

# Computational Science and Engineering at Berkeley

Jim Demmel

EECS & Math Departments

[www.cs.berkeley.edu/~demmel](http://www.cs.berkeley.edu/~demmel)

# 4 Big Events

- Establishment of a new graduate program in Computational Science and Engineering (CSE)
- “Multicore revolution”, requiring all software (where performance matters!) to change
  - ParLab
- New Buildings to house research activities
  - CITRIS and CRT
- Cloud computing
  - RadLab

# Outline

- New “Designated Emphasis” in CSE
  - Goals
  - Participants (112 faculty – so far)
  - Resources and Opportunities
- A few research projects
  - Computational Medicine – treating stroke

# Designated Emphasis (DE) in CSE

- New “graduate minor” – started July 1, 2008
  - Much easier than a new department!
- Motivation
  - Widespread need to train PhD students in CSE
  - Opportunities for collaboration, across campus, LBNL, industry
  - 18 (20) departments, 85 (112) faculty signed up (so far)
- Graduate students participate by
  - Getting accepted into existing department/program
  - Taking CSE course requirements
  - Qualifying examination with CSE component
  - Thesis with CSE component
  - Receive “PhD in X with a DE in CSE”
  - Details at [cse.berkeley.edu](http://cse.berkeley.edu)

## Participating Departments (1/2)

( # faculty by “primary affiliation”, # courses )

- Astronomy (7,3)
- Bioengineering (3,1)
- Biostatistics (2,0)
- Chemical Engineering (6,0)
- Chemistry (8,1)
- Civil and Environmental Engineering (7,8)
- Earth and Planetary Science (6,3)
- EECS (19,14)
- IEOR (5,5)
- School of Information (1,0)

## Participating Departments (2/2)

( # faculty by “primary affiliation”, # courses )

- Integrative Biology (1,0)
- Materials Science and Engineering (2,1)
- Mathematics (15, 4)
- Mechanical Engineering (9, 6)
- Neuroscience (7,1)
- Nuclear Engineering (2,1)
- Physics (1,1)
- Political Science (2,0)
- Statistics (5, 11)
- New: Biostatistics, Public Health

# Course Structure

- 3 kinds of students, course requirements
  - CS , Math, “Applications”
- Each kind of student has 3 course requirements in other two fields
  - Goal: enforce cross-disciplinary training
  - Ex: “Applications” students takes courses from EECS, Math, Statistics, IEOR
- We have \$ to support new course development
  - Many proposed, some underway...

# Example Course – CS267

- “Applications of Parallel Computing”
  - see [www.cs.berkeley.edu/~demmel](http://www.cs.berkeley.edu/~demmel)
- Taught every Spring, this semester to:
  - UC Berkeley, UC Merced, UC Santa Cruz UC Davis
  - All lectures on web (slides + video), freely available
  - 38 Grad + 5 Undergrad
  - 2/3 from EECS, rest ME, Chem, BioE, BioPhys, IntBio
- Google “parallel computing course”, with “I’m feeling lucky”, to get older version
- 3 day “bootcamp” version in August

# A few sample CS267 Class Projects

(all posters and video on web page)

- Content based image recognition
  - “Find me other pictures of the person in this picture”
- Faster molecular dynamics, applied to Alzheimer’s Disease
- Better speech recognition through a faster “inference engine”
- Faster algorithms to tolerate errors in new genome sequencers
- Faster simulation of marine zooplankton population
- Sharing cell-phone bandwidth for faster transfers

