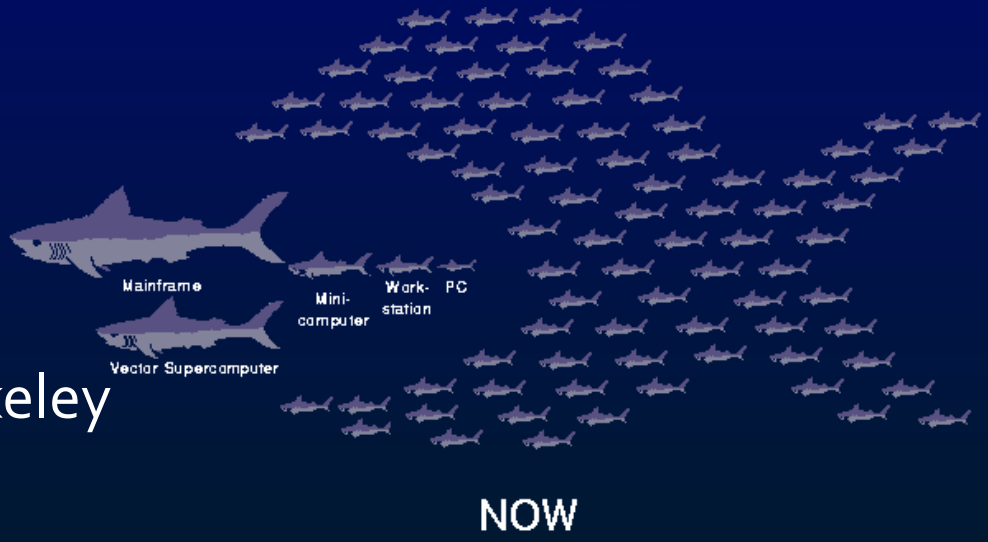
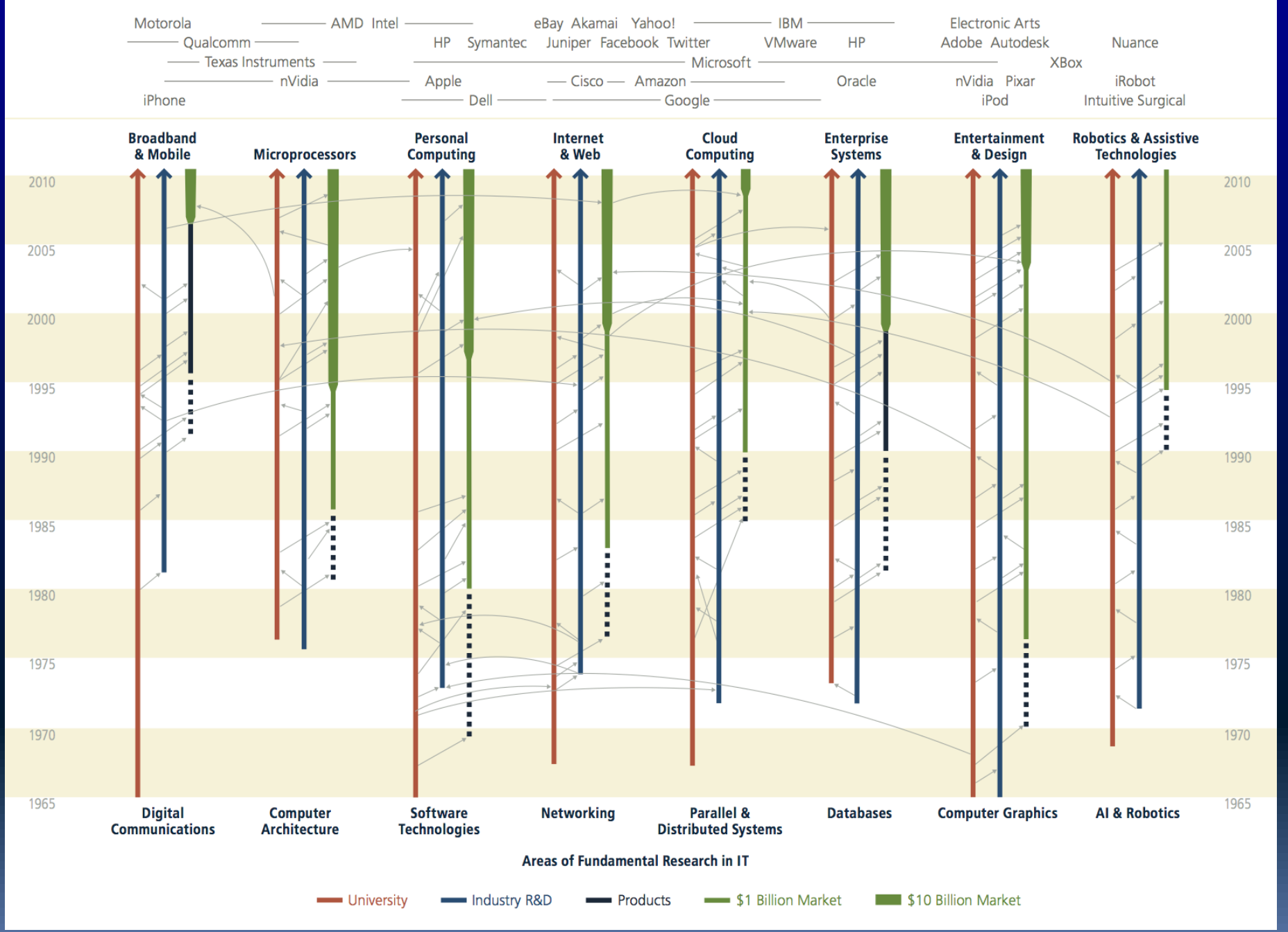
Tiretracks nouveau
- the network systems slice

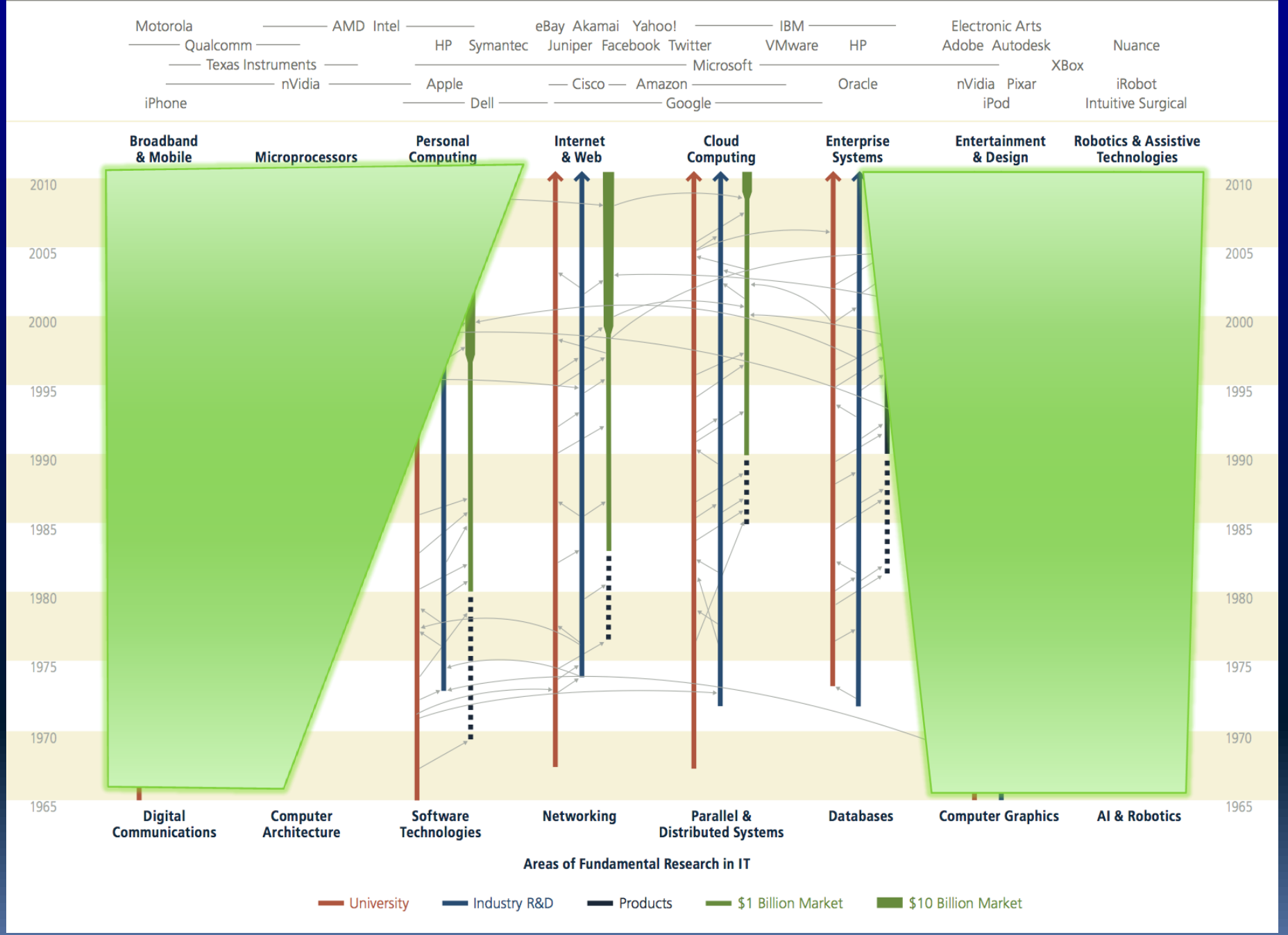
David E. Culler
University of California, Berkeley
July 23, 2012



