Research Management in and Era of Hyperchange

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Industry-University Collaborative Research

- Organizing R&D in an Era of Hyperchange: A Balance Between the Priests and the Shamans
- Disruptive Technologies or Disruptive Methodologies: Multidisciplinary Research Will Maximize Impact
- Working with Universities: A Source of Disruptive Innovation or a Course of Last Resort?
- Case Studies: The GSRC and CITRIS
- Implementing an Effective R&D Relationship with Universities

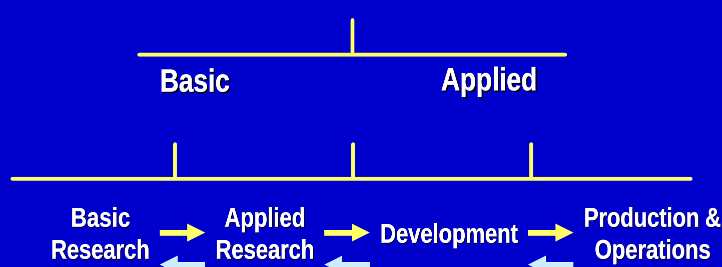
"Science, the Endless Frontier"

Vannevar Bush

(Washington: National Science Foundation, 1944, Reprinted 1990)

- His view of basic science and its relation to technological innovation became a foundation of the US science policy for the post-war decades
- Sought to:
  - Extend the Government's support of basic science into peacetime
  - While drastically reducing the Government's control of the performance of the research
- "Basic research is performed without the thought of practical ends" (the static aspect)
  - The creativity of basic science will be lost if it is constrained by premature thought of practical use
- "Basic research is the pacemaker of technological progress" (the dynamic aspect)
  - Basic research, if undertaken at arms length, will prove to be a powerful dynamo of technological progress

"Science, the Endless Frontier"



"From these definitions it is clear that each successive Stage depends on the previous one"... V. Bush

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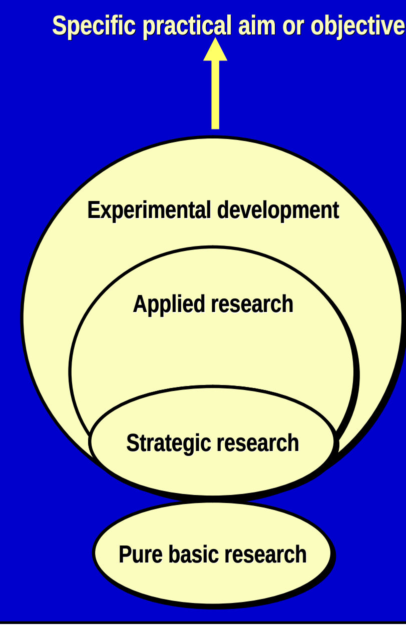
OECD's Frascati Manual: 1963, 1980



Pasteur's Quadrant

Donald E. Stokes

Quest for fundamental understanding?	Considerations of Use? No	Considerations of Use? Yes
Yes	Pure basic research (Bohr)	Use-inspired Basic research (Pascal)
No	Modern music (Metallica)	Pure applied research (Edison)

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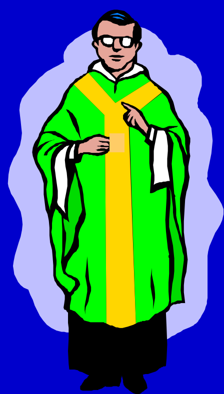
The Priests versus the Shamans



- In this context, the priests represent the practitioners of a conventional (relatively static), bureaucratic, top-down organizational structure
  - Aspire to leadership and control
  - Failure is negative and should be avoided
  - Responsibility beholden should be widely distributed
  - A masculine energy

The Priests versus the Shamans

- The shamans represent the practitioners of pure individualistic entrepreneurism—beholden to no-one except themselves
  - Avoid explicit leadership roles
  - Failure is a positive, learning experience
  - Responsibility for risk rests with individuals themselves
  - A feminine energy
- Conjecture: One group cannot survive and thrive without the other!

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Aerial view of Bell Labs, Murray Hill, New Jersey:
A recent bastion of priesthood and shadow of its former self…

The Xerox Palo Alto Research Center (PARC):
The Shamans left—the end of a critical institution!

Organizing for High-Impact R&D

The Priests versus the Shamans

"Although in many primitive cultures there is a recognized division of function between priests and shamans, in the more highly developed cultures in which cults have become strongly organized churches, the priesthood fights an unrelenting war against shamans.... Priests work in a rigorously structured hierarchy fixed in a firm set of traditions. Their power comes from and is vested in the organization itself. They constitute a religious bureaucracy.

Shamans, on the other hand, are arrant individualists. Each is on his own, undisciplined by bureaucratic control; hence a shaman is always a threat to the order of the organized church. In the view of the priests, they are presumptive pretenders. Joan of Arc was a shaman for she communed directly with the angels of God. She steadfastly refused to recant and admit delusion and her martyrdom was ordained by the functionaries of the Church. The struggle between shaman and priest may well be a death struggle."

