Lecture 23:
Course Summary, Future Predictions, and Your Cal Cultural History

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Computer Science 252

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Final Lecture

- **Review CS 252, follow on courses**
- **Research style**
- **Discussion on Future of CS&E Research?**
- **Learning about your heritage as Cal students/ future alumni**
- **Course evaluation by HKN**
- **Pizza at LaVal's**

Chapter 1: Performance and Cost

- **Amdahl's Law: perennial pitfall**
  - **Make the common case fast**
- **Integrated Circuits will continue to dominate computer technology: 30M to 100M transistors/ microprocessor by end of decade**
- **Cost vs. Price**
- **Margins pay the workers of the computer industry**
- **For better or worse, benchmarks shape a field**
- **Interested in learning more on integrated circuits? EE 241 "Advanced Digital Integrated Circuits" CS 250 "VLSI Systems Design" (TA?)**
- **Interested in learning more on performance? CS 266 "Introduction to Systems Performance"**

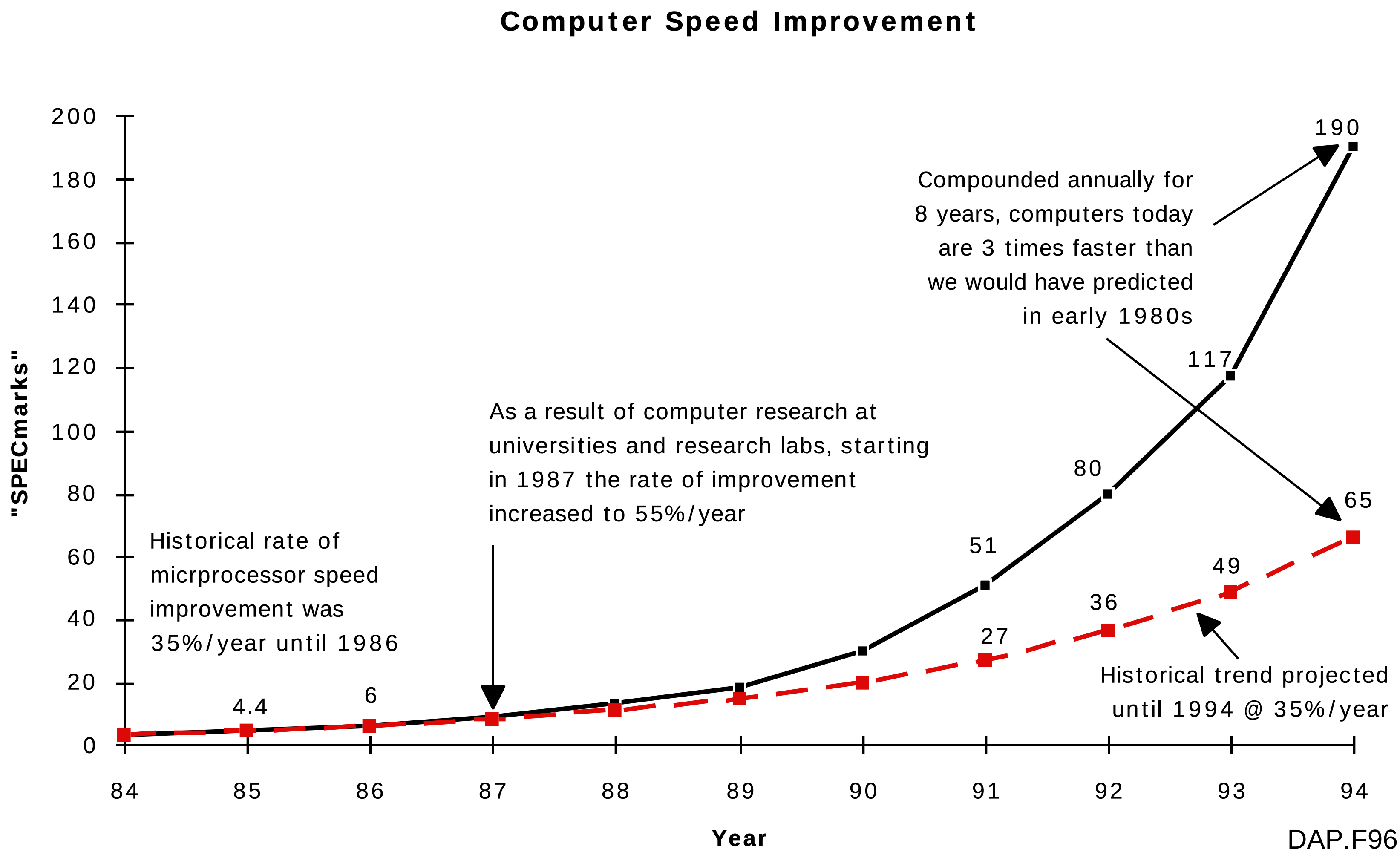
Chapter 2: Instruction Set Architecture

- **What ISA looks like to pipeline?**
  - **Cray: load/store machine; registers; simple instr. format**
- **RISC: Making an ISA that supports pipelined execution**
- **VAX: Making an ISA that minimizes opcode space, easy for compilers (many addr. modes, few reg.)**