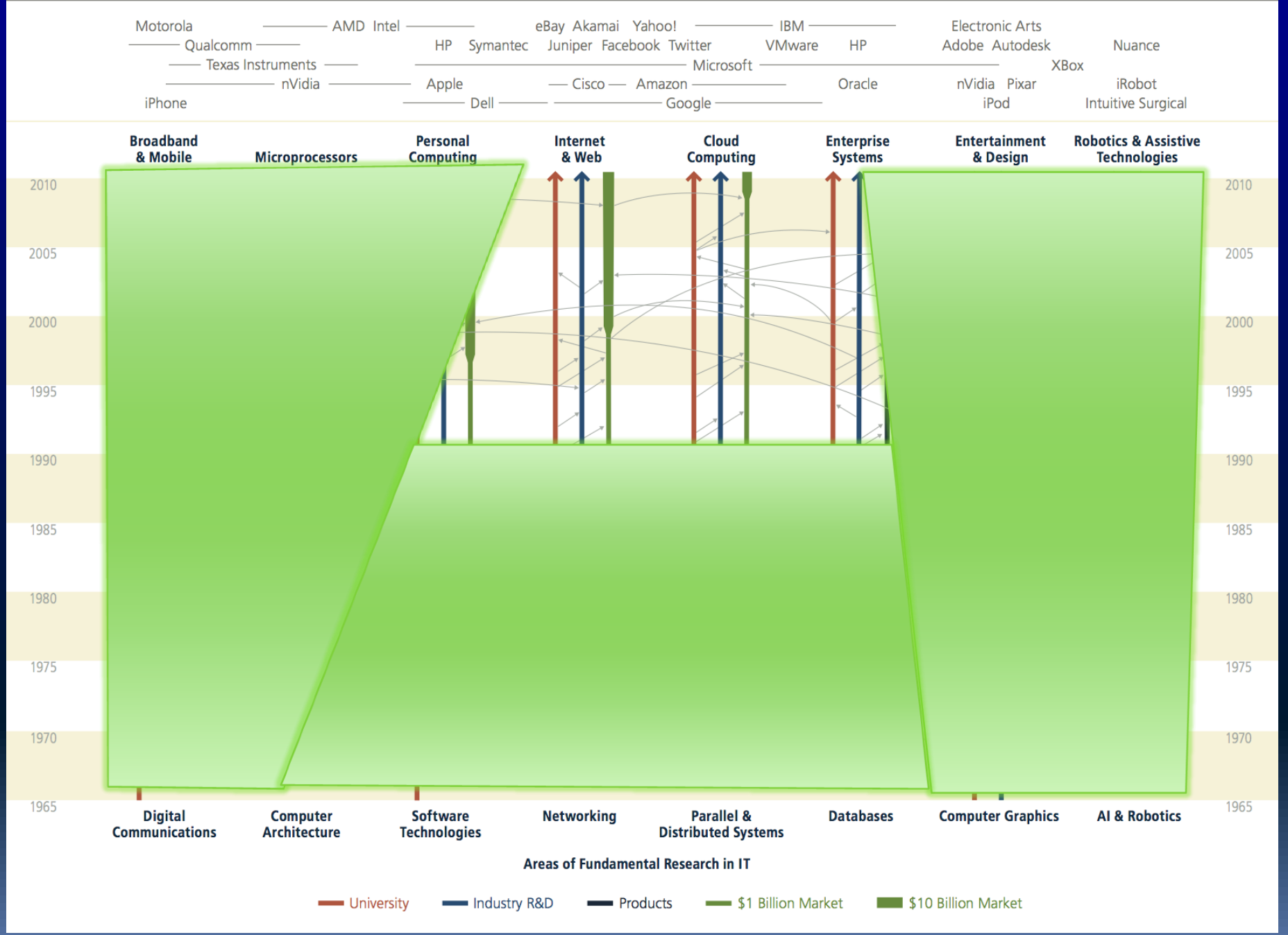
IT Sectors With Large Economic Impact



IT Sectors With Large Economic Impact



IT Sectors With Large Economic Impact



Clusters, Internet Services, Cloud …

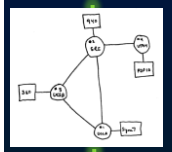
2.0 B 1/26/11

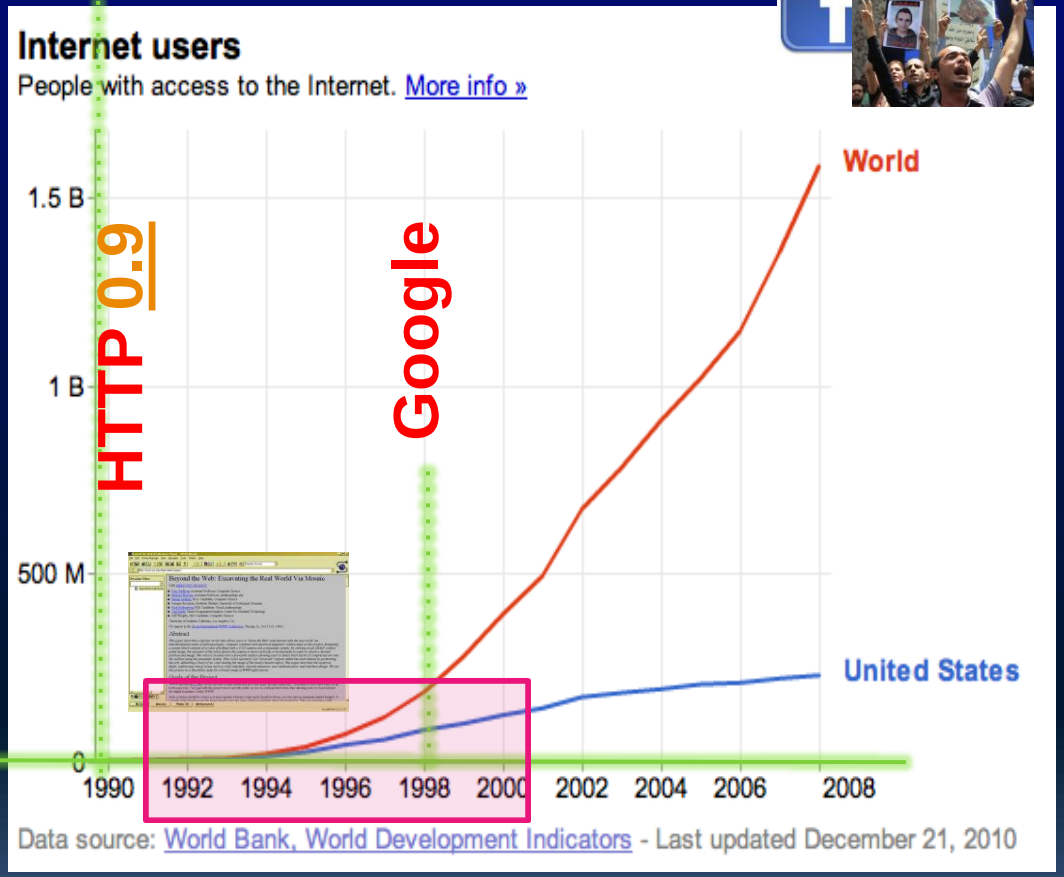
Internet

WWW

ARPANet

RFC 675 TCP/IP



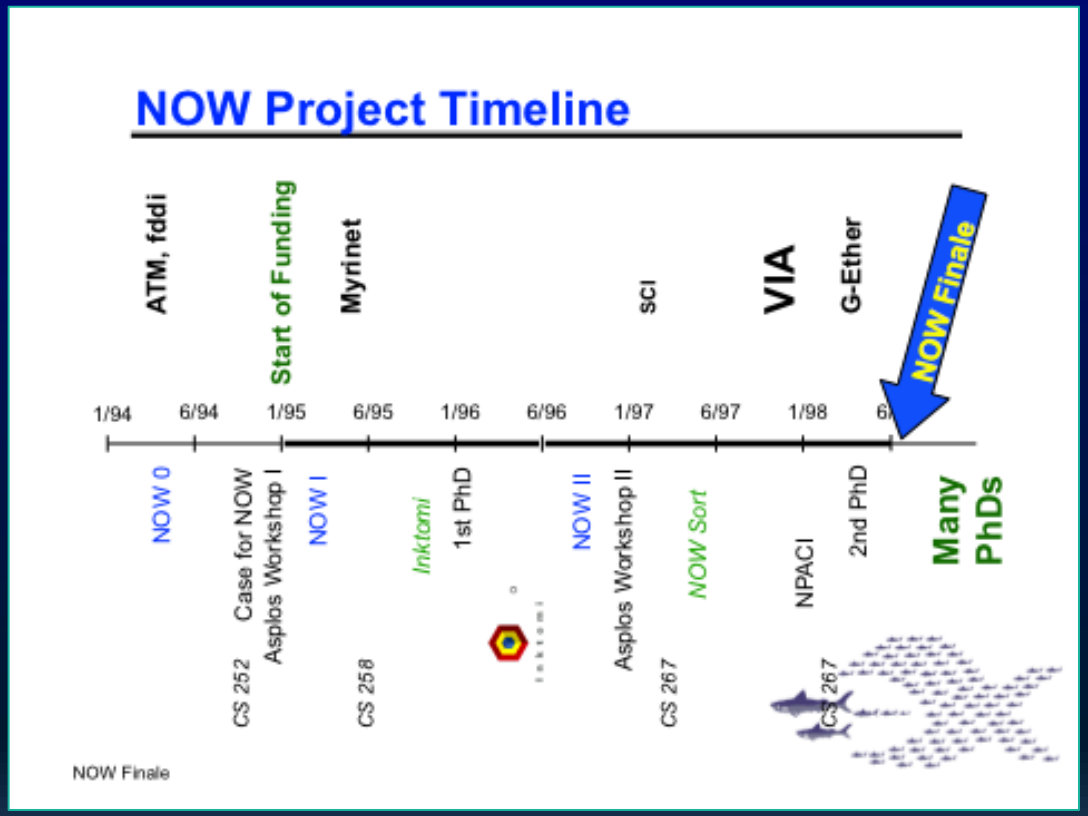


1969 1974

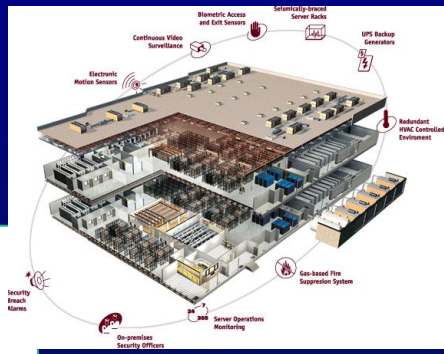