E. A. Hoebel

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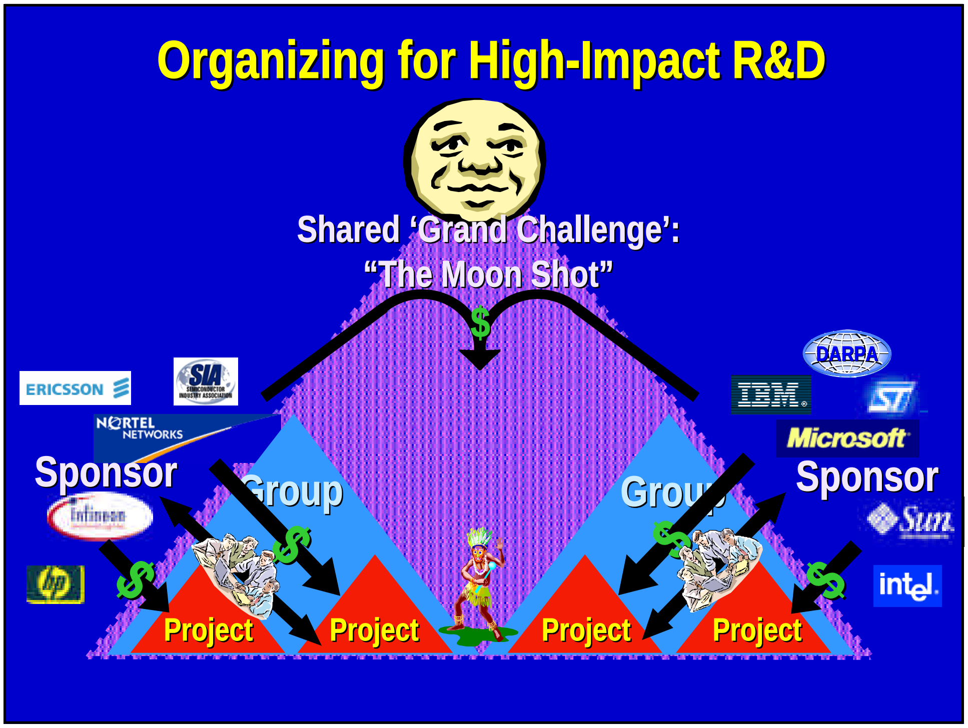

Organizing for Success in R&D: The Priests versus the Shamans

Priests
- Traditional hierarchical approach: CTO, lab managers, lab directors, MTS, ...
- Budget flows along organizational lines
- New projects reviewed at more than one level
- Difficult to start large-scale, multi-disciplinary projects

Shamans
- Research projects initiated and driven by individuals or small groups
- Usually a random collection of sub-critical-mass projects
- Difficult to predict likelihood of success—usually a "back the winner" scenario
- Usually no overall shared vision of the future

The "Moon Shot" Approach
- Use an overarching, long-range goal to organize and loosely direct the research: A 'Grand Challenge'
- Usually application-driven
- Organize the effort as a loose confederation of tightly-knit sub-projects
- Even if you don't reach the moon, lots of good stuff will be produced

Industry-University Collaborative Research

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Disruptive Technologies

Or why good management can lead to failure!

"The Innovator's Dilemma," Clayton Christensen

Sustaining versus Disruptive technologies

- Sustaining technologies: Most new technologies foster improved product performance
  - Some sustaining technologies can be discontinuous or radical in nature
- Disruptive technologies: usually result in worse product performance in the short term
  - Are usually responsible for precipitation a leading firm's failure

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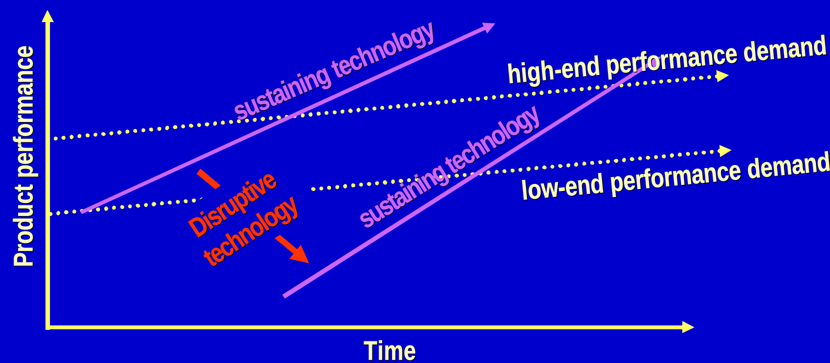
Disruptive Technologies

- Trajectories of market need versus technology improvement
  - Technologies can progress faster than market demand
  - Incumbents often give customers more than they need or are willing to pay for

