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## Expanding the Pipeline

## - Broadening Participation in Computing Fields by Preparing More Professionals with

 Disabilities- Beyond Graduate Admissions: Strategies for Diversifying the Computer Science Workforce CCC Announces New Council Members

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Cover Photo: Roy Austin, former White House Domestic Policy Council, speaking during the Public Welfare panel at the 2016 CCC Artificial Intelligence for Social Good workshop.

## Computing Research News

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## CRA

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This article, written by a team currently at Kennesaw State University, gives a firsthand perspective of the program's benefits.

## CERP

62 More CREU Students Attend Graduate School Compared to Other REU Students CERP compared post-graduation plans of undergraduate students with different REU experiences using CERP's annual spring survey for graduating students. CREU students went on to attend graduate school at a higher rate than other REU participants as well as students who did not participate in an REU.

## CCC

63 CCC Announces New Council Members
CRA, in consultation with NSF, has appointed six new members to the CCC Council.

66 Congressional Briefing on Cybersecurity for Manufacturers Recap
CCC and MForesight: Alliance for Manufacturing Foresight (MForesight), in conjunction with the House Manufacturing Caucus, held a Congressional briefing on Cybersecurity for Manufacturers.
67 A National Research Agenda for Intelligent Infrastructure
The CCC in collaboration with the Electrical and Computer Engineering Department Heads Association (ECEDHA) recently released eight white papers describing a collective research agenda for intelligent infrastructure.

## Announcements

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70 Eric Horvitz, Former CCC Council Member, is New Head of Research at Microsoft
71 Former CRA Board Member Among 2016 ACM Software System Award Recipients

[^0]
# 2016 Taulbee Survey <br> Generation CS Continues to Produce Record Undergrad Enrollment; Graduate Degree Production Rises at both Master's and Doctoral Levels 

By Stuart Zweben and Betsy Bizot

This article and the accompanying figures and tables present the results from the 46th annual CRA Taulbee Survey'. The survey, conducted annually by the Computing Research Association, documents trends in student enrollment, degree production, employment of graduates, and faculty salaries in academic units in the United States and Canada that grant the Ph.D. in computer science (CS), computer engineering (CE), or information (I) ${ }^{2}$. Most of these academic units are departments, but some are colleges or schools of information or computing. In this report, we will use the term "department" to refer to the unit offering the program.

CRA gathers survey data during the fall. Responses received by February 17, 2017 are included in the analysis. The period covered by the data varies from table to table. Degree production and enrollment (Ph.D., Master's, and Bachelor's) refer to the previous academic year (2015-16). Data for new students in all categories refer to the current academic year (2016-17). Projected student production and information on faculty salaries are also for the current academic year; salaries are those effective January 1, 2017.

We surveyed a total of 268 Ph.D.-granting departments; we received salary responses from 173 and main survey responses from 168, for a total of 183 departments responding to one or both parts of the survey. The response rate was 68 percent, similar to last year's 67 percent. The response rates from CE and Canadian departments continue to be rather low, and this year the CE response rate is the same as last year's unusually low rate. U.S. CS, U.S. I, and Canadian response rates were similar to last year, with U.S. CS slightly up and Canadian slightly down. Figure 1 shows the history of the survey's response rates. Response rates are inexact because some departments provide only partial data, and some institutions provide a single joint response
for multiple departments. Thus, in some tables the number of departments shown as reporting will not equal the overall total number of respondents shown in Figure 1 for that category of department.

To account for the changes in response rate, we will comment not only on aggregate totals but also on averages per department reporting or data from those departments that responded to both 2015 and 2016 surveys. This is a more meaningful indication of the one-year changes affecting the data.

Departments that responded to the survey were sent preliminary results about faculty salaries in December 2016; these results included additional distributional information not contained in this report. The CRA Board views this as a benefit of participating in the survey.

Degree, enrollment, and faculty salary data for the U.S CS departments are stratified according to: a) whether the institution is public or private; and b) the tenure-track faculty size of the reporting department. The faculty size strata deliberately overlap, so that data from most departments affect multiple strata. This may be especially useful to departments near the boundary of one stratum. Salary data is also stratified according to the population of the locale in which the institution is located. ${ }^{3}$ These stratifications allow our readers to see multiple views of important data, and hopefully gain new insights from them. In addition to tabular presentations of data, we will use "box and whisker" diagrams to show medians, quartiles, and the range between the 10th and 90th percentile data points.

In this year's survey, we made some modifications to the list of research areas for doctoral degree graduates in order to better reflect current areas of focus. We also began to

Figure 1. Number of Respondents to the Taulbee Survey

| Year | US CS Depts. | US CE Depts. | Canadian | US Information | Total |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 1995 | 110/133 (83\%) | 9/13 (69\%) | 11/16 (69\%) |  | 130/162 (80\%) |
| 1996 | 98/131 (75\%) | 8/13 (62\%) | 9/16 (56\%) |  | 115/160 (72\%) |
| 1997 | 111/133 (83\%) | 6/13 (46\%) | 13/17 (76\%) |  | 130/163 (80\%) |
| 1998 | 122/145 (84\%) | 7/19 (37\%) | 12/18 (67\%) |  | 141/182 (77\%) |
| 1999 | 132/156 (85\%) | 5/24 (21\%) | 19/23 (83\%) |  | 156/203 (77\%) |
| 2000 | 148/163 (91\%) | 6/28 (21\%) | 19/23 (83\%) |  | 173/214 (81\%) |
| 2001 | 142/164 (87\%) | 8/28 (29\%) | 23/23 (100\%) |  | 173/215 (80\%) |
| 2002 | 150/170 (88\%) | 10/28 (36\%) | 22/27 (82\%) |  | 182/225 (80\%) |
| 2003 | 148/170 (87\%) | 6/28 (21\%) | 19/27 (70\%) |  | 173/225 (77\%) |
| 2004 | 158/172 (92\%) | 10/30 (33\%) | 21/27 (78\%) |  | 189/229 (83\%) |
| 2005 | 156/174 (90\%) | 10/31 (32\%) | 22/27 (81\%) |  | 188/232 (81\%) |
| 2006 | 156/175 (89\%) | 12/33 (36\%) | 20/28 (71\%) |  | 188/235 (80\%) |
| 2007 | 155/176 (88\%) | 10/30 (33\%) | 21/28 (75\%) |  | 186/234 (79\%) |
| 2008 | 151/181 (83\%) | 12/32 (38\%) | 20/30 (67\%) | 9/19 (47\%) | 192/264 (73\%) |
| 2009 | 147/184 (80\%) | 13/31 (42\%) | 16/30 (53.3\%) | 12/20 (60\%) | 188/265 (71\%) |
| 2010 | 150/184 (82\%) | 12/30 (40\%) | 18/29 (62\%) | 15/22 (68\%) | 195/265 (74\%) |
| 2011 | 142/85 (77\%) | 13/31 (42\%) | 13/30 (43\%) | 16/21 (76\%) | 184/267 (69\%) |
| 2012 | 152/189 (80\%) | 11/32 (34\%) | 14/30 (47\%) | 16/26 (62\%) | 193/277 (70\%) |
| 2013 | 144/188 (77\%) | 10/30 (33\%) | 14/26 (54\%) | 11/22 (50\%) | 179/266 (67\%) |
| 2014 | 143/188 (76\%) | 13/31 (42\%) | 12/26 (46\%) | 13/19 (68\%) | 181/268 (68\%) |
| 2015 | 146/190 (77\%) | 8/32 (25\%) | 12/26 (46\%) | 12/18 (67\%) | 178/266 (67\%) |
| 2016 | 150/188 (80\%) | 8/33 (24\%) | 11/26 (42\%) | 14/21 (67\%) | 183/268 (68\%) |

collect enrollment data from certain key undergraduate CS courses, in a format similar to what was used in last year's CRA Enrollment Survey, the results of which can be found at www.cra.org/data/generation-cs. This will enable some ongoing tracking of enrollment changes at a finer level of detail than is now possible with the Taulbee Survey. Finally, this year we asked departments about their interest in getting additional data about the employment of teaching faculty as part of the survey. The responses will guide decisions that will be implemented in future Taulbee Surveys.

We thank all of the respondents to this year's questionnaire. The participating departments are listed at the end of this article. CRA member respondents will again be given the opportunity to obtain certain survey information for a self-selected peer group. Instructions for doing this will be emailed to all such departments.

## Doctoral Degree Production, Enrollment, and Employment

## (Tables DI-DIO; Figures DI-D6)

## Degree Production

Doctoral degree production rose this year, after last year's dip. This year's respondents produced 1,888 doctoral degrees in 2015-16, an increase of 6.1 percent overall and 6.7 percent on a per department basis. Total production is still below the record of 1,991 set in 2012-13. There were increases, on average, for all department types (Table DI).

Among all departments reporting both this year and last year, the number of total doctoral degrees increased by 7.4 percent, but among U.S. CS departments reporting both years, the increase was 6.3 percent.

Women comprised 17.1 percent of CS doctoral graduates and 18.5 percent of all doctoral computing graduates (Table D2).

Both values are lower than those reported last year (last year's values were 18.3 and 20.2 percent, respectively). The percentage of CS doctoral degrees that went to Non-resident Aliens continued to rise, to 63.1 percent compared with last year's reported 60.7 percent, while the percentage that went to resident Asians rose to 7.6 percent from 6.4 percent. CE had a similar percentage of Non-resident Aliens to CS, and was less gender diverse. Among I doctoral degrees, Nonresident Aliens now comprise more than 50 percent of the
doctoral graduates, though a smaller percentage than for CS or CE; the fraction of I doctoral degrees going to Whites remained at 33.8 percent.

The percentage of CS doctoral graduates who were American Indian or Alaska Native, Black or African American, Native Hawaiian/Pacific Islander, Hispanic, or Multiracial NonHispanic was just 2.6 percent, down from 4.0 percent and to the same level reported in 2013-14. In aggregate across CS,

Table DI. PhD Production and Pipeline by Department Type

| Department <br> Type | \# Depts | PhDs Awarded |  | PhDs Next Year |  | Passed Qualifier |  | Passed Thesis (if dept has) |  |  |
| :--- | ---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | \# | Avg/ Dept | \# | Avg/ Dept | \# | Avg/ Dept | \# | \# Dept | Avg/ Dept |
| US CS Public | 95 | 1,211 | 12.7 | 1,337 | 14.1 | 1,289 | 14.5 | 906 | 76 | 11.8 |
| US CS Private | 34 | 444 | 13.5 | 593 | 17.4 | 409 | 12.4 | 158 | 22 | 8.8 |
| US CS Total | 129 | 1,655 | 12.9 | 1,930 | 15.0 | 1,698 | 13.9 | 1,064 | 98 | 11.1 |
| US CE | 5 | 28 | 4.7 | 69 | 13.8 | 90 | 18.0 | 60 | 3 | 28.9 |
| US Info | 12 | 83 | 8.3 | 95 | 7.9 | 119 | 9.2 | 64 | 10 | 8.0 |
| Canadian | 11 | 122 | 12.2 | 154 | 14.0 | 118 | 11.8 | 95 | 7 | 12.8 |
| Grand Total | 157 | 1,888 | 12.3 | 2,248 | 14.3 | 2,025 | 13.5 | 1,283 | 118 | 12.0 |

Table D2. PhDs Awarded by Gender

|  | CS |  | CE |  | I |  | Total |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | :---: | :---: |
| Male | 1,368 | $82.9 \%$ | 78 | $87.6 \%$ | 83 | $60.6 \%$ | 1,529 | $81.5 \%$ |
| Female | 282 | $17.1 \%$ | 11 | $12.4 \%$ | 54 | $39.4 \%$ | 347 | $18.5 \%$ |
| Total Known Gender | 1,650 |  | 89 |  | 137 |  | 1,876 |  |
| Gender Unknown | 9 |  | 1 |  | 2 |  | 12 |  |
| Grand Total | 1,659 |  | 90 |  | 139 |  | 1,888 |  |

Table D3. PhDs Awarded by Ethnicity

|  | CS |  | CE |  | I |  | Total |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | :---: |
| Nonresident Alien | 964 | $63.1 \%$ | 53 | $60.2 \%$ | 67 | $51.5 \%$ | 1084 |  |
| Amer Indian or Alaska Native | 1 | $0.1 \%$ | 0 | $0.0 \%$ | 0 | $0.0 \%$ | 1 |  |
| Asian | 116 | $7.6 \%$ | 12 | $13.6 \%$ | 7 | $5.4 \%$ | 135 |  |
| Black or African-American | 17 | $1.1 \%$ | 3 | $3.4 \%$ | 4 | $3.1 \%$ | 24 |  |
| Native Hawaiian/Pac Islander | 5 | $0.3 \%$ | 1 | $1.1 \%$ | 0 | $0.0 \%$ | 6 |  |
| White | 407 | $26.7 \%$ | 15 | $17.0 \%$ | 44 | $33.8 \%$ | 466 |  |
| Multiracial, not Hispanic | 2 | $0.1 \%$ | 3 | $3.4 \%$ | 1 | $0.8 \%$ | 6 |  |
| Hispanic, any race | 15 | $1.0 \%$ | 1 | $1.1 \%$ | 7 | $5.4 \%$ | 23 |  |
| Total Residency \& Ethnicity Known | 1,527 |  | 88 |  | 130 |  | 1,745 |  |
| Resident, ethnicity unknown | 64 |  | 1 |  | 4 |  | 69 |  |
| Residency unknown | 68 |  | 1 |  | 5 |  | $7.3 \%$ |  |
| Grand Total | 1,659 |  | 90 |  | 139 |  | 1,888 |  |

Table D4. Employment of New PhD Recipients By Specialty

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | $\begin{aligned} & \text { ぁ } \\ & \text { \# } \end{aligned}$ | $\stackrel{\bar{\square}}{\square}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |

North American PhD Granting Depts.

| Tenure-track | 7 | 2 | 8 | 5 | 1 | 7 | 10 | 4 | 16 | 2 | 6 | 9 | 8 | 4 | 1 | 11 | 5 | 8 | 9 | 12 | 135 | $9.0 \%$ |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Researcher | 2 | 0 | 0 | 3 | 0 | 0 | 1 | 9 | 0 | 1 | 3 | 0 | 0 | 1 | 1 | 2 | 1 | 2 | 0 | 2 | 28 | $1.9 \%$ |
| Postdoc | 44 | 4 | 9 | 13 | 3 | 2 | 12 | 17 | 6 | 0 | 9 | 5 | 6 | 13 | 2 | 10 | 2 | 7 | 23 | 27 | 214 | $14.3 \%$ |
| Teaching Faculty | 6 | 5 | 3 | 3 | 0 | 1 | 1 | 1 | 0 | 0 | 6 | 2 | 3 | 1 | 1 | 2 | 4 | 4 | 2 | 11 | 56 | $3.7 \%$ |

## North American, Other Academic

| Other CS/CE/I Dept. | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 4 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 4 | 6 | 24 | $1.6 \%$ |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Non-CS/CE/I Dept | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | $0.2 \%$ |

North American, Non-Academic

| Industry | 134 | 3 | 65 | 51 | 39 | 26 | 21 | 22 | 13 | 11 | 54 | 32 | 30 | 45 | 11 | 53 | 10 | 84 | 39 | 115 | 858 | $57.2 \%$ |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Government | 4 | 0 | 3 | 1 | 3 | 4 | 2 | 2 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 4 | 0 | 3 | 0 | 1 | 33 | $2.2 \%$ |
| Self-Employed | 5 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 2 | 1 | 3 | 1 | 0 | 1 | 0 | 18 | $1.2 \%$ |
| Unemployed | 3 | 0 | 1 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 4 | 14 | $0.9 \%$ |
| Other | 1 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 7 | $0.5 \%$ |

Total Inside North America

|  | 210 | 14 | 91 | 78 | 48 | 40 | 49 | 57 | 36 | 18 | 83 | 49 | 51 | 68 | 20 | 87 | 24 | 109 | 79 | 179 | 1,390 | 92.7\% |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Outside North America |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Ten-Track in PhD | 4 | 2 | 2 | 4 | 0 | 2 | 2 | 1 | 1 | 0 | 3 | 0 | 0 | 1 | 1 | 2 | 0 | 3 | 1 | 7 | 36 | 2.4\% |
| Researcher in PhD | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 3 | 0.2\% |
| Postdoc in PhD | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 3 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 3 | 2 | 16 | 1.1\% |
| Teaching in PhD | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 5 | 0.3\% |
| Other Academic | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 1 | 9 | 0.6\% |
| Industry | 8 | 0 | 1 | 0 | 3 | 0 | 0 | 1 | 0 | 1 | 1 | 2 | 5 | 0 | 1 | 3 | 0 | 2 | 1 | 2 | 31 | 2.1\% |
| Government | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0.1\% |
| Self-Employed | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0.1\% |
| Unemployed | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0\% |
| Other | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 6 | 0.4\% |
| Total Outside NA | 16 | 2 | 3 | 5 | 5 | 3 | 3 | 5 | 1 | 1 | 8 | 4 | 6 | 3 | 2 | 7 | 1 | 9 | 7 | 19 | 110 | 7.3\% |

Total with Employment Data, Inside North America plus Outside North America

| 226 | 16 | 94 | 83 | 53 | 43 | 52 | 62 | 37 | 19 | 91 | 53 | 57 | 71 | 22 | 94 | 25 | 118 | 86 | 198 | 1,500 |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |

Employment Type \& Location Unknown

|  | 30 | 3 | 17 | 11 | 14 | 4 | 9 | 9 | 5 | 4 | 11 | 3 | 6 | 6 | 3 | 12 | 3 | 13 | 12 | 213 | 388 |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Grand Total | $\mathbf{2 5 6}$ | $\mathbf{1 9}$ | $\mathbf{1 1 1}$ | $\mathbf{9 4}$ | $\mathbf{6 7}$ | $\mathbf{4 7}$ | $\mathbf{6 1}$ | $\mathbf{7 1}$ | $\mathbf{4 2}$ | $\mathbf{2 3}$ | $\mathbf{1 0 2}$ | $\mathbf{5 6}$ | $\mathbf{6 3}$ | $\mathbf{7 7}$ | $\mathbf{2 5}$ | $\mathbf{1 0 6}$ | $\mathbf{2 8}$ | $\mathbf{1 3 1}$ | $\mathbf{9 8}$ | $\mathbf{4 1 1}$ | $\mathbf{1 , 8 8 8}$ |  |

CE, and I graduated 3.4 percent from these categories (vs. 4.5 percent in 2014-15). As we have found in previous years, Nonresident Aliens again comprised a higher percentage of the CS female doctoral graduates than they did CS male graduates, while Whites comprised a lower percentage of the female
graduates as compared with male graduates. This year's respondents reported that Resident Asians comprised an equal percentage of male CS doctoral graduates and female CS doctoral graduates; in previous years, Asians comprised a higher percentage of female graduates (Table D9).

Table D4a. Detail of Industry Employment

|  |  |  |  |  |  |  |  | Informatics: Biomedica/ Other Science |  |  |  | $\begin{aligned} & \text { n } \\ & \text { n } \\ & \sum_{0}^{2} \\ & \frac{0}{2} \end{aligned}$ |  |  |  |  |  |  |  |  | $\begin{aligned} & \text { む } \\ & \text { \# } \end{aligned}$ | $\begin{aligned} & \overline{\mathrm{I}} \\ & \stackrel{\text { n }}{0} \end{aligned}$ |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Inside North America |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Research | 84 | 0 | 43 | 20 | 20 | 11 | 15 | 14 | 8 | 5 | 29 | 23 | 16 | 31 | 6 | 33 | 5 | 30 | 20 | 11 | 49 | 473 | 55.1\% |
| Non-Research | 37 | 1 | 18 | 24 | 16 | 14 | 6 | 4 | 3 | 5 | 21 | 8 | 12 | 12 | 2 | 15 | 5 | 49 | 13 | 12 | 17 | 294 | 34.3\% |
| Postdoctorate | 5 | 0 | 0 | 2 | 1 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 2 | 0 | 1 | 0 | 0 | 0 | 17 | 2.0\% |
| Type Not Specified | 8 | 2 | 4 | 5 | 2 | 0 | 0 | 2 | 2 | 1 | 4 | 1 | 2 | 0 | 2 | 3 | 0 | 4 | 6 | 20 | 6 | 74 | 8.6\% |
| Total Inside NA | 134 | 3 | 65 | 51 | 39 | 26 | 21 | 22 | 13 | 11 | 54 | 32 | 30 | 45 | 11 | 53 | 10 | 84 | 39 | 43 | 72 | 858 |  |
| Outside North America |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Research | 6 | 0 | 1 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 5 | 0 | 1 | 2 | 0 | 2 | 0 | 0 | 0 | 22 | 71.0\% |
| Non-Research | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 6 | 19.4\% |
| Postdoctorate | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 6.5\% |
| Type Not Specified | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 3.2\% |
| Total Outside NA | 8 | 0 | 1 | 0 | 3 | 0 | 0 | 1 | 0 | 1 | 1 | 2 | 5 | 0 | 1 | 3 | 0 | 2 | 1 | 1 | 1 | 31 |  |

Table D5. New PhD Students by Department Type

|  | CS |  |  |  | CE |  |  |  | I |  |  |  | Total |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Department Type | New Admit | $\begin{aligned} & \text { MS } \\ & \text { to } \\ & \text { PhD } \end{aligned}$ | Total | Avg. <br> per <br> Dept. | New Admit | MS to PhD | Total | Avg. <br> per <br> Dept. | New Admit | MS to PhD | Total | Avg. <br> per <br> Dept. | Total | Avg. <br> per <br> Dept |
| US CS Public | 1,512 | 228 | 1,740 | 18.3 | 84 | 20 | 104 | 5.2 | 94 | 2 | 96 | 12.0 | 1,940 | 20.2 |
| US CS Private | 685 | 22 | 707 | 20.8 | 13 | 1 | 14 | 2.8 | 11 | 0 | 11 | 3.7 | 732 | 21.5 |
| US CS Total | 2,197 | 250 | 2,447 | 19.0 | 97 | 21 | 118 | 4.7 | 105 | 2 | 107 | 9.7 | 2,672 | 20.6 |
| US CE | 0 | 0 | 0 | 0.0 | 54 | 3 | 57 | 9.5 | 0 | 0 | 0 | 0.0 | 57 | 9.5 |
| US Information | 6 | 1 | 7 | 7.0 | 0 | 0 | 0 | 0.0 | 121 | 17 | 138 | 9.9 | 145 | 10.4 |
| Canadian | 105 | 17 | 122 | 11.1 | 0 | 0 | 0 | 0.0 | 0 | 0 | 0 | 0.0 | 122 | 11.1 |
| Grand Total | 2,308 | 268 | 2,576 | 18.3 | 151 | 24 | 175 | 5.6 | 226 | 19 | 245 | 9.8 | 2,996 | 18.6 |

Table D5a. New PhD Students from Outside North America

| Department <br> Type | CS | CE | I | Total New <br> Outside | Total New | \% outside <br> North <br> America |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: |
| US CS Public | 1,148 | 71 | 56 | 1,275 | 1,940 | $65.7 \%$ |
| US CS Private | 381 | 11 | 9 | 401 | 732 | $54.8 \%$ |
| Total US CS | 1,529 | 82 | 65 | 1,676 | 2,672 | $62.7 \%$ |
| US CE | 0 | 32 | 0 | 32 | 57 | $56.1 \%$ |
| US Info | 5 | 0 | 73 | 78 | 145 | $53.8 \%$ |
| Canadian | 73 | 0 | 0 | 73 | 122 | $59.8 \%$ |
| Grand Total | 1,607 | 114 | 138 | 1,859 | 2,996 | $62.0 \%$ |

Table D6. PhD Enrollment by Department Type

| Department Type | \# Depts | CS |  | CE |  | I |  | Total |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| US CS Public | 100 | 8,903 | $66.2 \%$ | 636 | $66.2 \%$ | 386 | $66.2 \%$ | 9,925 | $66.2 \%$ |
| US CS Private | 37 | 3,206 | $24.2 \%$ | 74 | $24.2 \%$ | 38 | $24.2 \%$ | 3,318 | $24.2 \%$ |
| Total US CS | 137 | 12,109 | $90.3 \%$ | 710 | $90.3 \%$ | 424 | $90.3 \%$ | 13,243 | $90.3 \%$ |
| US CE | 6 | 0 | $0.1 \%$ | 293 | $0.1 \%$ | 16 | $0.1 \%$ | 309 | $0.1 \%$ |
| US Info | 12 | 28 | $0.2 \%$ | 0 | $0.2 \%$ | 643 | $0.2 \%$ | 671 | $0.2 \%$ |
| Canadian | 11 | 848 | $9.3 \%$ | 0 | $9.3 \%$ | 22 | $9.3 \%$ | 870 | $9.3 \%$ |
| Grand Total | 166 | 12,985 |  | 1,003 |  | 1,105 |  | 15,093 |  |

Table D7. PhD Enrollment by Gender

|  | CS |  | CE |  | I |  | Total |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Male | 9,964 | $79.9 \%$ | 744 | $79.2 \%$ | 667 | $60.6 \%$ | 11,375 | $78.4 \%$ |
| Female | 2,508 | $20.1 \%$ | 195 | $20.8 \%$ | 434 | $39.4 \%$ | 3,137 | $21.6 \%$ |
| Total Known <br> Gender | 12,472 |  | 939 |  | 1,101 |  | 14,512 |  |
| Gender Unknown | 513 |  | 64 |  | 4 |  | 581 |  |
| Grand Total | 12,985 |  | 1,003 |  | 1,105 |  | 15,093 |  |

Table D8. PhD Enrollment by Ethnicity

|  | CS |  | CE |  | I |  | Total |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Nonresident Alien | 7,596 | $63.9 \%$ | 673 | $69.7 \%$ | 517 | $51.0 \%$ | 8,786 | $63.4 \%$ |
| Amer Indian or Alaska Native | 54 | $0.5 \%$ | 2 | $0.2 \%$ | 3 | $0.3 \%$ | 59 | $0.4 \%$ |
| Asian | 841 | $7.1 \%$ | 61 | $6.3 \%$ | 60 | $5.9 \%$ | 962 | $6.9 \%$ |
| Black or African-American | 152 | $1.3 \%$ | 20 | $2.1 \%$ | 36 | $3.6 \%$ | 208 | $1.5 \%$ |
| Native Hawaiian/Pac Islander | 27 | $0.2 \%$ | 1 | $0.1 \%$ | 5 | $0.5 \%$ | 33 | $0.2 \%$ |
| White | 2,963 | $24.9 \%$ | 169 | $17.5 \%$ | 351 | $34.6 \%$ | 3,483 | $25.1 \%$ |
| Multiracial, not Hispanic | 58 | $0.5 \%$ | 9 | $0.9 \%$ | 16 | $1.6 \%$ | 83 | $0.6 \%$ |
| Hispanic, any race | 195 | $1.6 \%$ | 30 | $3.1 \%$ | 26 | $2.6 \%$ | 251 | $1.8 \%$ |
| Total Known | 11,886 |  | 965 |  | 1,014 |  | 13,865 |  |
| Resident, ethnicity unknown | 677 |  | 15 |  | 23 |  | 715 |  |
| Residency unknown | 422 |  | 23 |  | 68 |  | 513 |  |
| Grand Total | 12,985 |  | 1,003 |  | 1,105 |  | 15,093 |  |