1990

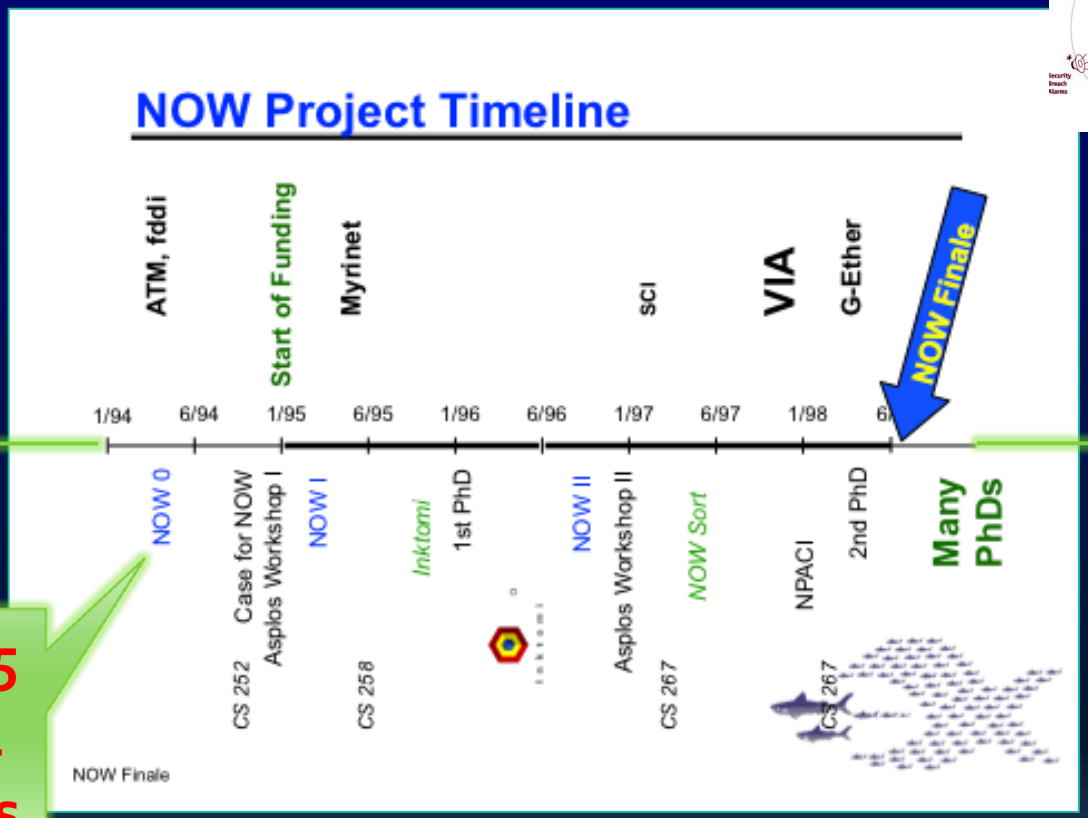
2010

NOW – Scalable Internet Service Cluster Design



NOW – Scalable Internet Service Cluster Design



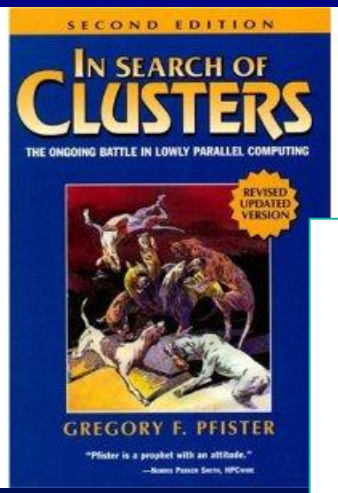


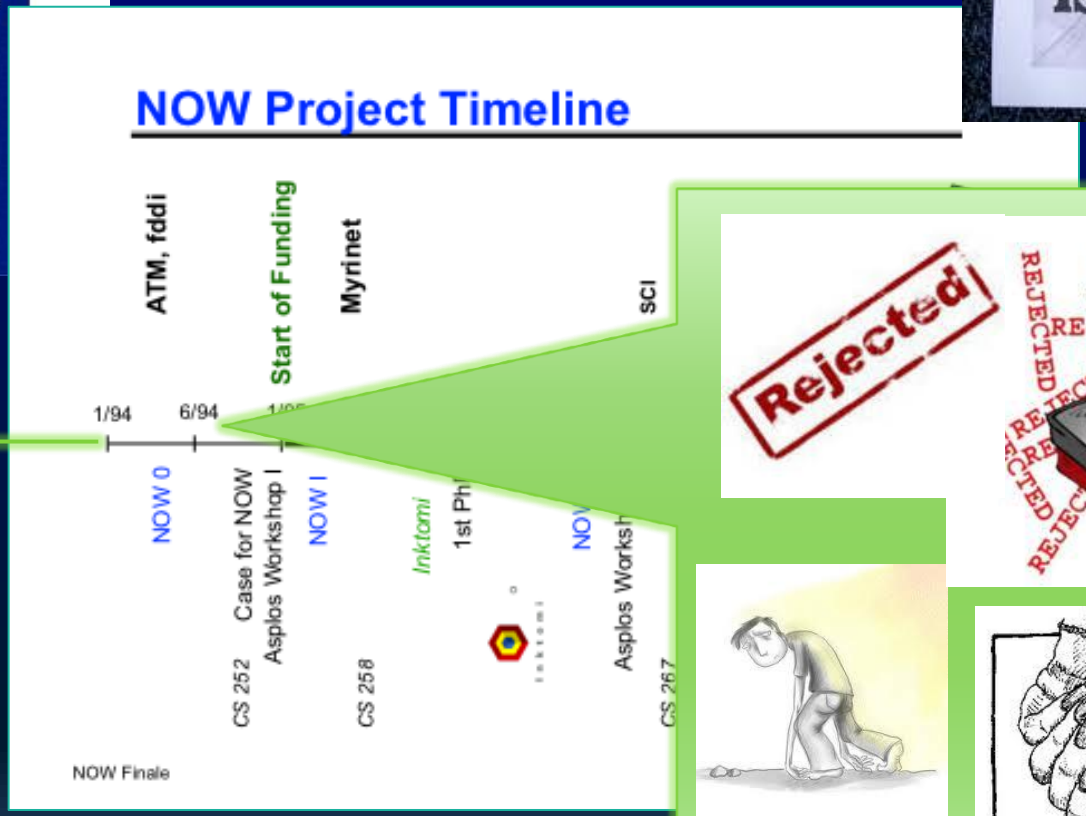
VAX clusters

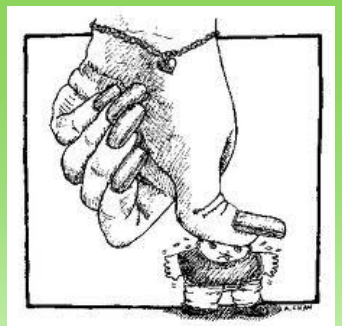
TMC CM5
IBM SP1
No nodes

Google

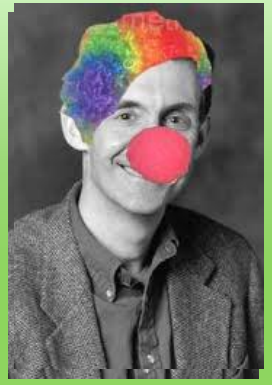
NOW – Scalable High Performance Clusters







