

# Tsunami or Sea Change?

## Responding to the Explosion of Student Interest in Computer Science

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**NCWIT 10<sup>th</sup> Anniversary Summit, May 2014**

**CRA Conference at Snowbird, July 2014**

(Updated 7/23/2014 following CRA Conference at Snowbird)

<http://lazowska.cs.washington.edu/NCWIT.pdf> or [Snowbird.pdf](#)



## Today

- Short presentation of trends
- Open discussion
  - Best practices: how to respond?
  - What's different this time around, and how can we demonstrate it?
  - A proactive agenda: what can we and our disciplinary organizations (CRA, CCC, ACM, NSF, CSTB, ...) do?





# Introductory course enrollments are exploding

SECTIONS HOME SEARCH The New York Times

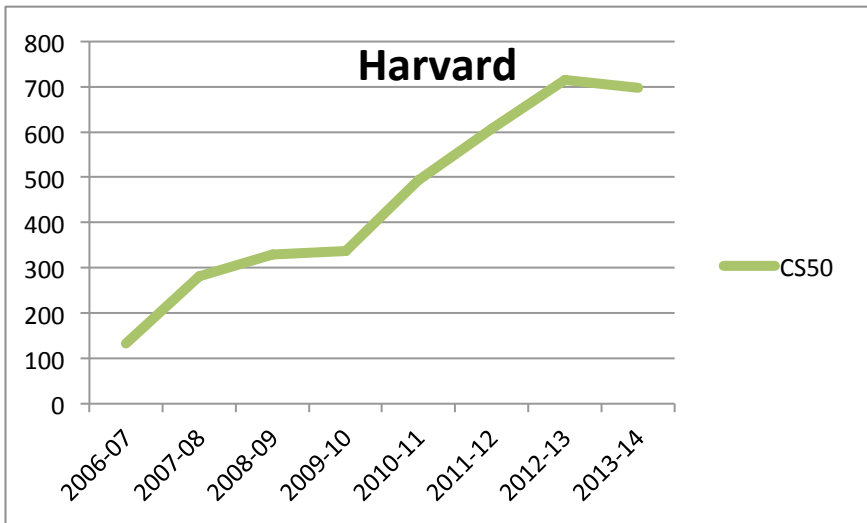
EDUCATION LIFE

## 10 Courses With a Twist

By LAURA PAPPANO APRIL 8, 2014

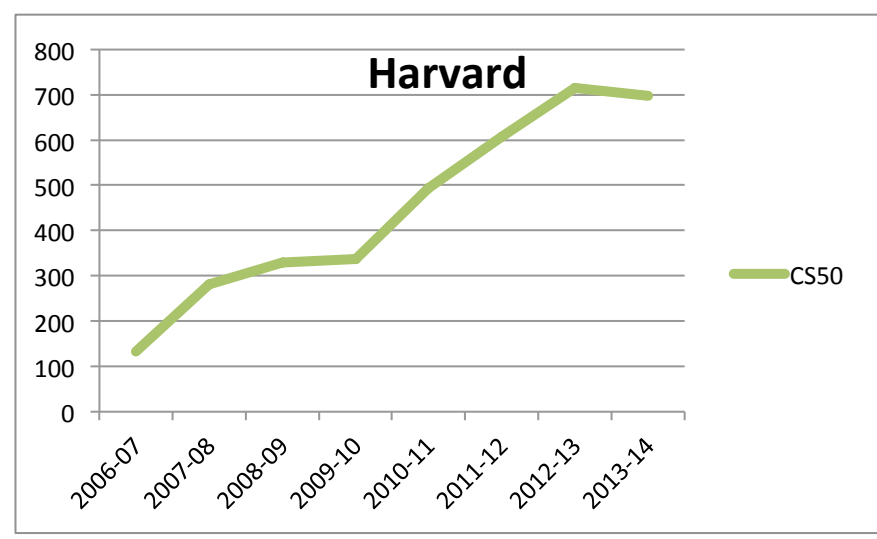
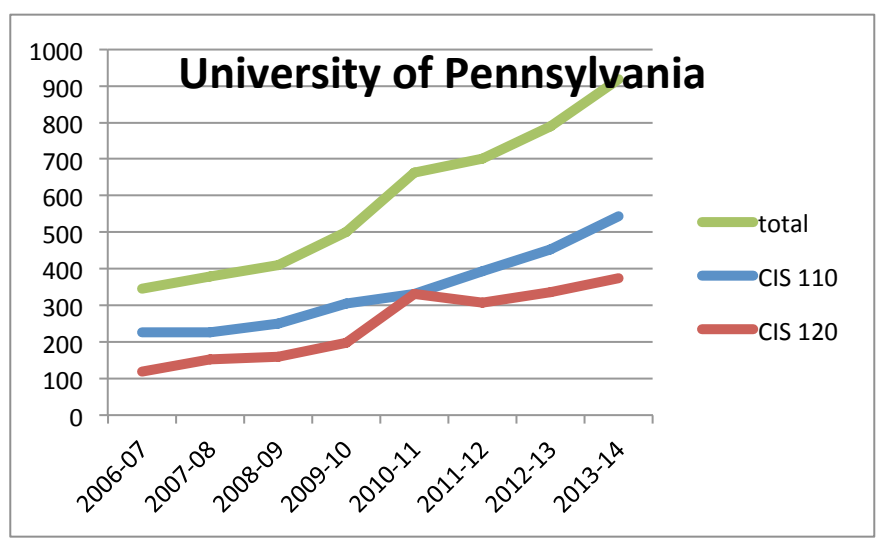
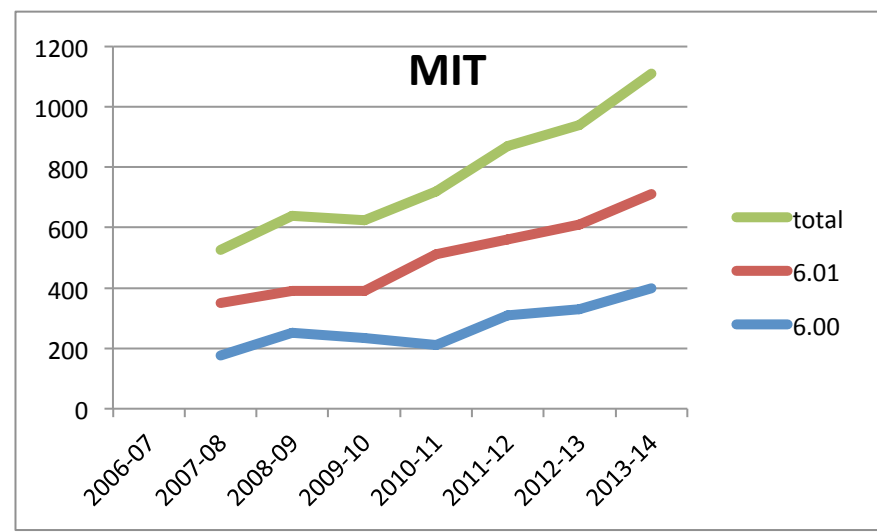
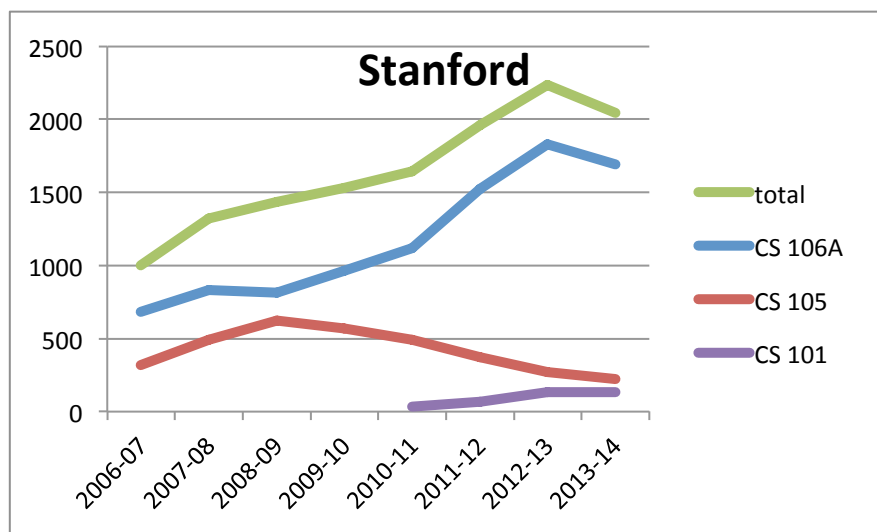