Table D9. PhDs Awarded by Gender and Ethnicity, From 154 Departments

|  | CS |  |  |  |  | CE |  |  |  |  | I |  |  |  |  | Ethnicity Totals |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Male | Fem | N/R | \% of M* | $\underset{F^{*}}{\%}$ | Male | Fem | N/R | \% of M* | $\% \text { of }$ $\mathrm{F}^{*}$ | Male | Fem | N/R | \% of M* | $\% \text { of }$ $F^{*}$ | Total | \% |
| Nonresident Alien | 795 | 169 | 0 | 63 | 66 | 44 | 9 | 0 | 57 | 82 | 46 | 21 | 0 | 60 | 40 | 1,084 | 62.1 |
| Amer Indian or Alaska Native | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.1 |
| Asian | 95 | 21 | 0 | 8 | 8 | 11 | 1 | 0 | 14 | 9 | 4 | 3 | 0 | 5 | 6 | 135 | 7.7 |
| Black or AfricanAmerican | 9 | 8 | 0 | 1 | 3 | 3 | 0 | 0 | 4 | 0 | 1 | 3 | 0 | 1 | 6 | 24 | 1.4 |
| Native Hawaiian/ Pac Islander | 4 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0.3 |
| White | 352 | 55 | 0 | 28 | 21 | 15 | 0 | 0 | 20 | 0 | 21 | 23 | 0 | 27 | 43 | 466 | 26.7 |
| Multiracial, not Hispanic | 1 | 1 | 0 | 0 | 0 | 2 | 1 | 0 | 3 | 9 | 1 | 0 | 0 | 1 | 0 | 6 | 0.3 |
| Hispanic, any race | 13 | 2 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 4 | 3 | 0 | 5 | 6 | 23 | 1.3 |
| Total Res \& Ethnicity Known | 1,270 | 257 | 0 | 0 | 0 | 77 | 11 | 0 |  |  | 77 | 53 | 0 |  |  | 1,745 |  |
| Resident, ethnicity unknown | 49 | 15 | 0 |  |  | 1 | 0 | 0 |  |  | 3 | 1 | 0 |  |  | 69 |  |
| Not Reported (N/R) | 49 | 10 | 9 |  |  | 0 | 0 | 1 |  |  | 3 | 0 | 2 |  |  | 74 |  |
| Gender Totals | 1,368 | 282 | 9 |  |  | 78 | 11 | 1 |  |  | 83 | 54 | 2 |  |  | 1,888 |  |
| \% | 82.9\% | 17.1\% |  |  |  | 87.6\% | 12.4\% |  |  |  | 60.6\% | 39.4\% |  |  |  |  |  |
| * \% of M and \% of F columns are the percent of that gender who are of the specified ethnicity, of those whose ethnicity is known |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

Table DIO. PhD Enrollment by Gender and Ethnicity, From 164 Departments Providing Breakdown Data

|  | CS |  |  |  |  | CE |  |  |  |  | I |  |  |  |  | Ethnicity Totals |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Male | Fem | N/R | \% of M* | \% of F* | Male | Fem | N/R | \% of $M^{*}$ | \% of F* | Male | Fem | N/R | \% of M* | \% of F* | Total | \% |
| Nonresident Alien | 5,605 | 1,456 | 269 | 63 | 66 | 502 | 130 | 41 | 70 | 69 | 326 | 191 | 0 | 54 | 47 | 8,786 | 63.4\% |
| Amer Indian or Alaska Native | 37 | 12 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 2 | 0 | 0 | 1 | 59 | 0.4\% |
| Asian | 633 | 183 | 20 | 7 | 8 | 48 | 10 | 3 | 7 | 5 | 32 | 28 | 0 | 5 | 7 | 962 | 6.9\% |
| Black or AfricanAmerican | 95 | 49 | 3 | 1 | 2 | 9 | 10 | 1 | 1 | 5 | 20 | 16 | 0 | 3 | 4 | 208 | 1.5\% |
| Native Hawaiian/ Pac Islander | 20 | 7 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 4 | 1 | 0 | 1 | 0 | 33 | 0.2\% |
| White | 2,333 | 471 | 145 | 26 | 21 | 135 | 28 | 6 | 19 | 15 | 200 | 151 | 0 | 33 | 37 | 3,483 | 25.1\% |
| Multiracial, not Hispanic | 37 | 10 | 6 | 0 | 1 | 8 | 1 | 0 | 1 | 1 | 8 | 8 | 0 | 1 | 2 | 83 | 0.6\% |
| Hispanic, any race | 155 | 32 | 8 | 2 | 1 | 19 | 7 | 4 | 3 | 4 | 13 | 13 | 0 | 2 | 3 | 251 | 1.8\% |
| Total Res \& Ethnicity Known | 8,915 | 2,220 | 452 |  |  | 722 | 188 |  |  |  | 604 | 410 | 0 |  |  | 13,865 |  |
| Resident, ethnicity unknown | 457 | 123 | 8 |  |  | 8 | 5 |  |  |  | 16 | 7 | 0 |  |  | 715 |  |
| Not Reported (N/R) | 292 | 77 | 53 |  |  | 14 | 2 |  |  |  | 47 | 17 | 4 |  |  | 513 |  |
| Gender Totals | 9,964 | 2,508 | 513 |  |  | 744 | 195 |  |  |  | 667 | 434 | 4 |  |  | 15,093 |  |
| \% | 79.9\% | 20.1\% |  |  |  | 79.2\% | 20.8\% |  |  |  | 60.6\% | 39.4\% | 0\% |  |  |  |  |
| * \% of M and \% of F columns are the percent of that gender who are of the specified ethnicity, of those whose ethnicity is known |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

Figure DI. PhD Production
CRA Taulbee Survey 2016


Figure D2. Nonresident Aliens as Fraction of PhD Enrollments CRA Taulbee Survey 2016



Figure D4. PhD Enrollment Normalized by Tenure-Track Size
CRA Taulbee Survey 2016

Cigure D5. CS Pipeline corrected for year of entry

Figure D6. Employment Trends for New Ph.D.s
CRA Taulbee Survey 2016


## Doctoral Program Enrollment

Among programs that reported both years, total doctoral enrollment decreased slightly, by 1.4 percent. If only U.S. computer science departments are considered, there was a very slight increase of 0.7 percent (Table I). Total doctoral enrollment by gender is more diverse compared with last year, with increases in diversity in all department areas (CS, CE, and I). The overall fraction of current doctoral students who are women is 21.6 percent, versus 20.2 percent last year (Table D7). The fraction of doctoral students who are not either Non-resident Aliens, Asian, or White remains below 5 percent (Table D8).
Among currently enrolled CS doctoral students whose ethnicity is known, we see the same direction of difference among Non-resident Aliens and Whites; Non-resident Aliens comprise a higher percent of the enrolled women than they do the enrolled men, and Whites comprise a lower percentage of enrolled women. This is similar to previous years' observations, and suggests that these directional differences among Non-resident aliens and Whites will continue to be seen in future years' graduation statistics. Resident Asians comprise a similar percentage of enrolled Asian men and Asian women (Table DIO).

Among those pursuing I degrees, 59 percent of the men and 54 percent of the women are Non-resident Aliens or Resident Asians. Last year these percentages were 62 and 55 , respectively. This year, Whites comprise a slightly higher percentage of women than they do men among those pursuing I degrees.

At U.S. CS departments, the average number of students per department who passed qualifier exams declined from 14.3 in 2014-15, to 13.9 in 2015-16. The 13.9 average is the same as it was in 2013-14. The drop was due to departments in public institutions; there was a slight increase in private institutions. The average number per department who passed thesis candidacy exams in 2015-16 (most, but not all, departments have such exams) decreased from 2014-15 at both public and private U.S. CS departments (Table DI).

The number of new Ph.D. students per department reporting increased slightly this year compared with the total from last year's reporting departments (Tables 1 and D5). This reflects increases in all categories of departments (CS, CE, I, and Canadian). Among all departments that reported both years, the number of new Ph.D. students increased 5.5 percent. If only U.S. CS departments that reported both years are considered, the increase was 4.2 percent.

Table 1. Degree Production and Enrollment Change From Previous Year

|  | Total |  |  |  |  |  | Only Departments Responding Both Years |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | US CS Only |  |  | All Departments |  |  | US CS Only |  |  | All Departments |  |  |
| PhDs | 2015 | 2016 | \% chg | 2015 | 2016 | \% chg | 2015 | 2016 | \% chg | 2015 | 2016 | \% chg |
| PhD Awarded | 1,570 | 1,655 | 5.4\% | 1,780 | 1,888 | 6.1\% | 1,482 | 1,569 | 5.9\% | 1,650 | 1,756 | 6.4\% |
| \#Units PhD Awd | 136 | 128 |  | 164 | 154 |  | 117 | 117 |  | 138 | 138 |  |
| PhD Enrollment | 13,063 | 13,243 | 1.4\% | 15,397 | 15,093 | -2.0\% | 12,439 | 12,531 | 0.7\% | 14,395 | 14,196 | -1.4\% |
| \#Units PhD Enr | 137 | 134 |  | 166 | 164 |  | 123 | 123 |  | 149 | 149 |  |
| New PhD Enroll | 2,475 | 2,672 | 8.0\% | 2,752 | 2,996 | 8.9\% | 2,307 | 2,395 | 3.8\% | 2,552 | 2,684 | 5.2\% |
| \#Units New PhD | 133 | 130 |  | 162 | 161 |  | 114 | 114 |  | 140 | 140 |  |
| Bachelor's | 2015 | 2016 | \% chg | 2015 | 2016 | \% chg | 2014 | 2015 | \% chg | 2014 | 2015 | \% chg |
| BS Awarded | 17,401 | 20,709 | 19.0\% | 21,880 | 25,508 | 16.6\% | 16,467 | 19,219 | 16.7\% | 20,290 | 23,972 | 18.1\% |
| \#Units BS Awd | 137 | 131 |  | 165 | 156 |  | 120 | 120 |  | 144 | 144 |  |
| BS Enrollment | 98,377 | 114,607 | 16.5\% | 119,919 | 136,589 | 13.9\% | 91,595 | 107,536 | 17.4\% | 110,777 | 129,362 | 16.8\% |
| \#Units BS Enr | 138 | 131 |  | 165 | 155 |  | 121 | 121 |  | 144 | 144 |  |
| New BS Majors | 25,256 | 27,266 | 8.0\% | 30,147 | 32,216 | 6.9\% | 21,906 | 23,344 | 6.6\% | 26,289 | 27,694 | 5.3\% |
| \#Units New BS | 123 | 112 |  | 147 | 137 |  | 97 | 97 |  | 117 | 117 |  |
| BS Enroll/Dept | 712.9 | 874.9 | 22.7\% | 726.8 | 881.2 | 21.2\% | 757.0 | 888.7 | 17.4\% | 769.3 | 898.3 | 16.8\% |

The proportion of new doctoral students from outside North America fell this year. It is now slightly lower than it was two years ago. This year's overall proportion is 62.0 percent while last year's was 65.7 percent. There were decreases in all categories of departments (Table D5a).

Figure D5 shows a graphical view of the Ph.D. pipeline for U.S. computer science and Canadian departments, the main producers of CS doctoral degrees. The data in this graph are normalized by the number of reporting departments. The graph offsets the qualifier data by two years from the data for new students, and offsets the graduation data by five years from the data for new students. These data have been useful in estimating the timing of changes in production rates. The graph suggests that there may be some further rise in doctoral production during the next few years. The departments are, in fact, forecasting a considerable increase in production during 2016-17 (Table DI).

## Ph.D. Employment

Figure D 6 shows the employment trend of new Ph.D.s in academia and industry within North America, those taking employment outside of North America, and those going to academia in North America who took positions in departments other than Ph.D.-granting CS and CE departments. Table D4 shows a more detailed breakdown of the employment data for new Ph.D.s. The percentage of new Ph.D.s who took positions in North American industry was 57.2 percent, similar to the percentage reported last year. Among those doctoral graduates who went to North American industry and for whom the type of industry position was known, about 60 percent took research positions (Table D4a). This is higher than the 57 percent reported in 2015. This year, definitive data was provided for 91 percent of the graduates who went to North American industry.

The percentage of Ph.D. graduates who took North American academic jobs rose in 2015-16 for the second straight year, to 30.7 from 29.0 last year. However, the percentage of graduates taking tenure-track positions in North American doctoral-granting computing departments fell from to 10.0 in 2014-15 to 9.0 in 2015-16. The percentage taking positions in

North American non-Ph.D.-granting computing departments fell from 2.3 percent to 1.6 percent, while the percentage taking North American academic postdoctoral positions jumped from 9.7 percent to 14.3 percent.

Among those whose employment is known, the proportion of Ph.D. graduates who were reported taking positions outside of North America fell from 7.8 percent to 7.3 percent. In 201516, 28 percent of those employed outside of North America went to industry compared to 24 percent reported last year. About 33 percent went to tenure-track academic positions, almost doubling last year's 17 percent, while approximately 15 percent went to academic postdoctoral positions, down from 20 percent last year. Of the doctoral graduates who went to non-North American industry positions, the positions were in research by more than a three-to-one margin. Definitive data was provided for 97 percent of these graduates.
Employment in industry postdoctoral positions is included in the overall industry numbers. When academic and industry postdocs are combined, the result is that 16.6 percent of 2015-16 doctoral graduates took some type of postdoctoral position, up from 12.6 percent last year and greater than the 15.6 percent in 2013-14. Only about 8 percent of these were industry postdocs, continuing a downward trend.

The unemployment rate for new Ph.D.s again this year was below 1 percent. In 2015-16, 20.6 percent of new Ph.D.s' employment status was unknown; in 2014-15 it was 21.0 percent. The lack of information about the employment of more than one in five graduates may skew the real overall percentages for certain employment categories.

Table D4 also indicates the areas of specialty of new Ph.D.s, using this year's slightly modified category names. Artificial intelligence/machine learning, software engineering, databases, security/information assurance, and networks are the most popular areas of specialization for doctoral graduates, in that order. Security/information assurance made the biggest gain of any area this past year. There are many Ph.D.s categorized as "other," which includes "unknown." It is unclear how many of these are really "other" and how many were just not categorized.

## Master's and Bachelor's Degree Production and Enrollments

This section reports data about enrollment and degree production for master's and bachelor's programs in the doctoral-granting departments. Although the absolute number of degrees and enrolled students reported herein only reflect departments that offer the doctoral degree, the trends observed in the master's and bachelor's data from these departments tend to strongly reflect trends in the larger population of programs that offer such degrees.

## Master's (Tables M1-M8; Figures M1-M2)

On a per department basis, CS master's degree production in U.S. CS departments rose nearly 17 percent in 2015-16; this follows a nearly 25 percent increase in 2014-15. Both public and private departments again reported large increases.

Overall production of master's degrees in the CE and Information areas also rose in 2015-16. U.S. CS departments, both public and private, showed an increased production of information master's degrees, as did U.S. I departments (Table MI).

The proportion of female graduates among CS master's degree recipients rose very slightly, from 24.9 percent to
25.2 percent. The overall percentage of master's degrees to women increased only 0.1 to 29.4 percent, due to a drop in CE from 23.9 percent to 21.4 percent while the I area was fairly constant with just a change of 0.1 percent downward (Table M2).

In CS, 75.6 percent of master's degrees went to Non-resident Aliens, a large increase over the 68.1 percent in 2014-15. In the Information area, the percentage of the master's recipients that were Non-resident Aliens also showed a large increase in 2015-16, to 49.9 percent as compared with 33.3 percent in 2014-15 and 28.1 percent 2013-14. In both CS and I, the fraction of master's degrees going to Whites and domestic Asians declined. The percentage of master's recipients among American Indian/Alaska Native, Black/African-American, Native Hawaiian/Pacific Islander, Hispanic, and Multiracial dropped in CS from nearly 4 percent in 2014-15 to under 3 percent in 2015-16. This percentage also dropped in I from 13.2 percent to 10.6 percent (Table M3).

Non-resident Aliens comprised a much larger proportion of female CS degree recipients than male CS degree recipients, while Whites comprised a larger percentage of male CS degree recipients than female CS degree recipients (Table M7). With somewhat differing percentages, the same observations

Table MI. Master's Degrees Awarded by Department Type

| Department <br> Type | \# Depts | CS |  | CE |  | I |  | Total |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| US CS Public | 100 | 6,500 | $57.8 \%$ | 418 | $56.7 \%$ | 832 | $30.2 \%$ | 7,750 | $52.6 \%$ |
| US CS Private | 34 | 4,098 | $36.5 \%$ | 78 | $10.6 \%$ | 392 | $14.2 \%$ | 4,568 | $31.0 \%$ |
| Total US CS | 134 | 10,598 | $94.3 \%$ | 496 | $67.3 \%$ | 1,224 | $44.4 \%$ | 12,318 | $83.6 \%$ |
| US CE | 6 | 0 | $0.0 \%$ | 236 | $32.0 \%$ | 0 | $0.0 \%$ | 236 | $1.6 \%$ |
| US Info | 12 | 34 | $0.3 \%$ | 0 | $0.0 \%$ | 1,516 | $55.0 \%$ | 1,550 | $10.5 \%$ |
| Canadian | 11 | 607 | $5.4 \%$ | 5 | $0.7 \%$ | 15 | $0.5 \%$ | 627 | $4.3 \%$ |
| Grand Total | 163 | 11,239 |  | 737 |  | 2,755 |  | 14,731 |  |

Table M2. Master’s Degrees Awarded by Gender

|  | CS |  | CE |  | I |  | Total |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Male | 8,041 | $74.8 \%$ | 562 | $78.6 \%$ | 1,401 | $52.1 \%$ | 10,004 | $70.6 \%$ |
| Female | 2,715 | $25.2 \%$ | 153 | $21.4 \%$ | 1,288 | $47.9 \%$ | 4,156 | $29.4 \%$ |
| Total Known Gender | 10,756 |  | 715 |  | 2,689 |  | 14,160 |  |
| Gender Unknown | 483 |  | 22 |  | 66 |  | 571 |  |
| Grand Total | 11,239 |  | 737 |  | 2,755 |  | 14,731 |  |

held for CE master's graduates. In the I area, Non-resident Aliens comprised a larger percentage of male master's graduates than female master's graduates, and Whites comprised a smaller fraction of male master's graduates than female master's graduates. These observations are
consistent with those of previous years, and the current enrollment breakdown by gender and ethnicity (Table M8) suggests that these observations will continue to be reflected in master's recipients in the near future.

Table M3. Master's Degrees Awarded by Ethnicity

|  | CS |  | CE |  | I |  | Total |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Nonresident Alien | 7,883 | $75.6 \%$ | 526 | $73.6 \%$ | 1,256 | $49.9 \%$ | 9,665 | $70.8 \%$ |
| Amer Indian or Alaska Native | 14 | $0.1 \%$ | 3 | $0.4 \%$ | 9 | $0.4 \%$ | 26 | $0.2 \%$ |
| Asian | 731 | $7.0 \%$ | 44 | $6.2 \%$ | 132 | $5.2 \%$ | 907 | $6.6 \%$ |
| Black or African-American | 78 | $0.7 \%$ | 4 | $0.6 \%$ | 117 | $4.6 \%$ | 199 | $1.5 \%$ |
| Native Hawaiian/Pac Island | 8 | $0.1 \%$ | 0 | $0.0 \%$ | 1 | $0.0 \%$ | 9 | $0.1 \%$ |
| White | 1,536 | $14.7 \%$ | 111 | $15.5 \%$ | 863 | $34.3 \%$ | 2,510 | $18.4 \%$ |
| Multiracial, not Hispanic | 48 | $0.5 \%$ | 9 | $1.3 \%$ | 42 | $1.7 \%$ | 99 | $0.7 \%$ |
| Hispanic, any race | 126 | $1.2 \%$ | 18 | $2.5 \%$ | 97 | $3.9 \%$ | 241 | $1.8 \%$ |
| Total Residency \& Ethnicity Known | 10,424 |  | 715 |  | 2,517 |  | 13,656 |  |
| Resident, ethnicity unknown | 285 |  | 10 |  | 86 |  | 381 |  |
| Residency unknown | 530 |  | 12 |  | 152 |  | 694 |  |
| Grand Total | 11,239 |  | 737 |  | 2,755 |  | 14,731 |  |

Table M4. Master's Degrees Expected Next Year by Department Type

| Department <br> Type | \# <br> Depts | CS |  | CE |  | I |  | Total |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| US CS Public | 97 | 5,807 | $62.7 \%$ | 308 | $49.8 \%$ | 624 | $24.8 \%$ | 6,739 | $54.4 \%$ |
| US CS Private | 27 | 2,866 | $30.9 \%$ | 74 | $12.0 \%$ | 353 | $14.0 \%$ | 3,293 | $26.6 \%$ |
| Total US CS | 124 | 8,673 | $93.7 \%$ | 382 | $61.8 \%$ | 977 | $38.8 \%$ | 10,032 | $80.9 \%$ |
| US CE | 6 | 0 | $0.0 \%$ | 226 | $36.6 \%$ | 0 | $0.0 \%$ | 226 | $1.8 \%$ |
| US Info | 12 | 35 | $0.4 \%$ | 0 | $0.0 \%$ | 1,538 | $61.2 \%$ | 1,573 | $12.7 \%$ |
| Canadian | 11 | 553 | $6.0 \%$ | 10 | $1.6 \%$ | 0 | $0.0 \%$ | 563 | $4.5 \%$ |
| Grand Total | 153 | 9,261 |  | 618 |  | 2,515 |  | 12,394 |  |

Table M5. New Master’s Students by Department Type

| Department Type | CS |  |  | CE |  |  | I |  |  | Total |  |  | Outside North America |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Total | Depts | Avg. <br> per <br> Dept. | Total | Depts | Avg. per Dept. | Total | Depts | Avg. <br> per <br> Dept. | Total | Depts | Avg. per Dept. | Depts | \% |
| US CS Public | 6,735 | 98 | 68.7 | 326 | 19 | 17.2 | 886 | 15 | 59.1 | 7,947 | 98 | 81.1 | 5,612 | 70.6\% |
| US CS Private | 3,275 | 32 | 102.3 | 113 | 5 | 22.6 | 252 | 3 | 84.0 | 3,640 | 32 | 113.8 | 2,213 | 60.8\% |
| Total US CS | 10,010 | 130 | 77.0 | 439 | 24 | 18.3 | 1,138 | 18 | 63.2 | 11,587 | 130 | 89.1 | 7,825 | 67.5\% |
| US CE | 0 | 0 | 0.0 | 259 | 6 | 43.2 | 0 | 0 | 0.0 | 259 | 6 | 43.2 | 203 | 78.4\% |
| US Info | 18 | 1 | 18.0 | 0 | 0 | 0.0 | 1,160 | 11 | 105.5 | 1,178 | 11 | 107.1 | 581 | 49.3\% |
| Canadian | 468 | 11 | 42.5 | 6 | 1 | 6.0 | 0 | 0 | 0.0 | 474 | 11 | 43.1 | 319 | 67.3\% |
| Grand Total | 10,496 | 142 | 73.9 | 704 | 31 | 22.7 | 2,298 | 29 | 79.2 | 13,498 | 158 | 85.4 | 8,928 | 66.1\% |

There were increases once again in the number of new master's students enrolled in U.S. CS departments, from an average of 80.7 per department in 2015 to 89.1 in 2016 (an increase of slightly over 10 percent). U.S. CS departments at both public and private institutions experienced similar increases (Table M5).

The fraction of new master's students in U.S. CS departments that is reported to be from outside North America rose from
63.3 percent in 2015-16 to 67.5 percent in 2016-17 (Table M5). The increase was in departments at public institutions; private institutions showed a slight decrease, from 61.3 percent to 60.8 percent. At U.S. Information departments, the fraction of new master's students from outside North America rose from 32.4 percent to 49.3 percent, following a decrease last year

Table M6. Total Master's Enrollment by Department Type

| DepartmentType тype | CS |  |  | CE |  |  | I |  |  | Total |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Total | Depts | Avg. per Dept. | Total | Depts | Avg. per Dept. | Total | $\begin{gathered} \text { \# } \\ \text { Depts } \end{gathered}$ | Avg. per Dept. | Total | Depts | Avg. per Dept. |
| US CS Public | 16,999 | 100 | 170.0 | 881 | 26 | 33.9 | 2,291 | 16 | 143.2 | 20,171 | 100 | 201.7 |
| US CS Private | 10,424 | 34 | 306.6 | 151 | 6 | 25.2 | 1,105 | 3 | 368.3 | 11,680 | 34 | 343.5 |
| Total US CS | 27,423 | 134 | 204.6 | 1,032 | 32 | 32.3 | 3,396 | 19 | 178.7 | 31,851 | 134 | 237.7 |
| US CE | 0 | 0 | 0.0 | 679 | 6 | 113.2 | 0 | 0 | 0.0 | 679 | 6 | 113.2 |
| US Info | 88 | 1 | 88.0 | 0 | 0 | 0.0 | 3,334 | 11 | 303.1 | 3,422 | 11 | 311.1 |
| Canadian | 1,164 | 11 | 105.8 | 17 | 1 | 17.0 | 48 | 1 | 48.0 | 1,229 | 11 | 111.7 |
| Grand Total | 28,675 | 146 | 196.4 | 1,728 | 39 | 44.3 | 6,778 | 31 | 218.6 | 37,181 | 162 | 229.5 |

Table M7. Masters Degrees Awarded by Gender and Ethnicity, From 163 Departments Providing Breakdown Data

|  | CS |  |  |  |  | CE |  |  |  |  | I |  |  |  |  | EthnicityTotals |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Male | Fem | N/R | $\begin{aligned} & \text { \% } \\ & \text { of } \\ & M^{*} \end{aligned}$ | $\begin{aligned} & \% \\ & \text { \% } \\ & \text { F } \end{aligned}$ | Male | Fem | N/R | $\begin{aligned} & \% \\ & \text { \%f } \\ & \mathrm{M}^{*} \end{aligned}$ | $\begin{aligned} & \% \\ & \text { \% } \\ & \text { F } \end{aligned}$ | Male | Fem | N/R | $\begin{aligned} & \% \\ & \text { \% } \\ & \text { M* } \end{aligned}$ | $\begin{aligned} & \% \\ & \text { of } \\ & \text { F* } \end{aligned}$ | Total | \% |
| Nonresident Alien | 5,652 | 2,086 | 92 | 74 | 81 | 390 | 124 | 12 | 72 | 83 | 689 | 528 | 39 | 54 | 44 | 9,665 | 70.8 |
| Amer Indian or Alaska Native | 5 | 8 | 1 | 0 | 0 | 3 | 0 | 0 | 1 | 0 | 6 | 3 | 0 | 1 | 0 | 26 | 0.2 |
| Asian | 508 | 211 | 6 | 7 | 8 | 31 | 11 | 2 | 6 | 7 | 73 | 55 | 4 | 6 | 5 | 907 | 6.6 |
| Black or AfricanAmerican | 52 | 25 | 1 | 1 | 1 | 3 | 1 | 0 | 1 | 1 | 65 | 49 | 3 | 5 | 4 | 199 | 1.5 |
| Native Hawaiian/ Pac Islander | 7 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 9 | 0.1 |
| White | 1,262 | 227 | 44 | 17 | 9 | 95 | 10 | 6 | 17 | 7 | 382 | 475 | 6 | 30 | 40 | 2,510 | 18.4 |
| Multiracial, not Hispanic | 33 | 12 | 2 | 0 | 1 | 7 | 2 | 0 | 1 | 1 | 9 | 33 | 0 | 1 | 3 | 99 | 0.7 |
| Hispanic, any race | 105 | 19 | 2 | 1 | 1 | 16 | 2 | 0 | 3 | 1 | 44 | 53 | 0 | 4 | 4 | 241 | 1.8 |
| Total Res \& Ethnicity Known | 7,624 | 2,589 | 148 |  |  | 545 | 150 | 20 |  |  | 1,269 | 1,196 | 52 |  |  | 13,656 |  |
| Resident, ethnicity unknown | 223 | 59 | 3 |  |  | 8 | 1 | 1 |  |  | 43 | 43 | 0 |  |  | 381 |  |
| Not Reported (N/R) | 151 | 47 | 332 |  |  | 9 | 2 | 1 |  |  | 89 | 49 | 14 |  |  | 694 |  |
| Gender Totals | 8,041 | 2,715 | 483 |  |  | 562 | 153 | 22 |  |  | 1,401 | 1,288 | 66 |  |  | 14,731 |  |
| \% | 74.8\% | 25.2\% |  |  |  | 78.6\% | 21.4\% |  |  |  | 52.1\% | 47.9\% |  |  |  |  |  |
| * \% of M and \% of F columns are the percent of that gender who are of the specified ethnicity, of those whose ethnicity is known |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

Table M8. Masters Enrollment by Gender and Ethnicity, From 162 Departments Providing Breakdown Data

|  | CS |  |  |  |  | CE |  |  |  |  | I |  |  |  |  | Ethnicity Totals |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Male | Fem | N/R | \% of M* | \% of F* | Male | Fem | N/R | $\begin{gathered} \% \text { of } \\ M^{*} \end{gathered}$ | $\%$ of F* | Male | Fem | N/R | \% of M* | \% of F* | Total | \% |
| Nonresident Alien | 11,486 | 5,169 | 886 | 63 | 78 | 955 | 328 | 29 | 76 | 86 | 1,784 | 1,275 | 13 | 51 | 45 | 22,211 | 65.0 |
| Amer Indian or Alaska Native | 19 | 5 | 0 | 0 | 0 | 6 | 0 | 0 | 1 | 0 | 1 | 4 | 0 | 0 | 0 | 36 | 0.1 |
| Asian | 1,619 | 610 | 11 | 9 | 9 | 50 | 15 | 6 | 4 | 4 | 261 | 167 | 0 | 8 | 6 | 2,742 | 8.0 |
| Black or AfricanAmerican | 284 | 85 | 2 | 2 | 1 | 10 | 5 | 0 | 1 | 1 | 191 | 131 | 0 | 6 | 5 | 71 | 2.1 |
| Native Hawaiian/ Pac Islander | 16 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 3 | 0 | 0 | 0 | 27 | 0.1 |
| White | 4,178 | 626 | 94 | 23 | 10 | 180 | 27 | 13 | 14 | 7 | 1,051 | 1,112 | 20 | 30 | 39 | 7,309 | 21.4 |
| Multiracial, not Hispanic | 137 | 31 | 0 | 1 | 1 | 9 | 1 | 0 | 1 | 0 | 44 | 62 | 0 | 1 | 2 | 285 | 0.8 |
| Hispanic, any race | 491 | 76 | 6 | 3 | 1 | 41 | 7 | 3 | 3 | 2 | 139 | 100 | 0 | 4 | 4 | 865 | 2.5 |
| Total Res \& Ethnicity Known | 18,230 | 6,605 | 999 |  |  | 1,251 | 383 | 51 |  |  | 3,476 | 2,854 | 33 |  |  | 34,186 |  |
| Resident, ethnicity unknown | 874 | 229 | 12 |  |  | 13 | 2 | 3 |  |  | 188 | 143 | 2 |  |  | 1558 |  |
| Not Reported (N/R) | 694 | 246 | 390 |  |  | 6 | 1 | 18 |  |  | 53 | 15 | 14 |  |  | 1,437 |  |
| Gender Totals | 20,108 | 7,166 | 1401 |  |  | 1,270 | 386 | 72 |  |  | 3,717 | 3,012 | 49 |  |  | 37,181 |  |
| \% | 73.7\% | 26.3\% |  |  |  | 76.7\% | 23.3\% |  |  |  | 55.2\% | 44.8\% |  |  |  |  |  |
| * \% of M and \% of F columns are the percent of that gender who are of the specified ethnicity, of those whose ethnicity is known |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |




## Bachelor's (Tables 1, BI-B8; Figures BI-B4)

When comparing bachelor's degree production reported by all departments this year to that reported by all departments last year, there was an overall increase in of 16.6 percent, and an increase of 23.3 percent per department. When considering only those departments that reported both years, the increase was 18.1 percent (Table I). Among U.S. computer science departments, the increases in overall bachelor's degree production were 19.0 percent overall and 24.5 percent
per department. The increase was 16.7 percent for those U.S. CS departments that reported both years. When only the CS area is considered, bachelor's degree production per department increased 26.2 percent at U.S. CS departments, and it increased 30.6 percent among all reporting departments (Table BI).