NOW – Scalable High Performance Clusters

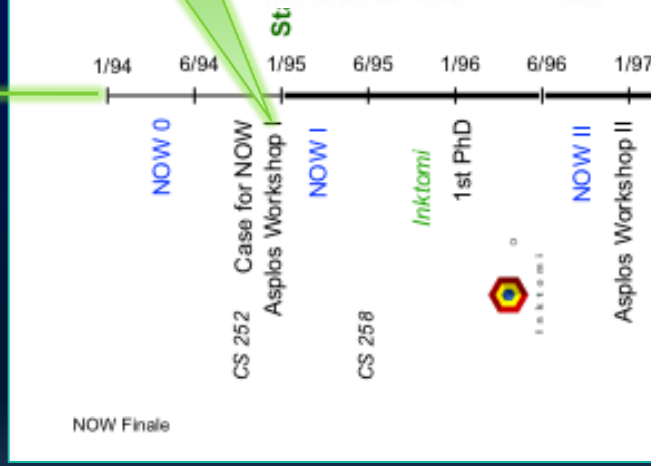


Yet
Another
Workstation
Network

Ed Lazowska
University of
Washington

G-Ether

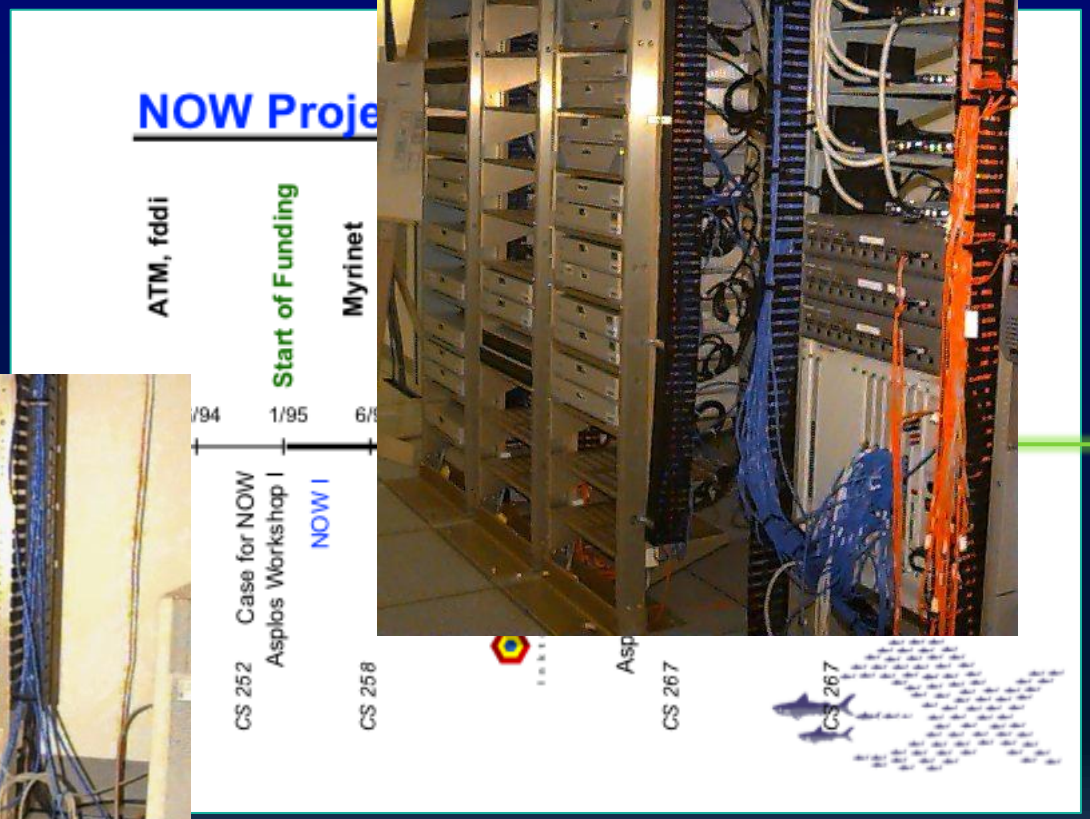
W Finale



STONE SOUP
AN OLD TALE

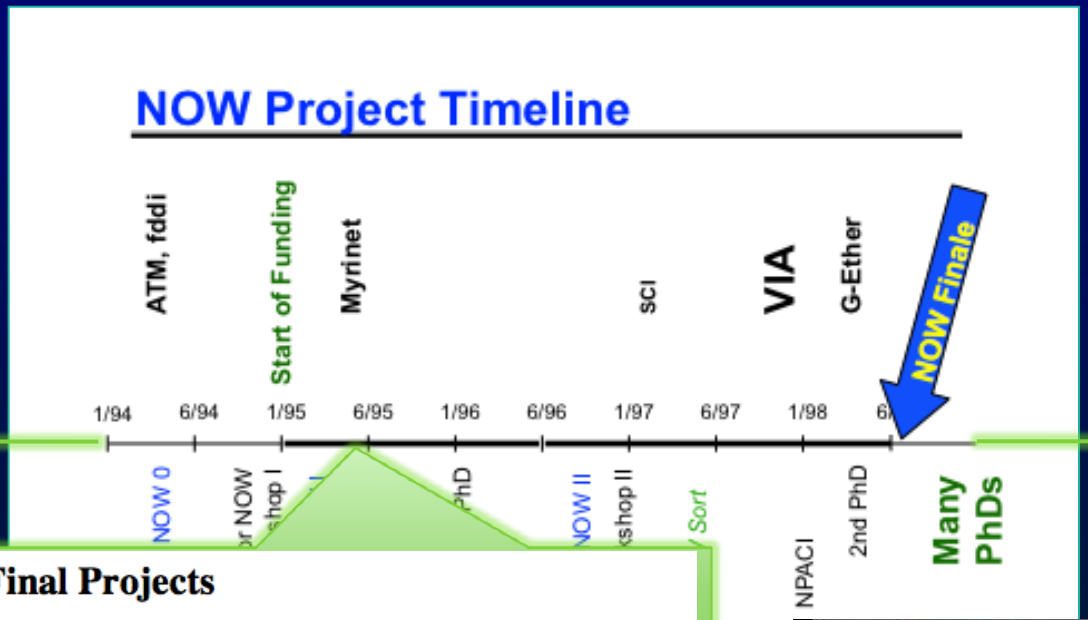
"This commodity parts multiprocessor is great.
But y'know, it'd be even better if only it had ..."

NOW – Scalable High Performance Clusters



Inktomi – Fast Massive Web Search
Fiat Lux - High Dynamic Range Imaging

Paul Gauthier



Lycos
infoseek

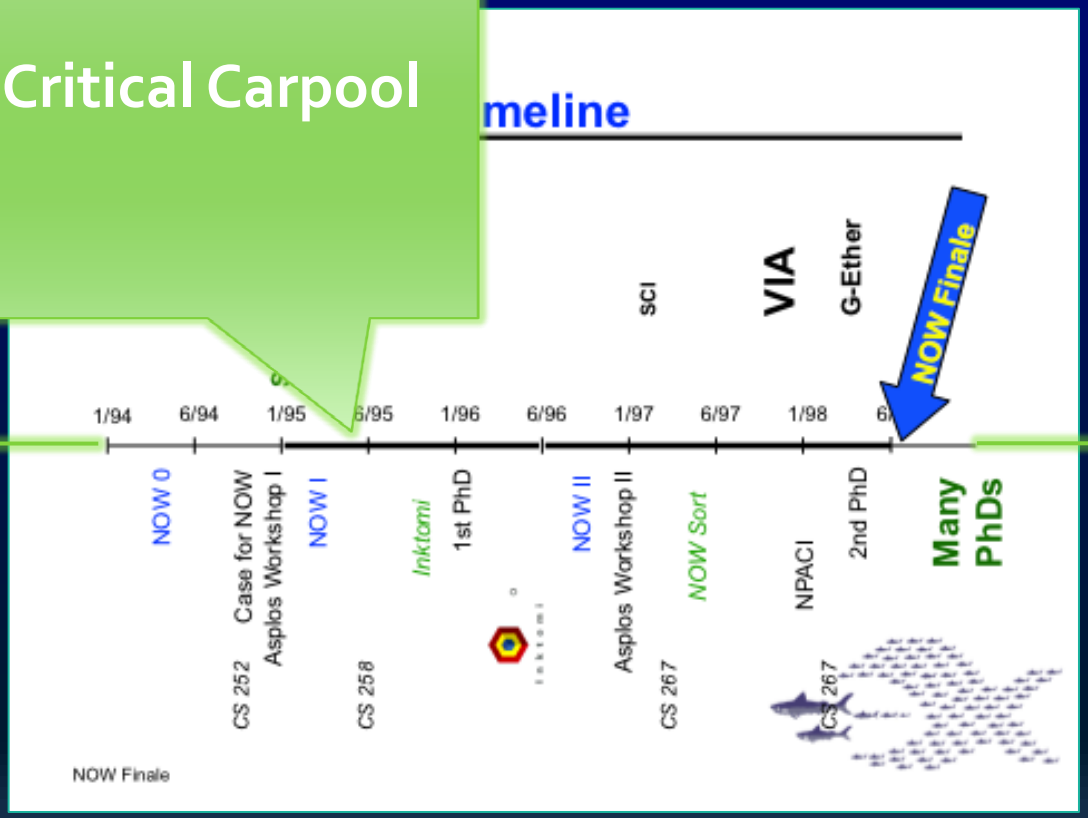
CS267, Spring 1995: Final Projects

- Fast Parallel Iterative Matrix Diagonalization
- Ptolemy C Code Generation and Scheduling for the Network of Workstations (NOW)
- Parallel Raytracing using a Network of Workstations for Rendering Spline Surface Animation
- Parallel Monte Carlo Simulation
- Berkeley Search Engine
- Porting and Characterization of GATOR, an Atmospheric Chemical Tracer Model
- A Distributed Memory Concurrent B-tree Implementation
- Design, Implementation, and Performance Evaluation of a Portable Distributed Task Queue
- Porting The BLACS From MPL To GAM On The SP-1
- Implementation of a Parallel Preconditioned Conjugate Gradient (PCG) Solver in Finite Element
- Parallelizing Impulse, a dynamic simulation system.
- Model of LPARX multigrid performance on the CM5