**FLASH AND DRIVE** With 700 students, David J. Malan's computer science course is one of Harvard's most popular.  
Joseph Ong



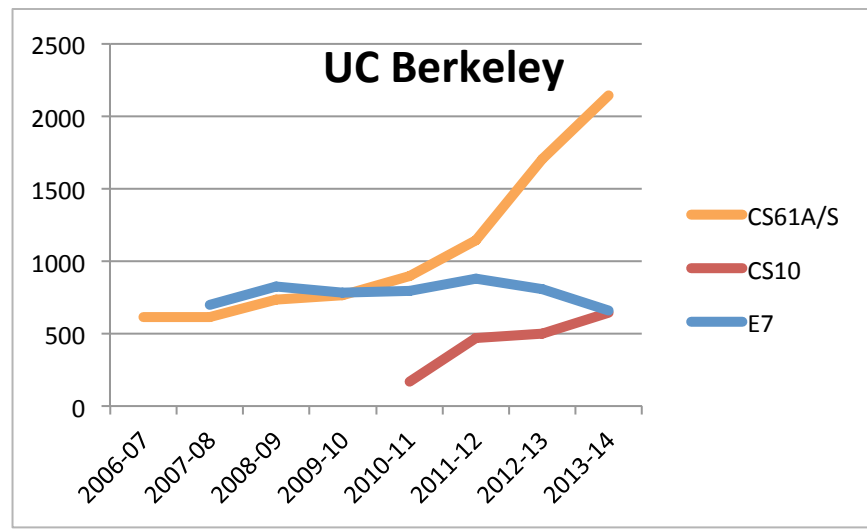
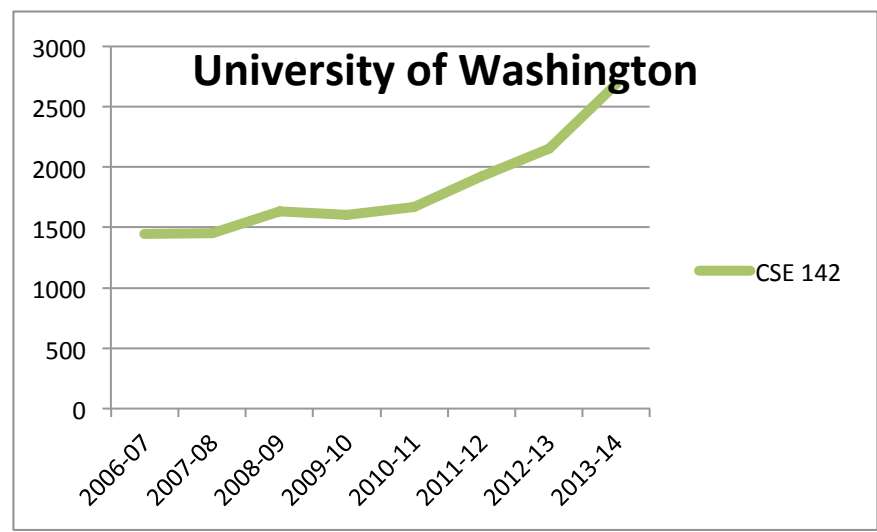
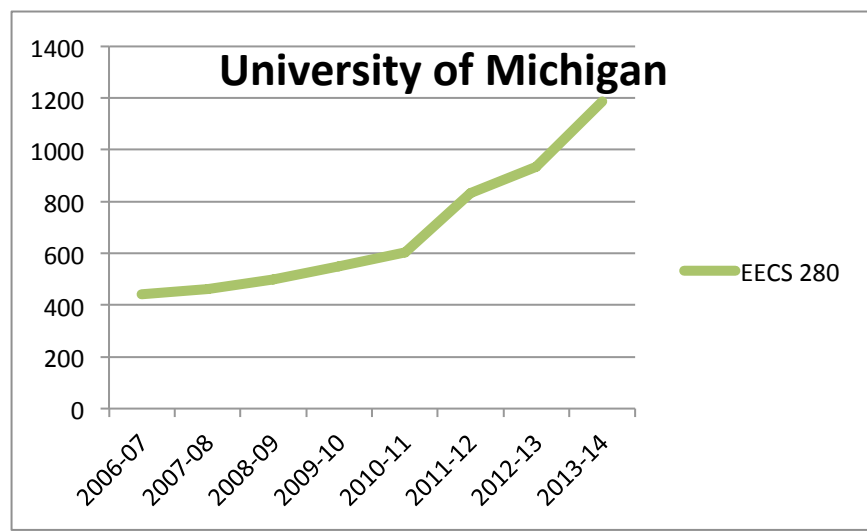