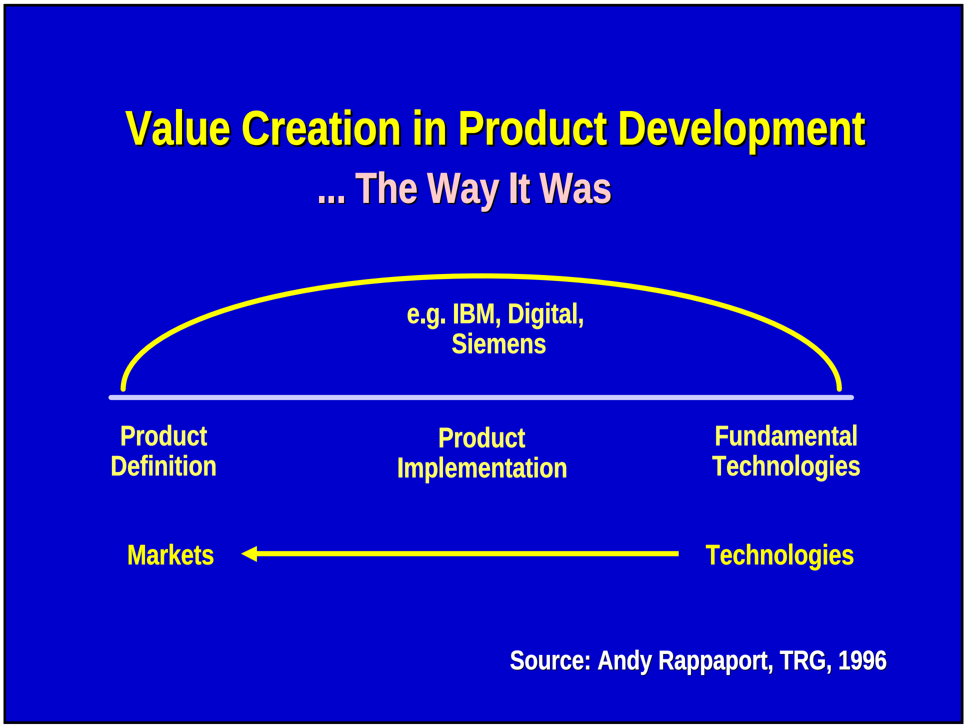


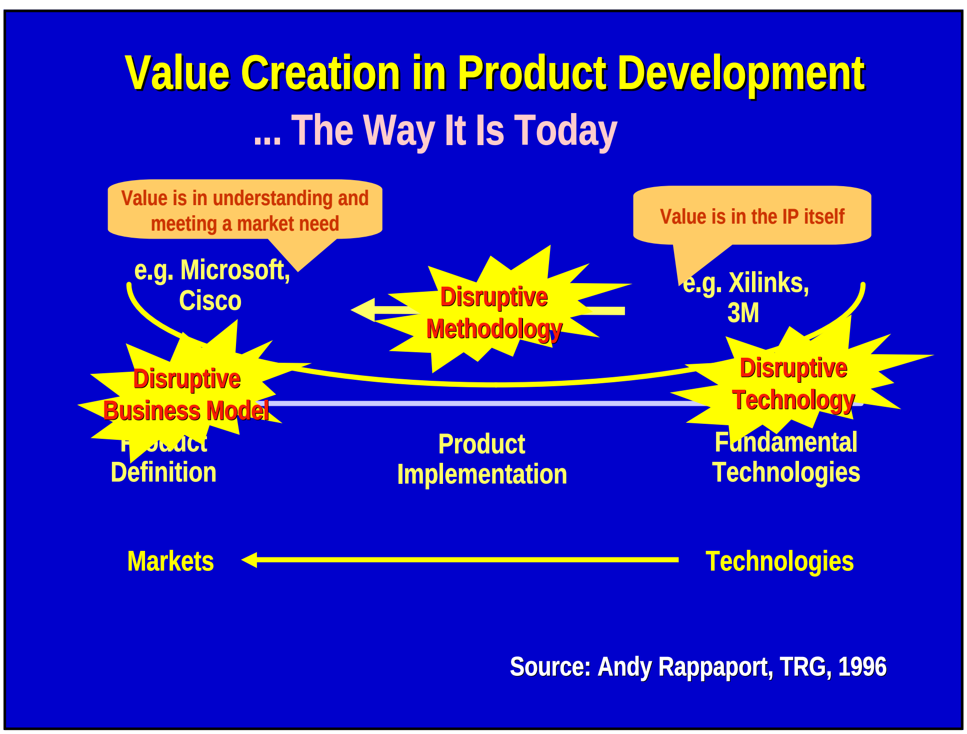
Source: Professor Clayton Christiensen

Disruptive Technologies

- Disruptive technologies versus rational investments
  - “Investing aggressively in disruptive technologies is not a rational financial decision”
  - Disruptive technologies are usually simpler and cheaper: implies lower margins, not greater profits
  - Usually first commercialized in emerging or insignificant markets
  - Leading firm’s most profitable customers generally don’t want, and initially can’t use, products based on disruptive technologies

Source: Professor Clayton Christiensen





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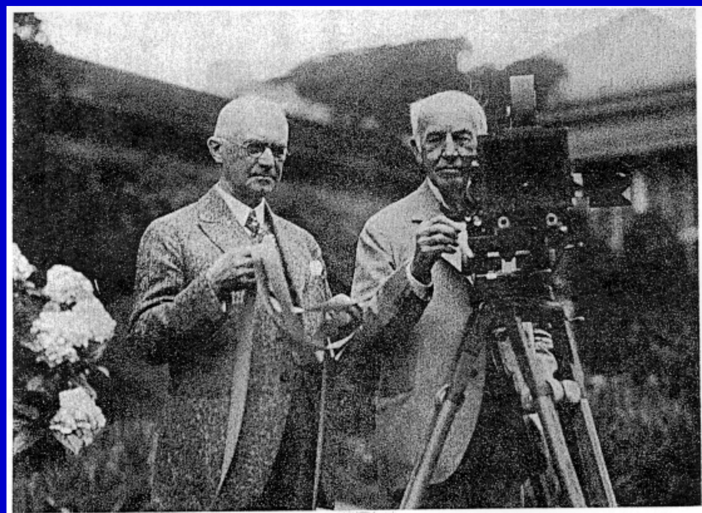
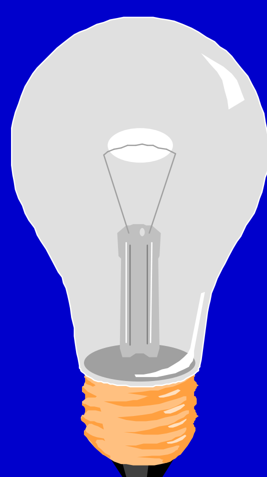


Thomas Edison (right) had George Eastman (left) to thank for developing the film that made motion pictures possible.

Source: Professor Jerry Engel

Who Invented the Light Bulb



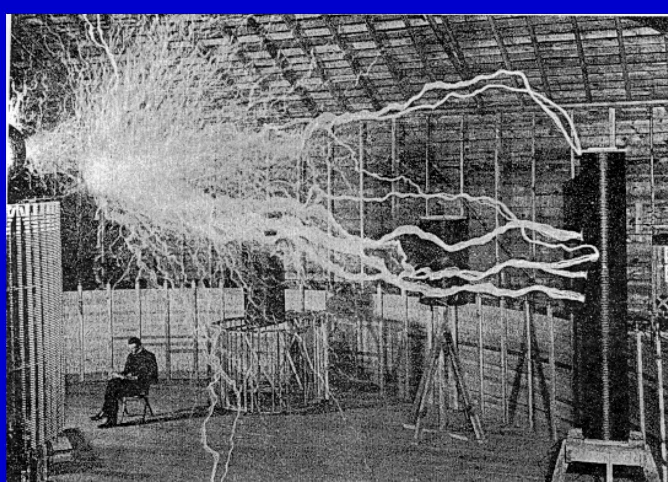
?

