browse the journals currently in the archive, from the list below.

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- BMC Journals
- BMJ
- Breast Cancer Research
- Critical Care
- Genome Biology
- Health Policy
- Genes & Development
- Genetics
- Gene Therapy
- Genomics
- Genomics and Proteomics
The Electronic Publishing Initiative at Columbia (EPIC) is a groundbreaking new initiative in digital publishing at Columbia University that involves Columbia University Press, the Libraries, and Academic Information Systems. Its mission is to create new kinds of scholarly and educational publications through the use of new media technologies in an integrated research and production environment. Working with the producers of intellectual property at Columbia University and other leading academic institutions, it aims to make these digital publications self-sustaining through subscription sales to institutions and individual users.

EPIC is committed to pursuing the highest standards in the development of content, use of technology, handling of issues of intellectual property and copyright, development of business plans, and evaluation of use. Its publications are designed to be innovative, efficient and cost-effective.
Bypass Publishers

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Authors: John Leitner.
Author's Affiliation: Department of Economics, University of Michigan
Archive: RePEc
Subject: Social_Sciences/Economics
Material Type: preprint
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Fact Sheet  *  Student and Faculty Login  *  Corporate Opportunities  *  Become a Faculty Member

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For-Profit Universities

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This course demonstrates how time-tested, Nobel-Prize winning economic principles are driving successful business models on the
The “Open Source” University
An Alternative: “The Open Source University”

- Linux software movement
- MIT Open Courseware Project (OCW)
- The Open Knowledge Initiative (OKI)
- Michigan CHEF Project
Welcome to the MIT OpenCourseWare Pilot

MIT and the OpenCourseWare team are excited to share with you a first sampling of course materials from MIT's Faculty. We invite educators around the world to draw upon the materials for their own curricula and encourage all learners to use the materials for self-study.

As you explore this pilot version of MIT OCW, we invite you to send us your feedback. Your comments will help to ensure that future editions of MIT OCW will be ever more useful.

A Message from the President

MIT OpenCourseWare reflects the commitment of the MIT faculty to advancing education by increasing access to their academic materials through the Internet and the World Wide Web. We believe that with modern communication technology we can not only transmit information but also stimulate and enhance the deeply human, person-to-person endeavor of education.

We hope the idea of openly sharing course materials will propagate throughout many institutions and create a global web of knowledge that will enhance the quality of learning and, therefore, the quality of life worldwide.

We are opening our pilot to the public for review and feedback. It contains a sample of MIT courses, offering an early look at the content and design of OCW. As we pursue our intensive work to find the most effective way to make OCW a valuable resource for all who use it, we will continue to add courses, until virtually all are available.

We thank our sponsors, the William and Flora Hewlett Foundation and the Andrew W. Mellon Foundation, as well as the faculty who have dedicated so much creative energy and time to this endeavor. We are pleased to have you as a participant in this educational journey.

Charles Vest, President, MIT

OpenCourseWare Timeline

- 2002-2003
  - DISCOVER / BUILD
    - Pilot: Representative courses from all five MIT schools
    - Representative content formats

- 2003-2005
  - PUBLISH / EXPAND
    - Hundreds of courses
    - Complete curriculum tracks
    - Metadata-based search
    - OAI compliance

- 2005-2007
  - ENHANCE
    - Near-full inclusion of ~2,000 MIT courses
    - Enhanced technology
    - Dissemination of best practices in publishing Web-based course content
    - Evaluation of OCW impact
Monday, November 4, 2002

PRESS

OKI Announces Developer Support Program »»

EVENTS

OKI Presentations at Educause 2002 »»

PROJECT UPDATES

Review latest API specs »»

To receive OKI news, please provide your e-mail address:

submit

INTERNAL DOCUMENTS

Access the latest internal project information here »»

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questions & comments to webmaster-oki@mit.edu
OKI – Standards for LMS APIs

- **Authentication Services**
- **Enterprise Information**
  - **Student Information Systems**
  - **Enterprise Data Exchange Specification**
- **OKI “Core” Reference Architecture**
  - **User Interface Specification**
  - **Modular Authentication**
- **Process**
- **Content**
- **Component Specification**
- **Asset Management**
  - **Digital Library Initiatives**
- **Users**
- **Content Outline**
- **Quiz**
- **White Board**
- **List Management**
- **Virtual Lab**
- **Portfolio Management**
CHEF and the Grid – Access to Nationally Distributed Computing Resources
Welcome to DSpace, a newly developed digital repository created to capture, distribute and preserve the intellectual output of MIT.