# Not just at Harvard



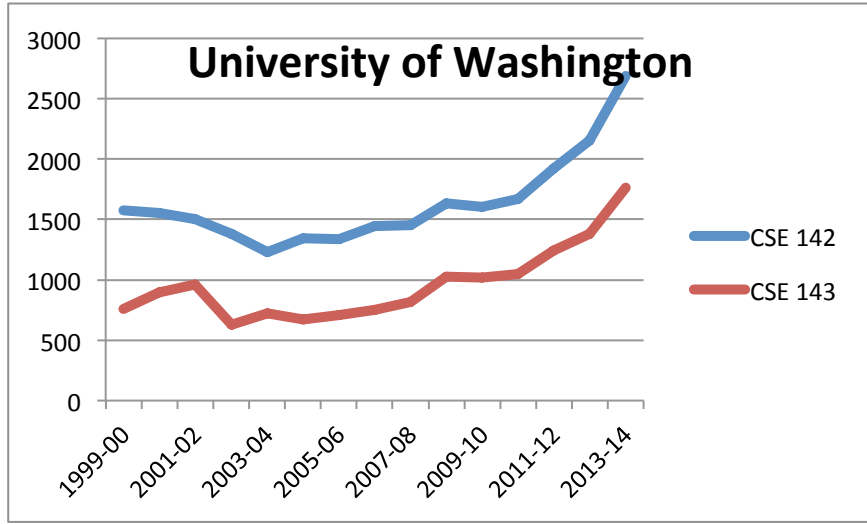


# Not just at elite private institutions



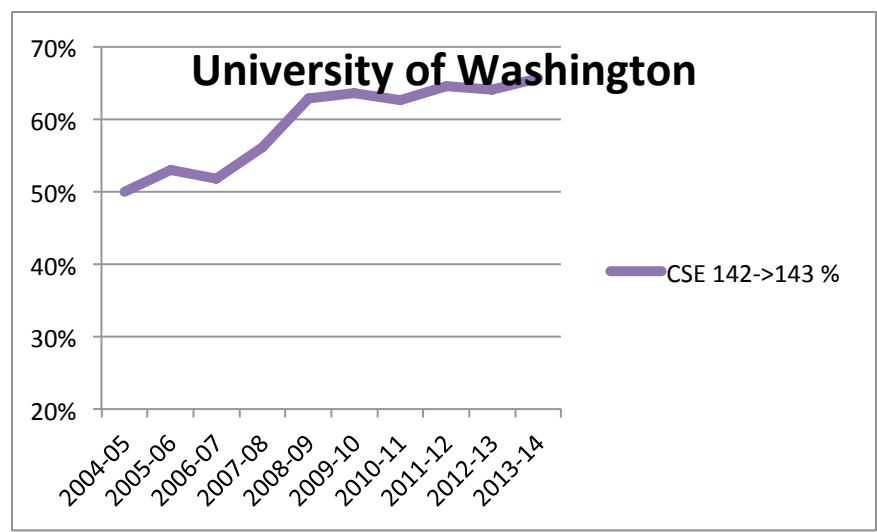


# These enrollments are blowing past previous highs



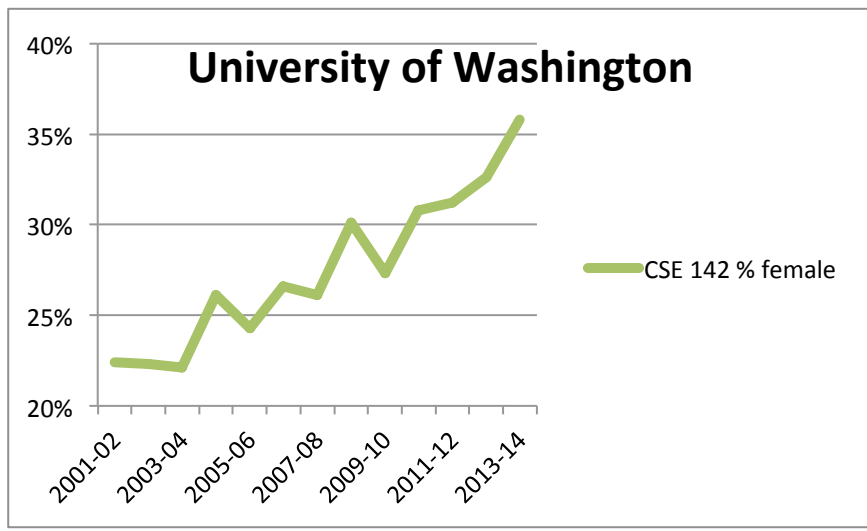


# Increasing proportions of students are taking second courses





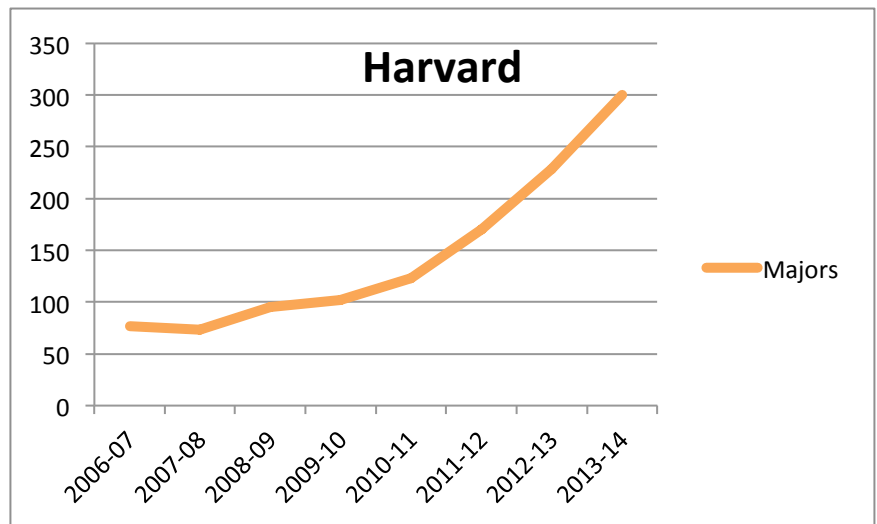
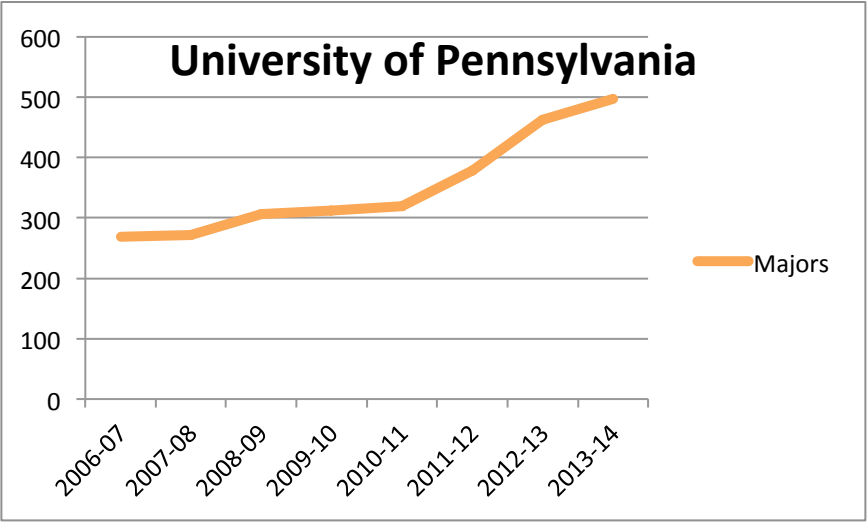
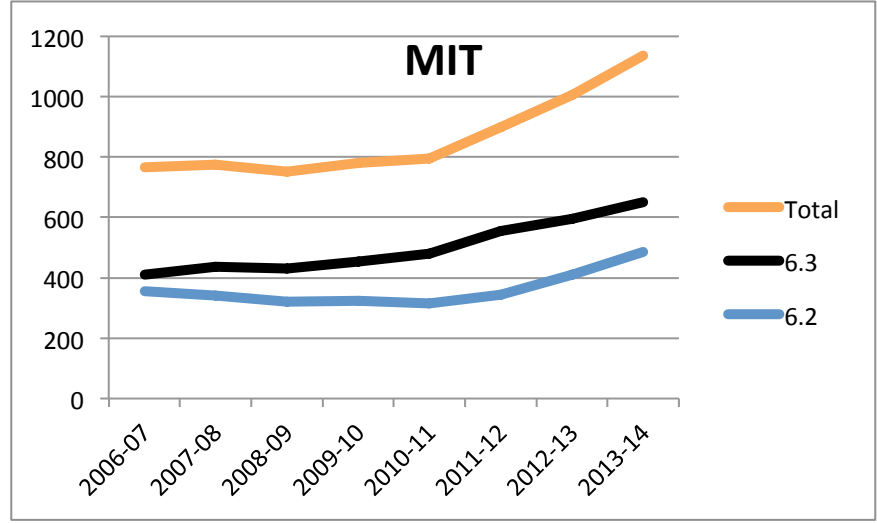
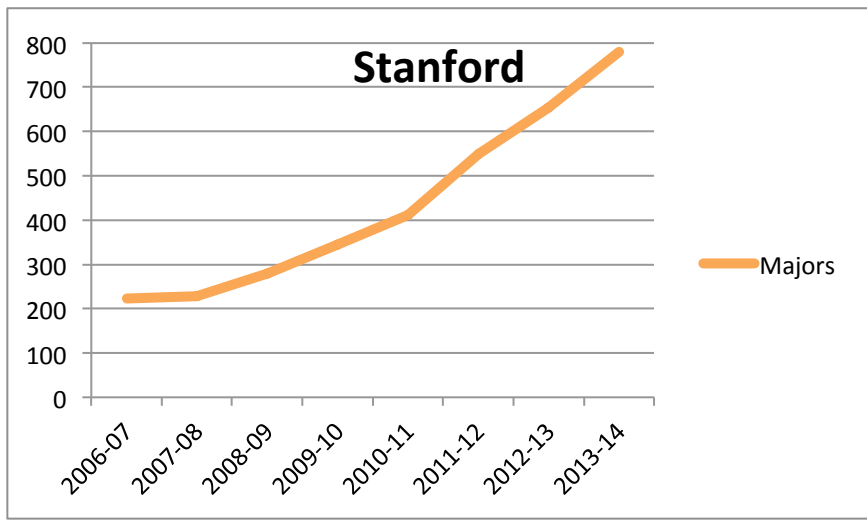
# In at least some cases, female participation is increasing







# Demand for the major is increasing





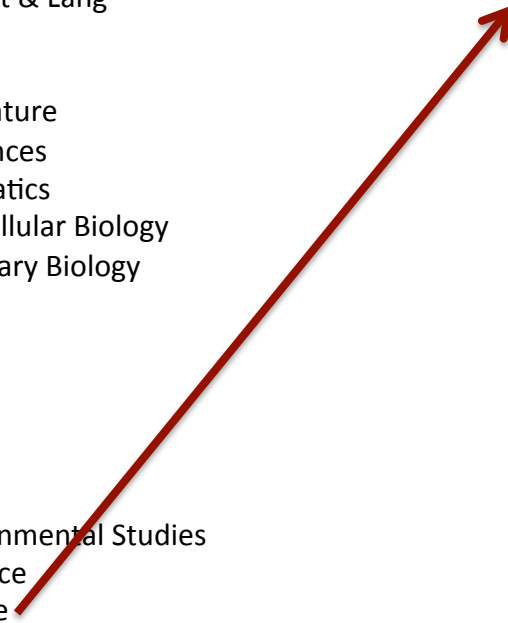
## Top 25 concentrations at Harvard

### 2007-08

Economics  
Government  
Social Studies  
Psychology (PSSR)  
English & Amer Lit & Lang  
History  
Anthropology  
History and Literature  
Biochemical Sciences  
Applied Mathematics  
Molecular and Cellular Biology  
Human Evolutionary Biology  
Neurobiology  
Biology  
Mathematics  
Sociology  
Chemistry  
Physics  
Visual and Environmental Studies  
History and Science  
Computer Science  
Engineering and Applied Science (AB)  
Chemical & Physical Biology  
Environ. Sci & Pub Policy  
Fine Arts / History of Art & Arch