Source: Professor Jerry Engel

The Light Bulb Hall of Fame

Date	Inventor	Nationality	Filament	Atmosphere
1802	Davy	English	platinum	air
1840	Grove	English	platinum	air
1841	De Moleyns	English	platinum	vacuum
1845	Starr	American	platinum carbon	air vacuum
1846	Greener	English	carbon	air
1848	Staite	English	platinum	air
1850	Shepard	American	carbon	vacuum
1852	Roberts	English	carbon	vacuum
1856	de Changy	French	platinum	air
1859	Farmer	American	platinum	air
1860	Swan	English	carbon	vacuum
1872	Lodyguine	Russian	carbon	nitrogen
1875	Woodward	Canadian	carbon	N/A
	Kosloff	Russian	carbon	nitrogen
	Konn	Russian	carbon	vacuum
1876	Fontaine	French	carbon	vacuum
1877	Maxim	American	platinum	air
1978	Sawyer	American	carbon	nitrogen
	Maxim	American	carbon	hydrocarbon
	Lane-Fox	English	platinum-iridium	air-nitrogen
	Farmer	American	carbon	nitrogen
1879	Jenkins	American	platinum	air
	Hall	American	platinum	air
	Edison	American	carbon	vacuum

Source: Professor Jerry Engel



Nicola Tesla. The unconventional genius seen sitting among "lighting bolts" of electricity in his lab. Tesla was invaluable in helping Westinghouse defeat Edison's bid to control the electrification of New York City.

Source: Professor Jerry Engel

Edison: Key Entrepreneurial Learning Points

- Good:
  - Incremental Enhancement: Not the "inventor"
  - Marketability of the solution (voting machine learning)
  - Developed a system, not a product (i.e., pet rock syndrome)
  - Understood how to attract investors (created comparable euphoria to biotech a century later)
- Bad:
  - Blind to opportunity of alternative solutions ("Not Invented Here" Syndrome)
- Lasting Impact:
  - Helped clarify the role of the laboratory vs. business

Source: Professor Jerry Engel

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Leading U.S. Engineering Programs

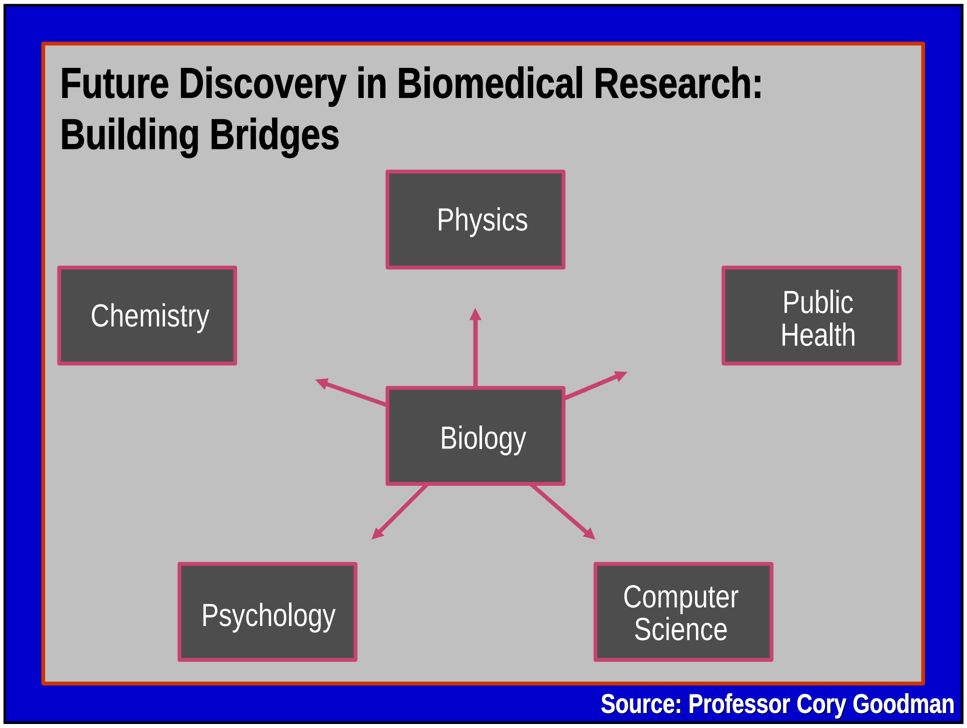
Chemical	# Fac.	Civil	# Fac.	Electrical	# Fac.	Comp. Sci.	# Fac.
1. Minnesota	37	1. MIT	59	1. Stanford	59	1. Stanford	30
2. MIT	34	2. Berkeley	42	2. MIT	70	2. MIT	39
3. Berkeley	24	3. Stanford	28	3. Berkeley	45	3. Berkeley	31
4. Wisconsin	25	4. Texas	58	4. Illinois	87	4. C.- Mellon	38
5. Illinois	17	5. Illinois	54	5. CIT	32	5. Cornell	29

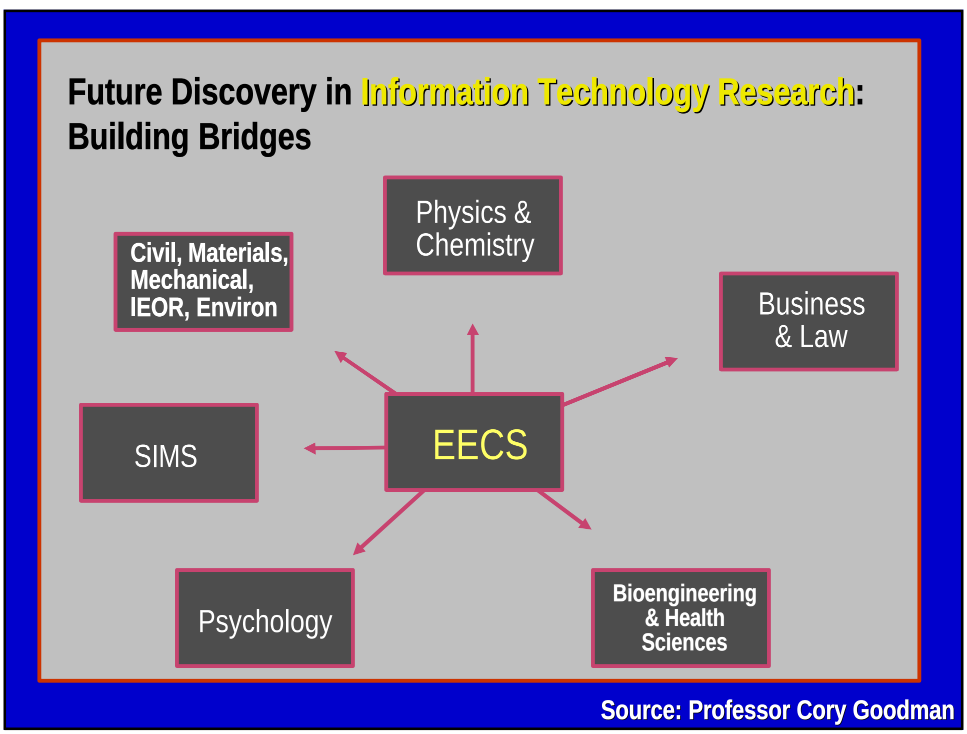
Industrial	# Fac.	Materials	# Fac.	Mechanical	# Fac.	Bioengineering	# Fac.
1. Georgia I.T.	61	1. MIT	35	1. Stanford	42	1. MIT	68
2. Berkeley	10	2. Northwestern	26	2. MIT	94	2. UC-San Diego	18
3. Purdue	30	3. Cornell	15	3. Berkeley	41	3. U-Washington	34
4. Michigan	28	4. Berkeley	20	4. CIT	15	4. Duke	28
5. Texas A&M	30	5. Illinois	43	5. Michigan	90	5. U-Pennsylvania	54
						6. Johns Hopkins	20
						7. UC-San Francisco	42
						8. Berkeley	27