- **80x86: importance of being their first**
- **Interested in learning more on compilers and ISA? CS 264/5 “Advanced Programming Language Design and Optimization” CS 294 “Reconfigurable Computers” (Wawzyrnek)**

Chapters 3/4: Pipelined Implementation

- **Miracle of Pipelining: Bandwidth vs. latency**
- **Superscalar to break single instruction/clock cycle limit**
  - **Hazards/Dependencies as limit: HW & SW techniques to overcome limits**
  - **Conditional Branches as one Limit: branch prediction**
  - **Memory system as another limit**
  - **compiler & machine organization try to overcome limits**
- **Out-of-order execution: paritally overcome some limits at dramatic complexity increase**
- **Sustaining 2X increase / 18 months rat race**

Processor Performance Over Time



Appendix B: Vector Processors

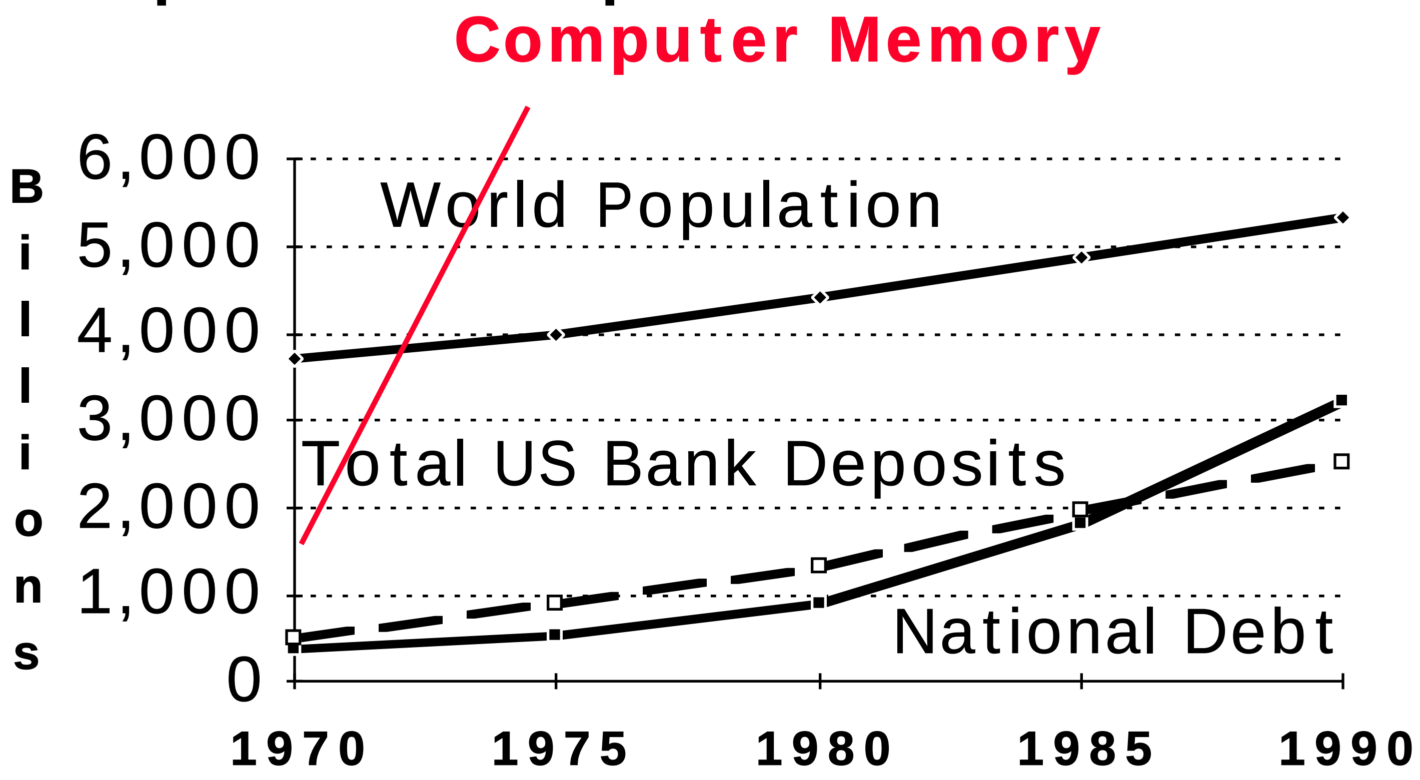
- High-level operations work on linear arrays: "vectors"
- Alternate model much easier for hardware: more powerful instructions, more predictable memory accesses, fewer branches, longer pipeline, ...
- Key terms: ***Chime, Convoy, Chaining, Initiation rate, Start-up time, Vector Length Register, Strip mining, Stride, Gather/Scatter, Vector Mask Register***
- Interesting metrics: R_∞(speed inifinite vector), $N_{1/2}$(length=1/2 speed R_∞), N_V (length faster than scalar)
- What % of computation is vectorizable? For new multimedia apps?