# Resources (1/4)

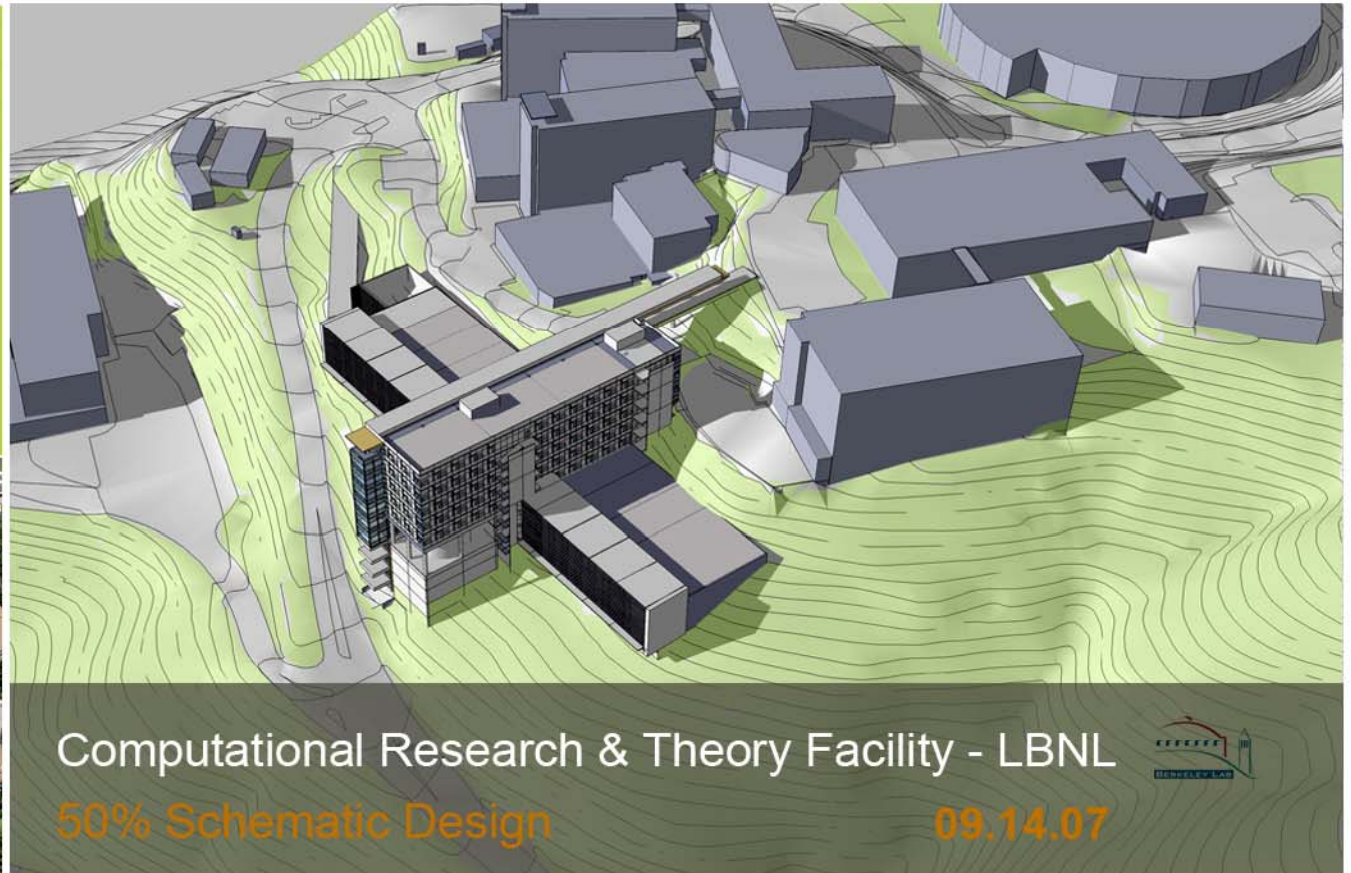
- Executive Director Masoud Nikravesh
- Money
  - Annual support from L&S and COE
  - Some one time support, for course development
  - More from Chemistry and VCR
  - CITRIS
    - Research initiation funds
    - Access to corporate partners
    - GSI support, broadcast to other campuses

# Resources (2/4)

- Space
  - CITRIS Building - welcome!
    - staff offices, seminar, machine room
  - LBNL CRT Building

# New Building to Support CSE at UC Berkeley and LBNL

Ideas + buildings  
that honor the broader  
goals of society



Computational Research & Theory Facility - LBNL

50% Schematic Design

09.14.07



\$112M, 32K ft<sup>2</sup> computer room, 45K ft<sup>2</sup> office space  
Move in ~2012

# Resources (3/4)

- Existing computing resources
  - EECS clusters
    - [www.millennium.berkeley.edu](http://www.millennium.berkeley.edu)
  - LBNL / NERSC
    - Start-up allocations on supercomputers
      - Needs to be of potential interest to DOE
    - [www.nersc.gov](http://www.nersc.gov)
- New computing resources
  - “Cloud computing” from Yahoo!
    - [cloud.citris-uc.org](http://cloud.citris-uc.org)
  - Looking for more