35 of the 36 units on the Campus are ranked in the top 10 in the nation!

The Berkeley Bioengineering and Health Sciences Initiative

- Facility houses Bioengineering Department, faculty and students from Structural Biology, Chemistry, Physics
- Site location ideal for cross-disciplinary collaboration
- Emphasis on flexibility and multiple-use laboratories





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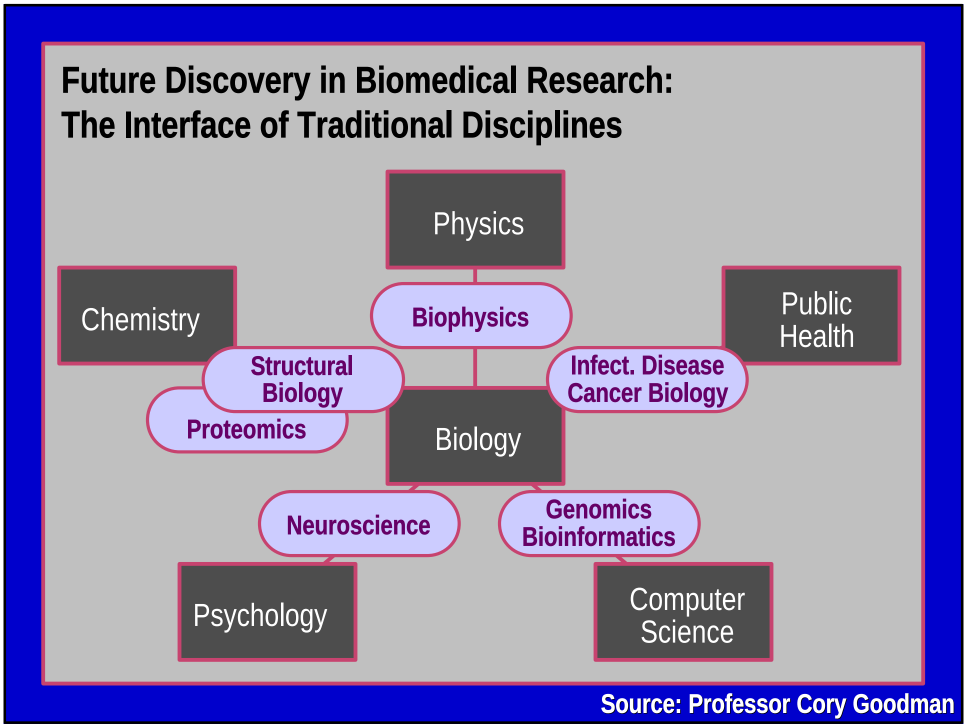
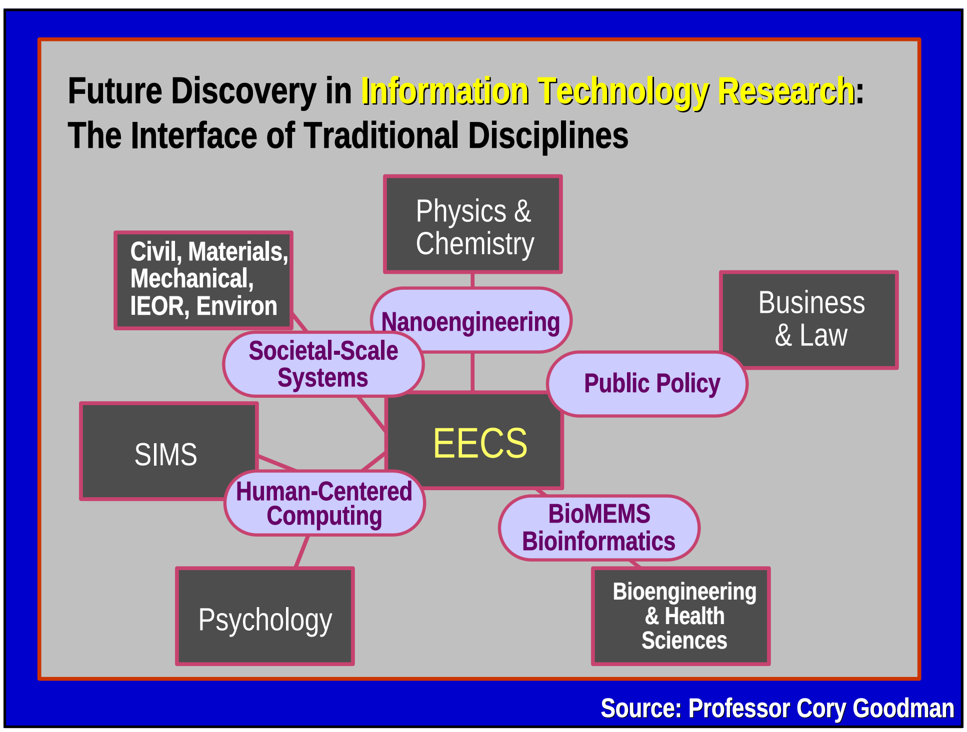
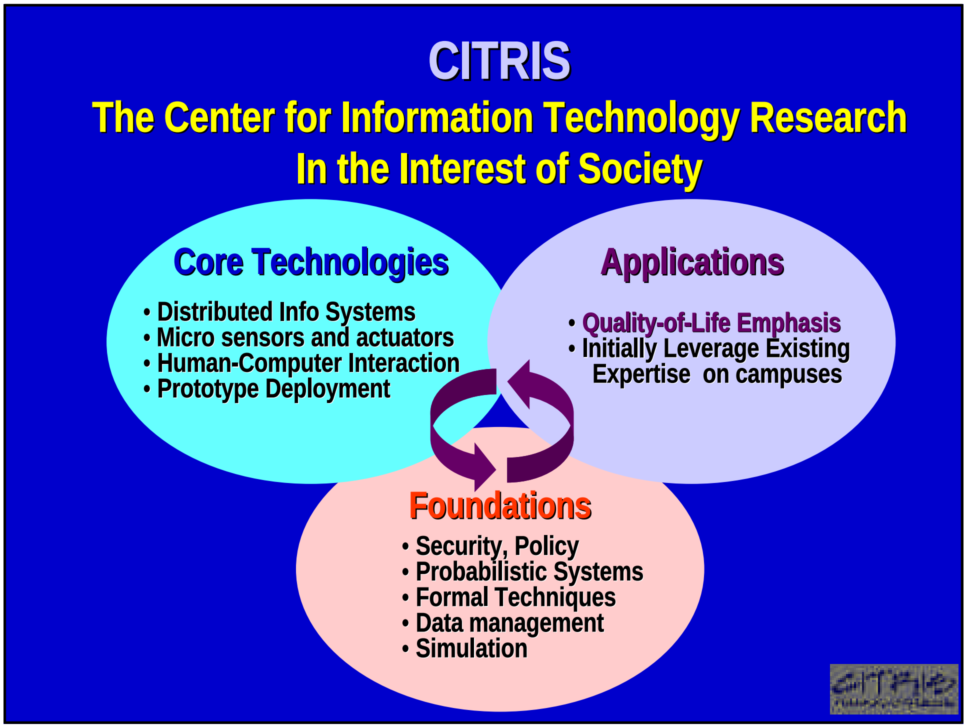