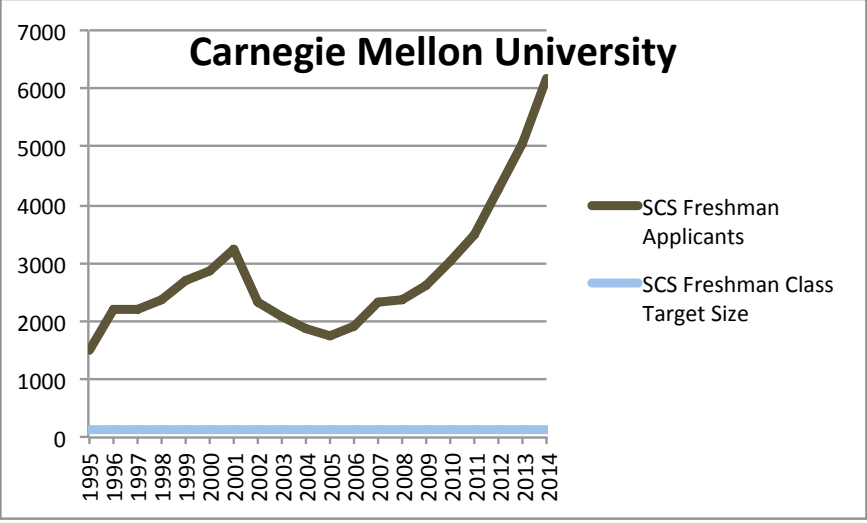
### 2013-14

Economics  
Government  
Social Studies  
Psychology (PSSR)  
Computer Science  
Applied Mathematics  
Neurobiology  
History  
English  
Human Developmental & Regener. Biol.  
Sociology  
History and Literature  
Statistics  
Human Evolutionary Biology  
Organismic & Evolutionary Biology  
History and Science  
Chemistry  
Mathematics  
Physics  
Molecular and Cellular Biology  
Engineering and Applied Science (SB)  
Anthropology  
Fine Arts / History of Art & Arch  
Biomedical Engineering  
Visual and Environmental Studies





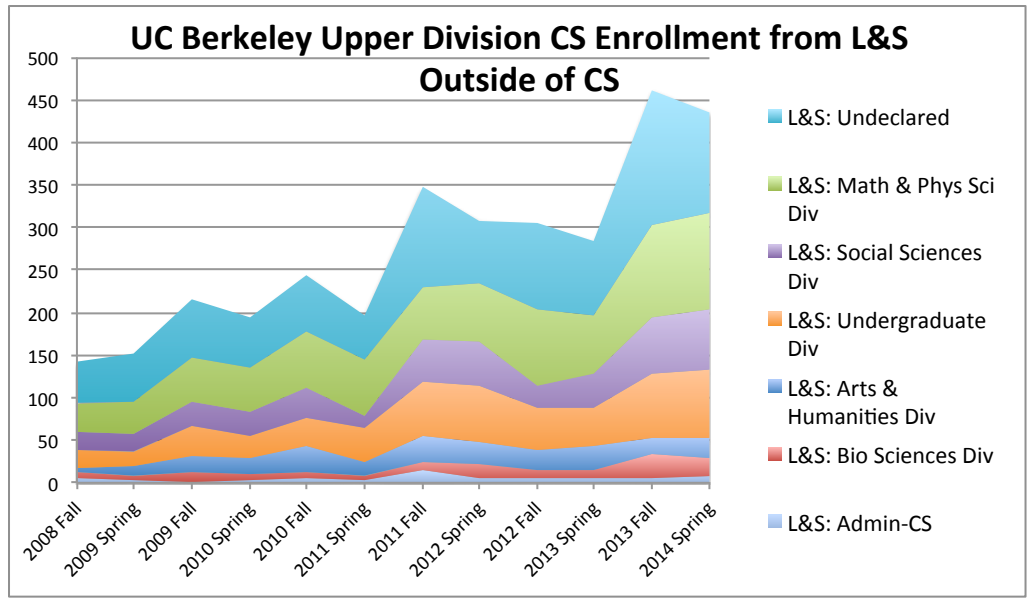
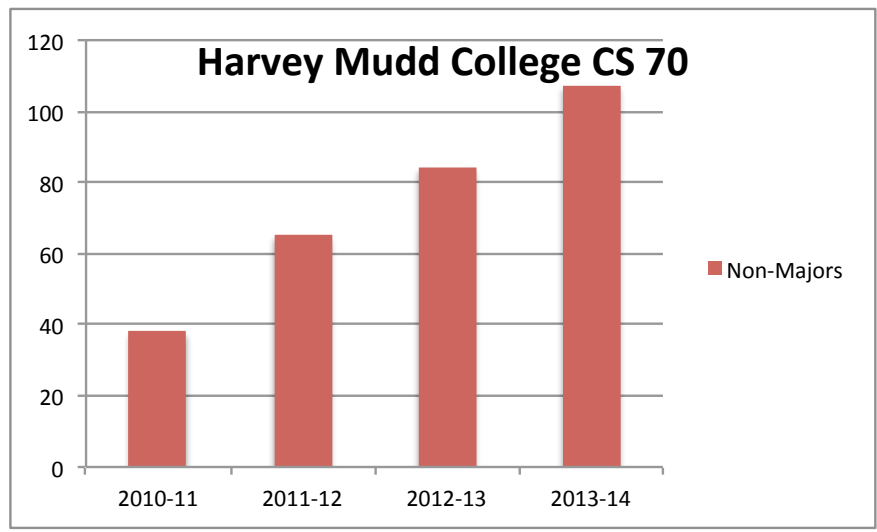
# CMU freshman applicants



Dot-com peak: 3,237  
Dot-bust trough: 1,732  
Most recent year: 6,174  
Target enrollment: 135  
(+ ~40 upper-division transfers)

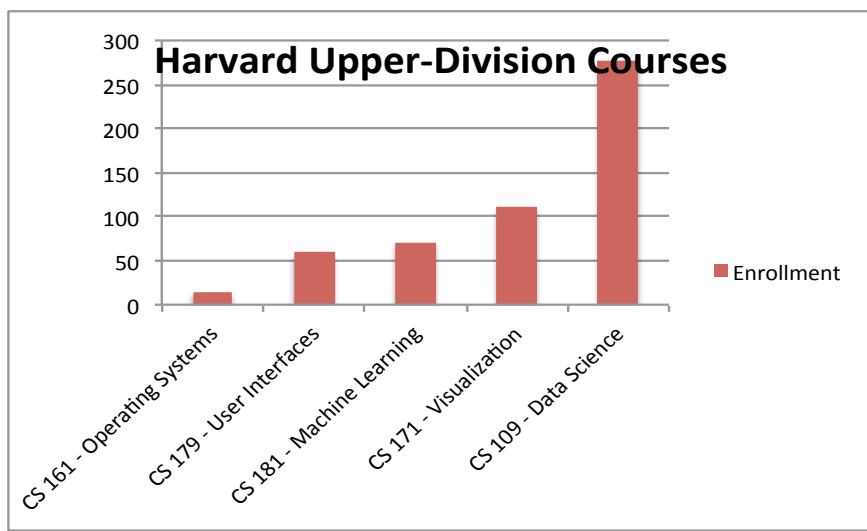
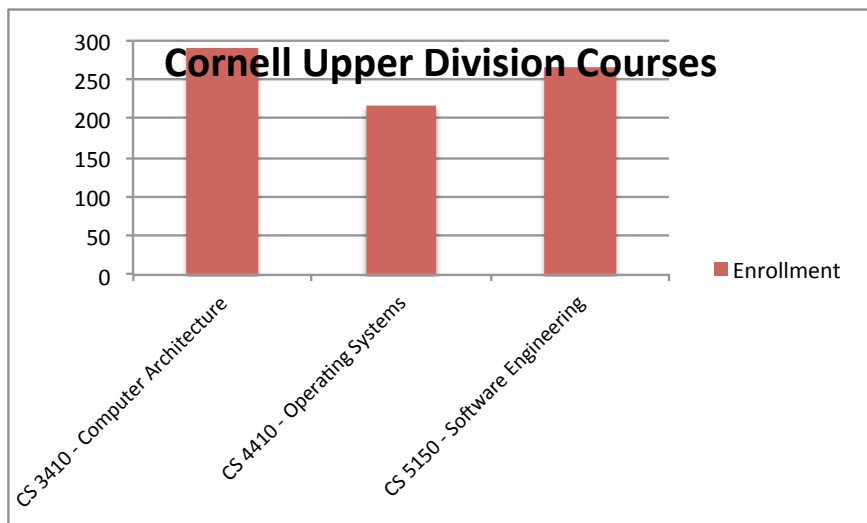