# Resources (4/4)

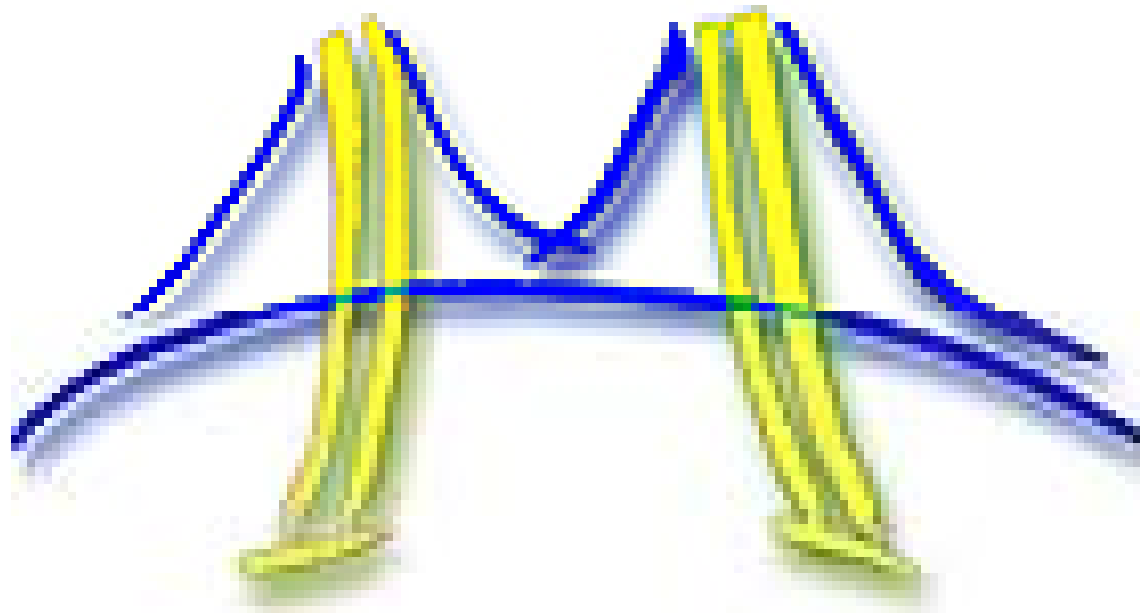
- LBNL
  - Besides space and cycles: Expert CSE advice, collaborators, short courses
  - Internships for students (grad or undergrad)
- MSRI –
  - Mathematical Sciences Research Institute
  - NSF funded institute, next to campus
  - Workshops, short courses

# Possible Research Topics for “Cloud” (1/2)

- *A small* selection from among the 112 faculty
  - Some ok on “cloud,” others may require tighter coupling
- Astronomy (10 faculty)
  - Some simulations (large scale, many smaller scale), some large data sets (up to terabytes/day)
- Chemistry and Chemical Engineering (12 faculty)
  - Some large-scale simulations, some less tightly coupled
    - Ex: New materials for energy via QMC, chemical database screening
- Neuroscience and Cognitive Computing (8 faculty)
  - Some large scale simulations (of brain, auditory system)
  - Some large data set analysis ([crcns.org](http://crcns.org))

# Possible Research Topics for “Cloud” (2/2)

- Computational systems biology (9 faculty)
  - “Digital Human”, many layers of simulation
- Econ/EECS/IEOR/Math/PoliSci/Stat (9 faculty)
  - Statistical analysis and visualization of large scale heterogeneous data bases of economic, financial, social data
  - Ex: [statnews.eecs.berkeley.edu/about/project](http://statnews.eecs.berkeley.edu/about/project) for news analysis
- Economics (8 faculty, including 1 Nobelist)
  - Econometric and social modeling
- Ultra-efficient Climate Computer (7 faculty + staff)
  - Joint with LBNL
  - 100x lower power than current supercomputers