Future Discovery in Biomedical Research:
The Interface of Traditional Disciplines
Physics
Chemistry
Biophysics
Public Health
Structural Biology
Infect. Disease Cancer Biology
Proteomics
Biology
Neuroscience
Genomics Bioinformatics
Psychology
Computer Science
Source: Professor Cory Goodman


Future Discovery in Information Technology Research:
The Interface of Traditional Disciplines
Physics & Chemistry
Civil, Materials, Mechanical, IEOR, Environ
Nanoengineering
Business & Law
Societal-Scale Systems
Public Policy
SIMS
EECS
Human-Centered Computing
BioMEMS Bioinformatics
Psychology
Bioengineering & Health Sciences
Source: Professor Cory Goodman

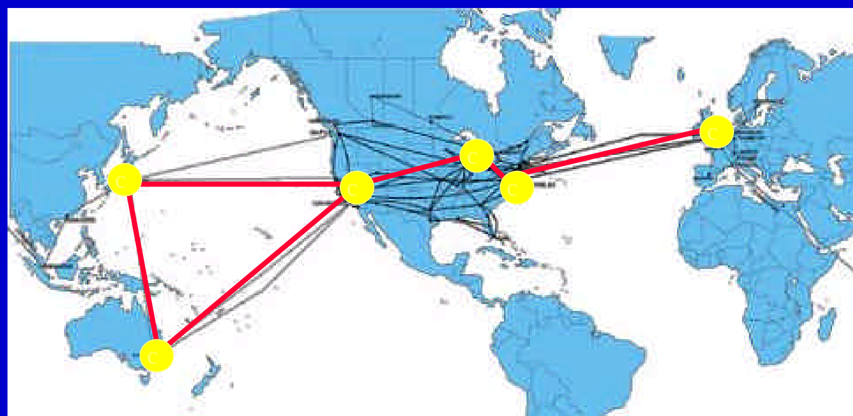

CITRIS
The Center for Information Technology Research
In the Interest of Society
Core Technologies
• Distributed Info Systems
• Micro sensors and actuators
• Human-Computer Interaction
• Prototype Deployment
Applications
• Quality-of-Life Emphasis
• Initially Leverage Existing Expertise on campuses
Foundations
• Security, Policy
• Probabilistic Systems
• Formal Techniques
• Data management
• Simulation


The Best Technology
for The World's Biggest Challenges
◆ Energy Efficiency
◆ Transportation Planning
◆ Monitoring Health Care


The Best Technology
for The World's Biggest Challenges
◆Education
◆Emergency Response
◆Land and Environment


eMerging Societal-Scale Systems
New System Architectures
New Enabled Applications
Diverse, Connected, Physical,
Virtual, Fluid
"Server"
"Client"
Scalable, Reliable,
Secure Services
Information
Appliances
MEMS
BioMonitoring
Source: Professor Randy Katz

Toward Smarter Networks

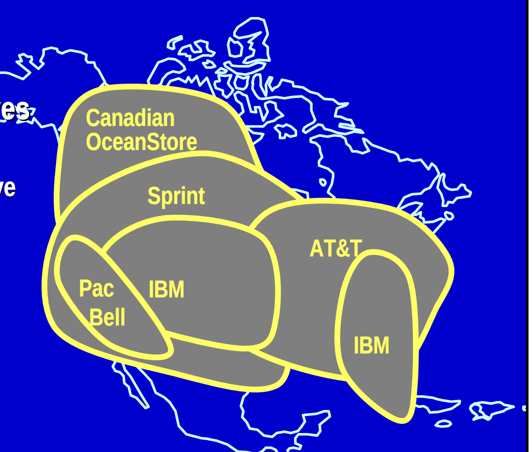


- Automatic replication
- Document routing, determination of nearby caches
- Deployed as secure, reliable services
- Data transformation