# Non-major demand for upper-division courses is increasing, also



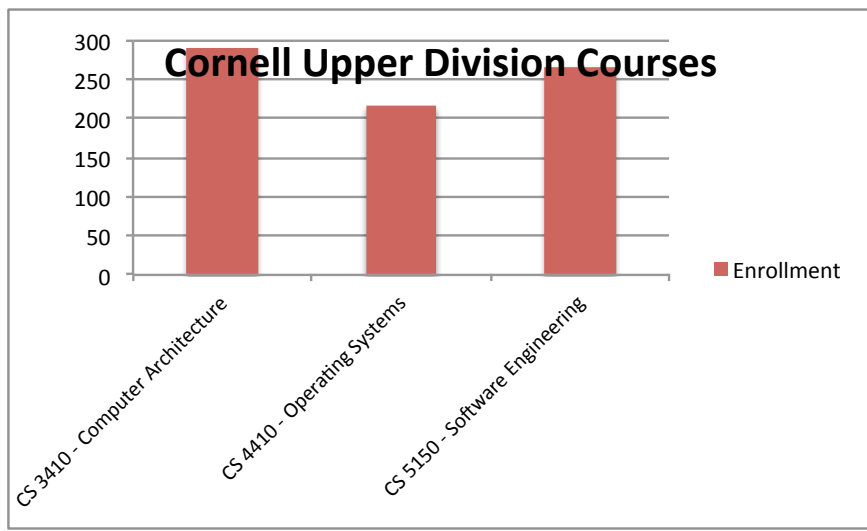


# Upper-division class sizes are going through the roof

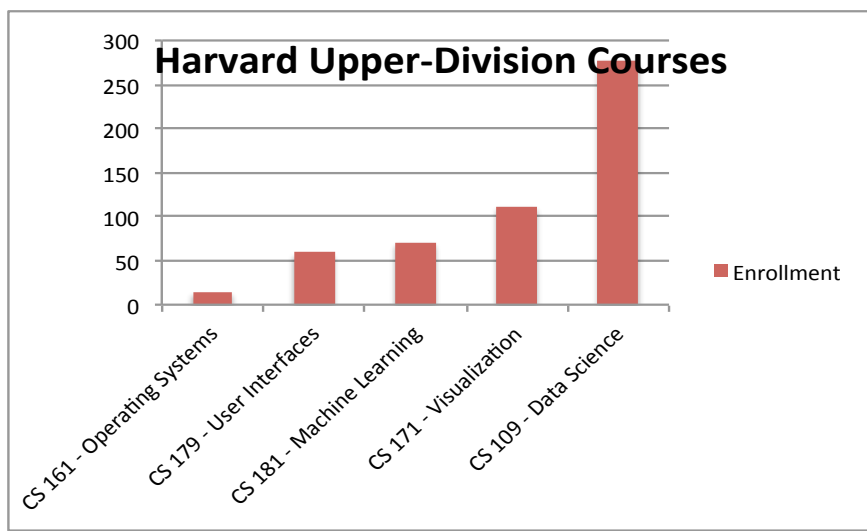




# Upper-division class sizes are going through the roof



## CS229 Machine Learning Autumn 2013



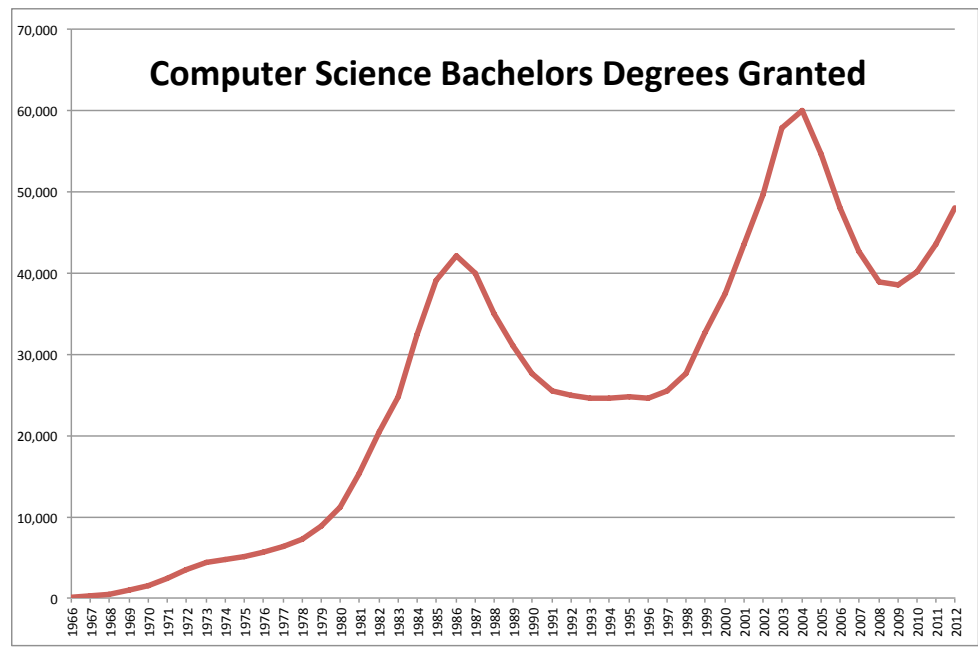
*760 students!*



Why is this man smiling?



# We're all familiar with cycles in demand





## But this time, it truly feels different

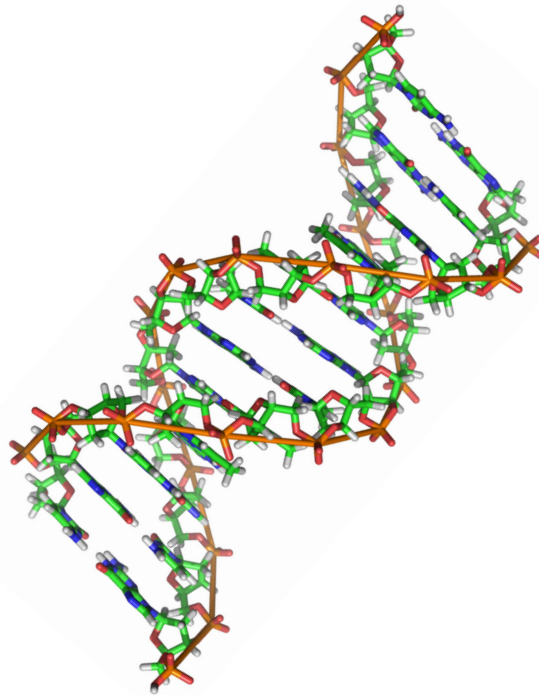
- Students are figuring out that every 21<sup>st</sup> century citizen needs to have facility with “computational thinking” – problem analysis and decomposition (stepwise refinement), abstraction, algorithmic thinking, algorithmic expression, stepwise fault isolation (debugging), modeling – driving introductory course demand
  - Programming is the hands-on, inquiry-based way that we teach computational thinking and the principles of computer science







- Students are figuring out that fields from Anthropology to Zoology are becoming *information* fields, and that those who can bend the power of the computer to their will – computational thinking, but also computer science in greater depth – will be positioned for greater success than those who can't