Paul Debevec

NOW – Scalable High Performance Clusters

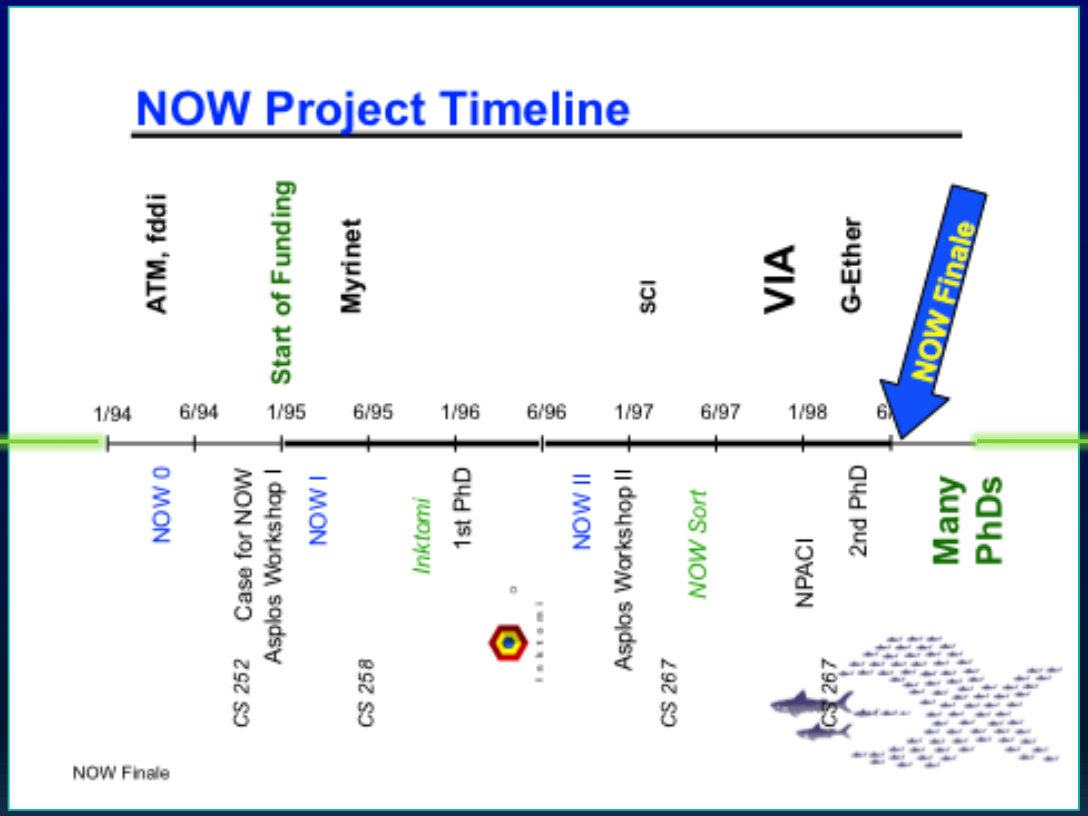
The Critical Carpool



inktomi.berkeley.edu

inktomi.com


HOTBOT

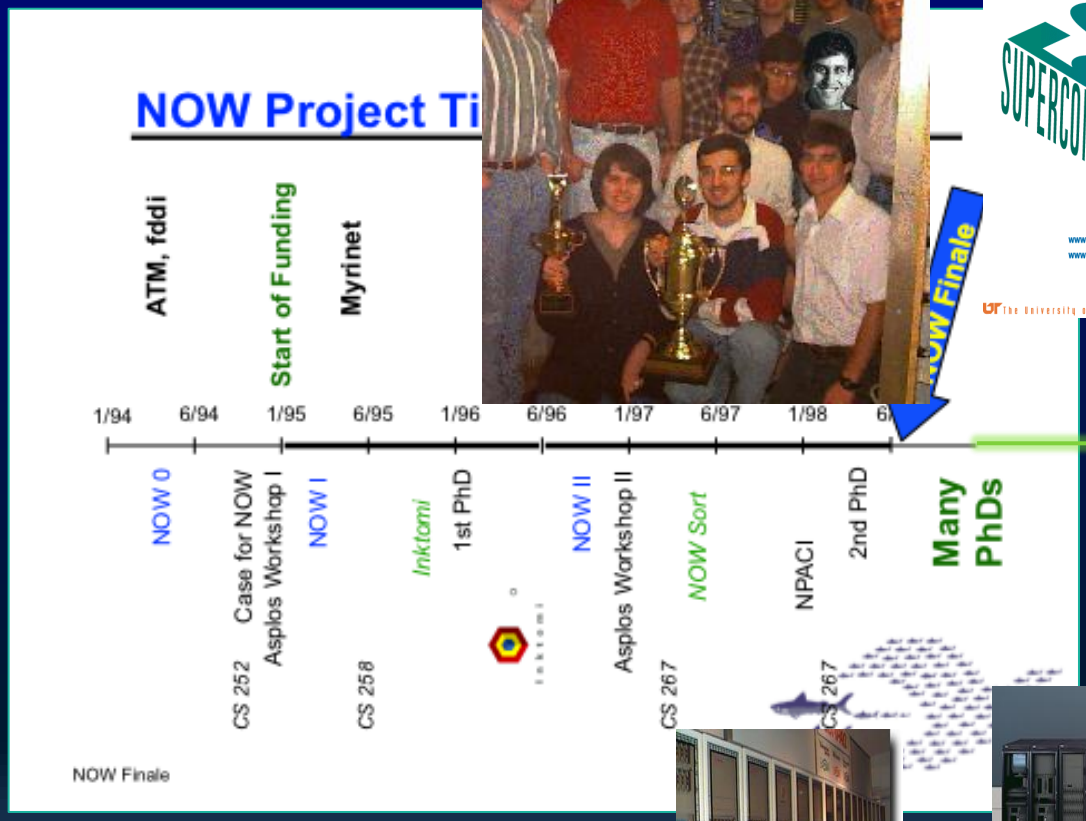

NOW Project Timeline
ATM, fddi
Start of Funding
Myrinet
SCI
VIA
G-Ether
NOW Finale
1/94
6/94
1/95
6/95
1/96
6/96
1/97
6/97
1/98
NOW 0
Case for NOW
Asplos Workshop I
NOW I
Inktomi
1st PhD
NOW II
Asplos Workshop II
NOW Sort
NPACI
2nd PhD
Many PhDs
CS 252
CS 258
CS 267
CS 267
NOW Finale