This marks the third consecutive year of double-digit percentage increases in bachelor's degree production. It is a natural outgrowth of the bachelor's enrollments surge reported for the past several years. Sizeable increases in bachelor's

Table BI. Bachelor's Degrees Awarded by Department Type

| Department <br> Type | \# Depts | CS |  | CE |  | I |  | Total |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| US CS Public | 98 | 12,630 | $66.6 \%$ | 1,858 | $71.2 \%$ | 1,835 | $46.5 \%$ | 16,323 | $64.0 \%$ |
| US CS Private | 33 | 3,800 | $20.0 \%$ | 254 | $9.7 \%$ | 332 | $8.4 \%$ | 4,386 | $17.2 \%$ |
| Total US CS | 131 | 16,430 | $86.7 \%$ | 2,112 | $80.9 \%$ | 2,167 | $55.0 \%$ | 20,709 | $81.2 \%$ |
| US CE | 6 | 0 | $0.0 \%$ | 431 | $16.5 \%$ | 201 | $5.1 \%$ | 632 | $2.5 \%$ |
| US Info | 9 | 98 | $0.5 \%$ | 0 | $0.0 \%$ | 1,208 | $30.6 \%$ | 1,306 | $5.1 \%$ |
| Canadian | 10 | 2,426 | $12.8 \%$ | 68 | $2.6 \%$ | 367 | $9.3 \%$ | 2,861 | $11.2 \%$ |
| Grand Total | 156 | 18,954 |  | 2,611 |  | 3,943 |  | 25,508 |  |

Table B2. Bachelor's Degrees Awarded by Gender

|  | CS |  | CE |  | I |  | Total |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Male | 14,259 | $82.1 \%$ | 2,103 | $87.4 \%$ | 2,830 | $77.1 \%$ | 19,192 | $81.9 \%$ |
| Female | 3,107 | $17.9 \%$ | 304 | $12.6 \%$ | 840 | $22.9 \%$ | 4,251 | $18.1 \%$ |
| Total Known Gender | 17,366 |  | 2,407 |  | 3,670 |  | 23,443 |  |
| Gender Unknown | 1,588 |  | 204 |  | 273 |  | 2,065 |  |
| Grand Total | 18,954 |  | 2,611 |  | 3,943 |  | 25,508 |  |

Table B3. Bachelor's Degrees Awarded by Ethnicity

|  | CS |  | CE |  | I |  | Total |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Nonresident Alien | 1,493 | $10.4 \%$ | 214 | $9.0 \%$ | 188 | $5.6 \%$ | 1,895 | $9.4 \%$ |
| Amer Indian or Alaska Native | 53 | $0.4 \%$ | 6 | $0.3 \%$ | 7 | $0.2 \%$ | 66 | $0.3 \%$ |
| Asian | 3,625 | $25.3 \%$ | 630 | $26.4 \%$ | 596 | $17.8 \%$ | 4,851 | $24.2 \%$ |
| Black or African-American | 440 | $3.1 \%$ | 99 | $4.1 \%$ | 256 | $7.6 \%$ | 795 | $4.0 \%$ |
| Native Hawaiian/Pac Islander | 26 | $0.2 \%$ | 2 | $0.1 \%$ | 18 | $0.5 \%$ | 46 | $0.2 \%$ |
| White | 7,202 | $50.3 \%$ | 1,172 | $49.1 \%$ | 1,760 | $52.4 \%$ | 10,134 | $50.5 \%$ |
| Multiracial, not Hispanic | 409 | $2.9 \%$ | 59 | $2.5 \%$ | 119 | $3.5 \%$ | 587 | $2.9 \%$ |
| Hispanic, any race | 1,069 | $7.5 \%$ | 205 | $8.6 \%$ | 412 | $12.3 \%$ | 1,686 | $8.4 \%$ |
| Total Residency \& Ethnicity Known | 14,317 |  | 2,387 |  | 3,356 |  | 20,060 |  |
| Resident, ethnicity unknown | 677 |  | 59 |  | 116 |  | 852 |  |
| Residency unknown | 3,960 |  | 165 |  | 471 |  | 4,596 |  |
| Grand Total | 18,954 |  | 2,611 |  | 3,943 |  | 25,508 |  |

degree production are likely to continue for the next few years based on current enrollments. Figure Bl shows the trend in total computing bachelor's degree production since 1995 for all departments reporting to the Taulbee Survey.

For the ninth consecutive year, there was an increase in the number of new undergraduate computing majors. This year's respondents reported 6.9 percent more new majors (but 14.7
percent more per department) than did last year's respondents. The increase is only 5.3 percent when considering only those departments reporting both this year and last year. Among U.S. computer science departments, the increase was 10.1 percent overall ( 18.6 percent per department), and 6.6 percent among departments reporting both this year and last year. If only increases in new CS majors at U.S. CS departments are considered, the average increase is 19.9 percent per

Table B4. Bachelor's Degrees Expected Next Year by Department Type

| Department <br> Type | \# Depts | CS |  | CE |  | I |  | Total |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| US CS Public | 91 | 13,140 | $67.4 \%$ | 1,800 | $64.4 \%$ | 1,430 | $51.0 \%$ | 16,370 | $65.3 \%$ |
| US CS Private | 27 | 3,830 | $19.7 \%$ | 294 | $10.5 \%$ | 23 | $0.8 \%$ | 4,147 | $16.5 \%$ |
| Total US CS | 118 | 16,970 | $87.1 \%$ | 2,094 | $75.0 \%$ | 1,453 | $51.8 \%$ | 20,517 | $81.8 \%$ |
| US CE | 6 | 0 | $0.0 \%$ | 607 | $21.7 \%$ | 0 | $0.0 \%$ | 607 | $2.4 \%$ |
| US Info | 8 | 0 | $0.0 \%$ | 0 | $0.0 \%$ | 1,344 | $47.9 \%$ | 1,344 | $5.4 \%$ |
| Canadian | 10 | 2,513 | $12.9 \%$ | 92 | $3.3 \%$ | 7 | $0.2 \%$ | 2,612 | $10.4 \%$ |
| Grand Total | 142 | 19,483 |  | 2,793 |  | 2,804 |  | 25,080 |  |

Table B5. New Bachelor's Students by Department Type

|  | CS |  |  |  | CE |  |  |  | I |  |  |  | Total |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Department Type | Major | PreMajor | Depts | Avg. <br> Major <br> /Dept | Total | PreMajor | Depts | Avg. <br> Major <br> /Dept | Total | PreMajor | Depts | Avg. <br> Major <br> /Dept | Total Major | Avg. <br> Major <br> /Dept |
| US CS Public | 18,302 | 8,450 | 85 | 215.3 | 2,217 | 849 | 27 | 82.1 | 836 | 234 | 21 | 39.8 | 21,355 | 251.2 |
| US CS Private | 5,239 | 1,771 | 27 | 194.0 | 353 | 15 | 8 | 44.1 | 319 | 13 | 4 | 79.8 | 5,911 | 218.9 |
| US CS Total | 23,541 | 10,221 | 112 | 210.2 | 2,570 | 864 | 35 | 73.4 | 1,155 | 247 | 25 | 46.2 | 27,266 | 243.4 |
| US CE | 0 | 0 | 0 | 0.0 | 470 | 363 | 6 | 78.3 | 0 | 0 | 0 | 0.0 | 470 | 78.3 |
| US Information | 200 | 0 | 1 | 200.0 | 0 | 0 | 0 | 0.0 | 935 | 150 | 10 | 93.5 | 1,135 | 113.5 |
| Canadian | 3,178 | 782 | 9 | 353.1 | 167 | 0 | 2 | 83.5 | 0 | 0 | 0 | 0.0 | 3,345 | 371.7 |
| Grand Total | 26,919 | 11,003 | 122 | 220.6 | 3,207 | 1,227 | 43 | 74.6 | 2,090 | 397 | 35 | 59.7 | 32,216 | 235.2 |

Table B6. Total Bachelor's Enrollment by Department Type

|  | CS |  |  |  | CE |  |  |  | I |  |  |  | Total |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Department Type | Major | PreMajor | Depts | Avg. <br> Major <br> IDept | Total | PreMajor | Depts | Avg. Major /Dept | Total | PreMajor | Dept | Avg. <br> Major <br> /Dept | Total Major | Avg. <br> Major <br> /Dept |
| US CS Public | 72,159 | 15,347 | 98 | 736.3 | 9,646 | 1,570 | 36 | 267.9 | 7,989 | 698 | 26 | 307.3 | 89,794 | 916.3 |
| US CS Private | 22,342 | 2,397 | 33 | 677.0 | 1,120 | 18 | 9 | 124.4 | 1,351 | 9 | 4 | 337.8 | 24,813 | 751.9 |
| US CS Total | 94,501 | 17,744 | 131 | 721.4 | 10,766 | 1,588 | 45 | 239.2 | 9,340 | 707 | 30 | 311.3 | 114,607 | 874.9 |
| US CE | 0 | 0 | 0 | 0.0 | 2,244 | 1,098 | 6 | 374.0 | 837 | 0 | 1 | 837.0 | 3,081 | 513.5 |
| US Info | 802 | 0 | 1 | 802.0 | 0 | 0 | 0 | 0.0 | 3,919 | 679 | 9 | 435.4 | 4,721 | 524.6 |
| Canadian | 9,845 | 3,042 | 9 | 1,093.9 | 216 | 499 | 1 | 216.0 | 4,119 | 0 | 4 | 1,029.8 | 14,180 | 1,575.6 |
| Grand Total | 105,148 | 20,786 | 141 | 745.7 | 13,226 | 3,185 | 52 | 254.3 | 18,215 | 1,386 | 44 | 414.0 | 136,589 | 881.2 |

department. Figure B2 illustrates the trend in the total number of newly declared computing undergraduate majors as reported in the Taulbee Survey.

Total undergraduate enrollment in computing majors among U.S. CS departments (i.e., the sum of the number of majors in CS, CE, and I at these departments) increased 16.4 percent ( 21.2 percent per department) when all respondents are compared, and increased 16.8 percent among U.S. CS departments reporting both this year and last year. Aggregate total enrollment (which combines CS departments, CE departments, I departments, and Canadian departments) once again increased in all three computing areas (CS, CE, and I), although the increase in CE was less than 1 percent and actually decreased slightly on a per-department basis (Table B6).

Per-department averages smooth out comparisons from year to year when there are differences in the number of reporting departments, but the averages include both very large and very small departments. Figures B3 and B4 show the distribution of
number of degrees awarded (Figure B3) and total enrollment (Figure B4) per tenured or tenure-track faculty member, in department size groupings for the U.S. CS departments.

The enrollment increases in CS are of particular interest to our community, and the recent CRA Enrollment Report (www. cra.org/data/generation-cs) discusses the current surge in considerable detail. This year's Taulbee Survey data shows that the per-department enrollment of CS bachelor's majors in U.S. CS departments increased by 24.8 percent over last year. Figure B5 shows the enrollment trend from Taulbee Survey data since this surge began a decade ago. The average enrollment per U.S. CS department has increased approximately 275 percent during this period; that is, it has nearly quadrupled. For the past three years, it has exceeded the previous peak reached during the dot-com enrollment surge. Analysis of the newly collected course-level enrollment data will be presented in future Taulbee Survey reports.

Table B7. Bachelors Degrees Awarded by Gender and Ethnicity, From 156 Departments Providing Breakdown Data

|  | CS |  |  |  |  | CE |  |  |  |  | I |  |  |  |  | EthnicityTotals |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Male | Fem | N/R | \% of M* | $\underset{F^{*}}{\%}$ | Male | Fem | N/R | $\% \text { of }$ $M^{*}$ | $\underset{F^{*}}{\%}$ | Male | Fem | N/R | $\begin{gathered} \% \text { of } \\ M^{*} \end{gathered}$ | \% of F* | Total | \% |
| Nonresident Alien | 1,141 | 344 | 3 | 10 | 14 | 171 | 41 | 2 | 9 | 14 | 140 | 43 | 5 | 6 | 6 | 1,895 | 9.4 |
| Amer Indian or Alaska Native | 46 | 5 | 2 | 0 | 0 | 5 | 1 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 66 | 0.3 |
| Asian | 2,738 | 870 | 8 | 24 | 35 | 522 | 97 | 11 | 26 | 33 | 398 | 181 | 17 | 16 | 24 | 4,851 | 24.2 |
| Black or AfricanAmerican | 350 | 79 | 5 | 3 | 3 | 73 | 19 | 7 | 4 | 7 | 174 | 62 | 20 | 7 | 8 | 795 | 4.0 |
| Native Hawaiian/ Pac Islander | 22 | 4 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 12 | 6 | 0 | 1 | 1 | 46 | 0.2 |
| White | 6,120 | 931 | 121 | 53 | 38 | 1,015 | 103 | 54 | 51 | 35 | 1,349 | 336 | 75 | 55 | 45 | 10,134 | 50.5 |
| Multiracial, not Hispanic | 322 | 75 | 6 | 3 | 3 | 49 | 10 | 0 | 3 | 3 | 75 | 41 | 3 | 3 | 6 | 587 | 2.9 |
| Hispanic, any race | 875 | 173 | 21 | 8 | 7 | 153 | 23 | 29 | 8 | 8 | 312 | 79 | 21 | 13 | 11 | 1,686 | 8.4 |
| Total Res \& Ethnicity Known | 11,614 | 2,481 | 166 |  |  | 1,990 | 294 | 103 |  |  | 2,467 | 748 | 141 |  |  | 20,060 |  |
| Resident, ethnicity unknown | 540 | 125 | 8 |  |  | 55 | 4 | 0 |  |  | 98 | 18 | 0 |  |  | 852 |  |
| Not Reported ( $\mathrm{N} / \mathrm{R}$ ) | 2,058 | 488 | 1,414 |  |  | 58 | 6 | 101 |  |  | 265 | 74 | 132 |  |  | 4,596 |  |
| Gender Totals | 14,259 | 3,107 | 1,588 |  |  | 2,103 | 304 | 204 |  |  | 2,830 | 840 | 273 |  |  | 25,508 |  |
| \% | 82.1\% | 17.9\% |  |  |  | 87.4\% | 12.6\% |  |  |  | 77.1\% | 22.9\% |  |  |  |  |  |
| * \% of M and \% of F columns are the percent of that gender who are of the specified ethnicity, of those whose ethnicity is known |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

Table B8. Bachelors Enrollment by Gender and Ethnicity, From 155 Departments Providing Breakdown Data

|  |  |  | CS |  |  |  |  | CE |  |  |  |  | I |  |  | Ethni |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Male | Fem | N/R | $\begin{gathered} \% \text { of } \\ M^{*} \end{gathered}$ | \% of F* | Male | Fem | N/R | $\begin{gathered} \% \text { of } \\ M^{*} \end{gathered}$ | $\%$ of F* | Male | Fem | N/R | $\begin{gathered} \% \text { of } \\ M^{*} \end{gathered}$ | $\underset{F^{*}}{\%}$ | Total | \% |
| Nonresident Alien | 6,717 | 1,916 | 20 | 11 | 14 | 866 | 176 | 11 | 9 | 11 | 451 | 177 | 12 | 5 | 7 | 10,360 | 10.0 |
| Amer Indian or Alaska Native | 221 | 40 | 5 | 0 | 0 | 19 | 10 | 0 | 0 | 1 | 34 | 6 | 2 | 0 | 0 | 337 | 0.3 |
| Asian | 14,175 | 4,312 | 128 | 22 | 32 | 2,390 | 589 | 38 | 24 | 36 | 1,675 | 668 | 72 | 17 | 26 | 24,175 | 23.2 |
| Black or AfricanAmerican | 2,874 | 787 | 93 | 5 | 6 | 485 | 97 | 43 | 5 | 6 | 833 | 248 | 85 | 8 | 10 | 5,601 | 5.4 |
| Native Hawaiian/ Pac Islander | 168 | 34 | 5 | 0 | 0 | 16 | 3 | 0 | 0 | 0 | 43 | 11 | 0 | 0 | 0 | 280 | 0.3 |
| White | 31,707 | 4,627 | 770 | 50 | 35 | 4,821 | 556 | 193 | 49 | 34 | 5,231 | 1,093 | 381 | 53 | 43 | 49,633 | 47.7 |
| Multiracial, not Hispanic | 1,849 | 423 | 55 | 3 | 3 | 289 | 36 | 9 | 3 | 2 | 324 | 87 | 22 | 3 | 3 | 3,114 | 3.0 |
| Hispanic, any race | 5,998 | 1,150 | 264 | 9 | 9 | 1,058 | 184 | 107 | 11 | 11 | 1,359 | 282 | 148 | 14 | 11 | 10,567 | 10.2 |
| Total Res \& Ethnicity Known | 63,709 | 13,289 | 1,340 |  |  | 9,944 | 1,651 | 401 |  |  | 9,950 | 2,572 | 722 |  |  | 104,067 |  |
| Resident, ethnicity unknown | 3,477 | 888 | 2,130 |  |  | 337 | 50 | 8 |  |  | 433 | 86 | 11 |  |  | 7,445 |  |
| Not Reported (N/R) | 11,245 | 3,435 | 5,121 |  |  | 362 | 59 | 414 |  |  | 3,272 | 966 | 203 |  |  | 25,077 |  |
| Gender Totals | 78,853 | 17,704 | 8,591 |  |  | 10,643 | 1,760 | 823 |  |  | 13,655 | 3,624 | 936 |  |  | 136,589 |  |
| \% | 81.7\% | 18.3\% |  |  |  | 85.8\% | 14.2\% |  |  |  | 79.0\% | 21.0\% |  |  |  |  |  |
| * \% of M and \% of F columns are the percent of that gender who are of the specified ethnicity, of those whose ethnicity is known |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

Figure BI. BS Production (CS \& CE)
CRA Taulbee Survey 2016


Figure B2. Newly Declared Undergraduate Majors: CS, CE, and I (beginning in 2008) CRA Taulbee Survey 2016


Figure B3. Bachelor’s Degrees Granted by Tenure-Track Size CRA Taulbee Survey 2016



Figure B5. Average New and Continuing CS Majors per Academic Unit (U.S. CS Programs Only) CRA Taulbee Survey 2016


Table Fl. Actual and Anticipated Faculty Size by Position and Department Type


The proportion of women among bachelor's graduates in CS rose once again, from 15.7 percent in 2014-15 to 17.9 percent in 2015-16. This is the highest percentage of female CS graduates among Taulbee Survey respondents since 2002-03. In CE, the percentage of female bachelor's graduates rose from 11.6 percent to 12.6 percent and the percentage of female bachelor's graduates in I rose from 21.7 percent to 22.9 percent (Table B2). The percentage of CS bachelor's degrees awarded to Whites again declined from 55.0 percent in 2013-14 to 50.3 percent in 2014-15, while the percentage awarded to Asians rose again, from 22.8 percent to 25.3 percent and the percentage awarded to Non-resident Aliens rose from 8.8 percent to 10.4 percent. Changes in other ethnicity categories were less than 1 percent in CS. In aggregate across the three degree areas, 50.5 percent of the graduates were White, 24.2 percent Asian, 9.4 percent Non-resident Aliens, and 15.8 percent all other ethnicity categories combined. However, in I programs, the other ethnicity categories accounted for more than 24 percent of the graduates (Table B3).

In all three computing areas (CS, CE, and I), Resident Asians and Non-resident Aliens comprise a larger fraction of female enrollment than male enrollment, while Whites comprise a larger fraction of male enrollment than female enrollment (Table B8). Table B7 indicates that the same comparisons hold true for degree awardees with the exception of I degrees to Non-resident Aliens, whose relative percentages of men and women are equal.

## Faculty Demographics (Tables FI-F9) ${ }^{4}$

Table Fl shows the current and anticipated sizes, in FTE, for tenure-track, teaching, and research faculty, and postdocs. The total tenure-track faculty count in U.S. CS departments $(3,971)$ represents only a 2.3 percent increase over last year. However, the average tenure-track faculty size per U.S. CS department grew from 28.1 to 29.4 during this period, a 4.6 percent increase. In these departments, the average number of teaching faculty increased from 6.9 to 7.7 and the average number of research faculty increased from 5.4 to 5.7 , while the average number of postdocs remained at 6.5. Canadian, CE, and I departments have much more volatile data due to the small number of departments reporting in each of these categories.

As noted in previous Taulbee reports, Canadian universities, on average, have several more tenure-track faculty members per department than do U.S. universities, while U.S. I and CE

Table F2. Vacant Positions 2014-2015 by Position and Department Type

|  | Tried to fill | Filled |
| :---: | :---: | :---: |
| US CS Public |  |  |
| TenureTrack | 302 | 221 |
| Teaching | 121 | 104 |
| Research | 46 | 45 |
| Postdoc | 96 | 115 |
| Total | 565 | 485 |
| US CS Private |  |  |
| TenureTrack | 116 | 83 |
| Teaching | 48 | 39 |
| Research | 22 | 24 |
| Postdoc | 90 | 84 |
| Total | 276 | 230 |
| All US CS |  |  |
| TenureTrack | 418 | 304 |
| Teaching | 169 | 143 |
| Research | 68 | 69 |
| Postdoc | 186 | 199 |
| Total | 841 | 715 |
| US CE |  |  |
| TenureTrack | 7 | 9 |
| Teaching | 18 | 18 |
| Research | 3 | 3 |
| Postdoc | 8 | 8 |
| Total | 36 | 38 |
| US I |  |  |
| TenureTrack | 39 | 26 |
| Teaching | 16 | 11 |
| Research | 1 | 1 |
| Postdoc | 9 | 8 |
| Total | 65 | 45 |
| Canadian |  |  |
| TenureTrack | 38 | 22 |
| Teaching | 11 | 11 |
| Research | 4 | 4 |
| Postdoc | 27 | 26 |
| Total | 80 | 63 |
| Grand Total |  |  |
| TenureTrack | 502 | 361 |
| Teaching | 214 | 183 |
| Research | 76 | 77 |
| Postdoc | 230 | 241 |
| Total | 1,022 | 861 |

departments, on average, are somewhat smaller than U.S. CS departments. The observations about U.S. CE and I departments may reflect the fact that we ask departments to report only computing-related faculty, so departments with Library Science or EE programs may report only part of their faculty.

Among U.S. CS departments, those at private universities have more of each category of faculty, including postdocs, than do
those at public universities on average. This has held true for the past two years except for tenure-track faculty, where last year the average size at public universities was slightly larger than that at private universities. The average tenure-track size at private universities jumped from 27.6 to 30.9 while the average at public universities showed a slim increase, from 28.3 to 28.9. The specific set of departments reporting from one year to the next can impact these figures.

Table F2a. Reasons Positions Left Unfilled

| Reason | \# Reported | \% of Reasons |
| :--- | :---: | :---: |
| Didn't find a person who met our hiring goals* | 25 | $16.3 \%$ |
| Offers turned down | 66 | $43.1 \%$ |
| Technically vacant, not filled for admin reasons | 9 | $5.9 \%$ |
| Hiring in progress | 47 | $30.7 \%$ |
| Other | 6 | $3.9 \%$ |
| Total Reasons Provided | 153 |  |
| *What hiring goals could not be met? |  | \# Given |
| Specific specialty area not found (no two the same) | 4 |  |
| Poor qualifications for teaching faculty | 4 |  |
| Not right qualifications or complement to current faculty |  | 9 |

Table F3. Gender of Newly Hired Faculty

|  | Tenure-Track |  | Teaching |  | Research |  | Postdoc |  | Total |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | :---: | :---: |
| Male | 271 | $75.7 \%$ | 118 | $70.2 \%$ | 51 | $77.3 \%$ | 161 | $77.8 \%$ | 601 | $75.2 \%$ |
| Female | 87 | $24.3 \%$ | 50 | $29.8 \%$ | 15 | $22.7 \%$ | 46 | $22.2 \%$ | 198 | $24.8 \%$ |
| Unknown | 0 |  | 0 |  | 0 |  | 1 |  | 1 |  |
| Total | 358 |  | 168 |  | 66 |  | 208 |  | 800 |  |

Table F4. Ethnicity of Newly Hired Faculty

|  | Tenure-Track |  | Teaching |  | Research |  | Postdoc |  | Total |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Nonresident Alien | 62 | $18.8 \%$ | 11 | $7.1 \%$ | 13 | $21.0 \%$ | 64 | $36.8 \%$ | 150 | $20.9 \%$ |
| American Indian / Alaska Native | 1 | $0.3 \%$ | 1 | $0.6 \%$ | 1 | $1.6 \%$ | 1 | $0.6 \%$ | 4 | $0.6 \%$ |
| Asian | 95 | $28.9 \%$ | 16 | $10.4 \%$ | 11 | $17.7 \%$ | 44 | $25.3 \%$ | 166 | $23.1 \%$ |
| Black or African-American | 12 | $3.6 \%$ | 4 | $2.6 \%$ | 0 | $0.0 \%$ | 0 | $0.0 \%$ | 16 | $2.2 \%$ |
| Native Hawaiian/ Pacific Islander | 0 | $0.0 \%$ | 5 | $3.2 \%$ | 0 | $0.0 \%$ | 0 | $0.0 \%$ | 5 | $0.7 \%$ |
| White | 144 | $43.8 \%$ | 94 | $61.0 \%$ | 28 | $45.2 \%$ | 51 | $29.3 \%$ | 317 | $44.1 \%$ |
| Multiracial, not Hispanic | 1 | $0.3 \%$ | 7 | $4.5 \%$ | 2 | $3.2 \%$ | 0 | $0.0 \%$ | 10 | $1.4 \%$ |
| Hispanic, any race | 2 | $0.6 \%$ | 8 | $5.2 \%$ | 3 | $4.8 \%$ | 2 | $1.1 \%$ | 15 | $2.1 \%$ |
| Resident, race/ethnic unknown | 12 | $3.6 \%$ | 8 | $5.2 \%$ | 4 | $6.5 \%$ | 12 | $6.9 \%$ | 36 | $5.0 \%$ |
| Total known residency | 329 |  | 154 |  | 62 |  | 174 |  | 719 |  |
| Residency Unknown | 29 |  | 14 |  | 4 |  | 34 |  | 81 |  |
| Total | 358 |  | 168 |  | 66 |  | 208 |  | 800 |  |

Table F2 summarizes faculty hiring this past year. The success rate for hiring tenure-track faculty at U.S. CS departments rose slightly, from 70.8 percent last year to 72.7 percent this year. The success rate was similar at public (73.2 percent) and private (7l.2 percent) departments. Again this year, Canadian departments had lower success rates, on average, than did U.S. CS, CE, and I departments. In aggregate, the tenure-track hiring success rate increased from 70.6 percent to 71.9 percent.