Chapter 5: Memory Hierarchy

- **Many, many options for caches**
- **4 Questions: where, who, which, write**
- **3 C: capacity, conflict, compulsory**
- **As CPUs get faster, more time spent in memory hierarchy: 150 clock cycles to DRAM x 4 instruction issues => potentially 600 instruction issues during miss**
- **DRAMs continue amazing capacity advance (4X/ 3 years) since 1970s but small advance in latency**
- **Memory hierarchy likely overriding issue in algorithms today; do algorithms and data structures of 1960s work with machines of 1990s?**

Technology: Memory Perspective

- **> 10,000X increase since 1970!**
  another > 50X by ≈2001!
- **Compared to other phenomena:**



- **Since 1970: < 10X Banks, Debt; < 2X population**

Chapter 6: Storage I/O

- **Bandwidth, Latency, Reliability**
- **Queuing theory**
- **RAID: performance and reliability**
- **Disks growing at 4X/ 3 years more recently**
  - **Still get email messages to reduce file storage**
- **Fantastic potential of tertiary storage: 100s TBs => Library on Congress at finger tips**
- **Interested in learning more on queueing theory? IEOR 161 (Ross), IEOR 267 (Wolff), IEOR 268**
- **Interested in learning more on SW storage systems? CS 286 "Implementation of Data Base Systems"**

Chapter 7: Networks

- Similarities of MPP interconnects, LANs, WANs
- Bandwidth vs. Latency in communication
- Switches everywhere, possibly even replacing memory busses
- Exciting Area: Internet read about in newspaper everyday
- Who will win: Sun 100 Mbit Ethernet, HP 100 Mbit Ethernet, Switched 10 Mbit Ethernet, ATM?
- Interested in learning more on networks? CS 268 "Computer Networks"

Chapter 8: Multiprocessors

- Potential for both performance and reliability
- Shared, uniform memory access vs. Shared non-uniform memory access vs. Message Passing
- Cache coherency protocols: Snooping vs. directory
- Successful today for file servers, time sharing, databases
- Will parallel programming become popular for production programs? If so, need to know 3As: Architecture, Applications, Algorithms
- Interested in learning more on multiprocessors:
  CS 258 "Parallel Computer Architecture"
  E 267 "Programming Parallel Computers"
  CS 273 "Foundations of Parallel Computation"