Large Ultra/Myrinet NOW

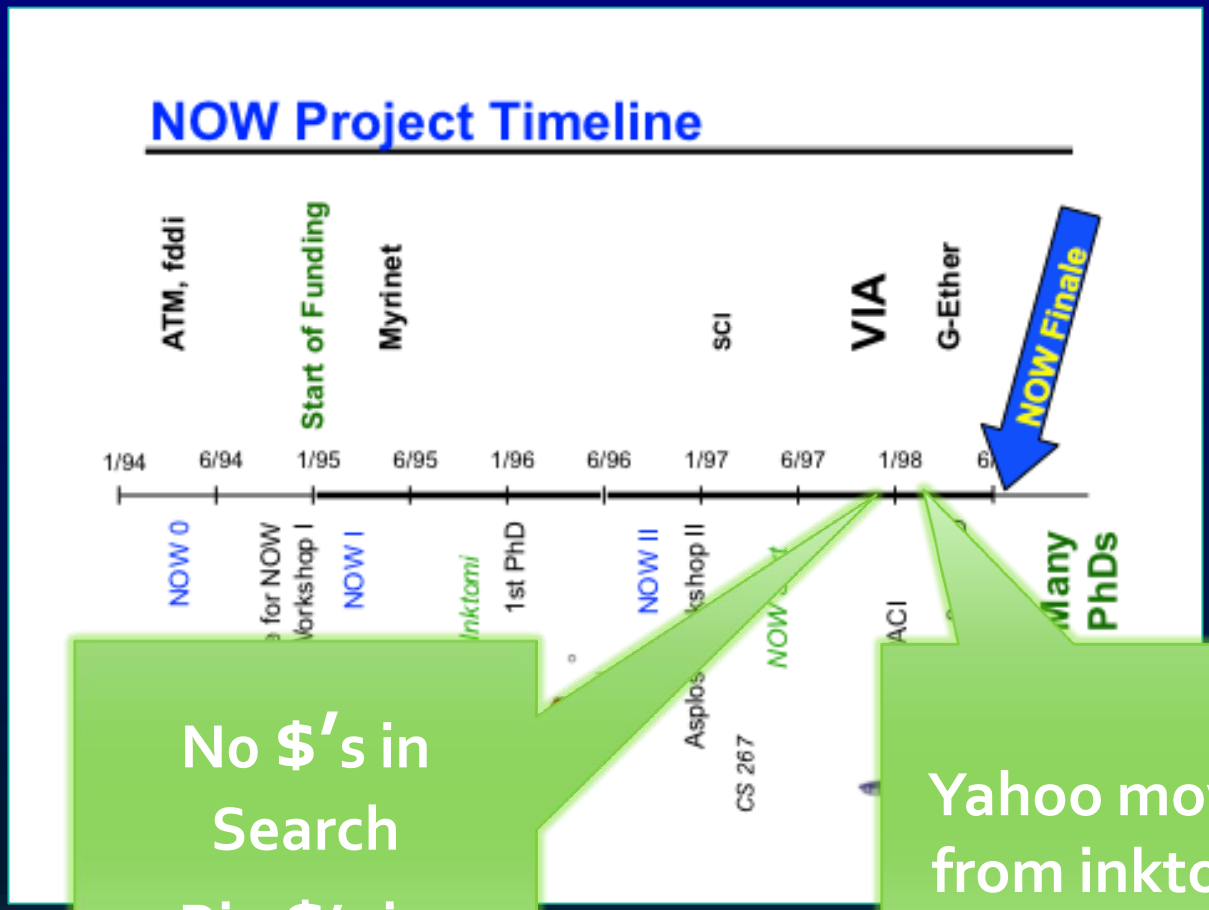
Massive Cheap Storage

Serving Fine Art at http://www.thinker.org/imagebase/

NOW performs '96



Google.com

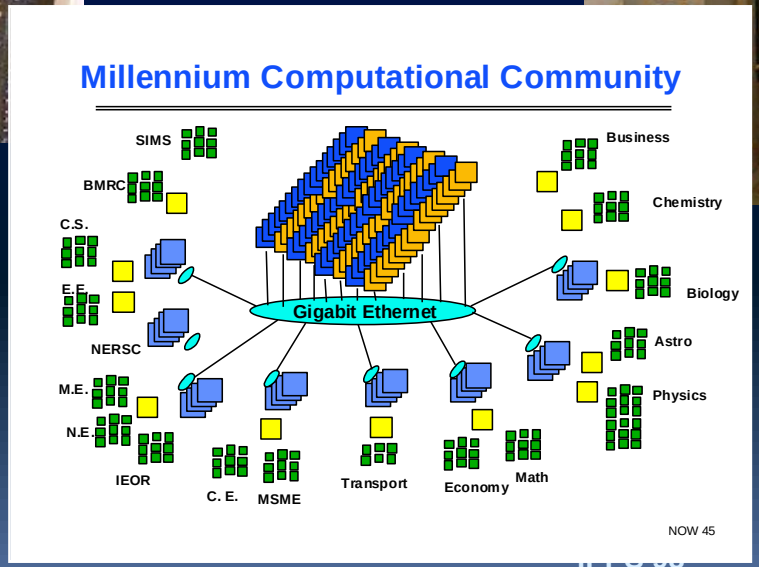


No $'s in Search

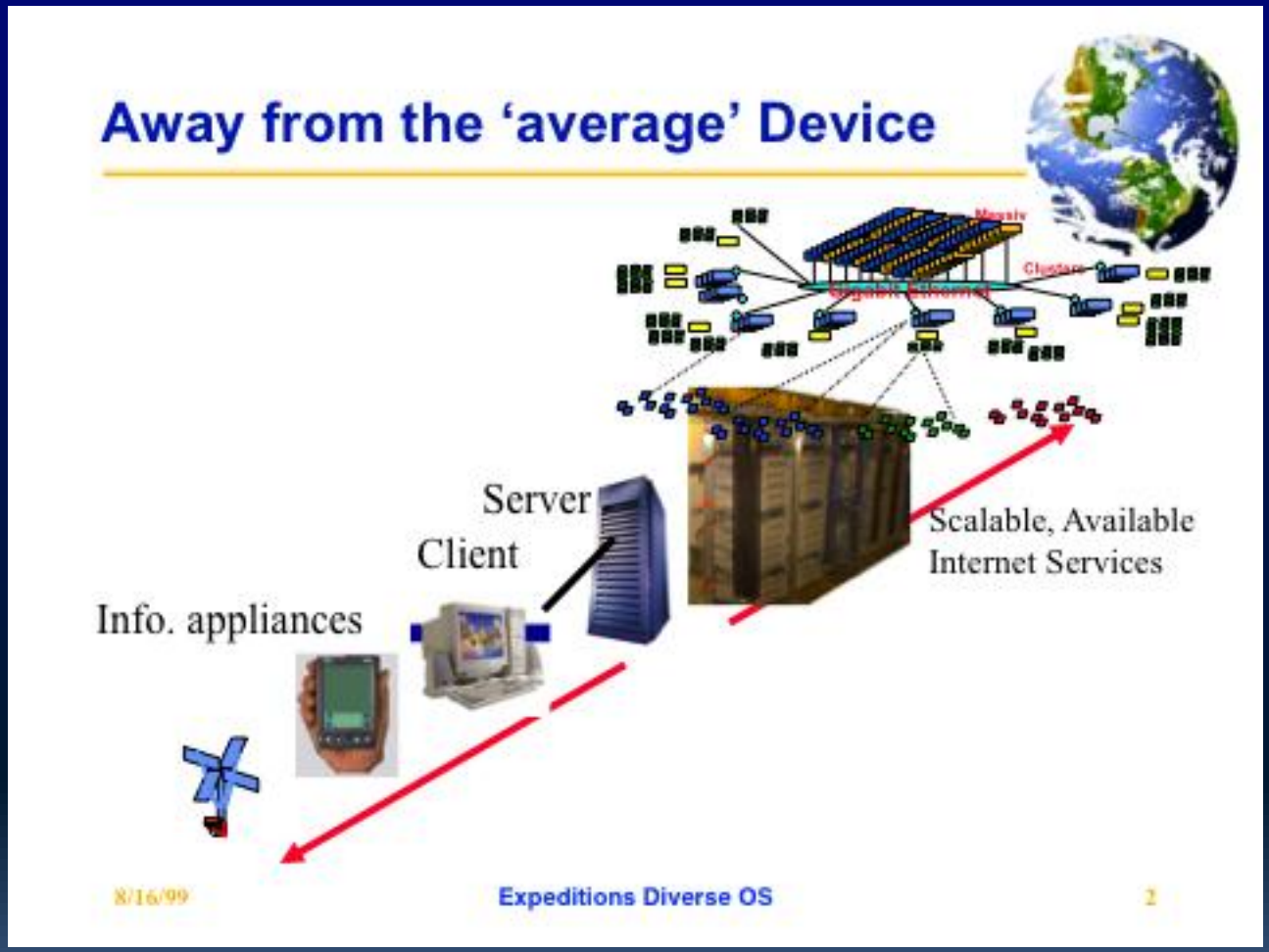
Big $'s in caches

Yahoo moves from inktomi to Google

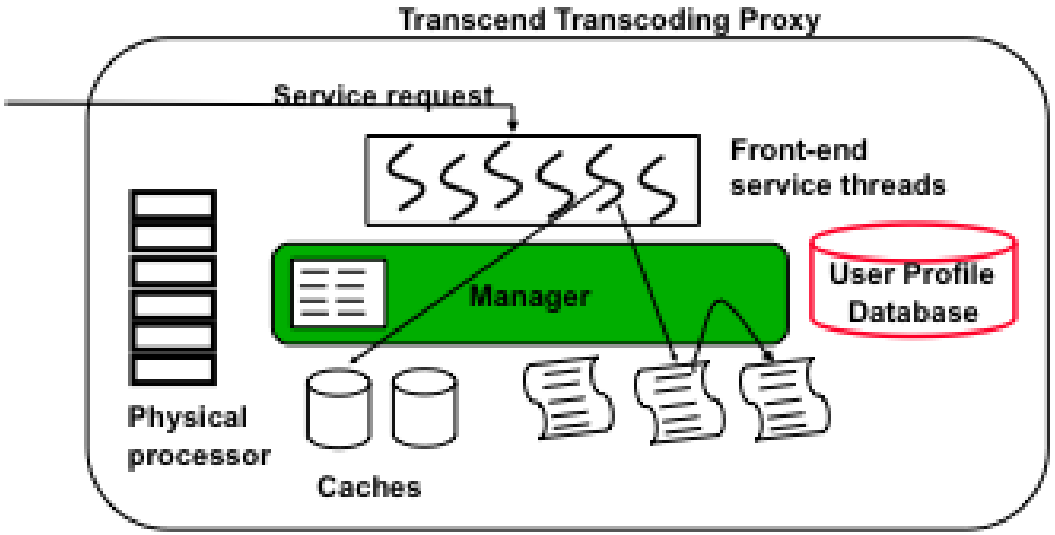
Cluster of SMPs (CLUMPS)



Expeditions to the 21st Century



Service Based Applications

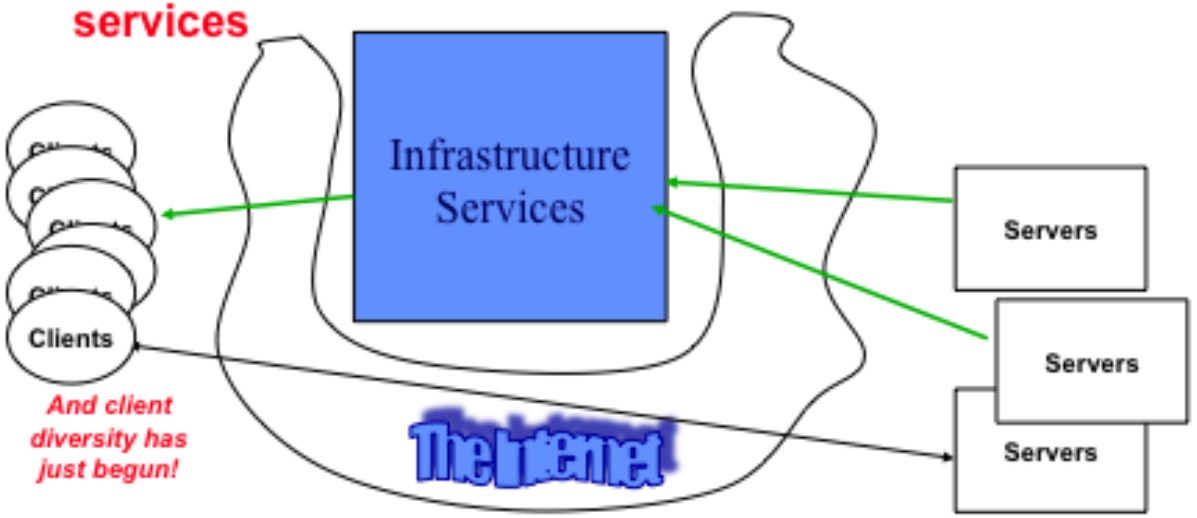


- Application provides services to clients
- Grows/Shrinks according to demand, availability, and faults