As a joint project of MIT Libraries and the Hewlett-Packard Company, DSpace provides stable long-term storage needed to house the digital products of MIT faculty and researchers.

- **For the user:** DSpace enables easy remote access and the ability to read and search DSpace items from one location: the World Wide Web.

- **For the contributor:** DSpace offers the advantages of digital distribution and long-term preservation for a variety of formats including text, audio, video, images, datasets and more. Authors can store their digital works in collections that are maintained by MIT communities.

- **For the institution:** DSpace offers the opportunity to provide access to all the research of the institution through one interface. The repository is organized to accommodate the varying policy and workflow issues inherent in a multi-disciplinary environment. Submission workflow and access policies can be customized to adhere closely to each community's needs.
Definition

DSpace is an open source software platform that enables institutions to:

- capture and describe digital works using a submission workflow module
- distribute an institution's digital works over the web through a search and retrieval system
- preserve digital works over the long term

Our knowledge is the amassed thought and experience of innumerable minds.

- Ralph Waldo Emerson

Mission

To create and establish an electronic system that captures, preserves and communicates the intellectual output of MIT's faculty and researchers.

To support adoption by and federation with other institutions.

Vision

A federation of systems makes available the collective intellectual resources of the world's leading research institutions.
An Alternative: “The Open Source University”

- Linux software movement
- MIT Open Courseware Project (OCW)
- The Open Knowledge Initiative (OKI)
- Michigan CHEF Project
An Alternative: “The Open Source University”

- Linux software movement
- MIT Open Courseware Project (OCW)
- The Open Knowledge Initiative (OKI)
- Michigan CHEF Project

An idea: Suppose a small group of the world’s leading comprehensive universities were to place in the public domain (for all to use) the digital resources supporting their entire curriculum (all academic disciplines and professional programs), along with open-source versions of the software tools and platforms necessary to use these resources…
Cyberinfrastructure
e-Science

- science increasingly done through *distributed global collaborations* between people, enabled by the internet
- using very large data collections, terascale computing resources and high performance visualisation
- derived from instruments and facilities controlled and shared via the infrastructure
- Scaling X1000 in processing power, data, bandwidth
Four LHC Experiments: The Petabyte to Exabyte Challenge

ATLAS, CMS, ALICE, LHCB

Higgs + New particles; Quark-Gluon Plasma; CP Violation

Data stored CPU

0.1 to 1

(2007) (~2012 ?)

~40 Petabytes/Year and UP; 0.30 Petaflops and UP

Exabyte (1 EB = \(10^{18}\) Bytes) for the LHC Experiments
Network for Earthquake Engineering Simulation

- Remote Users
- Instrumented Structures and Sites
- Laboratory Equipment
- Field Equipment
- Leading Edge Computation
- Curated Data Repository
- Global Connections
- High-Performance Network(s)
TELESCIENCE: REMOTE ACCESS FOR DATA ACQUISITION, GRID-BASED COMPUTING, DISTRIBUTED DATA STORAGE

Project leaders:
Mark Ellisman, UCSD;
Carl Kesselman, USC;
Fran Berman, UCSD;
Rich Wolski, UCSB;

Project Manager:
Steve Peltier, UCSD

Senior Participants:
Gwen Jacobs, Montana State U.
Reagan Moore, SDSC/UCSD
Maryann Martone, UCSD/NCMIR
Amarnath Gupta, SDSC/UCSD
Bertram Ludaescher, SDSC/UCSD
Chandri J Bajaj, U.Texas
Steve Lamont, UCSD
Shinji Shimojo, Osaka Univ.