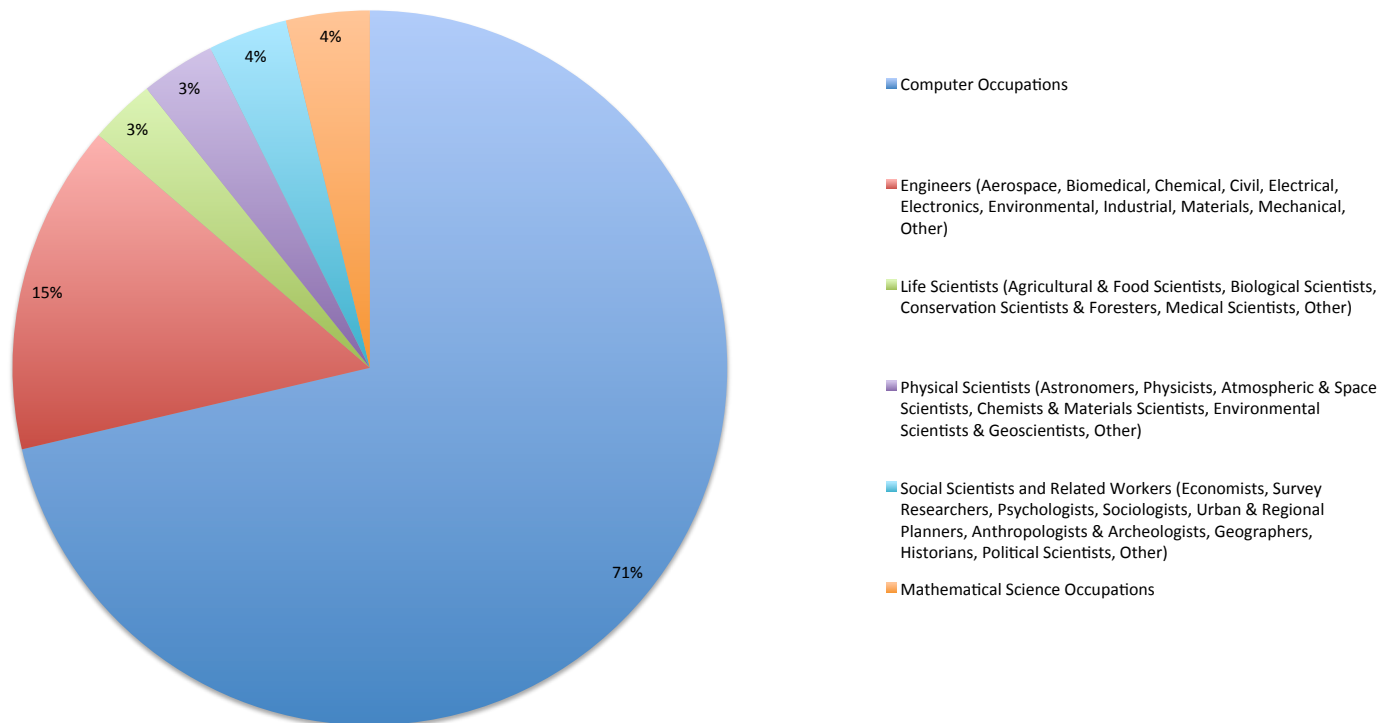
- Students are figuring out that computer science is not Dilbert – it’s an intellectually exciting, highly creative and interactive, “power to change the world” field





- Students are figuring out that all of the STEM jobs are in computer science

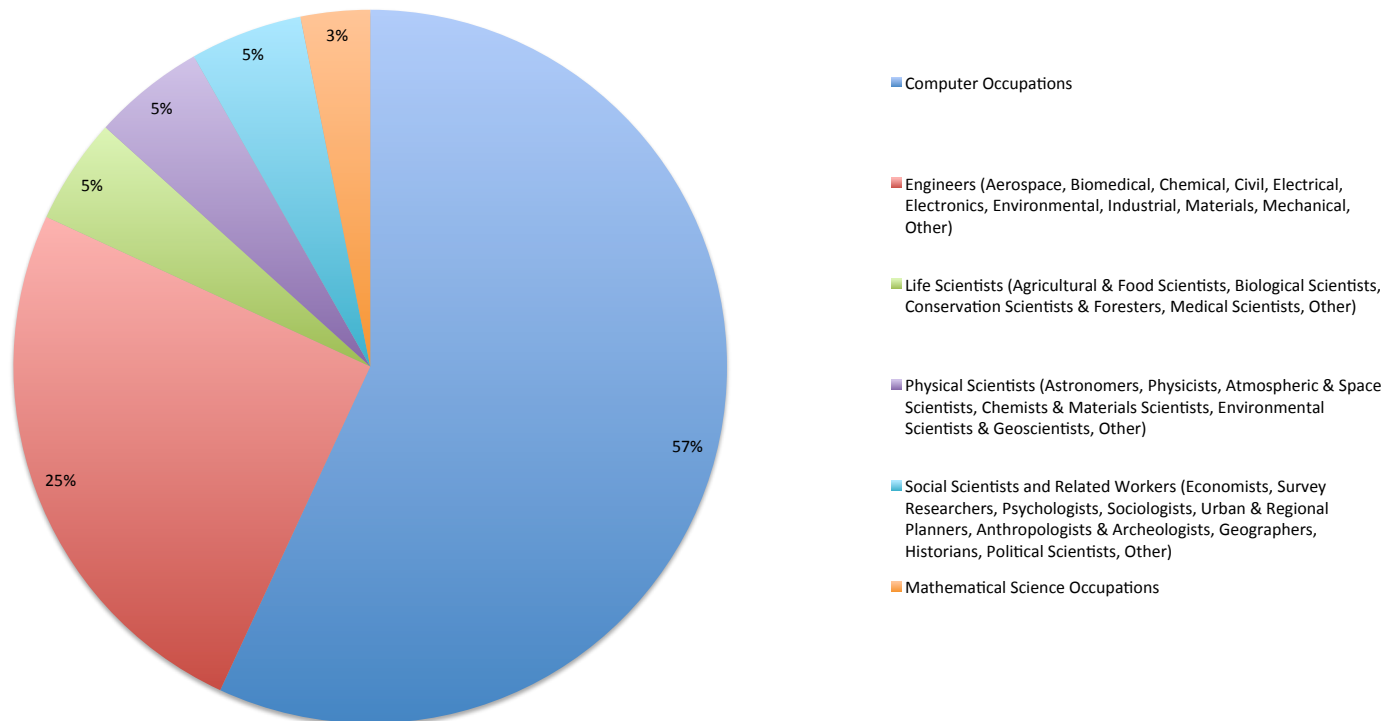
**Job Growth, 2012-22 - U.S. Bureau of Labor Statistics**  
Computer Occupations = 71% of all STEM





- Students are figuring out that all of the STEM jobs are in computer science

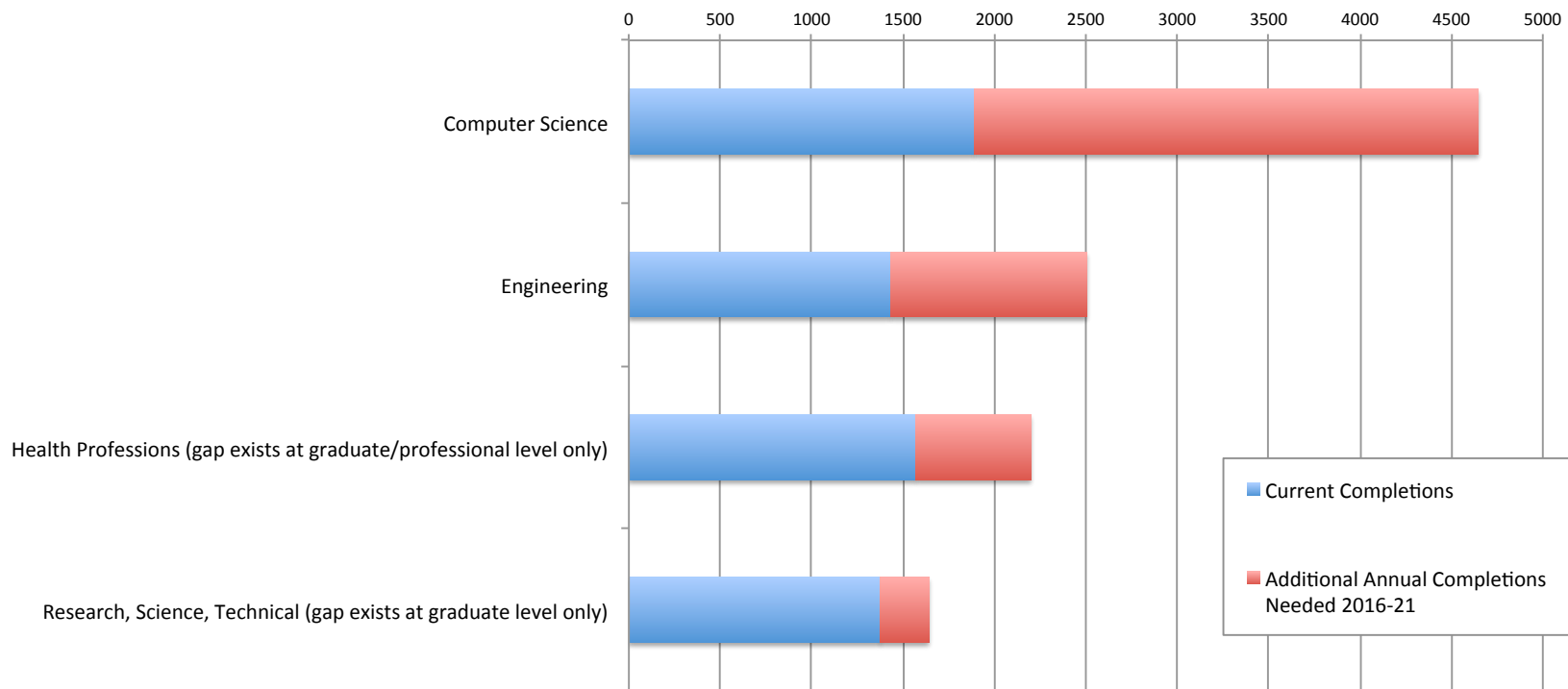
**Job Openings (Growth And Replacement), 2012-22 - U.S. Bureau of Labor Statistics**  
Computer Occupations = 57% of all STEM