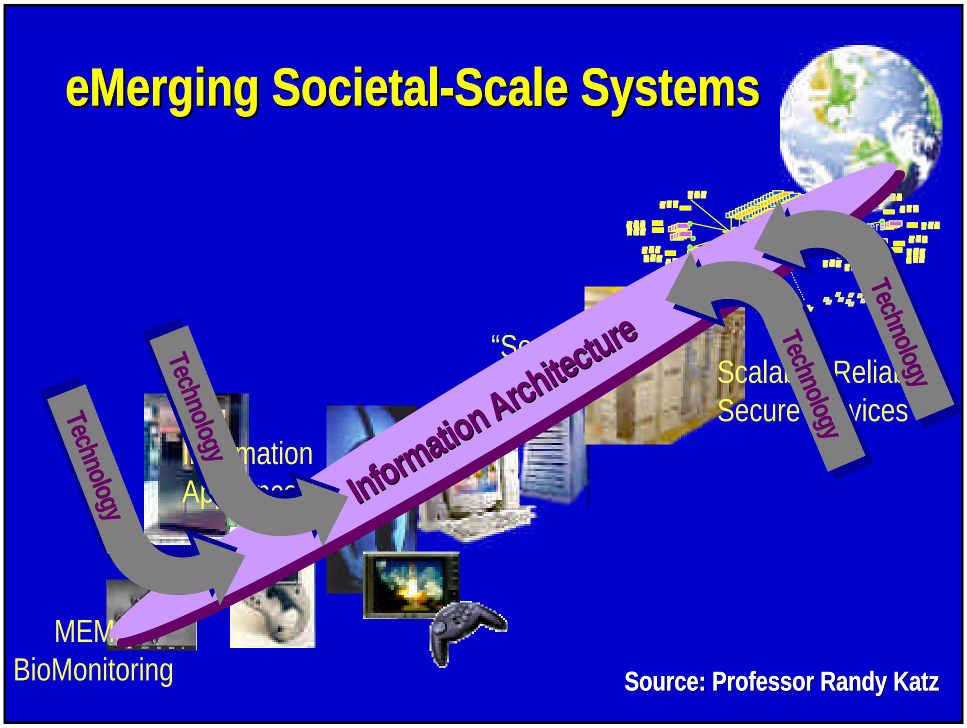
Source: Professor Eric Brewer

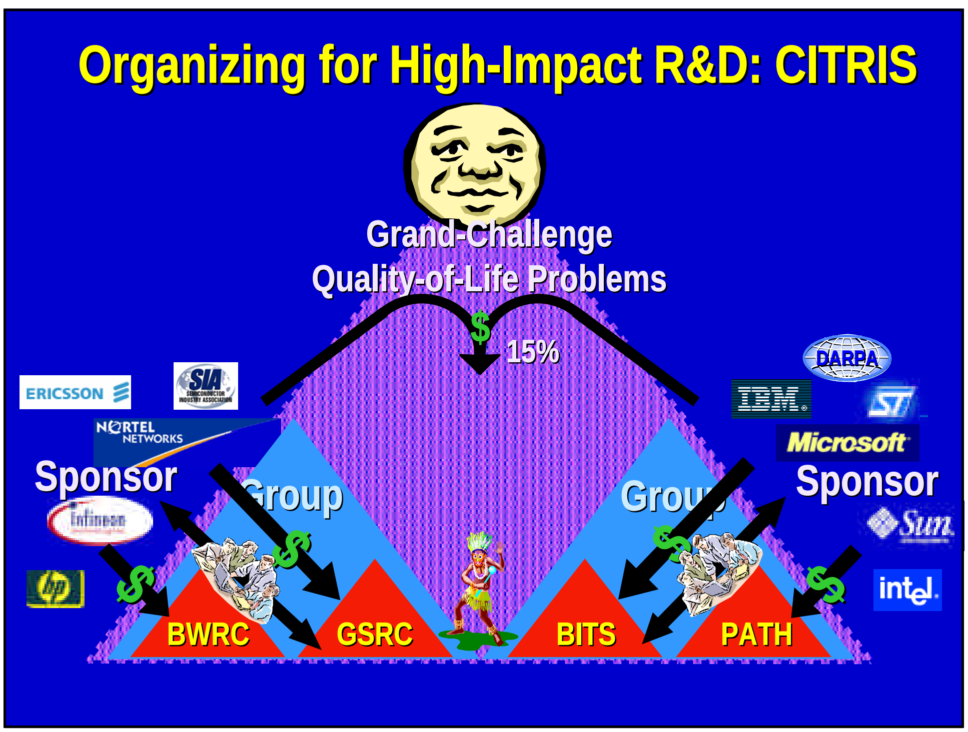
Implementation & Deployment of an Oceanic Data Information Utility

- Ubiquitous devices require ubiquitous storage
- 10,000 9Gbyte IBM Microdrives in a single rack provides 90terabytes/m^2 (Professors Dave Patterson & Kathy Yellick)
- Confederations of (Mutually Suspicious) Utilities



Source: Professor John Kubiatowicz





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Berkeley Endeavour Project
A CITRIS Prototype

Context-Aware Group Scheduling
and Group Activity Management Applications

Smart Spaces
Learning Environments

Data Charging/Decoupled Access

Telegraph: Cluster-based Storage Manager, Scalable Query Processing, Federated Service Providers, Internet-scale Service Discovery

ICEBERG: Wide-Area Service Creation/Mgmt for Computer-Telephony Integration

OceanStore: Distributed Storage Manager, Untrusted Service Providers, Service Discovery, Introspection

Ninja: Java-Based Scalable, Fault Tolerate, Available Service Execution Environment

Tiny OS Ad Hoc Wireless Networking "Dust Motes"

Millennium: "Cluster of Clusters" Scalable Processing Environment

CITRIS is a Partnership with Industry

"I believe we are now entering the Renaissance phase of the Information Age, where creativity and ideas are the new currency, and invention is a primary virtue, where technology truly has the power to transform lives, not just businesses, where technology can help us solve fundamental problems."