DATA ACQUISITION
PROCESSING, ANALYSIS
ADVANCED VISUALIZATION

NETWORK

IMAGING INSTRUMENTS
COMPUTATIONAL RESOURCES
LARGE-SCALE DATABASES

NPAC
NATIONAL PARTNERSHIP FOR ADVANCED COMPUTATIONAL INFRASTRUCTURE
(Cyber) infrastructure

• The term *infrastructure* has been used since the 1920’s to refer collectively to the roads, bridges, rail lines, and similar public works that are required for an industrial economy to function.

• The recent term *cyberinfrastructure* refers to an infrastructure based upon computer, information and communication technology (increasingly) required for discovery, dissemination, and preservation of knowledge.

• Traditional infrastructure is required for an industrial economy. Cyberinfrastructure is required for an information economy.
Cyberinfrastructure: the Middle Layer

<table>
<thead>
<tr>
<th>Applications in science and engineering research and education</th>
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<tbody>
<tr>
<td>Cyberinfrastructure: hardware, software, personnel, services, institutions</td>
</tr>
<tr>
<td>Base-technology: computation, storage, communication</td>
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Components of CI-enabled science & engineering

A broad, systemic, strategic conceptualization

- **Collaboration Services**
  - Knowledge management institutions for collection building and curation of data, information, literature, digital objects
  - High-performance computing for modeling, simulation, data processing/mining

- **Physical World**
  - Instruments for observation and characterization
  - Facilities for activation, manipulation and construction

- **Individual & Group Interfaces & Visualization**

- **Humans**
The number of nation-scale projects is growing rapidly!
More Diversity, New Devices, New Applications

- Personalized Medicine
- Sensors
- Wireless networks
- Knowledge from Data
- Instruments
Cyberinfrastructure is a First-Class Tool for Science
Futures: The Computing Continuum

Building Out

Building Up

Science, Policy and Education
Two leading U.S. initiatives

• Next Generation Abilene
  – Advanced Internet **backbone**
    • connects entire campus networks of the research universities
  – 10 Gbps nationally
• TeraGrid
  – **Virtual machine room** for distributed computing (Grid)
  – Connecting 4 HPC centers initially
    • Illinois: NCSA, Argonne
    • California: SDSC, Caltech
  – 4x10 Gbps: Chicago ↔ Los Angeles
• Ongoing collaboration between both projects
About Internet2®

Internet2 is a consortium being led by over 200 universities working in partnership with industry and government to develop and deploy advanced network applications and technologies, accelerating the creation of tomorrow's Internet. Internet2 is recreating the partnership among academia, industry and government that fostered today’s Internet in its infancy. The primary goals of Internet2 are to:

- Create a leading edge network capability for the national research community
- Enable revolutionary Internet applications
- Ensure the rapid transfer of new network services and applications to the broader Internet community.

Through Internet2 Working Groups and initiatives, Internet2 members are collaborating on:

- Advanced Applications
- Middleware
- New Networking Capabilities
- Advanced Network Infrastructure
- Partnerships and alliances
- Initiatives
TeraGrid Architecture – 13.6 TF

