A Working Partnership: A View From Academia

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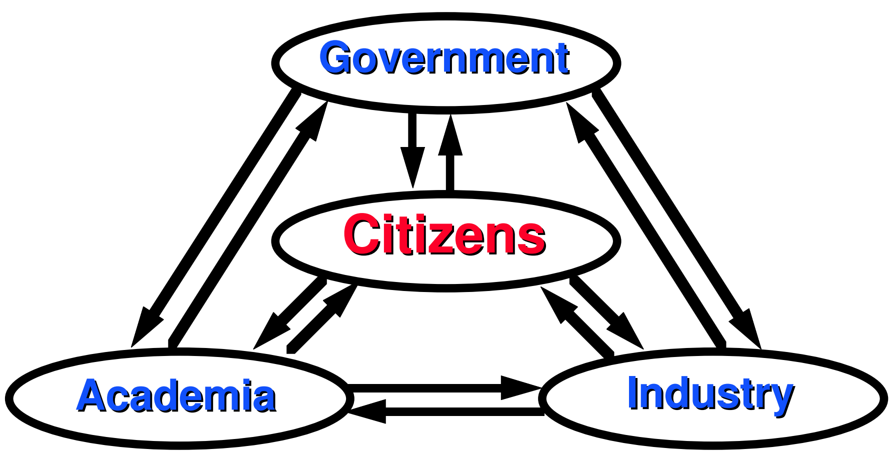
A Symbiotic Relationship?



Roles Played

- **Academia**
  - Educating Citizens
  - New Ideas /Technology
  - Expertise / Consulting
- **Industry**
  - Products
  - Jobs for Citizens
  - Problems to Solve
  - Expertise / Consulting
  - Research Funding
- **Government**
  - Helping Citizens
  - Research Funding
  - Research Agenda
- **Citizens**
  - Funding
  - Problems to Solve

Talk Outline

- State of Academia / Industry / Government Relationship
- 4 Examples of cooperation/ innovation
- State of Computing Yesterday / Today / Tomorrow
- Level of Industrial Participation in Future CS&E Research?
- Conclusion

Main Points

- CS&E research has led directly to billions of dollars in new products => jobs, taxes, research funding, …
- Faculty start companies or consult for companies to transfer technology
- Former students make major contribution shortly after graduate level education
- Academic research & industrial research together transfer technology
- Industrial CS&E research recently reduced both level and time to payoff; what is impact on field?

State of Relationship in CS&E

- Successful! Many examples of government funding of research leading to successful products, jobs, ...
- Speaker bias alert: Hardware, Berkeley, Academia, West Coast, ARPA, …
- UNIX Operating System
- Workstations
- Reduced Instruction Set Computers
- Massively Parallel Processors
- Also: Internet, Local Area Networks, Compilers, Relational Databases, VLSI CAD, IEEE Floating Point, X-windows, RAID, Object Oriented Design,Mosaic…

UNIX Operating System

- Problem: operating system reinvented for each new machine
- Forerunner: Multics at MIT; grand ideas, but too complicated and slow
- Thompson (Berkeley) + Ritchie (MIT) go to Bell Labs, build small OS for CS&E researchers on small machine (≈ 1970)
- ARPA picks UNIX as OS for CS&E research community for VAX (≈ 1979)
- "Berkeley UNIX" adds VM, utilities, networking, widely distributed (Joy)
- UNIX became standard OS for technical computing (≈ 1981)

Workstations

- Problem: sharing single computer gives unsatisfactory service
- Opportunity: lower-cost small computers
- Forerunners: Engelbart @ SRI (mouse, windows), Lampson, Thacker @ Xerox PARC (bit-mapped screen, Ethernet local area network)
- Stanford University Network (SUN) project using microprocessor based workstation, Berkeley UNIX, mouse, Ethernet network…
- Bechtolsheim (Stanford) + Joy (Berkeley) lead Sun Microsystems to top (≈ 1985)

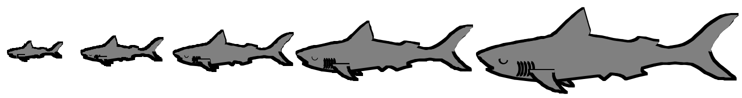
Reduced Instruction Set Computers

- Problem: Lethargic processor design, wrong goal (esthetics/code size vs. speed)
- Forerunner: CDC-6600 supercomputer
- Opportunity: VLSI + Compilers + UNIX
- 3 efforts: Cocke/801@IBM, Patterson/RISC @ Berkeley, Hennessy/MIPS @ Stanford
- Sun Microsystems RISC 1st commercial success, dominates market
- Workstation market defined by RISC + UNIX: Sun, HP, IBM, DEC, SGI, …
- RISC eliminates all but Intel; Intel builds 80x86s using RISC principles