Table F5. Faculty Losses

| Died | 13 |
| :--- | :---: |
| Retired | 90 |
| Took Academic Position Elsewhere | 89 |
| Took Nonacademic Position | 42 |
| Remained, but Changed to Part Time | 13 |
| Other | 22 |
| Unknown | 1 |
| Total | 270 |

Among those hired into all categories of academic positions (tenure-track, teaching faculty, research faculty, and postdoc) for 2016-17, 24.8 percent were women, higher than the 21.6 percent newly hired for 2015-16 (Table F3). Considering only tenure-track positions, the proportion of women among those newly hired rose from 20.3 percent last year to 24.3 percent this year. Only among research faculty positions was there a decrease in the percentage of positions going to women as compared with those reported last year. This is the exact opposite from what happened last year. The percentage of women among new tenure-track and faculty hires and among newly hired faculty overall are higher than the percentage of new female Ph.D.s produced this past year.

Among new tenure-track faculty, the fraction who are White declined slightly, from 44.8 percent to 43.8 percent, while the fraction who are Non-resident Alien or Asian new hires rose from 43.5 percent to 47.7 percent. Once again, Whites dominated the newly hired teaching faculty, with Asians and Non-resident Aliens accounting for much of the remainder. Among research faculty, Whites comprised 45.2 percent of new

Table F6. Gender of Current Faculty

|  | Full |  | Associate |  | Assistant |  | Teaching |  | Research |  | Postdoc |  | Total |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | :---: |
| Male | 1,979 | $85.2 \%$ | 1,040 | $77.6 \%$ | 843 | $76.2 \%$ | 893 | $72.5 \%$ | 366 | $81.5 \%$ | 534 | $79.7 \%$ | 5,655 |  |

Table F7. Ethnicity of Current Faculty

|  | Full |  |  | Associate | Assistant |  | Teaching |  | Research |  | Postdoc |  | Total |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Nonresident Alien | 26 | $1.2 \%$ | 11 | $0.9 \%$ | 153 | $15.0 \%$ | 40 | $3.6 \%$ | 58 | $13.5 \%$ | 220 | $36.0 \%$ | 508 | $7.8 \%$ |
| American Indian / <br> Alaska Native | 3 | $0.1 \%$ | 1 | $0.1 \%$ | 3 | $0.3 \%$ | 1 | $0.1 \%$ | 1 | $0.2 \%$ | 0 | $0.0 \%$ | 9 | $0.1 \%$ |
| Asian | 583 | $26.8 \%$ | 375 | $31.8 \%$ | 301 | $29.5 \%$ | 113 | $10.0 \%$ | 78 | $18.2 \%$ | 135 | $22.1 \%$ | 1,585 | $24.2 \%$ |
| Black or African-American | 15 | $0.7 \%$ | 33 | $2.8 \%$ | 26 | $2.5 \%$ | 57 | $5.1 \%$ | 3 | $0.7 \%$ | 7 | $1.1 \%$ | 141 | $2.2 \%$ |
| Native Hawaiian / <br> Pacific Islander | 2 | $0.1 \%$ | 1 | $0.1 \%$ | 1 | $0.1 \%$ | 14 | $1.2 \%$ | 0 | $0.0 \%$ | 1 | $0.2 \%$ | 19 | $0.3 \%$ |
| White | 1,411 | $64.8 \%$ | 685 | $58.1 \%$ | 487 | $47.7 \%$ | 820 | $72.9 \%$ | 265 | $61.8 \%$ | 199 | $32.6 \%$ | 3,867 | $59.1 \%$ |
| Multiracial, not Hispanic | 11 | $0.5 \%$ | 5 | $0.4 \%$ | 4 | $0.4 \%$ | 4 | $0.4 \%$ | 1 | $0.2 \%$ | 1 | $0.2 \%$ | 26 | $0.4 \%$ |
| Hispanic, any race | 46 | $2.1 \%$ | 31 | $2.6 \%$ | 20 | $2.0 \%$ | 26 | $2.3 \%$ | 11 | $2.6 \%$ | 13 | $2.1 \%$ | 147 | $2.2 \%$ |
| Resident, race/ethnic <br> unknown | 82 | $3.8 \%$ | 36 | $3.1 \%$ | 26 | $2.5 \%$ | 50 | $4.4 \%$ | 12 | $2.8 \%$ | 35 | $5.7 \%$ | 241 | $3.7 \%$ |
| Total known residency | 2,179 |  | 1,178 |  | 1,021 |  | 1,125 |  | 429 |  | 611 |  | 6,543 |  |
| Residency Unknown | 174 |  | 173 |  | 85 |  | 122 |  | 21 |  | 94 |  | 669 |  |
| Total | 2,353 |  | 1,351 |  | 1,106 |  | 1,247 |  | 450 |  | 705 |  | 7,212 |  |

Table F8. Current Tenured and Tenure-Track Faculty by Gender and Ethnicity, From 163 Departments

|  | Full Professor |  |  |  |  | Associate Professor |  |  |  |  | Assistant Professor |  |  |  |  | EthnicityTotals |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Male | Fem | N/R | \% of M* | \% of F* | Male | Fem | N/R | \% of M* | $\%$ of F* | Male | Fem | N/R | \% of M* | $\%$ of F* | Total | \% |
| Nonresident Alien | 19 | 7 | 0 | 1 | 2 | 9 | 2 | 0 | 1 | 1 | 122 | 31 | 0 | 16 | 13 | 190 | 4.5 |
| Amer Indian or Alaska Native | 2 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 7 | 0.2 |
| Asian | 511 | 65 | 7 | 29 | 21 | 282 | 92 | 1 | 32 | 36 | 232 | 69 | 0 | 31 | 29 | 1,259 | 29.7 |
| Black or AfricanAmerican | 12 | 3 | 0 | 1 | 1 | 19 | 14 | 0 | 2 | 5 | 15 | 11 | 0 | 2 | 5 | 74 | 1.7 |
| Native Hawaiian/ Pac Islander | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 4 | 0.1 |
| White | 1,175 | 219 | 17 | 67 | 72 | 537 | 144 | 4 | 61 | 56 | 369 | 118 | 0 | 49 | 50 | 2,583 | 61.0 |
| Multiracial, not Hispanic | 11 | 0 | 0 | 1 | 0 | 5 | 0 | 0 | 1 | 0 | 2 | 2 | 0 | 0 | 1 | 20 | 0.5 |
| Hispanic, any race | 34 | 10 | 2 | 2 | 3 | 25 | 5 | 1 | 3 | 2 | 14 | 6 | 0 | 2 | 3 | 97 | 2.3 |
| Total Res \& Ethnicity Known | 1,766 | 305 | 26 |  |  | 879 | 257 | 6 |  |  | 757 | 238 | 0 |  |  | 4,234 |  |
| Resident, ethnicity unknown | 66 | 13 | 3 |  |  | 22 | 10 | 4 |  |  | 18 | 8 | 0 |  |  | 144 |  |
| Not Reported (N/R) | 147 | 27 | 0 |  |  | 139 | 34 | 0 |  |  | 68 | 17 | 0 |  |  | 432 |  |
| Gender Totals | 1,979 | 345 | 29 |  |  | 1,040 | 301 | 10 |  |  | 843 | 263 | 0 |  |  | 4,810 |  |
| \% | 85.2\% | 14.8\% |  |  |  | 77.6\% | 22.4\% |  |  |  | 76.2\% | 23.8\% |  |  |  |  |  |
| * \%M and \%F columns are the percent of that gender who are of the specified ethnicity, of those whose ethnicity is known |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

Table F9. Current Non-Tenure-Track Faculty and Postdoctorates by Gender and Ethnicity, From 160 Departments

|  | Non-Tenure-Track Teaching |  |  |  |  | Non-Tenure-Track Research |  |  |  |  | Postdoctorates |  |  |  |  | EthnicityTotals |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Male | Fem | N/R | \% of M* | $\% \text { of }$ $F^{*}$ | Male | Fem | N/R | \% of M* | $\begin{gathered} \text { \% of } \\ F^{*} \end{gathered}$ | Male | Fem | N/R | \% of M* | \% of F* | Total | \% |
| Nonresident Alien | 27 | 11 | 2 | 4 | 4 | 41 | 16 | 1 | 12 | 21 | 186 | 30 | 4 | 40 | 28 | 318 | 15 |
| Amer Indian or Alaska Native | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| Asian | 75 | 38 | 0 | 10 | 13 | 66 | 12 | 0 | 19 | 16 | 100 | 30 | 5 | 22 | 28 | 326 | 16 |
| Black or AfricanAmerican | 37 | 20 | 0 | 5 | 7 | 1 | 2 | 0 | 0 | 3 | 4 | 3 | 0 | 1 | 3 | 67 | 3 |
| Native Hawaiian/ Pac Islander | 8 | 6 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 15 | 1 |
| White | 599 | 221 | 0 | 78 | 73 | 225 | 40 | 0 | 66 | 53 | 160 | 39 | 0 | 35 | 36 | 1,284 | 62 |
| Multiracial, not Hispanic | 4 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 6 | 0 |
| Hispanic, any race | 19 | 7 | 0 | 3 | 2 | 7 | 4 | 0 | 2 | 5 | 9 | 4 | 0 | 2 | 4 | 50 | 2 |
| Total Res \& Ethnicity Known | 770 | 303 | 2 |  |  | 341 | 75 | 1 |  |  | 460 | 107 | 9 |  |  | 2,068 |  |
| Resident, ethnicity unknown | 36 | 14 | 0 |  |  | 11 | 1 | 0 |  |  | 28 | 6 | 1 |  |  | 97 |  |
| Not Reported (N/R) | 87 | 22 | 13 |  |  | 14 | 7 | 0 |  |  | 46 | 23 | 25 |  |  | 237 |  |
| Gender Totals | 893 | 339 | 15 |  |  | 366 | 83 | 1 |  |  | 534 | 136 | 35 |  |  | 2,402 |  |
| \% | 72.5\% | 27.5\% |  |  |  | 81.5\% | 18.5\% |  |  |  | 79.7\% | 20.3\% |  |  |  |  |  |
| * \%M and \%F columns are the percent of that gender who are of the specified ethnicity, of those whose ethnicity is known |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

hires, while Non-resident Aliens or resident Asians in aggregate comprised 38.7 percent of new hires. The latter figure is much lower than last year's 53.8 percent, in part due to hires in other ethnicity categories where there were none last year. Among postdoc new hires, Whites comprised 29.3 percent, compared to 19.8 percent last year, with Non-resident Aliens and resident Asians collectively comprising 62.1 percent compared with just more than 75 percent last year (Table F4).

The Taulbee Survey recently began collecting information on the number of new faculty hires who had been postdocs in the previous year. In 2015, the departments reporting to the survey hired 233 new assistant professors. Of those, 78 (33 percent) had received their Ph.D. in the previous academic year, and 72 ( 31 percent) had previously been in a postdoc. In 2016, 279 new assistant professors were hired, 87 of whom were new Ph.D.s ( 31 percent) and 86 of whom were recent postdocs (also 31 percent).

There were slightly more faculty losses reported this year as compared with last year (Table F5). Retirements were comparable to last year, but there was increased movement from one academic position to another, and from an academic position to a nonacademic position. The latter category took the biggest jump, from 24 reported last year to 42 reported this year. Although the movement is not yet at the level seen during the height of the dot-com boom era, this increase bears watching. Are increased faculty workloads due to the large enrollment increases starting to affect faculty employment choices?

The proportion of women at the full professor rank rose slightly from 14.3 percent last year to 14.8 percent this year, while the proportion at the associate professor level rose from 22.1 percent to 22.4 percent. The proportion at the assistant professor level was 23.8 percent, which is about the same as last year (Table F6). There were also slight increases in the proportion of women among teaching faculty and postdocs, while there was a slight decrease in the proportion of women among research faculty. This is the reverse of what happened last year. Whites, Asians, and Non-resident Aliens account for more than 90 percent of each category of faculty members except for teaching faculty, where they account for more than 85 percent of the total (Table F7).

Among the departments who report gender by ethnicity breakdowns (which the vast majority of departments do),

Whites again comprised a greater percentage of female full professors than they do male full professors, while the reverse is true at the associate professor level. Asians comprise a greater percentage of male full professors than they do female full professors while the reverse is true at the associate professor level.

For next year, U.S. CS departments forecast a 6.1 percent growth in tenure-track faculty and an 9.1 percent growth in teaching faculty. They also forecast a 7.7 percent growth in postdocs. It should be noted that these departments missed last year's expectations for both tenure-track and postdoc hiring. They met their expectations for teaching faculty.

## Non-Tenure-Track Teaching Faculty

The 2016 Taulbee Survey contained several questions about non-tenure-track teaching faculty to help us decide what, if anything, the survey should collect differently about those faculty. This is potentially a concern to many doctoral departments; in 2016, 87 percent of departments reporting faculty data to the Taulbee Survey indicated at least one non-tenure-track teaching faculty member. Of those, 80 percent have multiple titles and/or levels of teaching faculty and 20 percent have a single title and level.

There were 120 responses to an open-ended question about titles and levels used within an academic unit. As expected, units varied widely in the number of titles and the specific titles they used. The titles included:

D Multiple levels of Lecturer, reported by 49 units (4l percent). Examples are Lecturer and Senior Lecturer; Lecturer, Senior Lecturer, and Principal Lecturer; Lecturer I - IV; or Lecturer with or without Security of Employment.

D An Assistant-Associate or Assistant-Associate-Full pattern, reported by 39 (33 percent). There were many variations on the complete title (e.g., Teaching, Clinical, Instructional, Collegiate, or Professor of Practice).

D A single level of Lecturer, reported by 36 (30 percent). In some units this was the only non-tenure-track teaching title, but in others there were, for example, both Lecturers and Professors of the Practice.

Drofessor of the Practice with no levels given, reported by 20 (17 percent).

D A single level of Instructor, reported by 12 (10 percent)

Dultiple levels of Instructor, reported by 9, (8 percent)
D Other, reported by 18 (15 percent), which included Fellow, Faculty Associate, Teaching Professor (without Assistant / Associate levels), Teaching Specialist, Security of Employment, and Visiting Faculty.

The majority of responding units ( 61 percent) were interested in having the Taulbee Survey provide more fine-grained information about non-tenure-track teaching faculty. Eighteen percent of units were not interested in the Taulbee Survey reporting more on this subject, and 21 percent had no opinion.

The survey committee will review these responses and determine what form any additional information should take before data collection begins in fall 2017.

## Research Expenditures (Table R1; Figures R1-R2)

Table RI shows the distribution of departments' total expenditure (including indirect costs or "overhead" as stated on project budgets) from external sources of support. Figures Rl and R2 show the per capita expenditure, where capitation is computed two ways. The first (Figure RI) is relative to the number of tenure-track faculty members. The second (Figure R2)

Table RI. Total Expenditure from External Sources for Computing Research

| Department Type | \# Depts | 10th | 25th | 50th | 75th | 90th |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: |
| US CS Public | 83 | $\$ 630,675$ | $\$ 1,487,632$ | $\$ 3,729,141$ | $\$ 8,584,860$ | $\$ 15,154,063$ |
| US CS Private | 27 | $\$ 1,673,644$ | $\$ 2,376,724$ | $\$ 6,242,489$ | $\$ 10,629,352$ | $\$ 18,776,986$ |
| US CE | 5 |  |  | $\$ 1,748,209$ |  |  |
| US Information | 11 | $\$ 941,347$ | $\$ 2,027,403$ | $\$ 2,820,124$ | $\$ 3,747,854$ | $\$ 4,083,321$ |
| Canadian | 6 |  | $\$ 804,225$ | $\$ 1,852,028$ | $\$ 4,622,617$ |  |

Figure RI. Research Expenditures Normalized by Tenure-Track Size CRA Taulbee Survey 2016

is relative to research faculty and postdocs as well as tenuretrack faculty. Canadian levels are shown in Canadian dollars.
Overall median research expenditures for 2015-16 at U.S. CS public departments increased 5.7 percent in comparison with 2014-15. At U.S. CS departments in private institutions, median expenditures fell 9.3 percent. The direction of change in each case was the reverse of what was experienced last year. The median research expenditure at U.S. CS departments in private institutions is considerably higher that of public institutions. Median expenditures fell slightly at U.S. I departments. Fewer I departments provided research
expenditure data this year than did so last year and the sample size is small, which makes these comparisons subject to more volatility. Due to an insufficient number of Canadian and CE departments reporting data, we are unable to provide any meaningful comparative results.

The U.S. CS data show a tendency for larger departments to have more external funding per capita than smaller departments. The effect of size of the department on research expenditures per capita at private institutions is more clearly seen when capitation includes research faculty and postdocs as well as tenure-track faculty.


## Graduate Student Support (Tables GI-G2; Figures GI-G3)

Table Gl shows the number of graduate students supported as full-time students as of fall 2016, further categorized as teaching assistants (TAs), research assistants (RAs), and full-support fellows. The table also shows the split between those on institutional vs. external funds. The average number of TAs on institutional funds in U.S. CS departments was within 1 percent of its value last year. Public universities reported a slight increase, while the average at private universities declined by 7.6 percent after almost doubling last year. The reported values at private universities have been
somewhat volatile in recent years. Since there are many less of them, compared with public universities, they are more sensitive to the specific units reporting in a given year. The small number of CE , I , and Canadian departments also make these comparative averages subject to volatility.

The average number of RAs on external funding stayed fairly constant at both public and private U.S. CS departments, while the average number of RAs supported on institutional funds declined sharply. The average number of fullsupport fellows on internal funds rose at in U.S. CS public departments and stayed fairly steady at U.S. private

Table GI. Graduate Students Supported as Full-Time Students by Department Type

| On Institutional Funds |  |  |  |  |  |  |  | On External Funds |  |  |  |  | Total |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Department <br> Type | \# <br> Dept | Teaching <br> Assistants | Research <br> Assistants | Full-Support <br> Fellows | Teaching <br> Assistants | Research <br> Assistants | Full-Support <br> Fellows |  |  |  |  |  |  |  |
| US CS Public | 89 | $3,225.4$ | $41.7 \%$ | 751.9 | $9.7 \%$ | 432.4 | $5.6 \%$ | 34.0 | $0.4 \%$ | $3,127.5$ | $40.4 \%$ | 165.9 | $2.1 \%$ | $7,737.1$ |
| US CS Private | 32 | $1,044.0$ | $27.7 \%$ | 517.2 | $13.7 \%$ | 232.0 | $6.1 \%$ | 0.0 | $0.0 \%$ | $1,838.9$ | $48.7 \%$ | 143.5 | $3.8 \%$ | $3,775.5$ |
| US CS Total | 121 | $4,269.4$ | $37.1 \%$ | $1,269.1$ | $11.0 \%$ | 664.4 | $5.8 \%$ | 34.0 | $0.3 \%$ | $4,966.4$ | $43.1 \%$ | 309.4 | $2.7 \%$ | $11,512.6$ |
| US CE | 5 | 180.0 | $34.6 \%$ | 23.0 | $4.4 \%$ | 13.0 | $2.5 \%$ | 0.0 | $0.0 \%$ | 299.5 | $57.7 \%$ | 4.0 | $0.8 \%$ | 519.5 |
| US I | 12 | 154.1 | $34.9 \%$ | 82.6 | $18.7 \%$ | 19.0 | $4.3 \%$ | 0.9 | $0.2 \%$ | 172.6 | $39.1 \%$ | 12.0 | $2.7 \%$ | 441.2 |
| Canadian | 7 | 257.5 | $57.2 \%$ | 45.0 | $10.0 \%$ | 0.0 | $0.0 \%$ | 0.0 | $0.0 \%$ | 148.0 | $32.9 \%$ | 0.0 | $0.0 \%$ | 450.5 |
| Grand Total | 145 | $4,861.0$ | $37.6 \%$ | $1,419.7$ | $11.0 \%$ | 696.4 | $5.4 \%$ | 34.9 | $0.3 \%$ | $5,586.4$ | $43.2 \%$ | 325.4 | $2.5 \%$ | $12,923.8$ |

Figure GI. Teaching Assistantship Stipends CRA Taulbee Survey 2016

departments. The average number of full-support fellows on external funds declined at U.S. CS departments in both public and private universities.

Table G2 shows the distribution of stipends for TAs, RAs, and full-support fellows. U.S. CS data are further broken down in this table by public and private institution. Figures $\mathrm{Gl}-\mathrm{G} 3$ further break down the U.S. CS data by size of department and by geographic location of the university.

The median TA salaries at U.S. CS departments increased 1.8 percent at public universities and increased 4.4 percent
at private universities. Median salaries of RAs rose 3.4 percent at public universities but rose 2.3 percent at private universities. For full-support fellows, median salaries rose 0.6 percent at U.S. public universities and 4.0 percent at U.S. private universities.

Stipends tend to be higher at private U.S. CS departments, compared with public U.S. CS departments, in each of the three stipend categories. Stipends at U.S. I schools fall in between those at public and private U.S. CS departments. These relationships are unchanged from last year.

Table G2. Fall 2016 Academic-Year Graduate Stipends by Department Type and Support Type

| Teaching Assistantships |  |  |  |  |  |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Percentiles of Department Averages |  |  |  |  |
| Department Type | \# Depts | 10th | 25th | 50th | 75th | 90th |
| US CS Public | 98 | $\$ 13,522$ | $\$ 15,300$ | $\$ 18,000$ | $\$ 19,901$ | $\$ 23,225$ |
| US CS Private | 26 | $\$ 18,900$ | $\$ 21,508$ | $\$ 23,963$ | $\$ 26,858$ | $\$ 28,900$ |
| US CE | 6 |  | $\$ 14,695$ | $\$ 17,665$ | $\$ 21,744$ |  |
| US Info | 12 | $\$ 16,856$ | $\$ 19,180$ | $\$ 20,979$ | $\$ 23,375$ | $\$ 25,087$ |
| Canadian | 8 |  | $\$ 10,924$ | $\$ 14,044$ | $\$ 17,657$ |  |
|  |  |  |  |  |  |  |

Research Assistantships


Figure G2. Research Assistantship Stipends
CRA Taulbee Survey 2016


Figure G3. Full Support Fellows Stipends
CRA Taulbee Survey 2016


## Faculty Salaries (Tables Sl-S21; Figures SI-S9)

Each department was asked to report individual (but anonymous) faculty salaries if possible; otherwise, the department was requested to provide the mean salary for each rank (full, associate, and assistant professors and non-tenure-track teaching faculty, research faculty, and post-doctorates) and the number of persons at each rank. The salaries are those in effect on January 1,2017 for U.S. departments; nine-month salaries are reported in U.S. dollars. For Canadian departments, twelve-month salaries are reported in Canadian dollars. Respondents were asked to include salary supplements such as salary monies from endowed positions.
U.S. CS data are reported in Tables SI -S16 and in the box and whiskers diagrams. Data for CE, I, Canadian, and new Ph.D.s are reported in Tables S17-S20. The tables and diagrams contain distributional data (first decile, quartiles, and ninth decile) computed from the department averages only. Thus, for example, a table row labeled " 50 " or the median line in a diagram is the median of the averages for the
departments that reported within the stratum (the number of such departments reporting is shown in the "depts" row). Therefore, it is not a true median of all of the salaries.

We also report salary data for senior faculty based on time in rank, for more meaningful comparison of individual or departmental faculty salaries with national averages. We report associate professor salaries for time in rank of 7 years or less, and of more than 7 years. For full professors, we report time in rank of 7 years or less, 8 to 15 years, and more than 15 years.

Those departments reporting salary data were provided a summary report in December 2016. Those departments that provided individual salaries were additionally provided more comprehensive distributional information based on these individual salaries. This year, 72 percent of those reporting salary data provided salaries at the individual level.

The remainder of this section summarizes the basic report provided in December 2016 to all departments that provided salary data. No additional salary data was received since the deadline for that report.

Table Sl. Nine-month Salaries, 143 Responses of 191 US CS Departments, Percentiles from Department Averages

|  | Full Professor |  |  |  | Associate |  |  |  | Assistant |  |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |

Table S2. Nine-month Salaries, 105 Responses of 138 US CS Public (All Public), Percentiles from Department Averages

|  | Full Professor |  |  |  | Associate |  |  | Assistant | Non-Tenure Track |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | $\begin{aligned} & \text { In rank } \\ & 16+\mathrm{yrs} \end{aligned}$ | In rank 8-15 yrs | In rank 0-7 years | All years in rank | In rank 8+ years | In rank 0-7 years | All years in rank |  | Teach | Research | Postdoc |
| Depts | 83 | 90 | 93 | 105 | 86 | 95 | 102 | 100 | 71 | 31 | 36 |
| Indiv | 437 | 388 | 520 | 1,408 | 324 | 445 | 807 | 674 | 505 | 175 | 172 |
| 10 | \$132,325 | \$119,744 | \$115,233 | \$122,407 | \$98,649 | \$100,644 | \$100,397 | \$88,962 | \$60,000 | \$47,848 | \$44,406 |
| 25 | \$145,099 | \$139,371 | \$129,530 | \$136,210 | \$104,949 | \$106,548 | \$106,488 | \$92,206 | \$67,028 | \$66,233 | \$47,986 |
| 50 | \$160,800 | \$153,565 | \$144,669 | \$154,365 | \$110,987 | \$113,723 | \$112,636 | \$99,945 | \$75,336 | \$80,000 | \$54,284 |
| 75 | \$178,396 | \$170,132 | \$159,354 | \$168,642 | \$121,564 | \$121,851 | \$120,709 | \$104,393 | \$82,908 | \$101,816 | \$56,696 |
| 90 | \$189,634 | \$184,901 | \$171,525 | \$177,246 | \$129,681 | \$129,258 | \$130,907 | \$108,520 | \$94,202 | \$111,700 | \$66,167 |

Salaries at private institutions tend to be higher than those at public institutions for all faculty types (Tables S2 and S3). This pattern is consistent with data from previous years.

When viewed relative to faculty size, salaries at each tenuretrack rank tend to be higher for larger departments at both public (Tables S4-S8) and private (Tables S9-S11) institutions. This pattern is consistent with last year's pattern. Salaries for teaching faculty also exhibit this pattern at both public and private institutions.

When viewed relative to type of locale, public institution salaries appear to be generally lower in smaller locales
than in mid-size or large cities for all tenure-track faculty ranks (Tables Sl2-Sl4), Private institution salaries tend to be slightly higher in smaller locales, except for full professors in rank 8-15 years and associate professors in rank 8+ years (Tables SI5-SI6). In previous years, public institution salaries only were lower in smaller locales for more junior faculty, and private institution salaries exhibited no consistent pattern relative to type of locale. Teaching faculty salaries exhibit no pattern relative to locale size among public institutions, while among private institutions the salaries are higher at smaller locales.