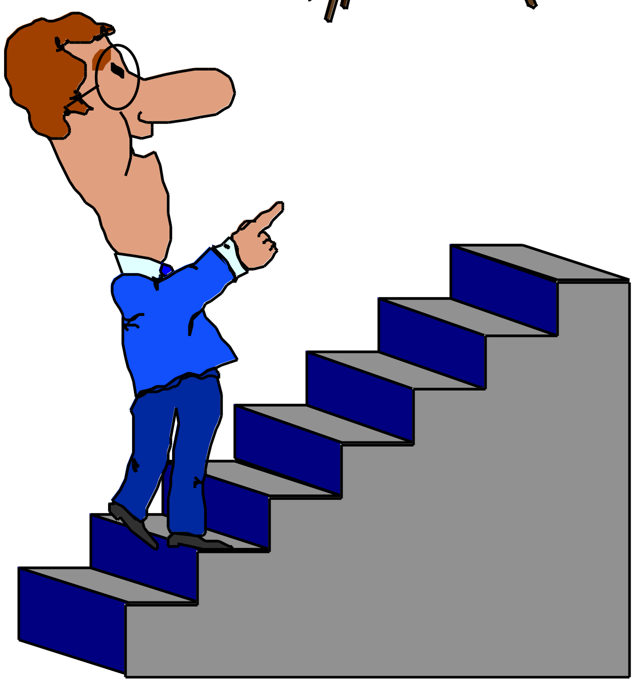
CS 252 Projects

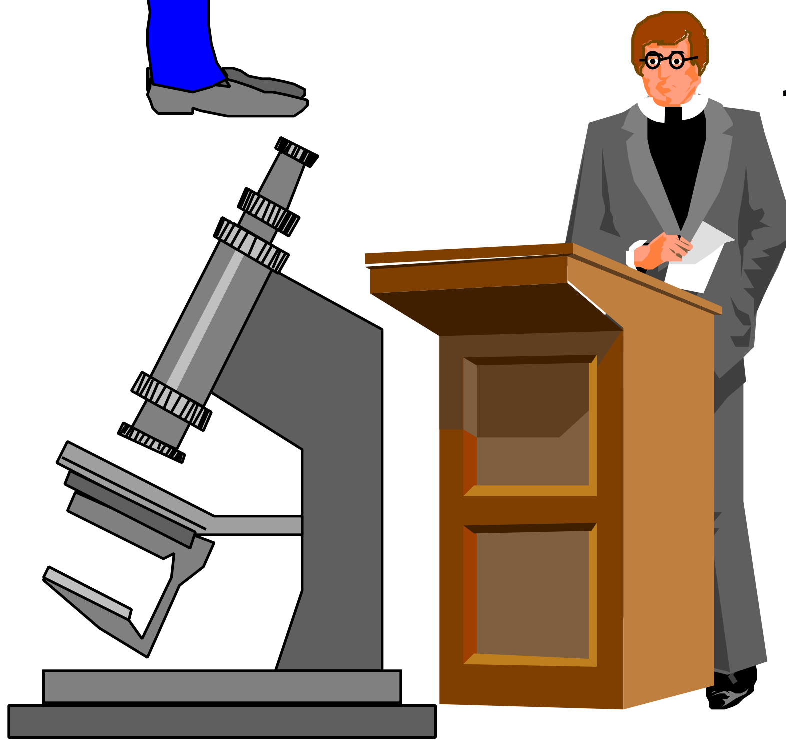
- Many, many interesting projects
- Several students and faculty said they enjoyed poster session and mentioned what great jobs you did
- Many capable of being turned into published papers, if you have the time
- You have seen the full conference cycle:
topic selection, investigation, real deadlines, poster session, written presentation

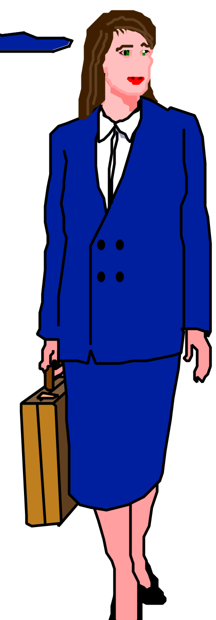
Doing Research: Don’t follow this Bad Career Advice

- Invent a Field and Stick to it
- Let Complexity be Your Guide
- Never be Proven Wrong
- Use the Computer Scientific Method
- Avoid Feedback
- Publishing Journal Papers IS Technology Transfer
- Write Many (Bad) Papers
- Give Bad Talks

Role Changes during Project







Alternatives to a Bad Career

- **Goal is to have impact:**
  Change way people do Computer Science & Engineering
  - **Evaluation of academic research uses bad benchmarks => skews academic behavior**
- **Many 3 - 5 year projects gives more chances for impact**
- **Feedback is key: seek out & value critics**
- **Do "Real Stuff": make sure you are solving some problem that someone cares about**
- **Taste is critical in selecting research problems, solutions, experiments, & communicating results; taste is acquired and improved by feedback**
- ***Students* are the coin of the academic realm**

Impact of Industry on Computer Architecture Research in the Future?

- **Will PCs drive out all traditional forms of hardware?**
- **Given cost of IC Fab line increasing to $1B investment, can anything but 80x86/PowerPC be justified economically? Video games? Set top units?**
- **What replaces the big computer (MPP/mainframe)? NOWs? Multiprocessor servers + Network Computers?**
- **Will parallel programming become commercially significant beyond databases and operating systems?**
- **Perhaps topics largely ignored will become focus of research:**
  - **Ease of Use, Manufacturing, Installation**
  - **Cost of Ownership**
  - **Fault Tolerance, Reliability**

CS&E Research in the Future?