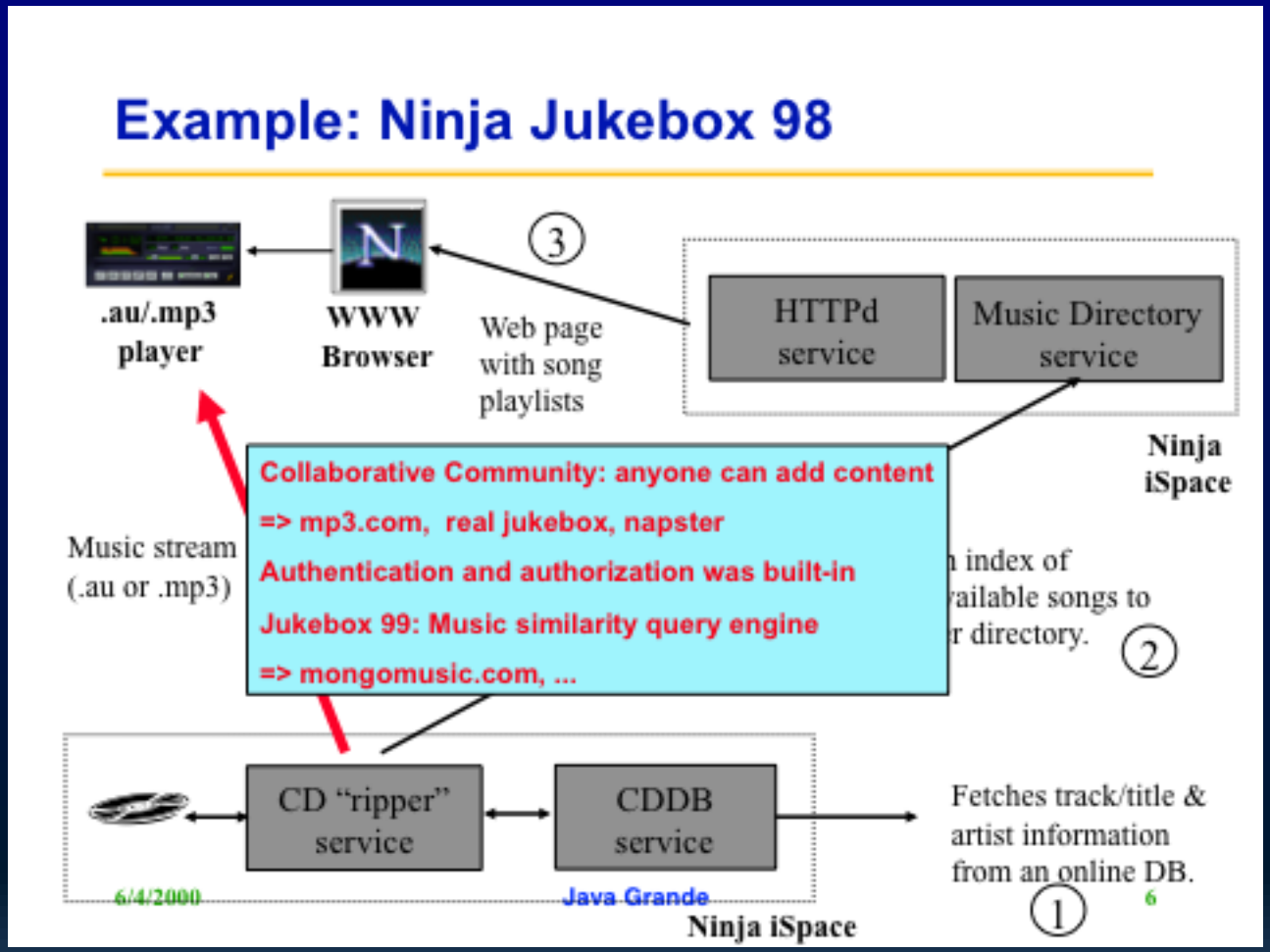
Ninja Internet Service Architecture

Opportunity: infrastructure services

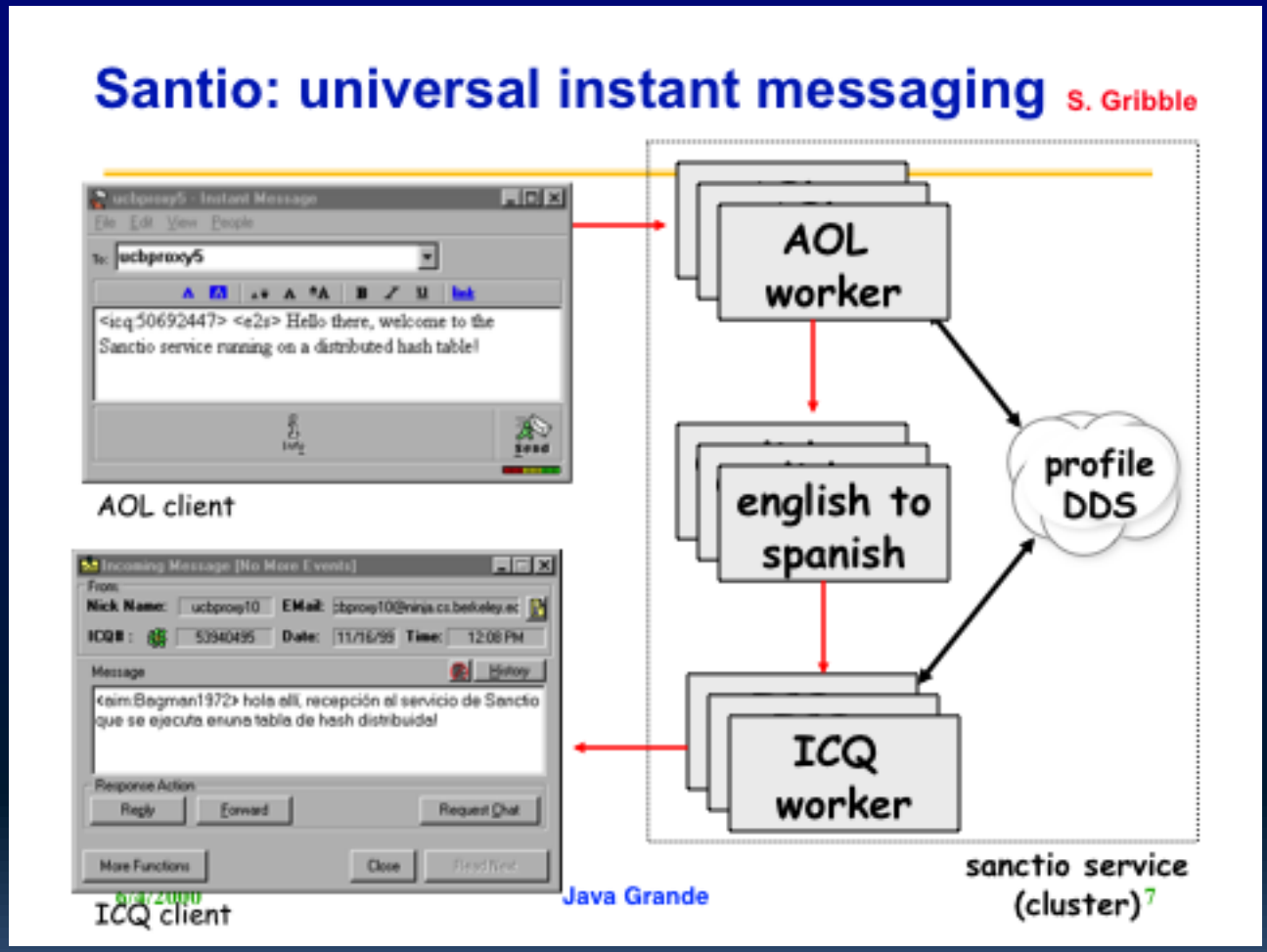
- Prehistoric: DNS, IP route tables, …
- Historic: crawl, index, search,
- Emerging: compose and manipulate data and services



Startup of the Week …



… and …


Santio: universal instant messaging
S. Gribble
AOL client
ICQ client
AOL worker
english to spanish
ICQ worker
profile DDS
sanctio service (cluster)
Java Grande

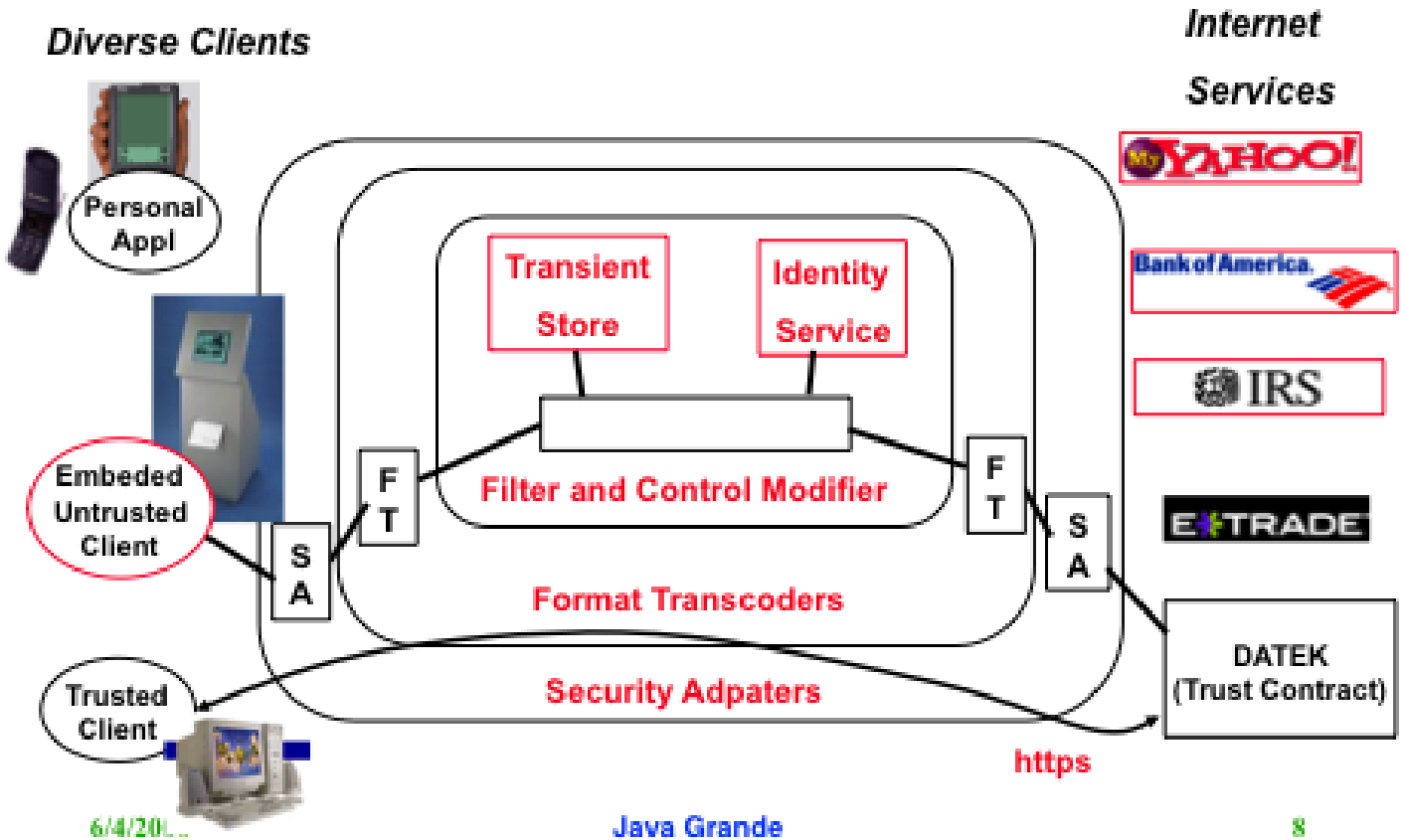
Existing Applications

- **Ninja "NOW Jukebox"**
  - Harnesses Berkeley Network of Workstations
  - Plays real-time MPEG-3 audio served from 110+ CD's worth of music
- **Voice-enabled room control**
  - Speech-to-text Operators control room services (camera, lights, microphone)
  - Eventual integration with GSM cell phones and PDA-based UI
- **Stock Trading Service**
  - Accesses real-time stock data from Internet
  - Programmatic interface to buy/sell/trade stocks through online brokerage
- **NinjaFAX**
  - Programmable remotely-accessed FAX machine service
  - Send/receive FAXes; authentication used for access control
- **Keiretsu: The Ninja Pager Service**
  - Provides instant messaging service via Web, 1/2-way pagers, WorkPads, etc.

Gribble, 99

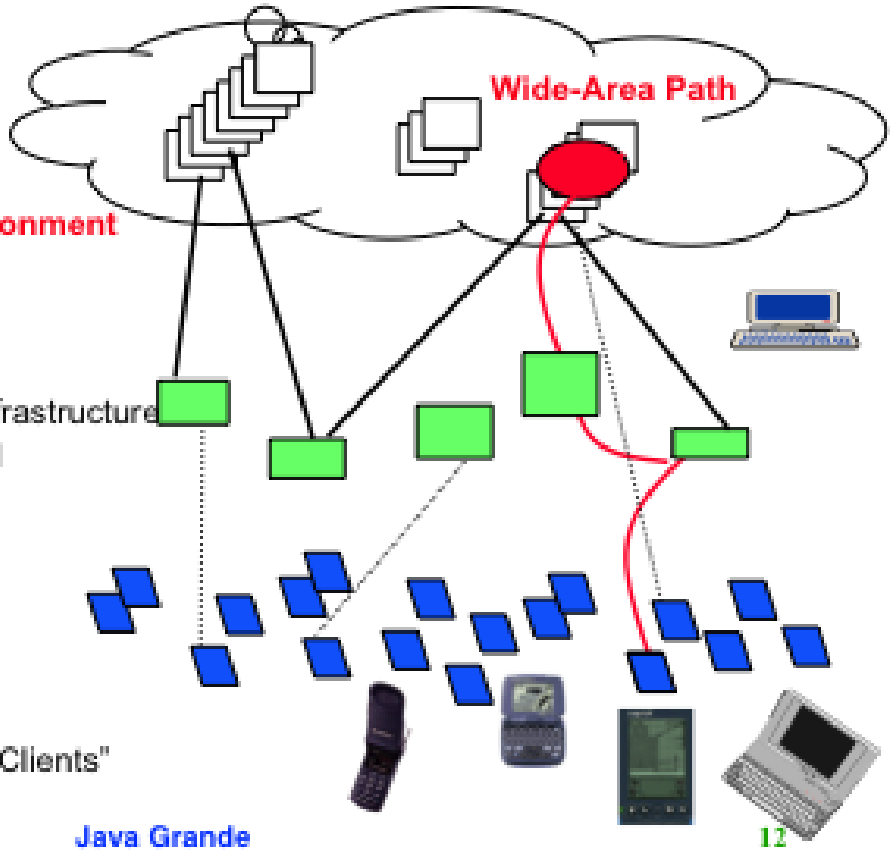
Composable, Secure Proxy Architecture for Post-PC devices