Table S3. Nine-month Salaries, 38 Responses of 53 US CS Private (All Private), Percentiles from Department Averages

|  | Full Professor |  |  |  | Associate |  |  | Assistant | Non-Tenure Track |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | In rank 16+ yrs | In rank 8-15 yrs | In rank 0-7 years | All years in rank | In rank <br> 8+ years | In rank 0-7 years | All years in rank |  | Teach | Research | Postdoc |
| Depts | 28 | 29 | 25 | 37 | 25 | 30 | 37 | 36 | 29 | 17 | 15 |
| Indiv | 177 | 152 | 166 | 546 | 107 | 148 | 285 | 245 | 251 | 117 | 175 |
| 10 | \$140,348 | \$132,222 | \$130,646 | \$134,527 | \$105,047 | \$106,167 | \$105,734 | \$97,411 | \$77,412 | \$74,750 | \$47,884 |
| 25 | \$163,840 | \$155,025 | \$140,413 | \$155,665 | \$108,722 | \$115,195 | \$112,533 | \$101,516 | \$81,275 | \$105,653 | \$55,877 |
| 50 | \$194,698 | \$184,379 | \$160,156 | \$181,700 | \$125,459 | \$127,200 | \$122,441 | \$111,083 | \$90,680 | \$127,872 | \$61,191 |
| 75 | \$212,205 | \$221,082 | \$189,332 | \$198,985 | \$131,250 | \$138,424 | \$137,667 | \$120,920 | \$103,883 | \$153,198 | \$65,062 |
| 90 | \$236,181 | \$232,099 | \$212,918 | \$216,827 | \$139,455 | \$146,162 | \$143,908 | \$124,530 | \$114,123 | \$181,250 | \$66,865 |

Table S4. Nine-month Salaries, 28 Responses of US CS Public With <-l5 Tenure-Track Faculty, Percentiles from Department Averages

|  | Full Professor |  |  |  | Associate |  |  | Assistant | Non-Tenure Track |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | In rank 16+ yrs | In rank 8-15 yrs | In rank 0-7 years | All years in rank | In rank 8+ years | In rank 0-7 years | All years in rank |  | Teach | Research | Postdoc |
| Depts | 15 | 19 | 23 | 28 | 23 | 21 | 26 | 26 | 13 | 2 | 2 |
| Indiv | 35 | 38 | 53 | 132 | 68 | 52 | 133 | 80 | 55 |  |  |
| 10 | \$107,945 | \$115,104 | \$111,783 | \$115,066 | \$95,414 | \$95,019 | \$94,369 | \$85,105 | \$54,678 |  |  |
| 25 | \$132,107 | \$118,496 | \$114,556 | \$121,243 | \$99,659 | \$99,655 | \$100,849 | \$86,921 | \$58,862 |  |  |
| 50 | \$143,802 | \$140,489 | \$130,515 | \$135,100 | \$107,808 | \$105,434 | \$106,725 | \$91,969 | \$68,986 |  |  |
| 75 | \$156,695 | \$149,810 | \$145,564 | \$148,974 | \$116,274 | \$115,562 | \$114,409 | \$96,095 | \$75,396 |  |  |
| 90 | \$164,102 | \$167,213 | \$161,619 | \$159,988 | \$130,803 | \$121,282 | \$125,428 | \$98,585 | \$81,459 |  |  |

Our analysis of faculty salary changes from one year to the next uses only those departments that reported both years; otherwise, the departments that reported during only one year can skew the comparison. Because some departments that reported both years provided only aggregate salaries for their full and associate professors during one year and in the other year reported them by years in rank, we only report salary changes for all full professors and for all associate professors in the year-to-year comparison. Table S21 shows, by type of faculty and type of department,
the change in the median of the average salaries from departments that reported both years (the number of departments being compared is indicated in parentheses in each column heading). Using the cell showing full professors at U.S. CS departments as an example, the table indicates that the median of the 124 average salaries for full professors was 2.4 percent higher in 2016 than was the median of the average full professor salaries in 2015 from these same 124 departments.

Table S5. Nine-month Salaries, 35 Responses of US CS Public With 10 < Tenure-Track Faculty <=20, Percentiles from Department Averages

|  | Full Professor |  |  |  | Associate |  |  | Assistant | Non-Tenure Track |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | In rank 16+ yrs | In rank 8-15 yrs | In rank 0-7 years | All years in rank | In rank 8+ years | In rank 0-7 years | All years in rank |  | Teach | Research | Postdoc |
| Depts | 23 | 28 | 28 | 35 | 32 | 31 | 35 | 34 | 18 | 3 | 4 |
| Indiv | 64 | 63 | 73 | 211 | 95 | 83 | 192 | 125 | 63 |  | 8 |
| 10 | \$127,753 | \$114,960 | \$113,654 | \$118,647 | \$96,032 | \$95,019 | \$95,278 | \$85,065 | \$53,732 |  |  |
| 25 | \$132,661 | \$122,591 | \$117,900 | \$126,413 | \$98,872 | \$99,974 | \$101,083 | \$88,400 | \$59,147 |  |  |
| 50 | \$143,802 | \$139,214 | \$132,237 | \$135,825 | \$106,676 | \$106,178 | \$107,330 | \$92,683 | \$68,839 |  | \$50,500 |
| 75 | \$159,757 | \$150,821 | \$146,515 | \$153,432 | \$113,739 | \$115,781 | \$113,316 | \$96,940 | \$74,718 |  |  |
| 90 | \$186,681 | \$178,092 | \$163,208 | \$167,728 | \$127,183 | \$122,965 | \$123,920 | \$99,867 | \$80,559 |  |  |

Table S6. Nine-month Salaries, 28 Responses of US CS Public With 15 < Tenure-Track Faculty <=25, Percentiles from Department Averages

|  | Full Professor |  |  |  | Associate |  |  | Assistant | Non-Tenure Track |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | $\underset{\substack{\text { In rank } \\ 16+\text { yrs }}}{ }$ | In rank 8-15 yrs | In rank 0-7 years | All years in rank | In rank 8+ years | In rank 0-7 years | All years in rank |  | Teach | Research | Postdoc |
| Depts | 23 | 25 | 23 | 28 | 24 | 25 | 27 | 26 | 20 | 6 | 7 |
| Indiv | 82 | 74 | 88 | 253 | 79 | 90 | 173 | 117 | 83 | 28 | 11 |
| 10 | \$129,476 | \$116,252 | \$120,260 | \$126,038 | \$97,314 | \$99,737 | \$95,854 | \$90,083 | \$58,502 |  |  |
| 25 | \$139,348 | \$127,613 | \$124,946 | \$134,581 | \$102,346 | \$106,000 | \$106,082 | \$91,195 | \$65,395 |  | \$44,796 |
| 50 | \$154,300 | \$148,518 | \$132,714 | \$144,676 | \$109,779 | \$111,791 | \$109,372 | \$99,723 | \$73,260 | \$78,812 | \$48,000 |
| 75 | \$174,035 | \$174,394 | \$151,972 | \$162,830 | \$116,480 | \$116,630 | \$113,917 | \$102,785 | \$76,811 |  | \$60,205 |
| 90 | \$187,781 | \$184,543 | \$166,173 | \$174,436 | \$123,602 | \$120,953 | \$119,104 | \$106,579 | \$81,420 |  |  |

When interpreting these changes, it is important to remember the effect that promotions have on the departmental data from one year to the next, since a promotion causes an individual faculty member to move from one rank to another. Thus, a department with a small number of faculty members in a particular rank can have its average salary in that rank change appreciably (in either direction) by a single promotion to or from that rank. Departures via resignation or retirement also impact these figures, particularly in the non-tenure-track categories. Because of the small number of Canadian, CE,
and I departments reporting, the values in those columns are considerably more volatile; this is evident in several of the entries in Table S21.

For new Ph.D.s in tenure-track positions at U.S. CS, CE, and I school departments (Table S20) the median of the averages was $\$ 100,000$, an increase of 1.5 percent vs. last year. This year there are not enough new tenure-track faculty salaries from Canadian institutions to report a salary distribution, so year-to-year comparisons cannot be made.

Table S7. Nine-month Salaries, 35 Responses of US CS Public With 20 < Tenure-Track Faculty <=35, Percentiles from Department Averages

|  | Full Professor |  |  |  | Associate |  |  | Assistant | Non-Tenure Track |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | In rank 16+ yrs | In rank 8-15 yrs | In rank 0-7 years | All years in rank | In rank 8+ years | In rank 0-7 years | All years in rank |  | Teach | Research | Postdoc |
| Depts | 30 | 32 | 32 | 35 | 28 | 33 | 34 | 32 | 25 | 11 | 11 |
| Indiv | 150 | 125 | 166 | 458 | 102 | 135 | 257 | 184 | 153 | 28 | 31 |
| 10 | \$136,081 | \$129,506 | \$120,991 | \$134,849 | \$101,406 | \$102,881 | \$103,702 | \$90,873 | \$61,077 | \$37,923 | \$44,592 |
| 25 | \$148,475 | \$144,715 | \$128,230 | \$142,271 | \$106,845 | \$110,083 | \$109,267 | \$95,832 | \$65,678 | \$52,854 | \$46,472 |
| 50 | \$159,609 | \$155,150 | \$142,664 | \$154,279 | \$111,734 | \$113,562 | \$112,421 | \$102,729 | \$72,723 | \$77,623 | \$50,000 |
| 75 | \$178,879 | \$170,115 | \$158,481 | \$170,252 | \$118,539 | \$118,567 | \$118,461 | \$106,751 | \$77,418 | \$91,566 | \$66,167 |
| 90 | \$188,836 | \$176,840 | \$169,517 | \$178,803 | \$124,561 | \$123,079 | \$123,257 | \$108,300 | \$90,426 | \$105,293 | \$70,000 |

Table S8. Nine-month Salaries, 39 Responses of US CS Public With Tenure-Track Faculty >30, Percentiles from Department Averages

|  | Full Professor |  |  |  | Associate |  |  |  | Assistant |  |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
|  | In rank <br> l6+ yrs | In rank <br> 8-15 yrs | In rank <br> 0-7 years | All years <br> in rank | In rank <br> $8+$ years | In rank <br> 0-7 years | All years <br> in rank |  | Teach | Research | Postdoc |
| Depts | 36 | 37 | 37 | 39 | 31 | 39 | 39 | 39 | 33 | 19 | 25 |
| Indiv | 281 | 237 | 315 | 881 | 143 | 262 | 426 | 411 | 318 | 131 | 149 |
| 10 | $\$ 148,006$ | $\$ 146,850$ | $\$ 133,559$ | $\$ 148,649$ | $\$ 101,715$ | $\$ 107,004$ | $\$ 105,577$ | $\$ 95,959$ | $\$ 66,634$ | $\$ 63,103$ | $\$ 46,011$ |
| 25 | $\$ 159,044$ | $\$ 149,985$ | $\$ 138,093$ | $\$ 154,954$ | $\$ 107,955$ | $\$ 112,571$ | $\$ 111,984$ | $\$ 100,099$ | $\$ 73,631$ | $\$ 73,951$ | $\$ 49,469$ |
| 50 | $\$ 171,098$ | $\$ 163,758$ | $\$ 152,695$ | $\$ 162,516$ | $\$ 112,610$ | $\$ 117,554$ | $\$ 117,554$ | $\$ 103,685$ | $\$ 80,997$ | $\$ 86,151$ | $\$ 55,701$ |
| 75 | $\$ 181,498$ | $\$ 171,377$ | $\$ 159,354$ | $\$ 171,149$ | $\$ 125,411$ | $\$ 128,467$ | $\$ 127,000$ | $\$ 107,455$ | $\$ 89,000$ | $\$ 105,218$ | $\$ 57,542$ |
| 90 | $\$ 191,825$ | $\$ 195,304$ | $\$ 174,573$ | $\$ 183,556$ | $\$ 141,070$ | $\$ 131,717$ | $\$ 133,767$ | $\$ 112,645$ | $\$ 106,075$ | $\$ 113,308$ | $\$ 65,777$ |

Table S9. Nine-month Salaries, 17 Responses of US CS Private With <=20 Tenure-Track Faculty, Percentiles from Department Averages

|  | Full Professor |  |  |  | Associate |  |  | Assistant | Non-Tenure Track |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | In rank 16+ yrs | In rank 8-15 yrs | In rank 0-7 years | All years in rank | In rank <br> 8+ years | In rank 0-7 years | All years in rank n |  | Teach | Research | Postdoc |
| Depts | 11 | 11 | 7 | 16 | 11 | 13 | 16 | 15 | 11 | 6 | 5 |
| Indiv | 45 | 34 | 17 | 117 | 27 | 37 | 75 | 47 | 46 | 27 | 38 |
| 10 | \$130,076 | \$131,956 |  | \$126,446 | \$105,204 | \$104,837 | \$102,796 | \$96,724 | \$71,828 |  |  |
| 25 | \$152,371 | \$134,310 | \$131,596 | \$145,786 | \$107,776 | \$114,942 | \$110,002 | \$101,372 | \$78,851 |  |  |
| 50 | \$165,000 | \$181,667 | \$144,632 | \$163,160 | \$117,725 | \$120,977 | \$118,404 | \$104,250 | \$81,577 | \$121,662 | \$60,000 |
| 75 | \$195,606 | \$221,035 | \$180,450 | \$186,741 | \$131,125 | \$129,324 | \$126,556 | \$114,298 | \$88,707 |  |  |
| 90 | \$203,230 | \$239,873 |  | \$202,146 | \$136,639 | \$139,517 | \$138,940 | \$124,007 | \$90,680 |  |  |

Table SIO. Nine-month Salaries, 16 Responses of US CS Private With 15 < Tenure-Track Faculty <=30, Percentiles from Department Averages

|  | Full Professor |  |  |  | Associate |  |  | Assistant | Non-Tenure Track |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | In rank 16+ yrs | In rank 8-15 yrs | In rank 0-7 years | All years in rank | In rank <br> 8+ years | In rank 0-7 years | All years in rank |  | Teach | Research | Postdoc |
| Depts | 11 | 12 | 11 | 16 | 10 | 11 | 16 | 16 | 13 | 7 | 8 |
| Indiv | 53 | 57 | 54 | 194 | 26 | 28 | 62 | 88 | 61 | 23 | 76 |
| 10 | \$179,850 | \$155,466 | \$133,190 | \$146,491 | \$104,711 | \$115,954 | \$110,311 | \$99,559 | \$74,041 |  |  |
| 25 | \$184,908 | \$164,913 | \$142,523 | \$169,124 | \$106,627 | \$117,762 | \$112,445 | \$103,016 | \$79,165 | \$106,561 | \$59,188 |
| 50 | \$202,296 | \$182,358 | \$157,583 | \$179,756 | \$127,250 | \$121,500 | \$121,971 | \$107,192 | \$90,680 | \$111,731 | \$61,096 |
| 75 | \$222,609 | \$206,073 | \$184,325 | \$193,714 | \$131,188 | \$130,417 | \$128,233 | \$121,019 | \$104,366 | \$135,970 | \$64,714 |
| 90 | \$236,077 | \$229,252 | \$213,088 | \$209,757 | \$141,930 | \$137,000 | \$134,692 | \$123,347 | \$118,639 |  |  |

Table SII. Nine-month Salaries, 21 Responses of US CS Private With Tenure-Track Faculty >20, Percentiles from Department Averages

|  | Full Professor |  |  |  | Associate |  |  | Assistant | Non-Tenure Track |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | In rank 16+ yrs | In rank 8-15 yrs | In rank 0-7 years | All years in rank | In rank 8+ years | In rank 0-7 years | All years in rank |  | Teach | Research | Postdoc |
| Depts | 17 | 18 | 18 | 21 | 14 | 17 | 21 | 21 | 18 | 11 | 10 |
| Indiv | 130 | 118 | 145 | 423 | 81 | 113 | 213 | 198 | 205 | 90 | 137 |
| 10 | \$163,814 | \$149,525 | \$131,787 | \$141,825 | \$105,213 | \$111,010 | \$109,726 | \$97,581 | \$80,075 | \$77,125 | \$43,833 |
| 25 | \$194,252 | \$166,972 | \$144,951 | \$171,993 | \$115,881 | \$115,954 | \$113,201 | \$101,924 | \$88,317 | \$106,561 | \$55,610 |
| 50 | \$205,975 | \$183,714 | \$165,875 | \$184,355 | \$126,932 | \$129,022 | \$128,333 | \$112,049 | \$98,963 | \$127,872 | \$64,100 |
| 75 | \$231,717 | \$217,333 | \$189,238 | \$204,342 | \$135,020 | \$138,898 | \$140,160 | \$121,430 | \$106,402 | \$151,713 | \$66,415 |
| 90 | \$242,085 | \$223,302 | \$212,790 | \$216,882 | \$139,531 | \$153,875 | \$147,014 | \$124,967 | \$114,601 | \$158,991 | \$67,219 |

Table SI2. Nine-month Salaries, 40 Responses of US CS Public In Large City or Suburbs, Percentiles from Department Averages

|  | Full Professor |  |  |  | Associate |  |  | Assistant | Non-Tenure Track |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | In rank 16+ yrs | In rank 8-15 yrs | In rank 0-7 years | All years in rank | In rank <br> 8+ years | In rank 0-7 years | All years in rank |  | Teach | Research | Postdoc |
| Depts | 35 | 35 | 37 | 40 | 34 | 38 | 40 | 39 | 28 | 14 | 14 |
| Indiv | 190 | 154 | 211 | 570 | 133 | 193 | 345 | 268 | 207 | 80 | 92 |
| 10 | \$137,002 | \$139,397 | \$118,935 | \$139,095 | \$99,050 | \$105,424 | \$103,900 | \$90,810 | \$63,727 | \$44,935 | \$42,617 |
| 25 | \$150,868 | \$147,765 | \$132,848 | \$144,264 | \$105,655 | \$110,151 | \$109,049 | \$96,149 | \$68,586 | \$67,219 | \$45,105 |
| 50 | \$166,634 | \$158,214 | \$144,669 | \$158,946 | \$110,938 | \$115,401 | \$114,219 | \$102,129 | \$76,851 | \$93,259 | \$52,775 |
| 75 | \$176,104 | \$169,793 | \$158,403 | \$168,492 | \$123,626 | \$119,880 | \$122,079 | \$105,679 | \$86,381 | \$104,570 | \$56,363 |
| 90 | \$185,844 | \$178,023 | \$167,555 | \$177,580 | \$131,192 | \$127,018 | \$126,734 | \$109,220 | \$107,635 | \$116,229 | \$62,424 |

Table SI3. Nine-month Salaries, 25 Responses of US CS Public In Midsize City or Suburbs, Percentiles from Department Averages

|  | Full Professor |  |  |  | Associate |  |  | Assistant | Non-Tenure Track |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | In rank $16+\mathrm{yrs}$ | In rank 8-15 yrs | In rank $0-7$ years 0-7 years | All years in rank | In rank 8+ years | In rank 0-7 years | All years in rank |  | Teach | Research | Postdoc |
| Depts | 21 | 22 | 20 | 25 | 19 | 23 | 25 | 22 | 17 | 6 | 6 |
| Indiv | 131 | 107 | 141 | 386 | 74 | 108 | 185 | 161 | 114 | 28 | 22 |
| 10 | \$130,718 | \$114,804 | \$128,662 | \$124,676 | \$98,282 | \$102,867 | \$99,356 | \$91,115 | \$54,156 |  |  |
| 25 | \$151,589 | \$134,292 | \$141,607 | \$137,203 | \$107,459 | \$110,962 | \$107,602 | \$93,723 | \$65,678 |  |  |
| 50 | \$164,895 | \$153,965 | \$150,787 | \$156,874 | \$111,647 | \$116,000 | \$113,110 | \$100,457 | \$72,019 | \$79,373 | \$55,976 |
| 75 | \$185,093 | \$167,430 | \$162,338 | \$171,912 | \$117,500 | \$128,467 | \$122,896 | \$106,251 | \$80,997 |  |  |
| 90 | \$194,109 | \$189,213 | \$184,508 | \$180,681 | \$127,704 | \$137,771 | \$135,876 | \$112,097 | \$87,923 |  |  |

Table S14. Nine-month Salaries, 40 Responses of US CS Public in Small City, Town, or Rural, Percentiles from Department Averages

|  | Full Professor |  |  |  | Associate |  |  | Assistant | Non-Tenure Track |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | In rank 16+ yrs | In rank 8-15 yrs | In rank 0-7 years | All years in rank | In rank 8+ years | In rank 0-7 years | All years in rank |  | Teach | Research | Postdoc |
| Depts | 27 | 33 | 36 | 40 | 33 | 34 | 37 | 39 | 26 | 11 | 16 |
| Indiv | 116 | 127 | 168 | 452 | 117 | 144 | 277 | 245 | 184 | 67 | 58 |
| 10 | \$129,432 | \$118,295 | \$114,135 | \$118,241 | \$98,712 | \$98,437 | \$100,009 | \$86,255 | \$59,540 | \$63,554 | \$47,421 |
| 25 | \$140,126 | \$125,894 | \$122,358 | \$130,187 | \$102,010 | \$102,698 | \$102,409 | \$89,702 | \$66,994 | \$66,233 | \$49,102 |
| 50 | \$156,254 | \$146,876 | \$135,587 | \$142,810 | \$110,656 | \$110,633 | \$111,183 | \$95,230 | \$74,645 | \$77,391 | \$54,000 |
| 75 | \$175,632 | \$171,377 | \$158,157 | \$161,808 | \$117,736 | \$120,609 | \$118,203 | \$100,695 | \$83,344 | \$84,026 | \$58,829 |
| 90 | \$187,024 | \$186,978 | \$170,319 | \$173,208 | \$126,356 | \$124,644 | \$127,813 | \$106,974 | \$90,546 | \$88,375 | \$65,389 |

Table SI5. Nine-month Salaries, 26 Responses of US CS Private in Large City or Suburbs, Percentiles from Department Averages

|  | Full Professor |  |  |  | Associate |  |  | Assistant | Non-Tenure Track |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | In rank <br> 16+ yrs | In rank 8-15 yrs | In rank 0-7 years | All years in rank | In rank $8+$ years | In rank 0-7 years | All years in rank |  | Teach | Research | Postdoc |
| Depts | 20 | 20 | 19 | 26 | 18 | 21 | 25 | 25 | 22 | 13 | 10 |
| Indiv | 11 | 108 | 129 | 387 | 96 | 116 | 233 | 187 | 225 | 103 | 113 |
| 10 | \$129,922 | \$132,161 | \$130,496 | \$134,129 | \$105,572 | \$106,357 | \$105,344 | \$97,376 | \$73,479 | \$72,950 | \$43,833 |
| 25 | \$160,267 | \$146,673 | \$136,336 | \$156,392 | \$109,265 | \$113,409 | \$112,842 | \$101,924 | \$79,693 | \$105,653 | \$54,063 |
| 50 | \$194,698 | \$187,517 | \$157,583 | \$175,606 | \$126,842 | \$126,200 | \$122,441 | \$110,764 | \$90,047 | \$127,872 | \$58,377 |
| 75 | \$207,425 | \$213,272 | \$189,145 | \$198,453 | \$130,950 | \$139,507 | \$138,360 | \$121,430 | \$100,660 | \$158,991 | \$61,517 |
| 90 | \$236,112 | \$224,526 | \$213,506 | \$216,836 | \$136,444 | \$152,340 | \$144,944 | \$124,617 | \$106,809 | \$190,671 | \$64,351 |

Table S16. Nine-month Salaries, 12 Responses of US CS Private in Other than Large City, Percentiles from Department Averages

|  | Full Professor |  |  |  | Associate |  |  | Assistant | Non-Tenure Track |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | In rank 16+ yrs | In rank 8-15 yrs | In rank 0-7 years | All years in rank | In rank 8+ years | In rank 0-7 years | All years in rank |  | Teach | Research | Postdoc |
| Depts | 8 | 9 | 6 | 11 | 7 | 9 | 12 | 11 | 7 | 4 | 5 |
| Indiv | 66 | 44 | 37 | 159 | 11 | 32 | 52 | 58 | 26 | 14 | 62 |
| 10 |  |  |  | \$141,825 |  |  | \$107,808 | \$99,258 |  |  |  |
| 25 | \$187,258 | \$167,667 |  | \$159,693 | \$111,465 | \$118,615 | \$112,445 | \$101,082 | \$86,154 |  |  |
| 50 | \$196,084 | \$184,379 | \$173,304 | \$183,369 | \$123,700 | \$128,200 | \$121,158 | \$112,049 | \$102,999 | \$126,040 | \$65,757 |
| 75 | \$218,054 | \$221,082 |  | \$198,987 | \$142,735 | \$137,000 | \$135,802 | \$115,835 | \$116,587 |  |  |
| 90 |  |  |  | \$214,206 |  |  | \$139,911 | \$122,813 |  |  |  |

Table SI7. Nine-month Salaries, 8 Responses of 34 US Computer Engineering Departments, Percentiles from Department Averages

|  | Full Professor |  |  |  |  | Associate |  |  |  | Assistant |  |  | Non-Tenure Track |  |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | :---: | :---: | :---: | :---: |
|  | In rank <br> l6+ yrs | In rank <br> 8-15 yrs | In rank <br> 0-7 years | All years <br> in rank | In rank <br> 8+ years | In rank <br> 0-7 years | All years <br> in rank |  | Teach | Research | Postdoc |  |  |  |  |
| Depts | 5 | 6 | 6 | 8 | 5 | 6 | 8 | 7 | 6 | 2 | 2 |  |  |  |  |
| Indiv | 26 | 11 | 30 | 78 | 10 | 32 | 48 | 25 | 18 |  |  |  |  |  |  |
| 10 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 25 |  |  |  | $\$ 144,269$ |  |  | $\$ 106,939$ | $\$ 92,074$ |  |  |  |  |  |  |  |
| 50 | $\$ 185,000$ | $\$ 141,825$ | $\$ 131,063$ | $\$ 161,993$ | $\$ 116,265$ | $\$ 111,059$ | $\$ 116,876$ | $\$ 101,000$ | $\$ 81,421$ |  |  |  |  |  |  |
| 75 |  |  |  | $\$ 177,519$ |  |  | $\$ 119,843$ | $\$ 102,689$ |  |  |  |  |  |  |  |
| 90 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

Table S18. Nine-month Salaries, 15 Responses of 20 US Information Departments, Percentiles from Department Averages

|  | Full Professor |  |  |  | Associate |  |  | Assistant | Non-Tenure Track |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | In rank $16+\mathrm{yrs}$ | In rank 8-15 yrs | In rank $0-7$ years | All years in rank | In rank <br> 8+ years | In rank 0-7 years | All years in rank |  | Teach | Research | Postdoc |
| Depts | 12 | 14 | 13 | 15 | 12 | 15 | 15 | 15 | 12 | 10 | 7 |
| Indiv | 33 | 47 | 75 | 155 | 55 | 93 | 148 | 135 | 145 | 51 | 38 |
| 10 | \$130,728 | \$136,037 | \$128,743 | \$137,719 | \$92,208 | \$95,549 | \$93,689 | \$83,558 | \$54,977 | \$66,535 |  |
| 25 | \$139,639 | \$155,332 | \$135,829 | \$147,118 | \$108,244 | \$98,574 | \$103,962 | \$89,274 | \$80,413 | \$67,436 | \$47,950 |
| 50 | \$165,568 | \$173,153 | \$143,305 | \$161,167 | \$111,863 | \$113,780 | \$115,067 | \$98,250 | \$91,306 | \$75,758 | \$59,333 |
| 75 | \$180,172 | \$191,903 | \$157,438 | \$168,134 | \$120,296 | \$125,344 | \$123,013 | \$104,765 | \$100,051 | \$93,390 | \$61,722 |
| 90 | \$191,591 | \$211,035 | \$174,234 | \$183,408 | \$135,124 | \$137,964 | \$137,341 | \$110,323 | \$118,636 | \$99,487 |  |