- **Are processors beyond resources of universities to compete (like DRAMs)? see Alpha 21264**
- **What about compilers? operating systems? data bases?**
- **Should CS&E systems research move up a level, standing on shoulders rather than on toes?**
- **Does CS&E theory make sense as a separate entity (courses/conferences/journals) v. spectrum of practical to theoretical architecture/DB/OS/…?**

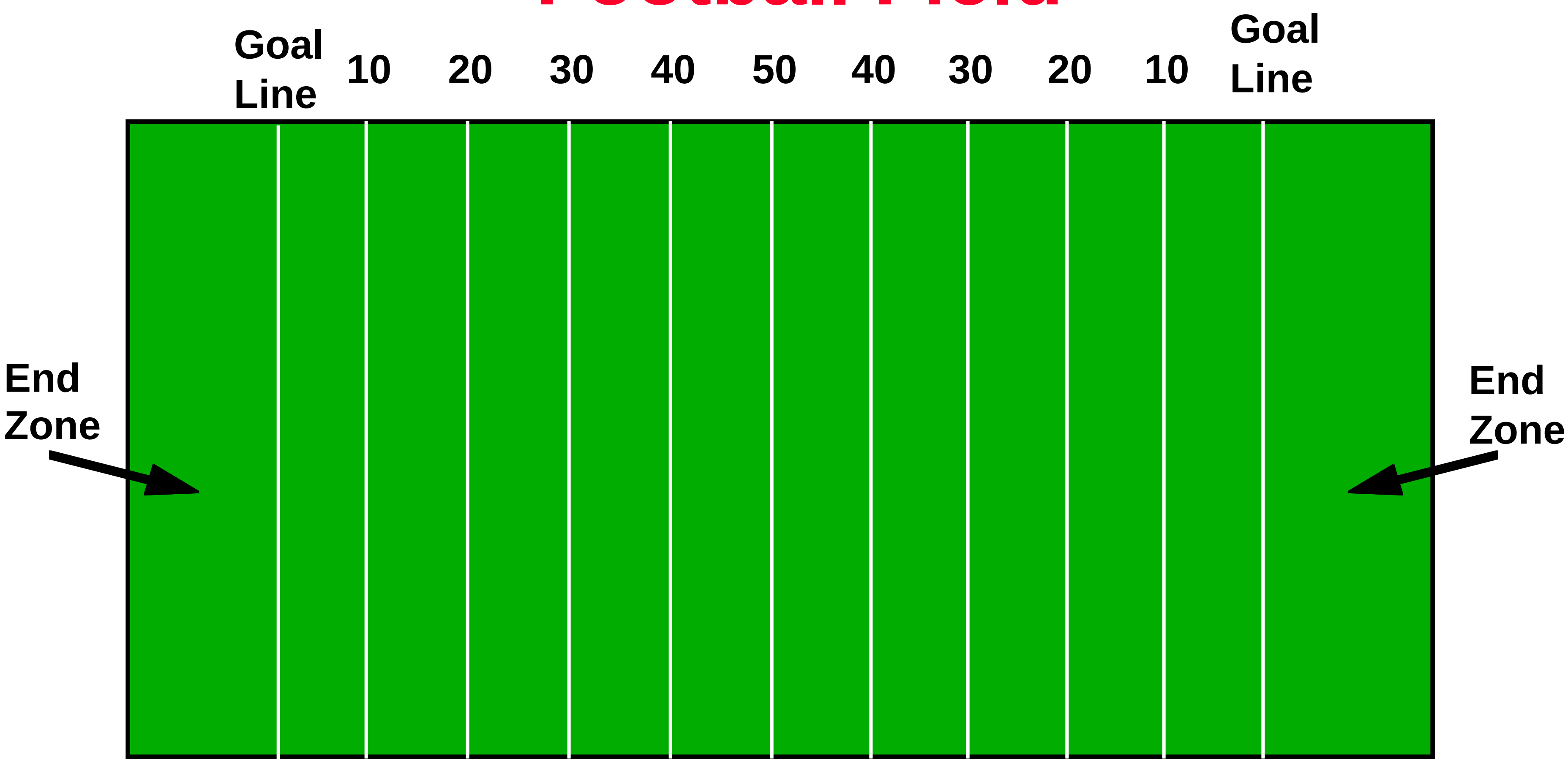
Support of CS&E Research in the Future?