S. Ross, J. Hill



A 'Structured Architecture' Approach

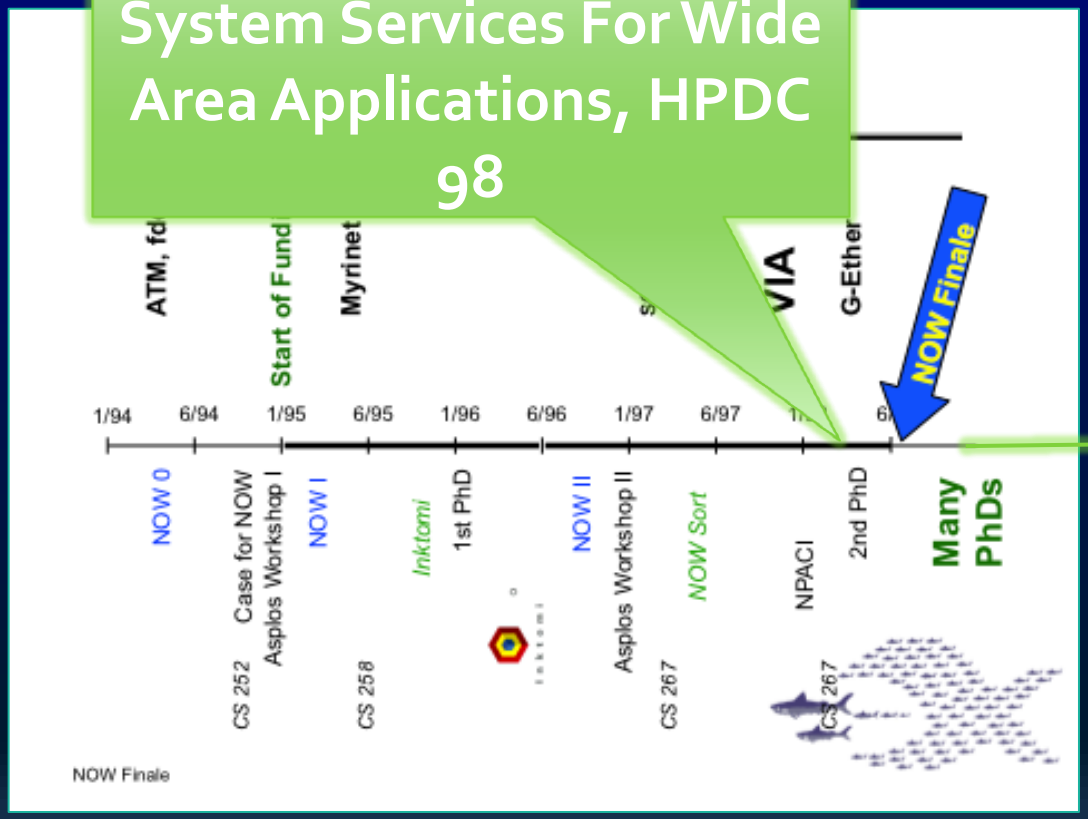
- Bases (1M's)
  - scalable, highly available
  - persistent state
  - databases, agents
  - "home" base per user
  - service programming environment
- Active Proxies (100M's)
  - not packet routers
  - bootstrap thin devices into infrastructure
  - soft-state and well-connected
- Units (1B's)
  - sensors / actuators
  - PDAs / smartphones / PCs
  - heterogeneous
  - Minimal functionality: "Smart Clients"



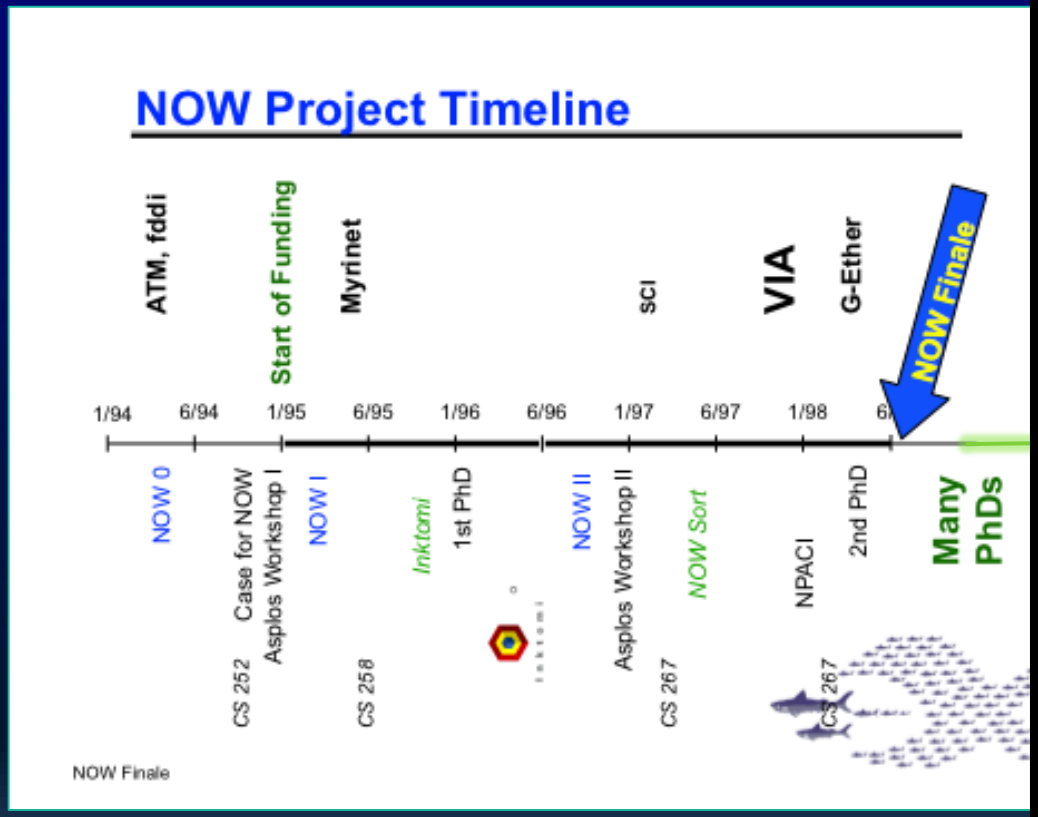
Delayed Gratification

HPDC Best in 20 years, April 2012

Webos: Operating System Services For Wide Area Applications, HPDC 98



99.9 Club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SCI
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6/94
1/95
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6/96
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6/97
1/98
NOW 0
Case for NOW
Asplos Workshop I
NOW I
Inktomi
1st PhD
NOW II
Asplos Workshop II
NOW Sort
NPACI
2nd PhD
Many PhDs
CS 252
CS 258
CS 267
CS 267
NOW Finale

10th ANNIVERSARY REUNION 2008

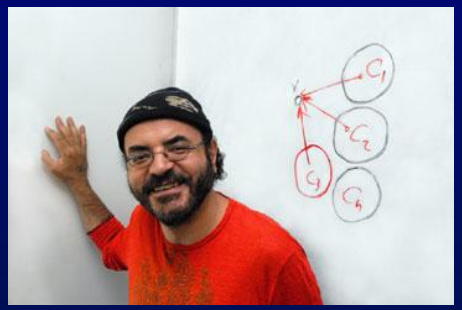
Network of Workstations (NOW): 1993-98

NOW Team 2008: L-R, front row: Prof. Tom Anderson†‡ (Washington), Prof. Rich Martin‡ (Rutgers), Prof. David Culler*†‡ (Berkeley), Prof. David Patterson*† (Berkeley).
Middle row: Eric Anderson (HP Labs), Prof. Mike Dahlin†‡ (Texas), Prof. Armando Fox‡ (Berkeley), Drew Roselli (Microsoft), Prof. Andrea Arpaci-Dusseau‡ (Wisconsin), Lok Liu, Joe Hsu.
Last row: Prof. Matt Welsh‡ (Harvard/Google), Eric Fraser, Chad Yoshikawa, Prof. Eric Brewer*†‡ (Berkeley), Prof. Jeanna Neefe Matthews (Clarkson), Prof. Amin Vahdat‡ (UCSD), Prof. Remzi Arpaci-Dusseau (Wisconsin), Prof. Steve Lumetta (Illinois).

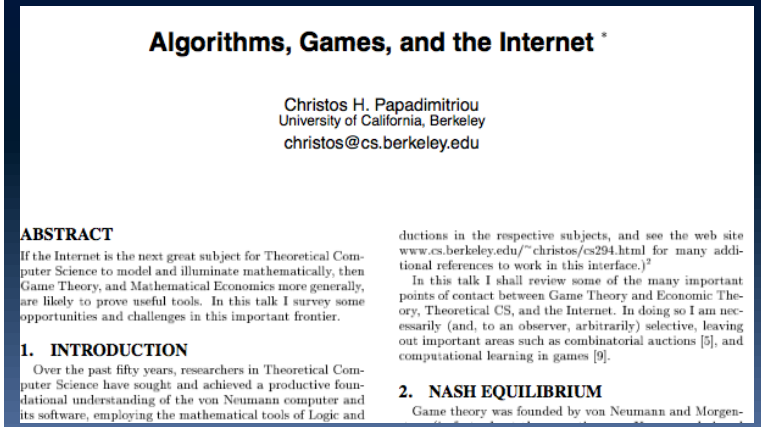
***3 NAE members †4 ACM fellows ‡9 NSF CAREER Awards**

Monitizing the internet …

Costis Daskalakis



Constantinos Daskalakis, Paul W. Goldberg and Christos H. Papadimitriou, *The Complexity of Computing a Nash Equilibrium, In the 38th ACM Symposium on Theory of Computing, STOC 2006*



Algorithms, Games, and the Internet *

Christos H. Papadimitriou
University of California, Berkeley
christos@cs.berkeley.edu

ABSTRACT

If the Internet is the next great subject for Theoretical Computer Science to model and illuminate mathematically, then Game Theory, and Mathematical Economics more generally, are likely to prove useful tools. In this talk I survey some opportunities and challenges in this important frontier.

1. INTRODUCTION

Over the past fifty years, researchers in Theoretical Computer Science have sought and achieved a productive foundational understanding of the von Neumann computer and its software, employing the mathematical tools of Logic and

ductions in the respective subjects, and see the web site www.cs.berkeley.edu/~christos/cs294.html for many additional references to work in this interface.)[2]

In this talk I shall review some of the many important points of contact between Game Theory and Economic Theory, Theoretical CS, and the Internet. In doing so I am necessarily (and, to an observer, arbitrarily) selective, leaving out important areas such as combinatorial auctions [5], and computational learning in games [9].

2. NASH EQUILIBRIUM

Game theory was founded by von Neumann and Morgen-

Research as "Time Travel"

- **Imagine** a technologically plausible future
- **Create** an approximation of that vision using technology that exists.
- Discover what is **True** in that world
  - Empirical experience
    - Bashing your head, stubbing your toe, reaching epiphany
  - Quantitative measurement and analysis
  - Analytics and Foundations
- Courage to 'break trail' and discipline to do the hard science