Table S19. Twelve-month Salaries, 9 Responses of 30 Canadian Departments, Percentiles from Department Averages

|  | Full Professor |  |  |  | Associate |  |  |  | Assistant | Non-Tenure Track |  |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | :---: |
|  | In rank <br> l6+ yrs | In rank <br> 8-15 yrs | In rank <br> 0-7 years | All years <br> in rank | In rank <br> $8+$ years | In rank <br> $0-7$ years | All years <br> in rank |  | Teach | Research | Postdoc |  |
| Depts | 9 | 9 | 9 | 9 | 9 | 8 | 9 | 9 | 7 | 3 | 5 |  |
| Indiv | 53 | 56 | 62 | 171 | 62 | 31 | 93 | 45 | 65 |  | 53 |  |
| 10 |  |  |  |  |  |  |  |  |  |  |  |  |
| 25 | $\$ 166,443$ | $\$ 158,430$ | $\$ 141,655$ | $\$ 153,031$ | $\$ 136,771$ | $\$ 121,156$ | $\$ 134,026$ | $\$ 102,328$ | $\$ 104,106$ |  |  |  |
| 50 | $\$ 203,564$ | $\$ 179,768$ | $\$ 161,422$ | $\$ 175,912$ | $\$ 146,088$ | $\$ 136,177$ | $\$ 145,177$ | $\$ 112,798$ | $\$ 124,968$ |  | $\$ 54,588$ |  |
| 75 | $\$ 214,459$ | $\$ 190,308$ | $\$ 175,405$ | $\$ 190,211$ | $\$ 157,144$ | $\$ 152,681$ | $\$ 155,631$ | $\$ 125,414$ | $\$ 131,249$ |  |  |  |
| 90 |  |  |  |  |  |  |  |  |  |  |  |  |

Table S20. Nine-month Salaries for New PhDs (Twelve-month for Canadian)

|  | US (CS, CE, and Info Combined) |  |  |  | Canadian |  |  |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: | :---: |
|  | Tenure-Track | Non-ten <br> Teaching | Non-ten <br> Research | Postdoc | Tenure-Track | Non-ten <br> Teaching | Non-ten <br> Research | Postdoc |
| Depts | 72 | 27 | 9 | 25 | 2 | 0 | 0 | 3 |
| Indiv | 131 | 52 | 17 | 89 | 2 |  |  | 5 |
| 10 | $\$ 88,000$ | $\$ 58,100$ | $\$ 33,733$ | $\$ 54,500$ |  |  |  |  |
| 25 | $\$ 91,000$ | $\$ 62,750$ | $\$ 33,733$ | $\$ 59,108$ |  |  |  |  |
| 50 | $\$ 100,000$ | $\$ 75,528$ | $\$ 65,040$ | $\$ 63,333$ |  |  |  |  |
| 75 | $\$ 105,600$ | $\$ 82,357$ | $\$ 88,000$ | $\$ 67,714$ |  |  |  |  |
| 90 | $\$ 110,000$ | $\$ 84,809$ | $\$ 90,300$ | $\$ 69,017$ |  |  |  |  |

Table S21. Change in Salary Median for Departments that Reported in Both 2015 and 2016

|  | U.S. CS | U.S. CE | U.S. I | Canadian |
| :--- | :---: | :---: | :---: | :---: |
| Departments | 124 | 6 | 10 | 9 |
| Full Profs | $2.4 \%$ | $7.2 \%$ | $1.8 \%$ | $0.2 \%$ |
| Assoc. Profs. | $2.8 \%$ | $4.2 \%$ | $-0.3 \%$ | $1.5 \%$ |
| Asst. Profs. | $2.6 \%$ | $3.6 \%$ | $2.5 \%$ | $-2.5 \%$ |
| Non-ten-track teaching faculty | $4.0 \%$ | $-1.4 \%$ | $3.8 \%$ | $12.5 \%$ |
| Research faculty | $0.3 \%$ | $0.0 \%$ | $-14.2 \%$ | $-36.3 \%$ |
| Post doctorates | $4.4 \%$ |  | $4.6 \%$ | $5.2 \%$ |

Figure SI. US CS Department Average Salary, Full Professor in Rank 16+ Years


Figure S2. US CS Department Average Salary, Full Professor in Rank 8-15 Years
CRA Taulbee Survey 2016


Figure S3. US CS Department Average Salary, Full Professor in Rank 0-7 Years CRA Taulbee Survey 2016



Figure S5. US CS Department Average Salary, Associate Professor in Rank 0-7 Years CRA Taulbee Survey 2016


Figure S6. US CS Department Average Salary, Assistant Professor
CRA Taulbee Survey 2016


Figure S7. US CS Department Average Salary, Non-Tenure Track Teaching Faculty CRA Taulbee Survey 2016



Figure S9. US CS Department Average Salary, Postdoctorates
CRA Taulbee Survey 2016


## Concluding Observations

The undergraduate enrollment surge continues in U.S. doctoral-granting computer science programs. At the same time, master's and doctoral production rose and the number of new students in the departments' graduate programs rose. Increases in tenure-track and teaching faculty are not keeping pace with the increases in students, and there was a sharp increase this year in the number of faculty moving from academic to non-academic positions. Departments and their administrations need to find sustainable solutions to both the student surge and the workload pressures being placed on their faculty.

## Participating CS, CE, I and Canadian Departments

U.S. CS Public (III): Arizona State, Auburn, Binghamton, Clemson, College of William \& Mary, Colorado School of Mines, Colorado State, Florida International, George Mason, Georgia Tech, Georgia State, Indiana, Iowa State, Kansas State, Kent State, Michigan State, Michigan Technological University, Mississippi State, Montana State, Naval Postgraduate School, New Jersey Institute of Technology, New Mexico State, North Carolina State, North Dakota State, Ohio State, Ohio, Oklahoma State, Old Dominion, Oregon State, Pennsylvania State, Portland State, Purdue, Rutgers, Southern Illinois (Carbondale), Stony Brook (SUNY), Texas A\&M, Texas Tech, Universities at Albany and Buffalo, Universities of: Alabama (Birmingham and Tuscaloosa), Arizona, Arkansas, Arkansas at Little Rock, California (Berkeley, Davis, Irvine, Los Angeles, Riverside, San Diego, Santa Barbara, and Santa Cruz), Central Florida, Colorado (Boulder), Connecticut, Delaware, Florida, Georgia, Hawaii, Houston, Illinois (Chicago and UrbanaChampaign), Iowa, Kansas, Kentucky, Louisiana at Lafayette, Maryland (College Park and Baltimore County), Massachusetts (Amherst, Boston, and Lowell), Memphis, Michigan, Minnesota,

Mississippi, Missouri (Columbia), Nebraska (Omaha and Lincoln), Nevada (Las Vegas and Reno), New Hampshire, New Mexico, North Carolina (Chapel Hill and Charlotte), North Texas, Oklahoma, Oregon, Pittsburgh, Rhode Island, South Carolina, South Florida, Southern Mississippi, Tennessee (Knoxville), Texas (Arlington, Austin, Dallas, and El Paso), Utah, Vermont, Virginia, Washington, Wisconsin (Madison and Milwaukee), Wyoming, Virginia Commonwealth, Virginia Tech, Washington State, Wayne State, Western Michigan, and Wright State.
U.S. CS Private (39): Boston University, Brandeis, Brown, Carnegie Mellon, Case Western Reserve, Clarkson, Columbia, Cornell, DePaul, Drexel, Duke, Emory, Florida Institute of Technology, George Washington, Georgetown, Harvard, Illinois Institute of Technology, Johns Hopkins, Lehigh, MIT, New York University, Northeastern, Northwestern, Polytechnic, Princeton, Rensselaer, Rice, Rochester Institute of Technology, Stanford, Stevens Institute of Technology, Toyota Technological Institute at Chicago, Tufts, Universities of: Chicago, Notre Dame, Pennsylvania, Rochester, Southern California, and Tulsa, Washington in St. Louis, Worcester Polytechnic Institute, and Yale.
U.S. CE (8): Iowa State, North Carolina State, Northeastern, Universities of: California (Santa Cruz), Central Florida, Illinois (Urbana-Champaign), New Mexico, and Southern California.
U.S. Information (14): Cornell, Drexel, Indiana, Penn State, Syracuse, Universities of: California (Berkeley), Illinois (UrbanaChampaign), Maryland (College Park CLIS and Baltimore County), Michigan, North Carolina (Chapel Hill), Pittsburgh, Texas (Austin), and Washington.

Canadian (II): Concordia, Simon Fraser, Universities of: British Columbia, Calgary, Manitoba, New Brunswick, Toronto, Victoria, Waterloo, Western Ontario, and York.
${ }^{1}$ The title of the survey honors Orrin E. Taulbee of the University of Pittsburgh, who conducted these surveys for the Computer Science Board until 1984, with retrospective annual data going back to 1970.
${ }^{2}$ Information (I) programs included here are Information Science, Information Systems, Information Technology, Informatics, and related disciplines with a strong computing component. Surveys were sent to CRA members, the CRA Deans group members, and participants in the iSchools Caucus (www.ischools.org) who met the criteria of granting Ph.D.s and being located in North America. Other I programs who meet these criteria and would like to participate in the survey in future years are invited to contact survey@cra.org for inclusion.
${ }^{3}$ Classification of the population of an institution's locale is in accordance with the Carnegie Classification database. Large cities are those with population $>=250,000$. Mid-size cities have population between 100,000 and 250,000 . Town/rural populations are less than 100,000.
${ }^{4}$ All faculty tables: The survey makes no distinction between faculty specializing in CS vs. CE programs. Every effort is made to minimize the inclusion of faculty in electrical engineering who are not computer engineers.

# Research Highlight: CRA Board Member Margo Seltzer 

By Margo Seltzer, Harvard University


"What are computer users doing that is wasting their time?" This question guides my research. I construe computer systems research quite broadly. If I can build it, it's a systems problem. This breadth has let me pursue questions in visualization as well as operating systems; machine learning and computer architecture; file systems, performance analysis, graph processing, databases, and numerous other areas. Some people might say I have a short attention span; I like to claim that I have broad interests!

There are many examples where my or my students observations about the world and how people's time and energy were being wasted led to interesting systems research problems.

For example, my group engaged in about a decade of research on data provenance because we kept hearing from scientists who wanted to be able to document their experiments, make them reproducible, and manage their unwieldy collections of code and data.

Data provenance is a formal description of the way data comes to be in its current form and location. It contains answers to questions such as "Where did this data come from? Who has seen it? How has it been transformed?"

While we started working in this area to solve the problems of computational scientists, we now hear from colleagues in industry who want to use data provenance to help them enforce their companies' data management policies or to comply with federal regulations such as HIPAA or Sarbanes-Oxley.

Provenance data is most frequently represented as a graph, so the study of data provenance led us to the investigation of graph databases and graph processing systems. We
thought we were starting out to build a graph database, and we developed some important pieces of technology -- native graph storage structures that support mutability and multiversion querying and high performance graph partitioning algorithms. Then we got distracted and started studying the structure of graphs and what metrics best described the semantic information encoded in them. Recently, one of my students completed a study that suggests that the community has not been doing a great job of evaluating graph processing systems.

Another area of research that has kept me busy for quite a while is our Automatically Scalable Computation (ASC) project, which is a collaboration with Boston University. It grew out of watching our colleagues in the domain sciences grow frustrated having to rewrite their software every time they got a new parallel machine from which they wanted to extract maximum performance. Our dream is "push button parallelization"; that is, you write your program just as you would for a single processor and if you detect that computational resources are available, you can take advantage of them to make your program run more quickly. Our current implementation of this vision transforms the problem into a machine learning and speculative execution problem. Our system monitors a program's execution, builds a model of it, and then when cores are available, launches threads to speculatively execute computations it thinks might be useful in the future.

Those are just a few examples of the kinds of projects my research group addresses. My other passion (besides women's soccer) is teaching or, as I like to call it, facilitating my students' learning.

Approximately five years ago, I began revising all my undergraduate courses so that I could teach them in a flipped style. That is a teaching approach where students complete reading or video assignments and answer a few questions on them prior to attending class. Then we spend
class time engaged in small-group problem solving, where I and my teaching staff wander around the classroom, interacting with the different groups and trying to spend our time with those students who can benefit most from our assistance.

My first experience flipping a course was with my insanely time-consuming operating systems course. Students report spending 30 hours per week completing the long but rewarding problem sets--students start with a simple operating system kernel and build user-level processes, a virtual memory system, and a journaling file system.

I blogged about my first experience flipping the course here: http://mis-misinformation.blogspot.com/2013/08/an-index-to-my-flipping-blog-postings.html

I distilled the experience into these 10 bullet points:

## 1. It's good for an old dog to learn new tricks.

This is really about making sure your teaching doesn't get stale. It's way too easy to keep teaching the same thing over and over again. Whether you use new pedagogy, new technological breakthroughs, or just good self-discipline, it's important to keep classes fresh.

## 2. Flipping lets me spend time with students for whom the material is challenging.

This is so obvious in retrospect, but so exhilarating in practice. I have always run a relatively interactive class, but for the most part, the students who ask and answer questions in class are not the ones who need you the most. They are typically the most confident students and are not struggling to understand the material. The silent ones are the ones who are frequently struggling, and the time spent helping these students in small groups during class time is incredibly useful.
3. Learning takes place by doing, not by listening to me.

There are a lot of different styles of hands-on learning, but I think this point cannot be emphasized enough. Learning is not just the process of transferring information from me to students. Learning is about gaining new information and knowing how to use it. That latter part requires practice.

## 4. Teaching fellows' engagement is critical.

We call our teaching assistants "teaching fellows" or TFs for short. Flipping effectively requires a staff who
are comfortable engaging with students, walking them through problems, and posing the right questions. I am extraordinarily fortunate to have truly amazing and dedicated teaching staff.

## 5. It takes a lot of effort to come up with effective inclass work.

It's important that the in-class exercises or problems relate to both the concepts the students are learning and the homework or problem sets they will be doing. Designing these exercises so they can be completed in the time allotted and add real value to the course is demanding.

## 6. Pre-class web forms are AWESOME.

They let me engage with students in an entirely different way and to gather lots of interesting data. This is perhaps the best surprise of all! I used Google forms to have students submit answers to the pre-class questions. This created a mechanism I could use to obtain all sorts of useful information, including how things were going in partnerships, how much time people were spending on various parts of the assignment, what was working for students, what wasn't working, etc. Once you have students regularly filling out forms, they will answer anything you put there, and you can use that information to make the class better. Score!

## 7. CS161 is even more time-intensive than I thought.

I had been saying 20 hours per week for decades; when the going gets rough, students were regularly reporting 30-hour weeks. Oops.

## 8. It would be useful to help students learn what it really means to design something.

Software design is hard! We spend a lot of time in class doing small group design exercises. I could imagine developing an entire course around this idea.

## 9. Flipping is a great equalizer when students enter with different experience levels or exposure to different topics.

It's relatively easy to provide supplementary material as pre-class work so that students who have gaps in their background can catch up.

## 10. Fully integrated and coordinated materials take real effort but pay off tremendously.

This should be a no-brainer, but thinking deeply about the relationship between the videos I prepared, the exercises we
completed in class, and the problem sets was time well spent.

## About the Author

Margo I. Seltzer is the Herchel Smith Professor of Computer Science and the faculty director of the Center for Research on Computation and Society (CRCS) in Harvard's John A. Paulson School of Engineering and Applied Sciences. Her research interests are in systems, construed quite broadly: systems for capturing and accessing data provenance, file systems, databases, transaction processing systems, storage and analysis of graph-structured data, new architectures for parallelizing execution, and systems that apply technology to problems in healthcare.

She is the author of several widely used software packages including database and transaction libraries and the 4.4BSD log-structured file system. Seltzer was a founder and CTO of Sleepycat Software, the makers of Berkeley DB, and is now an architect for Oracle Corporation. She is the USENIX representative to the Computing Research Association board of directors, a member of the Computer Science and Telecommunications Board of the National Academies, and a past president of the USENIX Association. She is a Sloan Foundation Fellow in computer science, an ACM Fellow, and a Bunting Fellow. She was the recipient of the 1996 Radcliffe Junior Faculty Fellowship and the University of California Microelectronics Scholarship. She is recognized as an outstanding teacher and won the Phi Beta Kappa teaching award in 1996 and the Abramson Teaching Award in 1999.

Professor Seltzer received an A.B. degree in applied mathematics from Harvard/Radcliffe College and a Ph.D. in computer science from the University of California, Berkeley.


# Expanding the Pipeline: 

# Broadening Participation in Computing Fields by Preparing More Professionals with Disabilities 

By Richard Ladner and Sheryl Burgstahler, University of Washington



CRA-W
Computing Research Association Women

Research and practice focused on broadening participation of underrepresented groups have revealed evidence-based strategies to include career awareness, academic preparation, mentoring experiences, research engagement, internships and other work-based learning opportunities, and other support at transition steps and all levels of education and employment. Most broadening participation efforts have focused on women and underrepresented minorities. However, for more than 10 years, AccessComputing has been funded by the National Science Foundation (NSF) to increase the successful participation of students with disabilities in academic programs and careers. Project leaders have found that much of the research on challenges and interventions for women and minorities applies to people with disabilities. Principal investigator (PI) Richard Ladner and co-PI Sheryl Burgstahler are joined in the current grant-funded project by co-PIs Andrew J. Ko and Jacob O. Wobbrock from the University of Washington Information School. Together, we bring expertise in computing, education, and research; technology for people with disabilities; and applications of evidence-based practices with multiple stakeholders that include faculty, technology companies, and students with disabilities.

People with disabilities are underrepresented in computing fields. According to the National Center for Education Statistics (Table 311.10), in 2012, engineering/ computer science/mathematics fields had about 10.6 percent of undergraduates and 4.8 percent of graduate students with disabilities. This is in contrast to the approximately 15 percent


AccessComputing hosted mock interviews.
of K-12 students who are identified as disabled. Challenges faced by students include access to keyboards and mice for those with limited mobility, content within images for students who are blind, and audio content for students who are deaf or hard of hearing. These access problems have well-documented solutions within guidelines for accessible IT. Success stories of the relatively few individuals with disabilities in computing fields-some supported by earlier NSF grants-demonstrate that opportunities do exist for those who develop academic and self-determination skills and successfully overcome barriers imposed by inaccessible facilities, curricula, and IT; inadequate academic supports; and lack of encouragement. For computing courses, integrating content about how IT can improve the lives of individuals with disabilities has the potential to increase the interest of students who may not otherwise consider a computing field.

AccessComputing addresses underrepresentation by providing multiple activities for students with disabilities that include online and on-site mentoring and near-peer support in an active online community, internships in industry, research experiences, computing conference engagement, and career development activities. Participants can choose to engage in an ongoing longitudinal study that dates back to 1993. Results of the 2016 Report of the AccessSTEM/AccessComputing/D0-IT Longitudinal Transition Study (ALTS) suggest that such interventions, particularly when a person engages in multiple interventions, lead to


Students learn programming on campus at an AccessComputing event.
higher levels of success in college and careers for students with disabilities (see www.uw.edu/doit/2016-report-accessstemaccesscomputingdo-it-longitudinal-transition-study-alts).

In the following stories, two AccessComputing participants share, in their own words, the value of specific experiences in AccessComputing:

Daniel Seita, a computer science Ph.D. student at the University of California, Berkeley, shares how engagement in AccessComputing led to a change in his career path.

In retrospect, I am surprised at my life's journey so far, as I had long viewed myself as a future doctor or lawyer. It was not until after I had attended AccessComputing's Summer Academy for Advancing Deaf
 and Hard of Hearing in Computing in 2011 that I seriously considered a career in computer science.
My experience at the Summer Academy, where I was surrounded by talented deaf students and did not have to worry much about communication, provided a welcome social change from college. I attended Williams College from 2010 to 2014 and was its first (and only) deaf student. Throughout my years at Williams, they provided me with excellent interpreting and note-taking services for my classes. The computer science professors were also friendly and supportive. In the summers after the Summer Academy, I participated in two NSF-funded Research Experiences for Undergraduates, which, along with my academic record, helped me get in Berkeley's Ph.D. program.

Every now and then, I think about how unbelievable it is that I got to where I am today. My journey into the world of computer science would not have been possible without all the help and support l've received in my years of school. My support network includes all my interpreters, my note-takers, deaf teachers and assistants, AccessComputing, and, of course, my parents. From elementary, middle, and high school at Guilderland, to four years at Williams, and now at Berkeley, they have
remained my strongest supporters. [http://www.uw.edu/ accesscomputing/resources/accesscomputing-news-january-2015/accesscomputing-student-profile-daniel-seita]

Kavita Krishnaswami is a Ph.D. student at the University of Maryland, Baltimore County. Her disability makes it difficult to travel, and she received financial support from AccessComputing to remotely "attend" several professional conferences and engage on a panel and in small groups. She shares one of her experiences in the below paragraphs.

Attending the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp 2014)


Kavita Krishnaswami's telepresence robot (left) alongside Richard Ladner (right).
in Seattle, Washington, via the Beam Telepresence Robot was an exceptional and memorable experience. Although I was unable to attend the conference in person, I participated in a user study, which provided me the opportunity to attend and interact with other attendees remotely. The telepresence initiative user study was organized by the co-chairs Carman Neustaedter, from Simon Fraser University in Canada, and Gina Venolia, from Microsoft Research.

The Beam robot, created by Suitable Technologies, allowed me to have mobility by using a wheeled batterypowered device with voice conferencing and telepresence capabilities. The Beam robot includes two wide-angle cameras, a six-microphone array with echo-canceling and noise reduction, a 17 -inch LCD screen, an eight hour-battery, two dual-band radios providing Internet connectivity, and a built-in speaker coupled to a mobile platform. The Beam has great maneuverability and can be driven using a mouse, keyboard, or Xbox controller. Participants were also given the option to personalize their Beam robot with a label that displayed their name and contact information.

I had the opportunity to meet amazing researchers from across the country as well as individuals from China, England, Sweden, and Italy and engage in discussions about varied and interesting research projects as a bridge to meaningful mentorship and guidance. Although I have spoken with Richard Ladner via phone, Skype, and email for more than 10 years, it was exciting and gratifying to meet physically him for the first time, albeit in virtual space thanks to the Beam robot.

Using the Beam robot provided a sense of dynamic and real-time presence in the actual conference environment. It was great to be able to join discussions after the presentations, and I enjoyed having autonomy and independence while driving and operating the Beam robot.

Nevertheless, the experience wasn't perfect. I would often lose my Internet connection inside the elevator and between presentation sessions when there was significant traffic on the network. Other challenges included audio and video problems. For example, feedback from my microphone caused disturbances in the sound quality, so I had to frequently adjust the volume on
the microphone. Although I felt totally immersed and connected at the sessions of the conference, I had a sort of "jet-lag" because of the time difference between Maryland and Seattle, and I felt a sense of disconnect because of the differences between my home and the conference site. [http://www.uw.edu/accesscomputing/ resources/accesscomputing-news-january-2015/attending-conferences-robots]

Besides working with students, AccessComputing helps faculty members be more prepared to work with students with disabilities in their courses and to include accessibility related content in their classes to ensure that computing professionals in the next generation are knowledgeable about creating products that are accessible to individuals with disabilities. The project also works with technology companies to increase the accessibility of their products and
to encourage them to hire individuals with disabilities and those that have expertise in accessible design.

For more information about AccessComputing activities and resources and about how you can engage in these efforts, check out the project website at http://www.uw.edu/ accesscomputing. In particular, computing educators at K-12 and postsecondary levels can join the Computing Faculty, Administrator, and Employer Community of Practice to increase their knowledge about disabilities and make changes in computing departments and companies that lead to more inclusive practices. Send a request to accesscomp@uw.edu and join us in fostering synergistic and lasting relationships among stakeholders to promote systemic changes toward inclusiveness in computing education and careers.

About the Authors
Richard Ladner is professor emeritus in the Paul G. Allen School of Computer Science \& Engineering at the University of Washington. Sheryl Burgstahler directs Accessible Technology Services and is an affiliate professor in the College of Education at the University of Washington.

# Expanding the Pipeline: Beyond Graduate Admissions - Strategies for Diversifying the Computer Science Workforce 

By Suzanne T. Ortega and Hironao Okahana, Council of Graduate Schools

## Gs <br> GRADUATE SCHOOLS

The majority of master's and doctoral students in the United States are women, but women are still underrepresented in science, technology, engineering, and mathematics (STEM) fields, including computer and information sciences. According to the most recent study by the Council of Graduate Schools (CGS), 57 percent of students who began pursuing master's and doctoral education in the United States in fall 2015 were women. Among persons of color, the representation of women is robust: sixty-nine percent of Black/African American, 64 percent of American Indian/Alaska Native, 63 percent of Hispanic/Latino, and 60 percent of Native Hawaiian/Other Pacific Islander who began their master's and doctoral education in fall 2015 were women. Similarly, 58 percent of master's degrees and 52 percent of doctoral degrees during the 2014-15 academic year were conferred to women. However, in STEM fields, including computer and information sciences, women still fall behind men by a wide margin.

According to another CGS report, 31 percent of first-time graduate enrollment in computer and information sciences and 29 percent of the total graduate enrollment in fall 2015 were women. Of the doctorate and master's degrees conferred in computer and information sciences, 29 percent were conferred to women between the 2014-15 academic year. Although women's representation in computer and information sciences is above that of most engineering fields, the field has one of the lowest representations of women among other STEM fields. However, there is some good news: enrollments for women has grown steadily in computer and information sciences in recent years, and the rate of growth is outpacing that of men. Between 2005 and 2015, the fall first-time enrollment of women in computer and information sciences
increased, on average, by 21 percent annually, while the average annual rate of growth for men was 13 percent.

This rather robust growth in first-time enrollment of women has not, however, translated into equally strong increases in the number of computer and information sciences graduate degrees conferred to women. Between academic year 200405 and 2014-15, the number of computer and information sciences master's degrees conferred to women grew, on average, 7 percent annually, compared to the average annual rate of growth of 5 percent for men; and for doctoral degrees, both men and women increased their numbers, on average, by 6 percent annually. There are some delayed effects in how changes in first-time enrollments translate into changes in degrees conferred over time. Nevertheless, this stark difference between rates of growth in women's first-time enrollment and degrees conferred suggests that in order to expand the educational pipelines for women in computer and information sciences, more efforts that focus on retention-and not just recruitment-may be a key factor.

This observation is not surprising. Nor is it unique to computer and information sciences alone. CGS's study on completion and attrition of underrepresented minority (URM) students in STEM doctoral fields also offered a similar conclusion. Supported by the National Science Foundation (NSF grant number 1138814), this study examined the enrollment data of all URM doctoral students in STEM fields at 21 U.S. doctoralgranting institutions between 1992 and 2012, in addition to collecting data about current URM STEM doctoral students through a survey and focus groups. A CGS report based on this project, Doctoral Initiative on Minority Attrition and Completion (DIMAC), found that most diversity and inclusion initiatives in STEM doctoral education focus on recruitment and early phases of doctoral studies. In fact, very few examples of formal programs and interventions focusing on students during
their post-enrollment were found at the 21 institutions that were part of this project.

Why is this so critical? The CGS study found that one-half of URM STEM doctoral students who left their graduate studies without a doctorate did so after their second year in their programs. This means that one-half of doctoral attrition likely occurs after students have completed their coursework and presumably moved on to the dissertation phase, which requires significant investments in time and effort on the part of both students and graduate programs. It only makes sense to provide the support these students need in the late stages of their doctoral studies to cross the finish line. The latter stage of doctoral studies, the CGS study also found, is the time more students feel emotionally and physically stressed, as well as isolated in their education pursuits. Providing semi-structured experiences for doctoral students in their dissertation phases may help alleviate some of these stresses. Dissertation writing groups and other forms of peer social interactions are becoming increasingly popular approaches to foster a sense of belonging and community for doctoral candidates while also encouraging them to earn their degrees in a timely manner.

Another area of promising practices in increasing participation in the advanced STEM workforce is professional development and career preparation. In the DIMAC report, 70 percent of URM students cited professional and career guidance as a factor that affected their ability to persist in STEM doctoral studies to a great or moderate extent, which is a greater share than effects attributed to advisors or faculty support. Helping students articulate their chosen career paths from a wide range of STEM professions-both in the professoriate and industry-may encourage progress and completion of their doctorates. Ninetyfour percent of URM STEM students in the CGS study cited motivation and determination as a factor that affected their ability to persist to a greater or moderate extent. Being able to articulate one's goals for earning a doctorate-helping students
propel themselves into their desired career paths being one of them-is likely a key driver for the needed motivation and determination to complete their doctoral studies.

This is an area where graduate programs and the industry can work closely together. In fact, another recent CGS study, "Graduate Students and the STEM Workforce (NSF grant number 1413827)," which focused on career preparation in STEM graduate education, called for a greater alignment and coordination of professional development experiences for advanced STEM graduate students. Professional development efforts that help students begin their careers have a potential to improve retention and degree completion. The study also underscores the importance of faculty mentorship in professional development. A more diverse student body may lead to a more diverse range of career interests, as a recent study suggests that women and URM in some STEM fields tend to prefer careers outside of the professoriate. Thus, it is important that faculty members and graduate programs encourage and guide students into the multitude of career pathways beyond the doctorates.