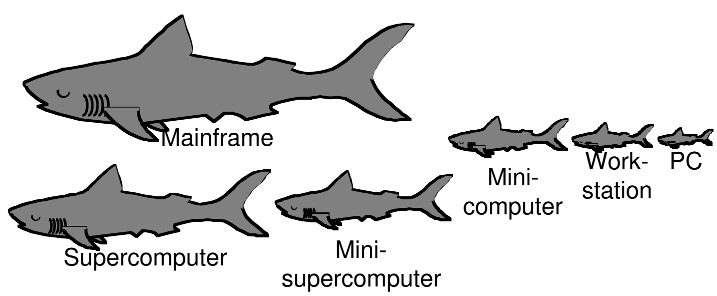
Massively Parallel Processors (MPP)

- Problem: Supercomputers expensive to design and to buy
- Forerunners: Illinois Illiac IV, Goodyear MPP, CMU C.mmp
- Opportunity: VLSI + UNIX
- 2 Projects: Connection Machine (Hillis/MIT), Cosmic Cube (Seitz/Caltech)
- Cosmic Cube => nCube, Intel Supercomputer
- Connection Machine => Thinking Machines
- These companies created MPP market

Original Food Chain Picture



1984 Computer Food Chain



Impact of Innovations

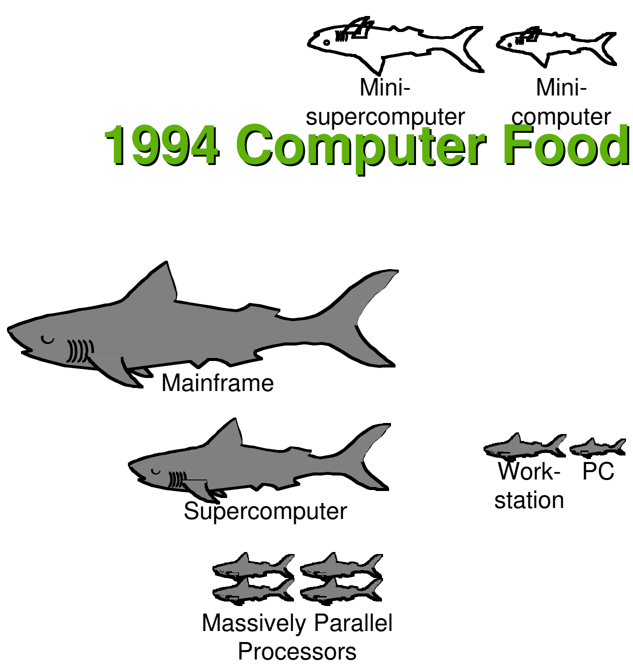
- **Workstations keep price near costs (low margins)**

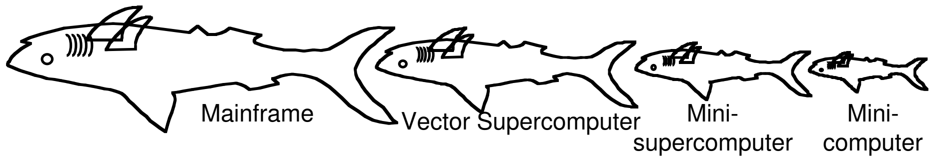
Price 1MB Main Memory (January 1994)

Class	Price	Ratio	(Model)
Workstation	\$42	1	(SS-10)
Mainframe	\$1920	46	(IBM 3090)
Super-	\$600	14	(M90 DRAM)
computer	\$1375	33	(C 15 ns SRAM)

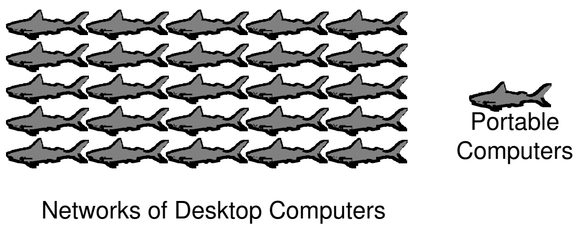
- **RISC => Processor improves 50% / year; 4%/month!**

1994 Computer Food Chain





2004 Computer Food Chain



Industrial Funding of CS&E Research?

- IBM, Bell Labs major industrial research
- DEC, IBM, HP, Bell aid academic research
  - Equipement donations, fellowships, summer interns, cash
- Money came from “cash dinosaurs”
- Dinosaurs becoming extinct
- Whither long term, industrial research?
  - Competition shortening industry research horizon
  - Low margins reducing amount of research support
  - Industry competes with academia for government funds?
- Continuing aid to academic research?

Conclusion

- Investing in Academic CS&E Research pays:
  - Inexpensive: $1M = 3 faculty + 12 grad students+ 3 staff since faculty are part time, students are apprentists
  - Educating innovators: Thompson, Ritchie, Engelbart, Lampson, Bechtolsheim, Joy, Hillis, ...
  - Faculty/student expertise to start companies (Sun, SGI, MIPS, TMC) or consult for companies (Sun, HP, DEC, Intel)
  - Innovations: UNIX, desktop computers, RISC, MPPs, …
- Rapid change of technology => frequent new opportunities => premium on education
- Generally CS&E successes involve industrial research & academic research
- Dramatic improvement in cost/performance may reduce industrial CS&E research!
- "Good deeds do not go unpunished" or continued investment in CS&E research?