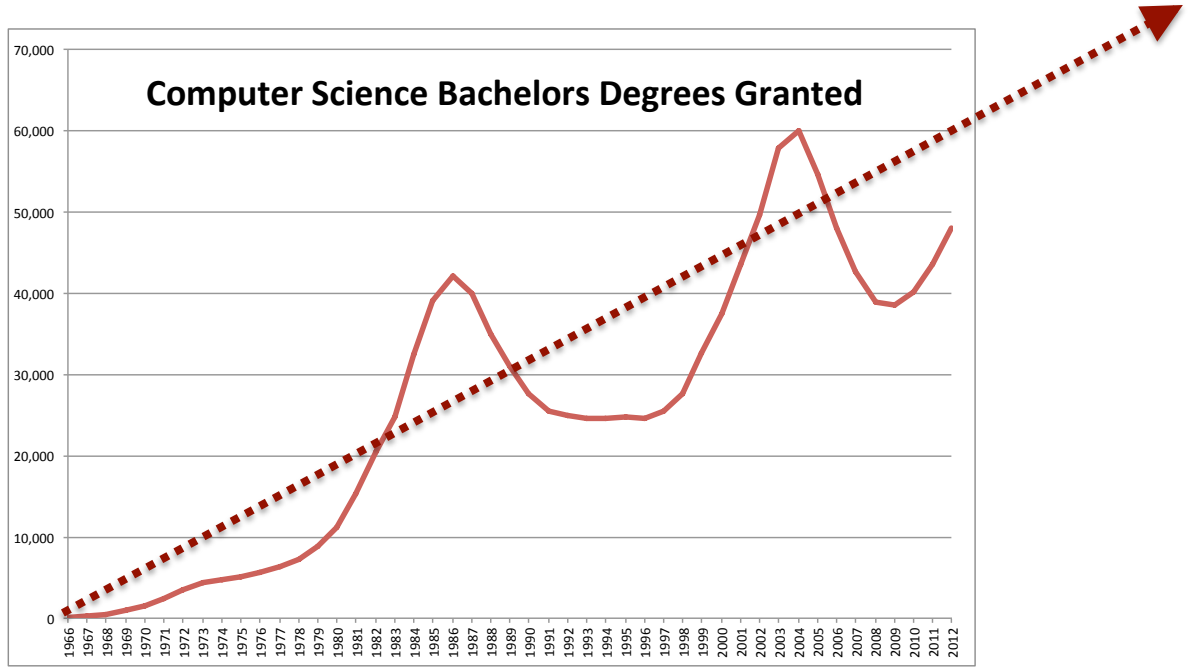
- Students are figuring out that all of the STEM jobs are in computer science

**Washington State High Demand Fields at Baccalaureate Level and Above**  
WSAC, SBCTC, WTECB, October 2013





It seems likely that the recent dramatic growth will continue (although cycles are inevitable)





## How are we, and our institutions, going to respond?

- 10% of Princeton's students are computer science majors
  - It's a far greater percentage at, e.g., MIT
- 10% of Princeton's faculty are unlikely to ever be in computer science!
  - Ditto, proportionately, at MIT
- And then there is
  - Introductory course demand ++
  - Upper-division non-major demand ++
  - Graduate non-major demand ++



## We have seen this movie before, and it wasn't pretty!

- In the middle 1980s and the middle 2000s, student demand increased tremendously
- Universities did not respond adequately
- Kent Curtis report:

“80% of universities are responding by increasing teaching loads, 50% by decreasing course offerings and concentrating their available faculty on larger but fewer courses, and 66% are using more graduate-student teaching assistants or part-time faculty. 35% report reduced research opportunities for faculty as a result ... these measures make the universities' environments less attractive for employment and are exactly counterproductive to their need to maintain and expand their labor supply.”

<http://cs.stanford.edu/~eroberts/Curtis-ComputerManpower/>





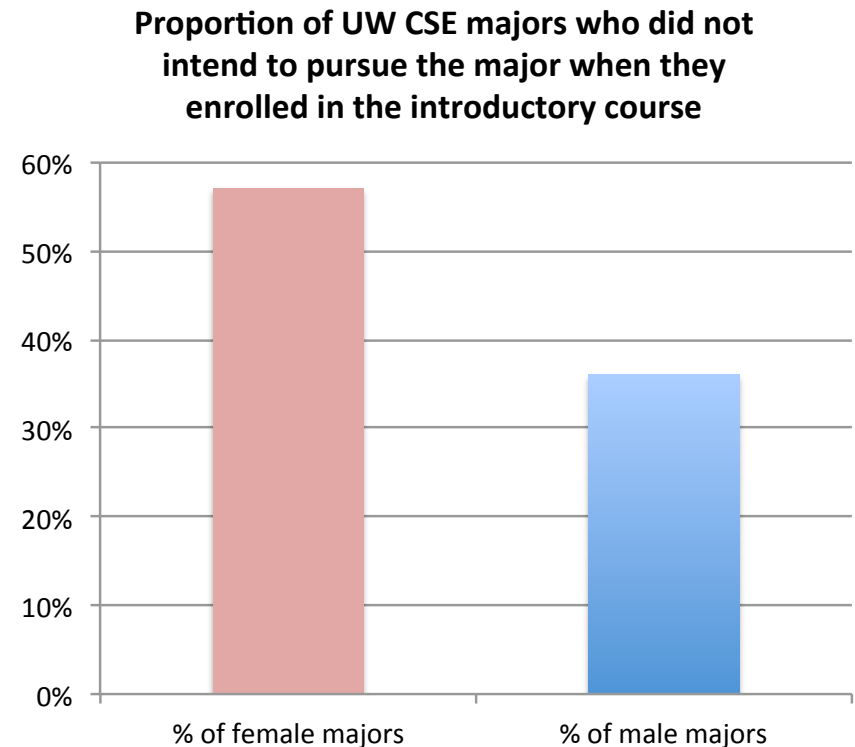
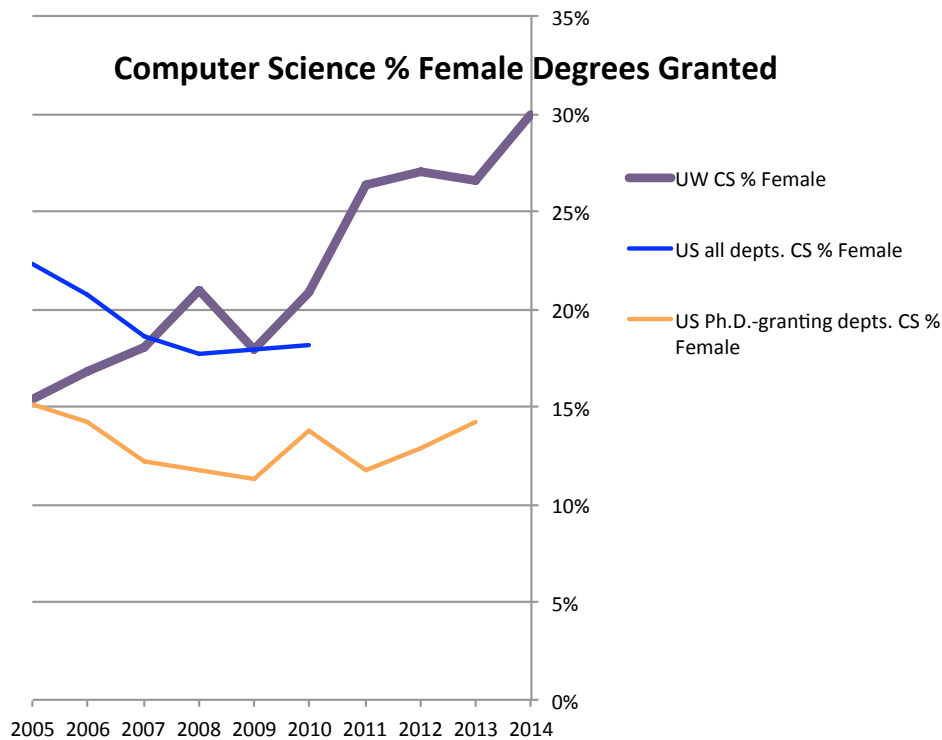
## Some possibilities ...