With graduate enrollment increasing for women in computer and information sciences, the entry point for the field's educational pipeline is more robust than ever. Yet, it appears that the challenge remains for computer and information sciences graduate programs-and for other STEM fields-to increase retention and completion of degrees. In order to expand the pipeline, our efforts must focus on both recruitment of potential talents and support throughout graduate studies that leads to desired career outcomes. The CGS study on URM STEM doctoral completion suggests that interventions in latter stages of doctoral programs, such as structured support for doctoral dissertation, as well as professional development programs may be a key in expanding the pathways to the advanced STEM workforce, including in computer and information sciences, for women and persons of color.

[^1]
# Discover More About the CRA-W's Collaborative REU Program: Consider Applying Today 

CRA-W's Collaborative Research Experience for Undergraduates (CREU) program supports students while they gain valuable experience by working on research projects under the guidance of faculty mentors. The article below, which is written by a team currently at Kennesaw State University, gives a firsthand perspective of the program's benefits. The team, which is funded by the CREU program, has presented their research at ACM Mid-Southeast 2016 in Gatlinburg, Tenn., and SIGCSE 2017 in Seattle, Wash. Faculty member Amber Wagner and her students Deja Jackson, Erica Pantoja, Cindi Simmons, and Kathelyn Zelaya from Kennesaw State University have been working on the research project "Analyzing the Potential of Learning Reading and Math Skills Through Computational Thinking" throughout the 2016-2017 academic year.

Research allows you to look at a problem and think both logically and creatively to find a solution. Since every project is so different and has such a varying goal, there isn't technically a wrong answer. In this project, we are examining how a block programming language can improve elementary students' math and literacy skills while increasing their computational thinking. Throughout this process we have learned a tremendous amount of new skills, including how to read research papers to gain information and, more importantly, how to decipher applicable research papers from nonapplicable research papers. We have also learned CSS, HTML, and JavaScript,
 which are not taught in any of our coursework. We have learned to use various tools to improve our teamwork (e.g., GitHub and Slack), which has helped us learn how to work together as a team. Working in this group project has been a surprisingly pleasant experience compared to classroom group projects because each of us are contributing and feel our voice is heard. Perhaps the most beneficial side effect of working on this project, thus far, has been experiencing an example of how we can apply the skills we have learned in the classroom to a real-life job or application as a developer. In fact, we have already translated these skills by serving as mentors in other groups due to the knowledge we gained on this project (i.e., Girls, Inc. of Greater Atlanta and Technovation Atlanta).

Because of the work we have conducted on this project, we were fortunate to present at ACM Mid-Southeast 2016 in Gatlinburg, Tenn., and SIGCSE 2017 in Seattle, Wash. Something exciting about both of these presentations was that the attendees showed genuine interest in our presentations and asked questions, which does not typically occur during class presentations. It taught us the importance of preparing thoughtful presentations and to think ahead about possible audience questions. Talking about the project with professors, other students, and industry professionals was beneficial, and they each provided unique and excellent advice regarding how we could expand or improve the project. Also, attending other presentations was fascinating. We learned about several new technologies, which inspired us to think about different applications to develop in the future.
Overall, this has been an incredible experience that allowed us to apply what we have learned in the classroom while creating something we passionately believe in and want to see succeed. We are grateful for the opportunity to spend our time doing research!

The CREU program is currently accepting applications for the 2017-2018 academic year. The application cycle is open through May 18. For more information regarding the eligibility and application materials, please visit http://cra.org/cra-w/creu/.

# More CREU Students Attend Graduate School Compared to Other REU Students 

By Burçin Tamer, CERP Research Scientist

This infographic compares post-graduation plans of undergraduate students with different REU (Research Experience for Undergraduates) experiences using CERP's annual spring survey for graduating students. Specifically, CRA-W/CDC Alliance's Collaborative Research Experiences for Undergraduates (CREU) participants, students who participated in other REUs, and students with no REU experience were compared in terms of whether they were attending graduate school (Master's or Ph.D.) in the upcoming fall semester. The students included in this analysis are men from racial/ethnic groups who are underrepresented in computing and women because the CREU program is targeted specifically toward these students. Approximately the same
 number of women and men are in all three groups.

The comparison shows that a greater percentage of CREU students went on to attend graduate school than other REU participants as well as students who did not participate in an REU. Further, students who participated in any REU program in general attended graduate school at a higher rate than those who did not have any REU experience. This underlines the importance of providing formal research opportunities for underrepresented undergraduate students in order to expand diversity in computing research.

For more information on CREU, visit http://cra.org/cra-w/creu/.
Notes. Students were grouped based on prior participation in undergraduate research programs: CREU ( $\mathrm{n}=43$ ), Other REU ( $\mathrm{n}=167$ ), or No REU ( $\mathrm{n}=272$ ). Students in the latter two groups were matched to CREU students based on their background characteristics using nearest neighbor l-to-l propensity score matching ensuring comparability across groups. These background characteristics were gender, race, institution type, and parents' highest education level. Matched samples of 43 students per group resulted in a total of 129 students for the final analysis. The difference between CREU participants and students with no REU participation was statistically significant, $p<.05$. The differences between CREU and other REU participants, and between other REU participants and students with no REU experience were not statistically significant at the commonly used $5 \%$ significance level, $p=.15$ and $p=.14$, respectively. Note, however, that when the sample is limited to women (underrepresented men are excluded from the analysis), CREU students are significantly more likely to go to graduate school than other REU students, $p<.05$. This suggests the CREU program may be particularly effective for women.

This analysis is brought to you by the CRA's Center for Evaluating the Research Pipeline (CERP). CERP provides social science research and comparative evaluation for the computing community. To subscribe to the CERP newsletter, click here.

## CCC Announces New Council Members

## By CCC Staff

The Computing Research Association (CRA), in consultation with the National Science Foundation (NSF), has appointed six new members to the Computing Community Consortium (CCC) Council:

D Nadya Bliss, Arizona State University
D Elizabeth Churchill, Google
D Juliana Freire, New York University
D Keith Marzullo, University of Maryland

- Greg Morrisett, Cornell University

D Manuela Veloso, Carnegie Mellon University
Beginning July 1 , the new members will each serve three-year terms. The CCC Council is comprised of 20 members who have expertise in diverse areas of computing. They are instrumental in leading CCC's visioning programs, which help create and enable visions for future computing research. Members serve staggered three-year terms that rotate every July

The CCC and CRA thank those Council members whose terms end on June 30 for their exceptional dedication and service to the CCC and to the broader computing research community:

- Lorenzo Alvisi, University of Texas at Austin
- Randal Bryant, Carnegie Mellon University
- Gregory Hager, Johns Hopkins University
- Vasant Honavar, Pennsylvania State University

Debra Richardson, University of California - Irvine

- Klara Nahrstedt, University of Illinois at Urbana-Champaign

The CCC encourages participation from all members of the computing research community. Each fall, the CCC issues a call for proposals for visioning activities. Each spring, the CCC issues a call for nominations for Council members effective the following July. For more information, please visit the CCC website or contact Dr. Ann W. Drobnis, CCC Director, at adrobnis@cra.org.

## Full Bios of New CCC Council Members

## Nadya Bliss

Dr. Nadya T. Bliss is the Director of the Global Security Initiative (GSI) at Arizona State University. GSI serves as the university-wide hub addressing emerging security challenges, including borderless threats (cyber security, health security, and resource security). These challenges are often characterized by complex interdependencies and present conflicting objectives requiring multi-disciplinary research and crossmission collaboration. Prior to taking on the GSI role, Dr. Bliss served as the Assistant Vice President, Research Strategy in the Office of Knowledge Enterprise Development.

Dr. Bliss holds a Professor of Practice appointment (and is a member of Graduate Faculty) in the School of Computing, Informatics, and Decision Systems Engineering; Senior Sustainability Scientist appointment in the
 Julie Ann Wrigley Global Institute of Sustainability; and affiliate appointments in the School for Future of Innovation in Society, the Center on the Future of War (collaboration between ASU and New America), and the Simon A. Levin Mathematical, Computational and Modeling Sciences Center. Dr. Bliss is also a Senior Fellow at New America. Before joining ASU in 2012, Dr. Bliss spent 10 years at MIT Lincoln Laboratory, most recently as the Group Leader of the Computing and Analytics Group.

## Elizabeth Churchill

Currently a Director of User Experience at Google, Dr. Elizabeth Churchill is an applied social scientist working in the area of human computer interaction, computer mediated communication, mobile/ubiquitous computing and social media. Her most recent research focuses on design systems and frameworks.

Originally a psychologist by training, throughout her career Elizabeth has focused on understanding people's social and collaborative interactions in their everyday digital and physical contexts. She has studied, designed and collaborated in creating online collaboration tools (e.g. virtual worlds, collaboration/ chat spaces), applications and services for mobile and personal devices, and media installations in public spaces for distributed collaboration and communication. In addition to being instrumental in the creation of innovative technologies, she has contributed to academic research through her publications in theoretical and applied psychology, cognitive science, human-computer interaction, mobile and ubiquitous computing, and computer supported cooperative work. She has published over 150 peer-reviewed publications, written two co-authored volumes (Foundations for Designing User Centered Systems with Frank Ritter and Gordon Baxter, and Designing with Data with Rochelle King and Caitlin Tan), and has co-edited 5 books. Topics she has written about include implicit learning, human-agent systems, mixed initiative dialogue systems, social aspects of information seeking, digital archive and memory, value sensitive design, feminism and design, Al \& agent-based collaborative technologies, frameworks for human-centered systems design and the development of emplaced media spaces. In addition to serving on advisory boards for a number of university departments, she is the current secretary/treasurer of the Association for Computing Machinery.

## Juliana Freire

Juliana Freire is a Professor of Computer Science and Engineering and Data Science at New York University. She holds faculty appointments at the Tandon School of Engineering, Center of Data Science, Courant Institute for Mathematical Science, and Center for Urban Science. She is the executive director and principal investigator of the NYU Moore-Sloan Data Science Environment. Her recent research has focused on big-data analysis and visualization, large-scale information integration, web crawling and domain discovery, provenance management, and computational reproducibility. Prof. Freire is an active member of the database and Web research communities, with over 180 technical papers, several opensource systems, and 12 U.S. patents. She is an ACM Fellow and a recipient of an NSF CAREER, two IBM Faculty awards, and a Google Faculty Research award. She has chaired or co-chaired workshops and conferences, and participated as a program committee member in over 70 events. Her work has been funded by the National Science Foundation, DARPA, Department of Energy, National Institutes of Health, Sloan Foundation, Gordon and Betty Moore Foundation, W. M. Keck Foundation, Google, Amazon, AT\&T, the University of Utah, New York University, Microsoft Research, Vahoo! and IBM.

## Keith Marzullo

Dr. Keith Marzullo is Dean of the College of Information Studies (also known as the iSchool) at the University of Maryland, College Park. He joined the iSchool from the White House Office of Science and Technology Policy, where he directed the Networking and Information Technology Research and Development (NITRD) Program. NITRD enables interagency coordination and cooperation among the over 20 member agencies which together spend over \$4B a year in NIT R\&D. Dr. Marzullo has also worked at the National Science Foundation (NSF), where he served as the Division Director for the Computer and Network Systems (CNS) Division in the Computer \& Information Science \& Engineering (CISE) Directorate, at UC San Diego where he was the CSE Department chair, and Cornell University. Dr. Marzullo received his Ph.D.
in Electrical Engineering from Stanford University, where he developed the Xerox Research Internet Clock Synchronization protocol, one of the first practical fault-tolerant protocols for keeping widely-distributed clocks synchronized with each other. His research interests are in distributed computing, fault-tolerant computing, cybersecurity, and privacy.

## Greg Morrisett

Greg Morrisett is the Dean of Computing and Information Sciences (CIS) at Cornell University, which houses the departments of Computer Science, Information Science, and Statistical Sciences. He received his bachelor's degree from the University of Richmond and both his Master's and Doctorate degrees from Carnegie Mellon University.

Professor Morrisett's research focuses on the application of programming language technology for building secure, reliable, and high-performance software systems. A common theme is the focus on systems-level languages and tools that can help detect or prevent common vulnerabilities in software. Past examples include typed assembly language, proof-carrying code, software fault isolation, and control-flow isolation.
 Recently, his research focuses on building provably correct and secure software, including a focus on cryptographic schemes, machine learning, and compilers.

Morrisett is a Fellow of the ACM and has received a number of awards for his research on programming languages, type systems, and software security, including a Presidential Early Career Award for Scientists and Engineers, an IBM Faculty Fellowship, an NSF Career Award, and an Alfred P. Sloan Fellowship.

## Manuela Veloso

Manuela M. Veloso is the Herbert A. Simon University Professor in the School of Computer Science at Carnegie Mellon University. She is the Head of the Machine Learning Department. She is a Past President of AAAI (Association for the Advancement of Artificial Intelligence), and the co-founder and a Past President of the RoboCup Federation. She is a fellow of ACM, IEEE, AAAS, and AAAI.

Manuela researches in artificial intelligence, with a focus in robotics and machine learning. Her longterm research goal is the effective construction of autonomous agents where cognition, perception, and action are combined to address planning, execution, and learning tasks. Her vision is that multiple intelligent AI agents, coexisting with humans, with different sets of complementary capabilities will provide a seamless synergy of intelligence. With her students, she has contributed a variety of autonomous robots. Her robot soccer teams have been RoboCup world champions multiple times, and the CoBot mobile service robots have autonomously navigated for more than $1,000 \mathrm{~km}$ in multi-floor university buildings. She founded and directs the CORAL research laboratory, for the study of agents that Collaborate, Observe, Reason, Act, and Learn. See www.cs.cmu.edu/~mmv for details.

# Congressional Briefing on Cybersecurity for Manufacturers Recap 

By Kevin Fu, University of Michigan and CCC Staff



Mike Russo introduces the panel

On April l2th, the Computing Community Consortium (CCC) and MForesight: Alliance for Manufacturing Foresight (MForesight), in conjunction with the House Manufacturing Caucus, held a Congressional briefing on Cybersecurity for Manufacturers that highlighted the outcomes of the March workshop of the same name and discussed the challenges to cybersecurity and potential next steps for its improvement in the U.S. manufacturing space.

The briefing featured members of the CCC and MForesight, as well as experts from government, academia, and the private sector:

- Ann Drobnis, CCC Director

D Robert Frazier, Lockheed Martin
D Kevin Fu, University of Michigan/CCC Council Member

- Sridhar Kota, University of Michigan/MForesight Director

D Kirk McConnell, Senate Armed Services Committee
D Michael Russo, GLOBALFOUNDRIES/MForesight Chair of Executive Committee

The panel stressed the need for a national initiative to address R\&D challenges and opportunities, technology implementation across the supply chain, and policy considerations. The R\&D section offers a research agenda to develop computational tools and testbeds for cyber security assessment, validation, verification and threat prevention in seven areas:
l. Automated risk assessment and detection tools
2. Robust part validation technology
3. Tools to audit the extent of attack
4. Testbeds to safely prototype and test new IT and OT
5. Development of a reference architecture with cross-cutting applicability
6. Cyber range to test component and system level vulnerabilities, train teams, act as a sandbox for new ideas and provide a "cyber autopsy" capability
7. Decoys for intelligence gathering; Prioritizing and Sharing Intelligence

The NIST cybersecurity framework explains that one cannot effectively control cybersecurity risks until after establishing a way to safely assess risk and detect threats in an automated fashion. The old way of conducting assessment involves the art form of penetration testing. This does not scale, depends on human labor, and does not provide continuous assessment. Research and development is needed to create technology that can replace penetration testing with continuous, automated assessment


Kirk McConnell discusses the national security implications of cybersecurity. that is safe when used on Operational Technology.

One of the greatest challenges to cybersecurity of manufacturing is the lack of testability. The problem is that many security issues arise at interfaces of interoperable components, often from different manufacturers. Whereas the National Highway Traffic Safety Administration (NHTSA) and the Nevada National Security Test Site have end-to-end facilities for testing crashworthiness of vehicles and survivability of systems, respectively, there is no analogue for cybersecurity of manufacturing. Large OEMs have the means to create entire test factory floors, but even such a facility will not suffice to gain reasonable cybersecurity assurance of the interoperable components in a realistic, messy environment. The federal government can play an important role in coordinating the construction of infrastructure for testing facilities that span multiple manufacturers and universities.

To learn more about the briefing, view the summary here. Video recordings coming soon!

# A National Research Agenda for Intelligent Infrastructure 

By Beth Mynatt and CCC Staff

The Computing Community Consortium (CCC) in collaboration with the Electrical and Computer Engineering Department Heads Association (ECEDHA) recently released eight white papers describing a collective research agenda for intelligent infrastructure. These papers draw from a large network of expertise including CCC Council members, former CCC Council members, CRA Board members, and other members of the academic and industry communities for a total of 40 different authors from 27 different institutions.

We will be blogging about each paper over the next few weeks. We start with the overview paper: A National Research Agenda for Intelligent Infrastructure.

Our infrastructure touches the day-to-day life of each of our fellow citizens, and its health is crucial to the overall competitiveness and prosperity of our country. Unfortunately, the current state of U.S. infrastructure is not good. The American Society of Civil Engineers' latest report on America's infrastructure ranked it at a $D^{+}$, stating that it is in need of $\$ 3.9$ trillion in new investments. This dire situation constrains the growth of our economy, threatens our quality of life, and puts our global leadership at risk.

Intelligent infrastructure is the deep embedding of sensing, computing, and communications capabilities into traditional urban and rural physical infrastructures such as roads, buildings, and bridges to increase efficiency, resiliency, and safety. It provides capabilities that are:

Descriptive: Provides an accurate and timely characterization of current state, e.g., water level in a storm drain or traffic congestion.

D Prescriptive: Recommends immediate and near-term actions, e.g., re-routing traffic or dispatching onsite service personnel.

D Predictive: Anticipate future challenges and opportunities, based on assessment of the current state, patterns of past activity and available resources and capabilities, e.g., street-level flooding by incorporating water sensors, weather patterns and runoff capabilities.
D Proactive: Guides complex decision making and scenario planning, incorporating economic data, to inform future investment.

Across disciplines ranging from engineering to computer science to public policy, intelligent infrastructure is increasingly seen as a solution to the long-standing problems that face local governments attempting to respond to both long term and short term threats to resilience: 1) strained resources spread across ever growing urban populations, 2) aging infrastructures and public services systems, 3) competitiveness in the global economy, and 4) acute human and environmental stressors due to rapid growth and change in regional areas.

How to design and deploy intelligent infrastructure to efficiently and effectively support our communities is one of the central questions going forward for the US. In this series of white papers, we looked at the potential of intelligent infrastructure across many domains including transportation, city services, energy, public safety and disaster response. We also examine the needs of rural communities for intelligent infrastructure and overarching safety and security challenges.

|  | Descriptive | Prescriptive | Predictive | Proactive |
| :---: | :---: | :---: | :---: | :---: |
| Intelligent Transportation | Real time traffic congestion information | Reroute traffic; <br> Adjust dynamic lane configuration (direction, HOV) | Anticipate rush hour / large event congestion; Anticipate weather related accidents | Suggest traffic patterns w/ intelligent stoplights; road diet plan |
| Intelligent Energy Management | Real time energy demand information | Improve asset utilization and management across transmission and distribution system | Anticipate demand response required to ensure grid reliability | Suggest new market approaches to integrate production and distribution capabilities |
| Intelligent Public Safety and Security | Real time crowd analysis | Threat detection; Dispatch public safety officers | Anticipate vulnerable settings and events | Suggest new communication and coordination response approaches |
| Intelligent Disaster Response | Real time water levels in flood prone areas | Timely levee management and evacuations as needed | Anticipate flood inundation with lowcost digital terrain maps | Inform National Flood Insurance Program; Inform vulnerable populations |
| Intelligent City Systems | Describe mobility patterns (pedestrian, cycling, automobile, trucking, electric and autonomous vehicles) | Adjust mobility management to improve safety; reduce energy usage | Anticipate changing needs for parking, charging stations, bike and ride share programs. | Inform future mobility capabilities to drive economic development and reduce barriers to employment |
| Intelligent Agriculture | Characterize spatial and temporal variability in soil, crop, and weather. | Advise based on environmental stressors and crop traits | Forecast crop yield; Anticipate seasonal water needs | Customize management practices and seed selection to local conditions |
| Rural Communities | Describe rural communities (skew towards aging adults) | Make sure rural Americans are not left behind in digital revolution | Anticipate rural population growth | Proposed Rural-focused Intelligent Infrastructure Act |

Three additional papers will be coming out soon on the respective agendas for Wireless Technologies, Intelligent Health, and Privacy for Intelligent infrastructure. See all the intelligent infrastructure white papers here.

# New Incoming CRA Board Member: Jaime Teevan 

On July l, Jaime Teevan will replace Margaret Martonosi on the CRA Board. We would like to thank Martonosi for her term of service on the CRA Board. Martonosi will step down a year early to focus on other activities. This fall, she will become a co-chair of CRA's Committee on the Status of Women in Computing Research, taking the place of current co-chair Nancy Amato, and serving along with Julia Hirschberg.

Jaime Teevan is a principal researcher at Microsoft Research and an affiliate associate professor at the University
of Washington. At Microsoft Research she leads the microproductivity team and shipped the first personalized search algorithm used by Bing. Teevan has published hundreds of award-winning research papers, technical articles, books, and patents, and given keynotes and lectures around the world. Her groundbreaking research at the intersection of information retrieval and human computer interaction has earned her the Technology Review TR35 Young Innovator, CRA-W Borg Early Career, and Karen Sparck Jones awards. She received a Ph.D. and S.M. from MIT and a B.S. with honors from Vale University.

## CRA Welcomes Claire Brady

CRA recently hired Claire Brady as program manager. In her new role, she is responsible for planning CRA's Committee on the Status of Women in Computing Research (CRA-W) program events and providing support for initiatives that enrich the community's awareness of CRA, its committees, mission, and services. In her first two weeks at CRA, Claire has created Undergraduate Town Hall resources, which provide answers to frequently asked questions on cyber security and computer science extracurricular activities. She published 2017 Grad Cohort
resources and the Scholarships for Women Studying Information Security (SWSIS) 2017 Scholars on the CRA-W website. She has also begun assisting program applicants for a number of CRA-W programs.

Before joining CRA, Claire worked at a health care technology firm where she developed resources and organized events for 900 hospitals with the goal of maximizing quality and utilization improvements at each hospital.

She holds a bachelor's of science in education in kinesiology as well as a master's of education in exercise physiology from the University of Virginia.

# Former CRA Board Member Jeannette Wing to Lead Columbia University's Data Science Institute 

On May I, Columbia University President Lee C. Bollinger announced that Jeannette M. Wing, currently corporate vice president of Microsoft Research, will become the Avanessians Director of Columbia's Data Science Institute and Professor of Computer Science.
From Columbia's Announcement:
"Jeannette Wing is a pioneering figure in the world of computer science research and education. Her addition to the University's academic leadership team reflects the continuing expansion of our work in this field," said Bollinger. "Our Data Science Institute is indispensable to virtually every scholarly initiative at the

University dedicated to addressing a societal problem. The benefits to be derived from Jeannette's leadership and her presence here will be immense."

Last November, Wing published an Executive Q\&A in Computing Research News. She joined Microsoft Research in January 2013, after holding positions in academia and government, including Carnegie Mellon University and the National Science Foundation (NSF). From 2007 to 2010, she served as assistant director of the Computer and Information Science and Engineering Directorate at the NSF. Wing is a former CRA board member and recipient of the 2011 CRA Distinguished Service Award.

# Eric Horvitz, Former CCC Council Member, is New Head of Research at Microsoft 

By Helen Wright CCC Senior Program Associate

It was recently announced that Eric Horvitz, CCC Council member and current Co-Chair of the Al and Robotics Task Force, is the new head of Microsoft Research.

Horvitz has long been a leading voice in Al safety and ethics. Recently, he announced the new Partnership on Al that consists of a consortium including Microsoft, Google, Amazon,
Facebook, and IBM. The goal of the partnership is to bring industry together to talk about the use of Al for humanity's benefit.
From Quartz:
Horvitz wants to fundamentally change the way humans interact with machines, whether that's building a new
way for Al to fly a coworker's plane or designing a virtual personal assistant that lives outside his office. He will get a chance to further his influence, with his appointment yesterday as head of all of Microsoft's research centers outside Asia.
In his new role, Horvitz will harness Al expertise from each lab-in Redmond, Washington; Bangalore, India; New York City, New York; Cambridge, Massachusetts; and Cambridge, England-into core Microsoft products, as well as setting up a dedicated Al initiative within Redmond. He also plans to make Microsoft Research a place that studies the societal and social influences of Al. The work he plans to do, he says, will be "game-changing."

# Former CRA Board Member Among 2016 ACM Software System Award Recipients 

Former CRA Board Member Alfred Z. Spector was named one of the recipients of the 2016 ACM Software System Award. Mahadev Satyanarayanan, Michael L. Kazar, Robert N. Sidebotham, David A. Nichols, Michael J. West, John H. Howard, Spector and Sherri M. Nichols were honored with the award for developing the Andrew File System (AFS).

From the ACM Announcement:

AFS was the first distributed file system designed for tens of thousands of machines, and pioneered the use
 of scalable, secure and ubiquitous access to shared file data. To achieve the goal of providing a common shared file system used by large networks of people, AFS introduced novel approaches to caching, security, management and administration. AFS is still in use today as both an open source system and as the file system in commercial applications. It has also inspired several cloud-based storage applications.

The ACM Software System Award is presented to an institution or individual(s) recognized for developing a software system that has had a lasting influence, reflected in contributions to concepts, in commercial acceptance, or both. The Software System Award carries a prize of $\$ 35,000$. Financial support for the Software System Award is provided by IBM.

## CRA Board Members

Sarita Adve, University of Illinois
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Evaluating the Research Pipeline
Heather Wright, Research Associate, Center for Evaluating the Research Pipeline
Helen Wright, Senior Program Associate, Computing Community Consortium

## Column Editor

Expanding the Pipeline
Patty Lopez, Intel

## Professional Opportunities

Computing R Association

## Columbia University School of Professional Studies

Lecturer in Discipline or Senior Lecturer in Discipline

The School of Professional Studies (SPS) at Columbia University invites applications for three or more full-time positions at the rank of Lecturer in Discipline or Senior Lecturer in Discipline to teach in the MS Program in Applied Analytics. This position will begin on July 1,2017 . This is a full-time appointment with multi-year renewal contingent on successful review.

Lecturers/Senior Lecturers in Discipline will teach courses related to applied analytics in one or more of the following areas:

- business and organizational aspects of analytics
- technical topics such as big data architecture or machine learning - programming languages, such as SQL and $R$

Successful candidates will exhibit a commitment to excellence in teaching, mentoring, instructional design, and professional practice and/or scholarship.

The ideal candidates will hold a doctoral degree, terminal degree, or its professional equivalent in computer science, information science, statistics, business, or a related field. Columbia University is an affirmative action, equal opportunity employer. The University is dedicated to the goal of building a culturally diverse and pluralistic faculty and staff committed to teaching and working in a diverse environment, and welcome applicants who share these values.

For more information, and to apply, please go to: https://academicjobs.columbia.edu/ applicants/Central?quickFind=64146.

Columbia University is an Equal Opportunityl Affirmative Action employer - Race/Gender/ Disability/Veteran.

## Lake Superior State University

Term Assistant Professor of Computer Science

Lake Superior State University seeks applicants for an open-rank, term faculty position in Computer Science/Computer Networking. This is a full-time position to begin in the fall semester, 2017. A term

## MONMOUTH UNIVERSITY

West Long Branch, NJ


## SPECIALIST PROFESSOR

The Department of Computer Science and Software Engineering at Monmouth University welcomes applications for an anticipated opening for a Specialist Professor position to begin in the fall 2017 semester.

Master's degree or higher in Computer Science, Software Engineering, or other related field. Three years of related experience. Familiarity with program accreditation and assessment. Experience teaching at an institute of higher education.

## Apply At: http://apptrkr.com/993440

## AA/EOE

position carries a contract of up to three years and requires teaching 12 credit hours per semester. The School offers Bachelor's degrees in Computer Science, Computer Networking, and Computer Networking Web Development Concentration.