## Overview of the Parallel Laboratory

Krste Asanovic, Ras Bodik, Jim Demmel,  
Tony Keaveny, Kurt Keutzer, John Kubiawicz, Edward Lee,  
Nelson Morgan, George Necula, Dave Patterson,  
Koushik Sen, John Wawrzynek, David Wessel, Kathy Yelick

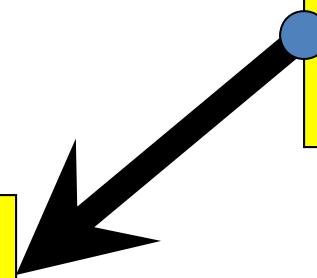
[parlab.eecs.berkeley.edu](http://parlab.eecs.berkeley.edu)

# The Vision...

Medical Imaging  
+  
Computation  
+

**Biomechanics**

**CLINICAL  
FUNCTION**



=  
Improved Healthcare

{  
Diagnostics  
Surgical Planning  
Management

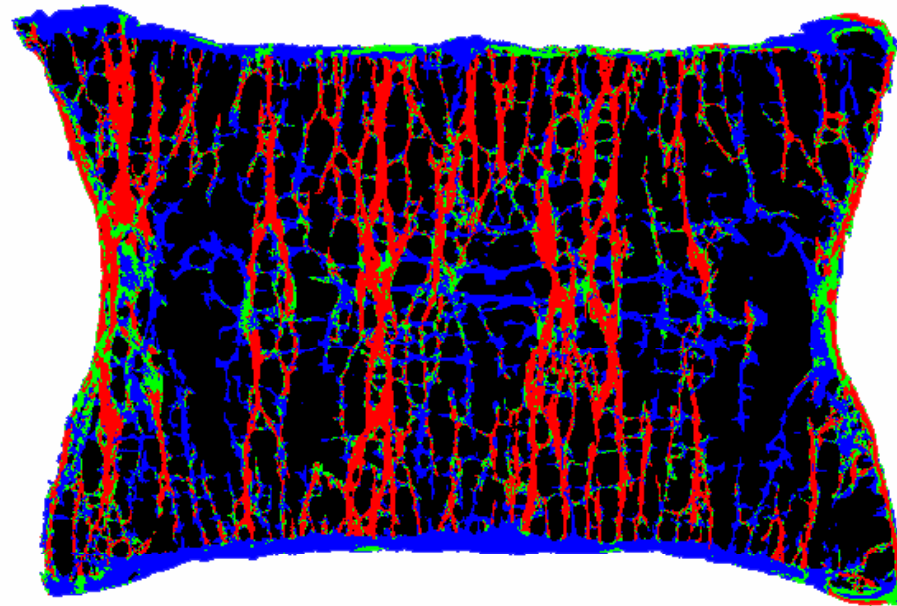
# Medicine and Biomechanics

- Cardiovascular disease (\$394B)
- Arthritis (\$128B)
- Osteoporosis (\$17B)
- Chronic back pain (\$30–70B)
- Repetitive injury



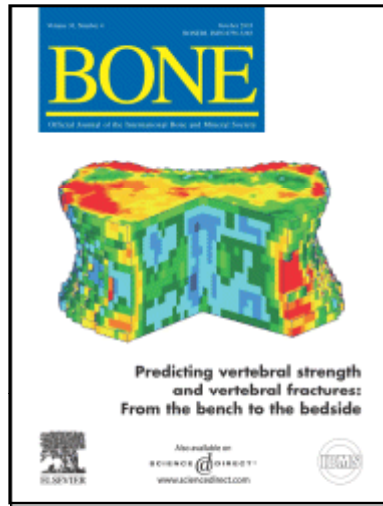
# Osteoporosis — Micro-mechanics

- Large parallel models (Gordon Bell Prize 2004)