Carly Fiorina, CEO, Hewlett Packard Corporation

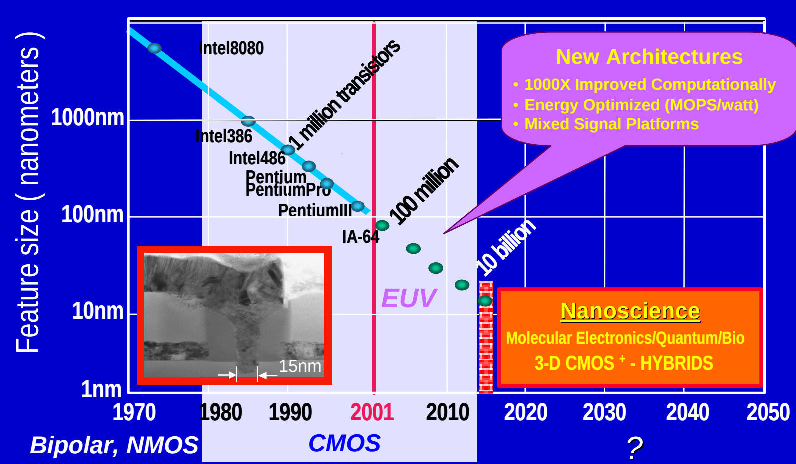
Founding Corporate Members of CITRIS

Berkeley Engineering: A Tradition of Impact in Research

- Berkeley Unix
- Relational Database Technology
- Electronic Design Automation: SPICE to Synopsys
- RISC (with Stanford)
- RAID
- CyberCut online manufacturing systems
- NOW (Networks of Workstations)
- IEEE Floating Point
- Infopad (now called WebPad)
- Semiconductor Devices & Modeling
- MEMS

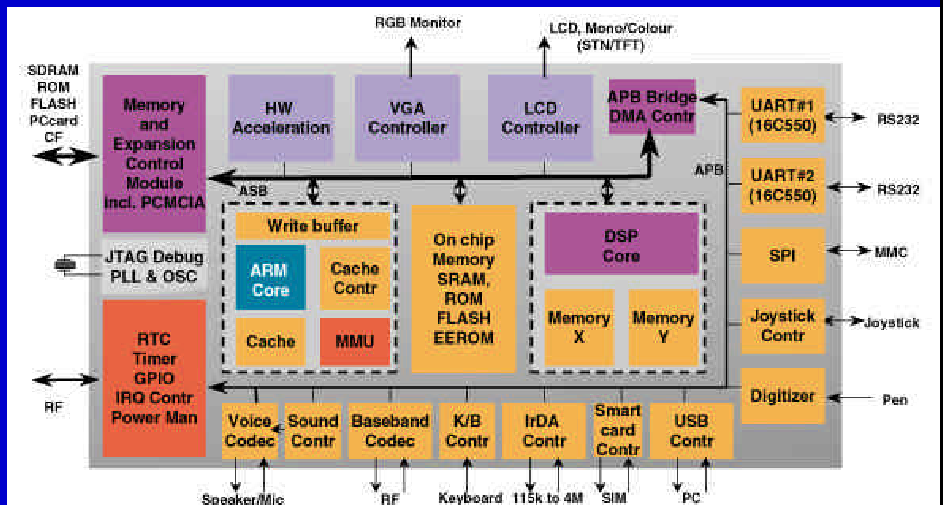
- Berkeley faculty are fundamentally motivated by high-potential-impact, long-range research

The Future of Moore's Law



Source: Professor Shankar Sastry

Complex SOC architecture



Source: Synopsys

Overarching GSRC Research Theme for 2001:

"From Ad-Hoc System-on-a-Chip Design to Disciplined, Platform-Based Design"

"It's a Moonshot, Not Rocket Science"

Overall Program Goals

- > 1 Billion transistor chip
- In a technology ~~< 0.1~~ micron 50nm
- Using IP from several sources (mixed-signal)
- Running at ~~>2~~ GHz on-chip 10GHz
- With a team of < 30 designers
- In < 6 months
- With competitive cost and power-delay-area product

Proposed GSRC 10-Year Goal, November 1997

http://www.gigascale.org

- **Example: August 2000**
  - **41,540 accesses**
  - **167,434 hits**
  - **Average visit 7 pages**
  - **Served 755 Mbytes**
  - **Broad range of users:**
    - 37% from *com*
    - 28% from *edu*
    - 2% from *mil, gov*
    - 21% overseas: 39 countries
      - France, Canada, Finland, Netherlands, Germany, Hong Kong, Japan heaviest visitors

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"Not Just Research As Usual"

- The GSRC is a unique experiment in long-range, collaborative research, enabling broad collaboration across many areas of EDA and Design
- In the 1960-1980's DARPA played a key role in creating and maintaining a collaborative community in design and architecture
  - Xerox PARC & the Alto, Berkeley Unix, RISC, RAID, Integrated EDA Systems…
- GSRC is about rebuilding and maintaining such a community of researchers in many fields related to silicon design productivity
  - By leveraging modern, distributed collaborative infrastructure
  - By enabling and supporting a series of research themes
  - By developing and maintaining a well-defined, but broad goal—the Moon Shot—that serves to integrate all participants

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How to Leverage University Research

- Place a small number of large bets and a larger number of smaller ones
  - In today's IT world, the long-term impact of many research projects are strongly influenced by an expensive commercial context
  - Identify the key schools, the key faculty in specific areas, and make them successful
- Employ an intellectual property policy that maximizes the impact of the research and maximizes your access to results
  - In information technology, that usually demands a very open ("public domain") approach!
  - In other areas of research, e.g. biological sciences, a more restrictive approach might be better—no one-size-fits-all!
- Couple the research closely to your own business units
  - "One-week-per-month" visitor approach
  - Build a small research laboratory adjacent to the University
  - Invest in a local, independent technology incubator to obtain an "unfair advantage."

Implementing a Local Research Laboratory

- There are many possible models—some Berkeley-located examples include:
  - Cadence Berkeley Laboratories
  - The Siemens Technology-to-Business Center
  - ST Microelectronics Berkeley Laboratory
  - Kawasaki Steel Corporation
  - Ericcson Berkeley Laboratories
  - Hughes Research Labs
  - AT&T
  - Intel Berkeley Labs
  - ...

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