**Caltech**
- 32 Nodes
- 0.5 TF
- 0.4 TB Memory
- 86 TB disk

**Argonne**
- 64 Nodes
- 1 TF
- 0.25 TB Memory
- 25 TB disk

**SDSC**
- 256 Nodes
- 4.1 TF
- 2 TB Memory
- 225 TB disk

**NCSA**
- 500 Nodes
- 8 TF
- 4 TB Memory
- 240 TB disk

**Caltech**
- 32 quad-processor McKinley Servers
  - (128p @ 4GF, 8GB memory/server)
- 0.4 TB Memory
- 86 TB disk

**Argonne**
- 32 quad-processor McKinley Servers
  - (128p @ 4GF, 12GB memory/server)
- 0.25 TB Memory
- 25 TB disk

**SDSC**
- 16 quad-processor McKinley Servers
  - (64p @ 4GF, 8GB memory/server)
- 2 TB Memory
- 225 TB disk

**NCSA**
- 240 TB disk

**Caltech**
- 86 TB disk

**Argonne**
- 25 TB disk

**SDSC**
- 225 TB disk

**NCSA**
- 240 TB disk

**HPSS**
- 256p HP X-Class
- 128p HP V2500
- 92p IA-32

**Calren**
- NTON
- OC-12 ATM

**vBNS**
- Abilene
- Calren
- ESnet

**HPSS**
- 1176p IBM SP
- Blue Horizon

**Sun**
- E10K

**Myrinet Clos Spine**
- = 32x FibreChannel
- = 32x Myrinet
- = 64x Myrinet

**10 GbE**
- = 8x FibreChannel

**IA-32 nodes**
- 574p IA-32
- Chiba City
- 128p Origin
- HR Display & VR Facilities
- HPSS

**ESnet**
- HSCC
- MREN/Abilene
- Starlight

**HPSS**
- 256p HP
- X-Class
- 128p HP
- V2500
- 92p IA-32

**Calren**
- 320p IA-64

**vBNS**
- Abilene
- ESnet
- MREN

**Calren**
- Blue Horizon

**Sun**
- Starcat

**1024p IA-32**
- 320p IA-64

**1500p Origin**
- 2

**vBNS**
- Abilene
- MREN

**Juniper M40**
- OC-12

**Juniper M160**
- OC-48

**OC-12 ATM**
- = 32x 1GbE

**OC-12**
- = 32x Myrinet

**OC-12**
- = 3x FibreChannel

**Myrinet Clos Spine**
- = 32x FibreChannel

**Router or Switch/Router**
- Fibre Channel Switch

**IA-32 nodes**
- 5

**OC-12**
- = 3x FibreChannel

**OC-12**
- = 3x FibreChannel

**OC-3**
- = 3x FibreChannel

**OC-48**
- = 8x FibreChannel

**OC-48**
- = 8x FibreChannel

**OC-12**
- = 8x FibreChannel

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WWW and “infocern”, the 1st web address ~1990
html (xml) open standards

• A great achievement and a fantastic idea, at the right time, making the internet available to everybody

• It proves something about the benefits of assembling together urgent needs, infrastructure and smart people, and letting them interact..

• And why it is exciting to work at CERN, and in computing

• And why we should not always listen to wise people who tell us that industry will always do better than we will….

Tim Berners-Lee
“A small group of thoughtful people could change the world. Indeed, it's the only thing that ever has.”

Margaret Mead
Some Remaining Questions
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Some Remaining Questions

1. How do we respond to the diverse educational and intellectual needs of knowledge-driven societies? (For example, as human capital becomes more important than physical or financial capital.)
2. Is higher education a public or a private good?
3. How do we balance the roles of public purpose versus market forces in determining the future of our universities? (Can public investment counter competitive and commercial market pressures?)
4. What should be the role of the research university within a changing higher education enterprise? Should we lead change? Or should we protect key values and traditions (e.g., academic freedom, social critic)?
And, perhaps the most important question of all…

Are we facing a period of evolution, revolution, or possible extinction of the university as we know it today?
One of civilization’s most enduring institutions

For a thousand years the university has benefited our civilization as a learning community where both the young and experienced could acquire not only knowledge and skills, but as well the values and discipline of the educated mind.

It has defended and propagated our cultural and intellectual heritage, while challenging our norms and beliefs.

It has produced the leaders of our governments, commerce, and professions.

It has both created and applied new knowledge to serve our society.

And it has done so while preserving those values and principles so essential to academic learning: the freedom of inquiry, an openness to new ideas, a commitment to rigorous study, and a love of learning.
The Continuity of Change

Clearly higher education will flourish in the decades ahead. In a knowledge intensive society, the need for advanced education and knowledge will become ever more pressing, both for individuals and societies more broadly.

Yet it is also likely that the university as we know it today–rather the current constellation of diverse institutions comprising the higher education enterprise–will change in profound ways to serve a changing world.
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Just as it has done, so many times in the past.