- Restrict the size of the major
  - Implications for diversity?
- Exclude non-majors from upper-division courses
- Retreat to “the core” – turn over many of our courses to other departments
- Have enormous class sizes and/or enormous teaching loads
- Utilize vast numbers of lecturers
- Have a beer while the students use Coursera



## A concrete reason for the concern about diversity

- Introductory courses are particularly important “attraction waters” for members of under-represented groups
- When introductory courses become “weed-out” courses, this disproportionately impacts members of those groups





## Our field is at a critical juncture!



- Best practices: how to respond?
- What's different this time around, and how can we document it?
- A proactive agenda: what can we and our disciplinary organizations (CRA, CCC, ACM, NSF, CSTB, ...) do?

(The ideas that follow come from audiences at NCWIT, the NSF CISE Advisory Committee, and the CRA Conference at Snowbird)



## Observations

- Administrators are going to want to address this problem in the least expensive and least permanent way: using TAs, contract instructors, faculty from other departments ...
- Even if CS faculty numbers expand, CS research funding may not
- If we don't teach the necessary courses, other units will; they have teaching resources due to the decrease in their own majors, and their students have the need
- We believe that computing is fundamental, but many others remain to be convinced
- Today, most of the majors in fields such as Psychology, Economics, and History are not intending to “practice” in that field. This may become true of CS; it would require changing our approach





## Observations (cont'd.)

- There are now 55 iSchools; we need to ensure complementarity and collaboration. (Interestingly, the undergraduate gender balance of iSchools is not significantly better than that of CS programs!)
- The local environment is important – there is no “one size fits all.” Does tuition revenue flow to the unit doing the teaching? Are the rewards for majors vs. minors comparable? Etc.





## Best practices: how to respond?

- Utilize undergraduate TAs – they scale with the demand!
- Women tend to drop out of computing industry careers. Might industry grant 2-year teaching sabbaticals to women?
- Automate grading in a variety of courses – this would relieve much of the drudgery of being a TA
- Partner with departments that can teach CS-relevant courses, spreading the load while maintaining a modicum of curricular control. (If we're growing, someone else must be shrinking; there are spare cycles *somewhere!*)
- Create a “culture of teaching”:
  - Value lecturers/instructors: reasonable salaries, 12-month appointments, multi-year contracts
  - Encourage graduate students to pursue teaching careers – e.g., institute “CS Education” reading groups
  - Like Biology, introduce “teaching postdocs” where the postdoc co-teaches with his/her faculty mentor – providing teaching cycles, another mentoring opportunity, and career value





## Best practices: how to respond? (cont'd.)

- Think carefully about what students *don't* need to know, as well as what they *do* need to know – CS is an ever-expanding sphere, and students cannot possibly learn all there is to know
  - Can we reduce the time required for students in our major to less than 4 years?
  - Is there an efficient version of Stanford's "CS+X"?
- "Take the long view":
  - Expand our view of what constitutes CS – suppress our egos regarding what constitutes "the core."
  - Grow to Schools or Colleges. (Among other things, this provides a degree of budgetary control – our success will be less likely to be used to subsidize others)
  - CS should grow to be the size of Engineering – it is of at least equal impact. Plan for this!





# What's different this time around, and how can we demonstrate it?

- At many leading institutions, a very large proportion of students are now choosing to take one or more CS courses (even though this is not required for many majors) – this trend is new
- Enrollment by non-majors in upper-division CS courses is rising rapidly – this trend is new
- Demand for the major is increasing very substantially – at some bellwether institutions, this demand is dramatically exceeding previous highs
- Computers, computational thinking, and computer science are ubiquitous – every field is becoming an information field. Students aren't blind to this!
  - Computing today is part of life and part of popular culture; it's not just about “computing industry jobs”
  - Today's students are interested in *using* computing, not merely in advancing the core. (Note: this student interest is not reflected the balance of our faculty!)







## What's different this time around, and how can we demonstrate it? (cont'd.)

- Workforce demand in computing is dramatically greater than in all other fields of STEM combined – BLS data clearly shows this
- Heads of other units are now asking us to “teach our students computer science” (vs. “teach them programming”)
- Looking at company participation in recruiting events, CS majors are attracting the full spectrum of industry – the full cross section of the economy
- The pervasiveness of computing in the economy suggests that, in the future, student demand for the major, and industry demand for graduates, will be cyclical with the health of the overall economy, rather than with that of the computing industry
- Today, increasing CS size/strength increases *institutional* strength – it's an investment that pays broad dividends





## A proactive agenda: what can we and our disciplinary organizations (CRA, CCC, ACM, NSF, CSTB, ...) do?

- Obtain broader, more authoritative data; what we have at present is “a clear sense” and “many stories” but not a compelling national case
- Understand the reasons for student behavior. In other words, the *trends* are clear, but the *reasons* are not. E.g., what are the specific reasons for the dramatic increases we are seeing in upper-division enrollment? Who *are* these students, and why are they there?
- Document that upper-division growth is something that’s *new* and *different*
- Initiate serious conversations with leaders in fields such Math, Biology, and Economics – they have scaled, and they teach many who will not “practice directly” in the field. Study how the huge majors do it. (Economics is perhaps the best model – it’s a big major and the faculty are well compensated)





## A proactive agenda: what can we and our disciplinary organizations (CRA, CCC, ACM, NSF, CSTB, ...) do?

- Argue, based on structural changes in the nation's economy, that we are observing a fundamental shift in the role of CS
- Advocate for graduate programs focused on CS education: students care about this, and they need a Ph.D. track and a career track that's respected
- Call on funding agencies to support flexible postdocs – research + teaching with a flexible proportion
  - Perhaps create a CIFellows-like postdoc program but with a teaching orientation
- Celebrate the situation! We are no longer merely the toolsmiths! We are now the solution providers!





## VOLUNTEERS to dig into this more fully?

- Send email to Jim Kurose and Ed Lazowska!



## Thanks for providing data!

- Colorado School of Mines: Tracy Camp
- Harvard Univ.: Greg Morrisett, Margo Seltzer
- Harvey Mudd College: Ran Libeskind-Hadas
- Johns Hopkins Univ.: Greg Hager
- MIT: Saman Amarasinghe, Anantha Chandrakasan, Eric Grimson, Laura Moses, Victoria Palay, Daniela Rus, Jacob White
- Rochester Institute of Technology: Andrew Sears
- Stanford Univ.: Eric Roberts, Claire Stager
- UC Berkeley: David Culler
- Univ. Michigan: H.V. Jagadish
- Univ. Pennsylvania: Sue Davidson
- Univ. Rochester: Henry Kautz
- Univ. Texas: Tiffany Grady, J Moore
- Univ. Utah: Ross Whitaker
- Univ. Washington: Raven Alexander, Crystal Eney, Ed Lazowska, Jen Pesicka
- Wellesley College: Takis Metaxas