- Re-evaluation of social contract between citizens and scientists has changed: transition from understanding-driven research that promises to somehow deliver a safer, healthier, and wealthier society to strategic research that helps directly with problems facing society: jobs, K-12 education, ...
  - Who will argue the research case in face of balanced budget?
- Will CS&E fair better than physics, chemistry?
  - Industrial Research increasing jobs for CS&E, radical cut back in other traditional sciences
- We are living that ancient Chinese curse: "May you live in interesting times."

Cal Cultural History: ABCs of American Football

- Started with soccer; still 11 on a team, 2 teams, 1 ball, on a field; object is to move ball into “goal”; most goals wins
- New World changes the rules to increase scoring:
  - Make goal bigger! (full width of field)
  - Carry ball with hands
  - Can toss ball to another player backwards or laterally (called a “lateral”) anytime and forwards (“a pass”) sometimes
- How to stop players carrying the ball? Grab them & knock them down by making knee hit the ground (“tackle”)
  - if drop ball (“fumble”), other players can pick it up and score
- Score by moving ball into goal (“cross the goal line” or “into the end zone”) scoring a “touchdown” (6 points), or kicking ball between 2 poles (“goal posts”) scoring a “field goal” (3, unless after touchdown = 1: “extra point”)
- Kick ball to other team after score (“kickoff”); laterals OK
- Game ends when no time left & person with ball is stopped

Football Field



The Spectacle of Football

- **Rose Bowl: Prestigious bonus game played January 1 if have a great year; preceeded by parade; national TV coverage**
- **Play nearby archrival for last game of season**
- **Cal's archrival is Stanford; stereotype is Private, Elitist, Snobs**
- **The Big Game: Cal vs. Stanford, winner gets a trophy ("The Axe") : Oldest rivalry west of Mississippi**
- **American college football is a spectacle**
  – **School colors (Cal: Blue & Gold; Stanford: Red & White)**
  – **School nicknames (Cal: Golden Bear; Stanford: Cardinal)**
  – **School mascot (Cal: Oski the bear; Stanford: a tree(!))**
  – **Leaders of cheers ("cheerleaders")**
- **"Bands" (orchestras that march) from both schools at games; before game, at halftime, after game**
  – **Stanford Band more like a drinking club; ≈ "Animal House"**
  – **Plays one song: "All Right Now"**
  – **Stanford used to yell "boring" at band during Cal's performance**

1929 Rose Bowl Game

- **Cal vs. Georgia Tech**
- **Cal going left to right (==>), GeorgiaTech right to left (<==)**
- **Georgia Tech player fumbles football**
- **Cal player, Roy Reigel, picks up football and tries to avoid Georgia Tech players**
- **Let’s see what happens on video**

1982 Big Game

- “There has never been anything in the history of college football to equal it for sheer madness.” ***Sports Illustrated***
- Stanford “Quarterback” (person who passes the ball forward) is John Elway, best ever? Goes on to be a professional All Star football player (still playing today)
- Cal Quarterback is Gail Gilbert, goes on to be a non-starting professional football player (still playing today)
- Stanford lost 4 games at end of game; if Stanford wins, it goes to a bowl game; Stanford is favored to win
- Let’s see what happens on video

Notes About "The Play"

- Cal only had 10 men on the field; last second another came on (170 pound Steve Dunn #3) & makes key 1st block
- Kevin Moen #26: never scored in 4 years at Cal
  - laterals to Rodgers (and doesn't give up)
- Richard Rodgers #5: "Don't fall with the ball." (Never give up)
  - laterals to Garner
- Dwight Garner #43: 5'9" 185 pound running back
  - almost tackled, laterals to Ford
- Mariet Ford #1: 5'9", 165 pound wide receiver
  - leg cramps, overhead lateral to Moen & blocks 3 players
- Moen cuts through Stanford band into end zone
- On the field for Stanford during touchdown: 22 football players, 3 cheerleaders, 3 members of Axe committee, 144 member Stanford band (172 for Stanford v. 11 for Cal)
- "Weakest part of the Stanford defense was the woodwinds."
- 4 Cal football players play + Stanford Trombone player (Gary Tyrrell) hold reunion every year at big game time

Your Cal Cultural History

- **Cal students/alumni heritage is the greatest college football plays in > 100 years**
- **Cal students/alumni work hard and play hard**
- **Cal students/alumni take pity on Stanford students/alumni**
- **Cal students/alumni never give up!**
- **Cal students/alumni triumph over great odds!**