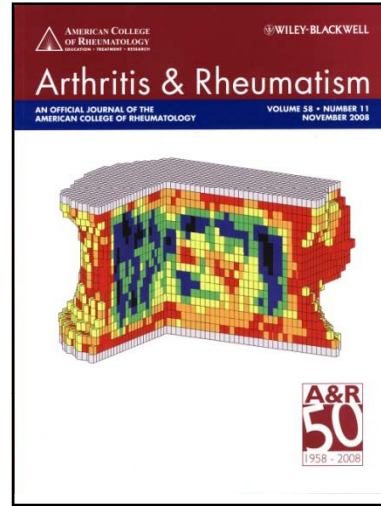


500M

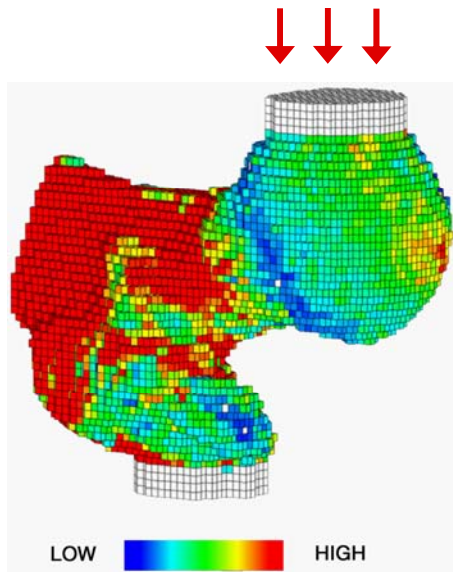
# Osteoporosis — Clinical: o.n. diagnostics



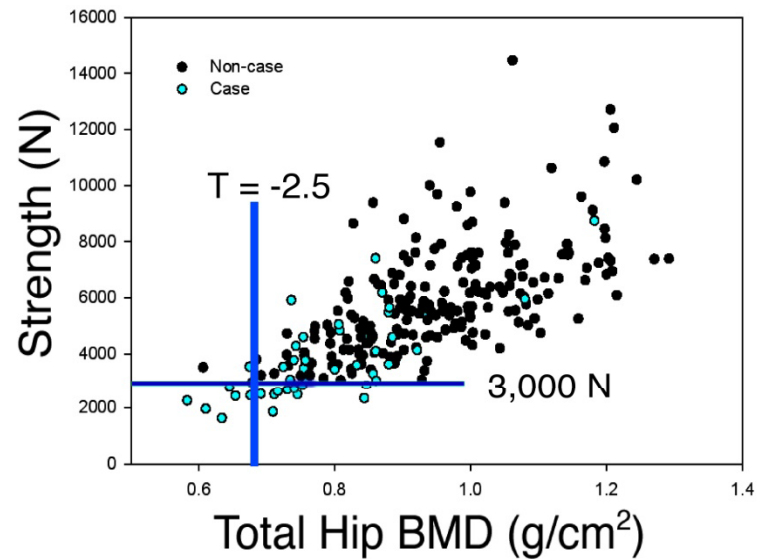
2003



2008

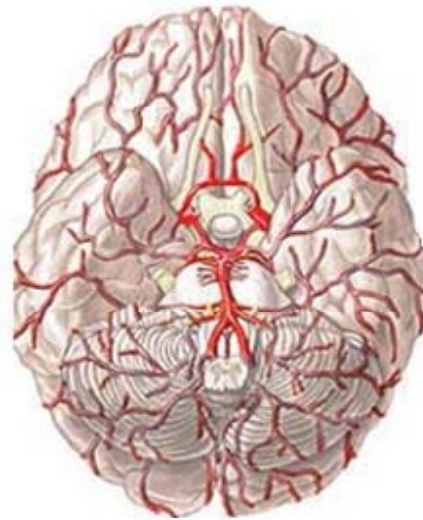
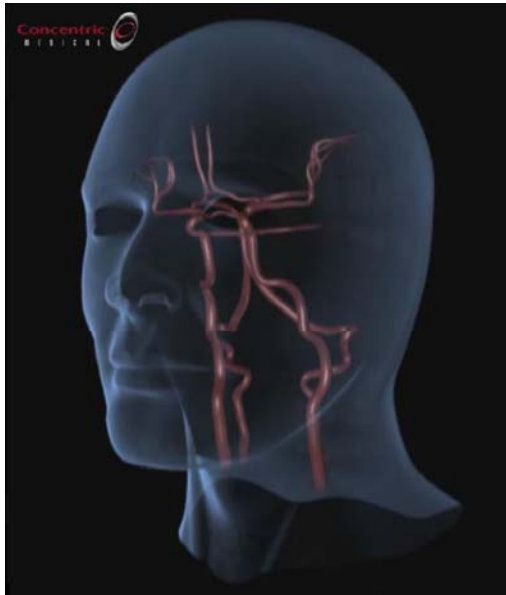