For a complete job posting and application visit us online at https://jobs.Issu.edu/

## Mount Holyoke College <br> Visiting Lecturer in Computer Science

The Computer Science Department at Mount Holyoke College invites applications for a full-time, l-year visiting faculty member in computer science to begin fall 2017. We will consider candidates from any research area who have a strong interest in teaching and working closely with undergraduate students.

The teaching load is five courses per year and the successful candidate will teach both introductory and advanced classes. The successful candidate will have a demonstrated record of strong teaching at the undergraduate level and experience mentoring students who are broadly diverse with regard to race, ethnicity, socioeconomic status, gender, nationality, sexual orientation and religion. All candidates should have their doctoral degree in computer science in hand by the start of the contract period. Teaching experience is required.

Please see our jobs website https://jobs. mtholyoke.edu/ for more information about the position, the college, and about how to apply or. Please contact the department chair Margaret Robinson (robinson@mtholyoke.edu).

## NC State University

Postdoctoral Researcher at NC State
NC State (ECE department) is inviting applications for a postdoctoral position in parallel computing focusing on numerical reproducibility. Candidates should have a

## Professional Opportunities

3) Research focus in computer vision, machine learning or robotics
4) Solid foundations in applied mathematics, optimization and statistical inference
5) Motivation to conduct independent
research from conception to implementation
Desirable skills:
6) Programming experience in $\mathrm{C}, \mathrm{C}^{++}$
7) Experience with automotive systems or robotic navigation
8) Experience with mobile or embedded systems

Visit our website www.nec-labs.com for more information about NEC Labs, and submit your CV and research statement through our career center at https://www. appone.com/MainInfoReq.asp?R_ID=1559874.

EOE-M/F/V/D

## NEC Laboratories America, Inc.

Researcher - Machine Learning
The Machine Learning Department in Princeton, NJ, has openings for researchers with a passion for developing the next generation of machine intelligence. Expertise in machine learning with an proven track record of original research as well as a keen sense for developing practical applications are prerequisites for this position. One opening is at the level of research staff member, the second one for a postdoc position.

At NEC Laboratories America (www.nec-labs. com) we pursue forward looking research, and our nine departments cover a broad range of technologies in computer and communication science. Our focus is on projects in high-impact areas where creative research can provide strong support for NEC's business.

The Machine Learning department has been at the forefront of research in such areas as deep learning, support vector machines and semantic analysis for over a decade. Many technologies developed in our group have
been integrated into innovative products and services of NEC, such as systems for recruiting, surveillance, sonar detection, and digital pathology. In addition to contributing to NEC's business, our research is published in premier venues. Among the challenges we are tackling now is how to move machine learning to more abstract reasoning and how this can enable new applications in traffic safety, video surveillance, human resource management, and automation of manufacturing. www.nec-labs.com/research-departments/ machine-learning/machine-learning-home

## Requirements:

- PhD in computer science, statistics, electrical engineering, or equivalent.
- Research experience in machine learning with strong publication record.
- Strong algorithm and numeric computation background.
- Programming experience in Python, Lua, $C^{++}$, or any other language.
- Experience with any of the deep learning libraries and platforms, e.g. Torch, TensorFlow, Caffe, or Chainer a plus.

For more information about NEC Labs, please access www.nec-labs.com and submit your CV and research statement through our career center at https://www. appone.com/MainInfoReq.asp?R_ID=1500523.

EOE-M/F/V/D

## NEC Laboratories America

Researcher - Mobile Communications and Networking

The Mobile Communications and Networking research department at NEC Laboratories
America in Princeton, NJ, has multiple Researcher positions available. In the last couple of years, the department has initiated research focusing on end-to-end wireless networking and sensing solutions in different vertical domains (such as retail, transportation, safety) leveraging technologies such as RFID, Bluetooth, WLAN

## Professional Opportunities

and cellular. Details about our projects can be found at http://www.nec-labs.com/research-departments/mobile-communications/mobile-communications-home.

The current search is for candidates who can contribute to aforementioned solutions oriented research. Specifically, candidates with experience in building wireless networking and/or sensing systems with expertise in one or more of the following: software radios, embedded systems, autonomous and mobile sensing platforms, are invited to apply. Applications are also welcome from candidates with networking and systems experience outside of the wireless area who can contribute to our endeavor at the mobile applications and services layer (e.g., mobile-edge computing platforms and services, loT services, etc.).

Candidates must have or expect to receive a PhD degree in EE or CS. Candidates should be able to carry out original research, develop and prototype innovative technologies, work towards technology transfer to relevant business units within the company and maintain a track record of high-quality peer-reviewed publications.

For more information about NEC Labs America, please access http://www.nec-labs.com/, and submit your CV and research statement through our career center at https://www. appone.com/MainlnfoReq.asp?R_ID=1528968.

EOE-M/F/D/V

## New York University

Industry Professor, Computer Science and Engineering

The Department of Computer Science and Engineering at the NYU Tandon School of Engineering invites applications for a full time, non-tenured, renewable faculty position in computer science, with a start date of September 1, 2017. New York University (NYU) is one of the top private universities in the United States, and the Tandon School of

Engineering has the distinct history of having been known previously as Brooklyn Poly and the NYU Polytechnic School of Engineering.

The NYU Tandon School of Engineering is part of a major research university, and it is deeply committed to excellence in teaching and learning. Tandon fosters student and faculty innovation and entrepreneurship that make a difference in the world.

The Computer Science and Engineering Department invites applicants for teaching in any areas of computer science, with particular emphasis on systems oriented courses at the undergraduate and masters degree levels.

The successful candidate should be an excellent teacher and mentor. The position may also entail some administrative work


## Associate Dean of Research

The College of Information Sciences and Technology (IST) at The Pennsylvania State University invites applications for Associate Dean of Research at the rank of Professor. We seek candidates with a strong track record of fundamental and applied research in IST's areas of research and a background in research management. Responsibilities include management of IST's research portfolio, interactions with research community within the university and outside, innovation management, and promotion and guidance of IST research directions. We welcome applications from exceptional candidates from a variety of disciplinary backgrounds (e.g., Computer Science, Statistics, and Informatics), and interdisciplinary interests (e.g., Life Sciences, Health Sciences, Cognitive Sciences, Brain Sciences, Social Sciences). Successful candidates will be expected to have a strong externally funded research program and contribute to graduate and undergraduate education and training. IST offers a highly collaborative interdisciplinary research environment, strong research programs in Artificial Intelligence, Data Sciences, Informatics, Human-Computer Interaction, Information Security and Privacy, and Socio-Technical Systems, a strong Ph.D. program (with over 100 Ph.D. students), and several highly successful undergraduate programs (including one in Data Sciences, offered in cooperation with Statistics and Computer Science and Engineering). IST faculty and students enjoy extensive opportunities for interdisciplinary collaborations with colleagues from a wide range of disciplines as well as a number of universitywide cross-cutting centers and institutes (e.g., The Center for Big Data Analytics and Discovery Informatics, the Institute for Cyberscience, the Huck Institutes of the Life Sciences, the Social Science Research Institute, the Materials Research Institute, and the Institute for Energy and the Environment.). The NIH-funded Clinical and Translational Sciences Institute, the NSF-funded North East Big Data Innovation Hub (wherein Penn State is one of the 5 lead institutions) and Interdisciplinary Graduate Training Programs in Bioinformatics and Genomics and in Biomedical Data Sciences (both funded by NIH), and in Social Data Analytics (funded by NSF) offer additional opportunities for collaborative research and graduate education.

To apply, please upload a cover letter detailing relevant qualifications for this job and a resume or curriculum vitae. Review of applications will start asap and continue until the position is filled. References will be requested at an appropriate point in the process.

## Apply online at http://apptrkr.com/985608

CAMPUS SECURITY CRIME STATISTICS: For more about safety at Penn State, and to review the Annual Security Report which contains information about crime statistics and other safety and security matters, please go to http://www.police.psu.edu/clery/, which will also provide you with detail on how to request a hard copy of the Annual Security Report.
Penn State is an equal opportunity, affirmative action employer, and is committed to providing employment opportunities to all qualified applicants without regard to race, color, religion, age, sex, sexual orientation, gender identity, national origin, disability or protected veteran status.

## Professional Opportunities

Consideration of applications will begin immediately and will continue until the position is filled

New York University is an Equal Opportunity Employer. NYU does not discriminate due to race, color, creed, religion, sex, sexual orientation, gender and/or gender identity or expression, marital or parental status, national origin, ethnicity, citizenship status,
and outreach. Candidates must have at least a master's degree in computer science or a related discipline (Ph.D. preferred) and a record of industrial experience and/or teaching in these areas. Applicants should include a cover letter, current CV and a teaching statement describing experience and teaching philosophy. All application materials should be submitted electronically at https://apply.interfolio.com/38859


## Computational Data Scientist/Engineer

Working with the Team Leader and peers inside and outside the team, this engineer is part of the team that develops and deploys of UCSF's Research Computing shared capability, which includes computing nodes, Very Large biomedical and health data ("Big Data"), shared and best-of-breed tools, metadata and catalog. The role includes data and tool management, curation, engineering and quality maintenance. Given the exciting, emergent nature of Data Science in Medicine, technical versatility is important to this role.

## Apply http://apptrkr.com/996603

UC San Francisco seeks candidates whose experience, teaching, research, or community service has prepared them to contribute to our commitment to diversity and excellence.

The University of California is an Equal Opportunity/Affirmative Action Employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, sexual orientation, gender identity, national origin, disability, age or protected veteran status.
veteran or military status, age, disability, unemployment status or any other legally protected basis, and to the extent permitted by law. Qualified candidates of diverse ethnic and racial backgrounds are encouraged to apply for vacant positions at all levels.

## Randolph-Macon College <br> Visiting Assistant Professor of Computer Science

Randolph-Macon College invites applications for a Visiting Instructor or Visiting Assistant Professor position in Computer Science to begin August 2017.

For additional information and to apply please visit: http://www.rmc.edu/offices/ human-resources/employment-opportunities

## Rhodes College

Visiting Assistant Professor of Computer Science

The Department of Mathematics and Computer Science at Rhodes College invites applications for a one-year position as a visiting assistant professor of computer science beginning in August 2017.

Please visit jobs.rhodes.edu for more information and to apply.

## Sarah Lawrence College

Full-Time Visiting Faculty Member
The Department of Computer Science at Sarah Lawrence College seeks to hire a fulltime visiting faculty member for the 2017-18 academic year. Candidates should have a commitment to excellence in teaching and should have completed or made significant progress towards a Ph.D. For more information and to apply, visit https://slc. peopleadmin.com/postings/835.

Review of applications will begin April 15, 2017
SLC is an Equal Opportunity/Affirmative
Action employer.

## Professional Opportunities

Computing R Association

Shanghai Jiao Tong University<br>Faculty Position at John Hopcroft Center for Computer Science<br>The John Hopcroft Center for Computer Science at Shanghai Jiao Tong University (SJTU) is seeking to fill several tenure-track positions in computer science at the rank of Assistant Professor and above.

Shanghai Jiao Tong University is one of the oldest and most prestigious universities in China, which enjoys a long history and a world-renowned reputation. John Hopcroft Center for Computer Science, founded in January 2017, focuses on the fundamental problems in computer science, exploring new theories and efficient algorithms for the future, and fostering talents in


This hands-on team leader is responsible for the development and deployment of UCSF's Research Computing shared capability, which includes computing nodes, Very Large biomedical and health data ("Big Data"), shared and best-of-breed tools, metadata and catalog. The role includes data and tool management, curation, engineering and quality maintenance. This leader staffs and manages computational/informatics talent, as well outsourced agencies engaged on a per-project basis. The team's scope is broad and may extend beyond the university. Given the exciting, emergent nature of Data Science in Medicine, flexibility and technical versatility is important to this role.

## Apply http://apptrkr.com/996600

UC San Francisco seeks candidates whose experience, teaching, research, or community service has prepared them to contribute to our commitment to diversity and excellence.

The University of California is an Equal Opportunity/Affirmative Action Employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, sexual orientation, gender identity, national origin, disability, age or protected veteran status.
computer science. The center will provide a favorable international academic environment for faculty members.

Professor John Hopcroft, 1986 Turing Award winner, has been working at SJTU since 2011. Over the last five years, he has dedicated tremendous amount of efforts and made great contributions to the development of computer science research and the undergraduate teaching quality in SJTU. In 2016, he was awarded the "Chinese Government Friendship Award", which is the highest recognition to a foreign expert who has made outstanding contributions to China's economic and social progress

Strong candidates in all areas will be considered with special consideration given (but not limited) to AI, BigData, and Mobile Internet etc. An internationally competitive package for salary and benefits will be offered by the Center. SJTU makes a great effort to provide a startup research grant. In addition to conduct research in the Center, faculty members are required to teach courses and supervise Ph.D. students and master students. The overall teaching load is one course per semester. Our equal opportunity and affirmative action program seek minorities, women and nonChinese scientists.

The criteria for promotion will be professional reputation as judged by international experts in the candidate's field and excellence in teaching.

Application, including vita and the names of three references, should be sent to Professor Xinbing Wang (xwang8@sjtu.edu.cn) and to Ms. Bing Li (binglisjtu@sjtu.edu.cn).

## Professional Opportunities

Computing Research Association

## UC, Riverside

Postdoc in System/Network Security We are looking for a postdoc in the general area of system/network security. We are interested both in researchers who have hands-on experiences in either attacks or defenses (broadly-defined). The work will be done under the context of a new collaborative research alliance (CRA) on cyber security established by the Army Research Laboratories, and will be highly collaborative in nature. For more details on the CRA, please visit http://www.cra.psu.edu. The offer is expected to last two years long.

For more information on our research group, please visit our webpages (http://www. cs.ucr.edu/~zhiyunq and http://www.cs.ucr. edu/~krish) or the networks group webpage at (http://networks.cs.ucr.edu).

Interested candidates should e-mail their CV to krish@cs.ucr.edu and/or zhiyunq@cs.ucr.edu. We are especially interested in candidates that can start before Apr 1, 2017.

University of Denver<br>Visiting Professor (Open Rank), Data Science

The Department of Computer Science at the University of Denver invites applications for a non-tenure track Visiting Professor (open rank) position for the academic year 2017-2018 beginning September 1, 2017. Associate and Full professor appointments are dependent on the applicant holding the same level appointment at their current institution. The individual hired will be responsible for teaching professional masters degree courses, working with our faculty on curriculum development, and potentially collaborative research. The appointment will be based on a one-year contract, possibly renewable on a yearly basis contingent on performance review.

## Essential Functions

Duties include conducting research for $50 \%$ of the appointment and teaching three quarter-based system courses per year, curriculum development and student advising.

## $\square$ University of Colorado Denver

## ASSISTANT PROFESSOR

Computer Science and Bngineering
The Department of Computer Science and Engineering in the College of Engineering and Applied Science at the University of Colorado Denver invites applications for the multiple Assistant Professor positions.
The candidate will be expected to develop and teach lecture and laboratory courses at all levels, establish an active, externally funded research program; conduct high quality research involving students at all levels, leading to sponsored research and refereed publications; advise students; and contribute to Department, College, and University governance and to the profession. The candidate must have a Ph.D. in Computer Science or closely related field and demonstrated expertise in computer science as evidenced by the candidate's record. Areas of cybersecurity, software engineering, artificial intelligence, machine learning, or a related field are preferred.
Applications are accepted electronically at
http://www.cu.edu/cu-careers (refer to job posting 02763).
The University of Colorado is committed to diversity and equality in education and employment.

- This position will participate in Department and University services as needed.


## Required Qualifications

- PhD in Computer Science or related discipline.
- Demonstrated ability to conduct research and teach data science courses in some subset of the following topics: machine learning, data visualization and analytics, noSQL databases, data streaming and cleaning, data mining, parallel and distributed computing, and cloud computing.


## To Apply \& for application details:

 https://du-openhire.silkroad.com/ epostings/index.cfm?fuseaction=app. welcome\&company_id=16973\&version=1 Enter Search Terms: 005757The University of Denver is committed to enhancing the diversity of its faculty and staff and encourages applications from women, minorities, members of the LBGT community, people with disabilities and veterans. The University is an equal opportunity/affirmative action employer.
All offers of employment are based upon satisfactory completion of a criminal history background check.

## University of Denver <br> Teaching Assistant Professor

The Department of Computer Science at the University of Denver is committed to building a culturally diverse and pluralistic faculty and staff committed to teaching and working in a multicultural environment. We invite applications for two full-time nontenure track Teaching Assistant Professors for the 2017-2018 academic year beginning September 1, 2017.

## Position Summary

The hired individuals will be responsible for teaching introductory, higher level undergraduate, and possibly graduate level computer science courses. Duties include

## Professional Opportunities

six quarter-based system courses per year, advising students, and participating in department and university service. These positions do not require research. The successful applicant will have a passion for teaching and a demonstrated ability to teach undergraduate Computer Science courses with above-average student evaluations. In addition to teaching, the successful applicant will actively participate in meetings and student advising, and participate in Department and University service as needed.

## Knowledge, Skills, and Abilities

- A passion for teaching and a demonstrated ability to teach undergraduate Computer Science courses with above-average student evaluations.


## Required Qualifications

- PhD in Computer Science related disciplines is required by time of appointment.
- Demonstrated ability to teach undergraduate courses


## Preferred Qualifications

- One year of previous experience teaching undergraduate courses.
- Demonstrated knowledge and experience with culturally responsive teaching methods and/or pedagogies to effectively engage broadly diverse student populations


## To Apply \& for application details:

 https://du-openhire.silkroad.com/ epostings/index.cfm?fuseaction=app. welcome\&company_id=16973\&version=1 Enter Serach Terms: 004129The University of Denver is committed to enhancing the diversity of its faculty and staff and encourages applications from women, minorities, members of the LBGT community, people with disabilities and veterans. The University is an equal opportunity/affirmative action employer.

## University of Memphis

Assistant Professor
The Department of Computer Science at the University of Memphis is seeking candidates for Assistant Professor position beginning Fall 2017. Exceptionally qualified candidates in all areas of computer science are invited while candidates with core expertise in systems, data science, security \& privacy, and software engineering and an interest in emerging and interdisciplinary applications such as smart health, smart vehicles, smart transportation, smart energy, and CS education are particularly encouraged to apply. The successful candidate is expected to develop externally sponsored research programs, teach both undergraduate and graduate courses and provide academic advising to students at all levels.

Applicant should hold a PhD in Computer Science, or related discipline, and be committed to excellence in both research and teaching. Salary is highly competitive and dependent upon qualifications. The Department of Computer Science (www. cs.memphis.edu) offers B.S., M.S., and Ph.D. programs as well as graduate certificates in Data Science and Information Assurance, and an M.S. program in Bioinformatics (through the College of Arts and Sciences). The Department has been ranked 55th among CS departments with federally funded research. The Department regularly engages in large-scale multiuniversity collaborations across the nation. For example, CS faculty lead the NIH-funded Big Data "Center of Excellence for Mobile Sensor Data-to-Knowledge (MD2K)" and the "Center for Information Assurance (CFIA)". In addition, CS faculty work closely with multidisciplinary centers at the university such as the "Institute for Intelligent Systems (IIS)".

Screening of applications will continue until the position is filled. To apply, please visit https://workforum.memphis. edul. Include a cover letter, curriculum vitae, statement of teaching philosophy,
research statement, and a list of three references. Direct all inquiries to Kendra Tillis (ktillis@memphis.edu).

A background check will be required for employment. The University of Memphis is an Equal Opportunity/Equal Access/ Affirmative Action employer committed to achieving a diverse workforce.

## University of Minnesota

Assistant Professor Measurement Science and Agro-Bioinformatics Department of Bioproducts and Biosystems Engineering

The University of Minnesota invites applications for a 9-month tenure-track assistant professor position in the broader area of measurement science and agrobioinformatics with research and teaching ( $50 \% / 50 \%$ ) responsibilities.

For a full position description and to apply online: https://humanresources.umn.edu/ jobs. Enter Job ID 315687.

## University of Pennsylvania

Professor of Practice - Technical Innovation and Entrepreneurship

The School of Engineering and Applied Science at the University of Pennsylvania invites applications for a Professor of Practice position in technological innovation and entrepreneurship. This position is for distinguished, highly experienced individuals who have achieved success in their fields and whose skills and knowledge are essential to the educational process at both the undergraduate and graduate levels.

Responsibilities of this position include educating and training students in technological innovation and entrepreneurship, and fostering partnerships between the Penn Engineering community and entrepreneurs and investors in the Greater Philadelphia region to catalyze new ventures and enhance the innovation ecosystem.

The ideal candidate will have a proven record of entrepreneurship as a founder,

# RESEARCH ASSISTANT PROFESSOR <br> MD2K Center of Excellence \& University of Memphis - Memphis, TN 

The Computer Science Department at the University of Memphis plans to recruit a non-tenure track Research Assistant Professor with responsibilities for conducting research and developing research proposals in the area of mobile sensors to work with Dr. Santosh Kumar, Professor and Lillian \& Morrie Moss Chair of Excellence in Computer Science and Director, NIH Center of Excellence for Mobile Sensor Data-to-Knowledge.

The Computer Science Department invites applications from outstanding candidates with research interests in mobile sensors and its related subfields including Human Computer Interaction (HCI), Big Data, and Mobile Computing, at the Research Assistant Professor level. Required qualifications include a Ph.D. in computer science or a related discipline, record of publications in mobile health or a related subfield, and prior mentored and/or independent research experience with demonstrated interests in mobile health. This non-tenure track position is for 12 months and is renewable based on performance and availability of funding.

The successful candidate will work closely with NIH-funded Center of Excellence for Mobile Sensor Data-toKnowledge (MD2K) for mobile health (mHealth) and with a new project on monitoring performance of employees at workplaces using mobile sensors. The candidate will be joining a department with active research groups in all major areas of computer science that has been ranked $55^{\text {th }}$ in the Nation in federally funded research. Full information about the department can be found at http://www.cs.memphis.edu.

We invite applications from outstanding candidates with the following qualifications and interests:

- A sharp mind for using computer science and mobile sensors to advance biomedical discovery
- Working in a fast-paced, highly public research environment to harnesses state-of-the art sensor data analytics for personalization and structured prediction
- Experience and/or interest in working in an interdisciplinary research environment or other advanced technology setting; willingness and ability to interact with nation's leading academic researchers from 15 large universities
- Interest in mobile sensor big data, mobile health (mHealth), data provenance, and mobile computing

The successful candidate will be joining a nationally prominent team of scientists, engineers, and health researchers in mHealth. The candidate will work directly with the software engineers and scientific leadership at the MD2K Center. This post-doc position will provide the selected candidate with a one-of-a-kind opportunity to showcase their work in the national spotlight as data science and health communities from both academia and industry across the country adopt MD2K research and software. He or she will will ultimately contribute to building the next generation of a sensor-driven research workforce that unleashes the potential of mobile sensor data to improve health, wellness, and work performance.

Review will begin on immediately and continue until the position is filled, subject to budgetary app

To apply, please follow the instructions at https://workforum.memphis.edu (Position \#: L16522). Plea letter, vitae, statement of research philosophy, and a minimum of three references. chayes1@memphis.edu.

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More information about MD2K is available here: https://md2k.org
The University of Memphis is a Tennessee Board of Regents Institution and an Equal Opportunity/Affirmative Action Employer. We urge all qualified applicants to apply for this position. Appointment will be based on qualifications as they relate to position requirements without regard to race, color, national origin, religion, age, sex, disability or veteran status. Successful candidates must meet guidelines of the immigration and Reform Control Act of 1986.

## Professional Opportunities

faculty/open-positions.php. The position will remain open until filled and applications will be reviewed as they are submitted.
The University of Pennsylvania is an affirmative action/equal opportunity employer. All qualified applicants will receive consideration for employment and will not be discriminated against on the basis of race, color, religion, sex, sexual orientation, gender identity, creed, national or ethnic origin, citizenship status, disability, veteran status, or any other characteristic protected by law.

## University of Rochester <br> Deputy Director and Instructor in Data Science

The University of Rochester Goergen Institute for Data Science (GIDS) seeks applicants for a full time Deputy Director for GIDS, who will also serve as an instructor in data science. We seek candidates with

## UNBC <br> UNIVERSITY OF NORTHERN BRITISH COLUMBIA

# Computer Science Program Collage of Science and Management 


#### Abstract

Assistant Professor (Tenure-Track Position) The University of Northern British Columbia's Computer Science Department http://www.unbc.ca/computer-science invites applications for a full-time, tenure-track position, at the rank of Assistant Professor. The successful applicant will have expertise in either Big Data or the Internet of Things. Strong candidates from other emerging areas will also be considered. The primary responsibilities for this position are, teaching at both undergraduate and graduate (MSc) levels, development of course materials in collaboration with other faculty, and establishing an externally funded research program in a field relevant to the Computer Science department. The preferred start date for this position is July 1, 2017, though a later start date may be negotiable.

Applicants for this position must hold a doctorate in Computer Science, or closely related field and demonstrate capacity to develop an original, externally funded research program. Applicants are strongly encouraged to present evidence of excellence in teaching. The candidate's research will be evaluated in the context of UNBC's undergraduate and graduate educational mission to foster multidisciplinary research and encourage collaborations across academic departments.

Application domains of particular interest include, management of natural resources, environmental science, health science, management information science, and other areas relevant to the University's mission

For a full version of this posting and application details, please visit http://www.unbc.ca/faculty-postings .


[^2]
## Professional Opportunities

Applications accepted on-line, https://www. rochester.edu/faculty-recruiting

Candidates should upload a cover letter of interest, curriculum vitae, and teaching statement describing teaching experience and teaching philosophy. Review of applicants will begin immediately and continue until the position is filled.

The University of Rochester, an Equal Opportunity Employer, has a strong commitment to diversity and actively encourages applications from candidates from groups underrepresented in higher education.

EOE Minorities/Females/Protected Veterans/ Disabled

## University of Washington Bothell

## Post-doc - Software Engineering

The University of Washington Bothell has one open Postdoc Position in Software Engineering. The successful applicant will engage in research in software engineering (e.g., architecture recovery/reverse engineering, software evolution, etc.) to assist domain scientists with understanding and managing their software and data.

Initial appointment will be for one year, and will be renewable, pending review of performance in the first year. Opportunities for career advancement also available.

Review of applications will begin upon receipt however complete applications received prior to June 30, 2017 will receive priority consideration. The position will remain open until filled.

For more information, see http:// ap.washington.edu/ahr/academic-jobs/ position/nn18643/

## Wellesley College

Instructor in Science Laboratory, Computer Science

Wellesley College invites applications for a full-time Instructor in Computer Science Laboratory, starting in the fall of 2017.

See the full ad at http://career.wellesley.edu/ postings/1607

## Yahoo Research <br> Research Scientist

We are looking for PhD Research Scientists with a strong research track record in Applied Machine Learning, Data Mining, Visualization, Security, or related areas.

## Details:

https://tas-yahoo.taleo.net/
careersection/yahoo_us_cs/jobdetail.
ftl?lang=en\&job=1646039
Please send CV and research statement to yifanhu@yahoo-inc.com.

## Yahoo Research

Research Scientist
Yahoo Research is growing its strategic research teams to enable the company to build new products and platforms that our customers need, now and in the future. We have exciting job openings in several technical focus areas (data mining, optimization, machine learning, computational economics) that are located in our New York City office located one block from Times Square.

The full job description is available here http://careers.yahoo.com (job number 1742024) or https://tas-yahoo.taleo.net/ careersection/yahoo_us_cs/jobdetail. ftl?job=1742024

Please send your CV and a short letter of interest to Maxim Sviridenko (sviri at yahooinc dot com).



[^0]:    72 CRA Board Members CRA Board Officers CRA Staff Column Editor

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[^1]:    About the Authors
    Suzanne T. Ortega is president of the Council of Graduate Schools, the only national organization in the United States that is dedicated solely to the advancement of graduate education and research. She is also principal investigator for the Completion and Attrition in AGEP and non-AGEP Institutions project (National Science Foundation grant number 1138814).

    Hironao Okahana is assistant vice president, Research \& Policy Analysis at the Council of Graduate Schools, where he serves as co-principal investigator for the Completion and Attrition in AGEP and non-AGEP Institutions project. He is also an adjunct faculty member for the higher education program at George Mason University.

[^2]:    Applications received on or before April 7, 2017, will receive full consideration; however, applications will be accepted until the position is filled.