50K



# Health Application: Stroke Treatment

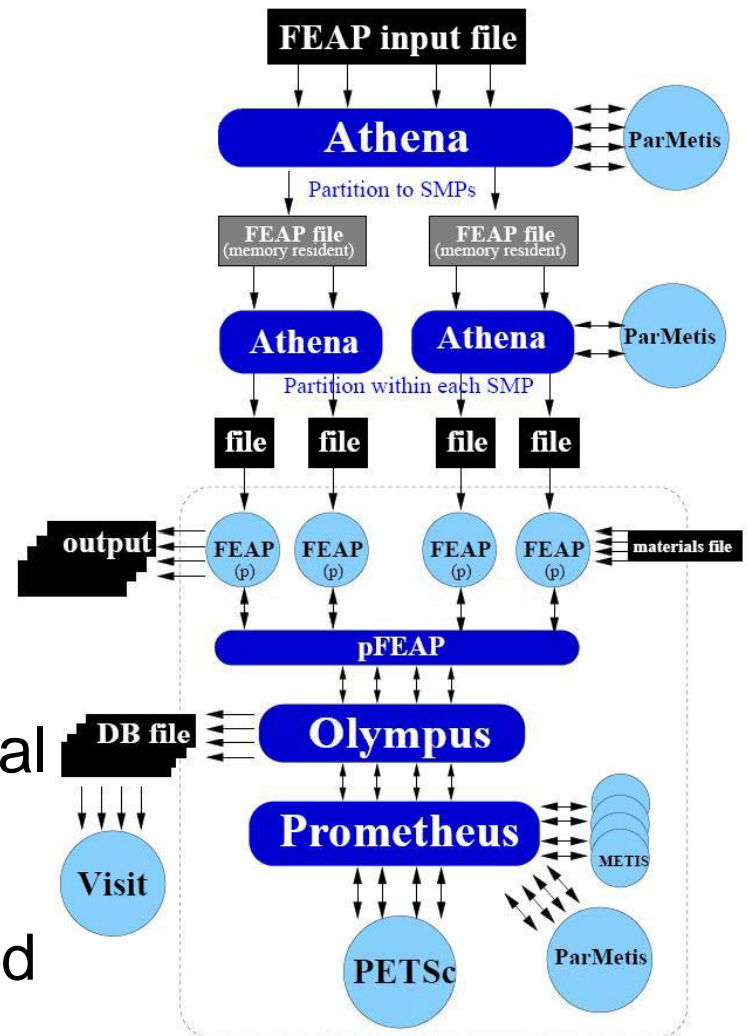
(Tony Keaveny)



Bottom view of brain

© ADAM, Inc.

- Stroke treatment time-critical, need supercomputer performance in hospital
- Goal: First true 3D Fluid-Solid Interaction analysis of Circle of Willis
- Based on existing codes for distributed clusters



# The Parlab Health-App Team

## **Primary Faculty**

Tony Keaveny  
Jim Demmel  
Kathy Yelick  
Panos Papadopoulos

## **Other Faculty**

Max Wintermark  
David Saloner  
Stan Berger  
Mohammad Mofrad  
Mark Adams

## **LBL Collaborators**

Phil Colella  
Terry Ligocki  
Brian van Straalen  
Dan Graves

## **Students**

Meriem Ben Salah  
Razvan Carbunescu  
Mehrzaad Tartibi  
Chris Wilkens  
Andrew Gearhart

# Music and Hearing Application

(David Wessel)

- Musicians have an insatiable appetite for computation + real-time demands
  - More channels, instruments, more processing, more interaction!
  - Latency must be low (5 ms)
  - Must be reliable (No clicks!)

## 1. Music Enhancer

- Enhanced sound delivery systems for home sound systems using large microphone and speaker arrays
- Laptop/Handheld recreate 3D sound over ear buds

## 2. Hearing Augmenter

- Handheld as accelerator for hearing aid

## 3. Novel Instrument User Interface

- New composition and performance systems beyond keyboards
- Input device for Laptop/Handheld



Berkeley Center for New Music and Audio Technology (CNMAT) created a compact loudspeaker array: 10-inch-diameter icosahedron incorporating 120 tweeters.