An Academic Career in Engineering

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Outline

• Graduate school in engineering
  - What is it like?
  - Knowing that, why apply?
  - How to get in, how to survive?

• Graduate schools in EE and MEMS

• Life as an engineering professor
The M.S. Degree

- The M.S. in engineering is highly sought after by industry and good programs are available at dozens of universities.

- The “M” in M.S. means “Master” ... and it really means that!

  M.S.-level recruiting is much more targeted; some companies view the M.S. degree as the de facto entry-level professional degree.

A co-terminal B.S./M.S. ...
M.S. Degrees Aren’t Standardized

• Stanford: no report or thesis
  - Why? 600 or more MSEE students and less than 50 professors!
  - Many M.S.-level project courses provide the design experience; degree is highly valued by industry

• Berkeley, MIT: project is typically required
  - M.S. is a way station on the way to the Ph.D. for most students, or a consolation prize after failing the Ph.D. qualifying exam
  - M.S. isn’t even required for a Ph.D. in EECS at Berkeley
Goals of Graduate Education

• Learn more core technical knowledge
  - You take fewer, more intensive courses
  - You actually learn (a.k.a. “master” the material)

• Learn how to discover new knowledge
  - Can this be taught? Not clear!
  - The proof that you’ve arrived: a Ph.D.* thesis
    Ph.D. = doctor of philosophy ... in EE?
Why Ph.D.s are Valued by Industry

• Clear vision into the future and the ability to push the boundaries of technology
• Networked to fellow students and faculty
• Strong technical skills, including a deep knowledge of micro/nanofabrication
• “Proof-tested” in a high-stress environment: pre-screening by admission and oral exams

- The Ph.D. in engineering is excellent training for start-up or large company success in the specific field ... and increasingly, is viewed by consulting firms and financial institutions in the same way
Graduate School

• Can be a very tough time, depending on your research progress, group dynamics,
• Major contrast with medical and law school:
  - Little in common with other students: don’t take same course sequence, fragmented into research groups

• Can be the “best time of your life” … freedom to explore, no responsibilities, little or no money … but will likely be supported by research/teaching assistantships or fellowships at most schools (in the Ph.D. program)
The Gauntlet, Step 1

- The Ph.D. Oral Screening Exam a.k.a. the qualifying exam (Stanford) or prelim exam (Berkeley)
  - Stanford: 10, one-on-one 10 minute oral exams by 10 different professors in one-day in four technical areas, offered once per year
  - Berkeley: 1, 1 hour oral exam by three professors covering three technical areas offered twice per year

- The “experience”
  - Lifetime stress peak (for most)
  - Usually get two chances to pass, with second timers having the benefit from input from advisor (if they have one)
The Gauntlet, Step 2

• Thesis Defense (Stanford)
  - Taken near filing the thesis as a “shake-down”
  - 4 professors, 3-5+ hours, first hour is open

• Qualifying Exam (Berkeley)
  - Taken after the thesis is underway to verify that the research plan is doable
  - 3-4 professors, 1.5-3 hours (typically around 2 hrs)

• Failure happens occasionally and a second chance is usually given
What is a Ph.D. Thesis?

• The product of “independent investigation under faculty supervision”
• Certified by a committee of professors
• Varies depending on field
  - Length 80-450 pages
  - Time required varies (experimental vs. theory): my students average around 5.5 years from B.S. to Ph.D.
Is a Ph.D. for You?

• Just going to a “terminal point” in academic career ... family expectations
• Want to (have to?) teach → Ph.D. is the “union card” for an academic career
• Highly motivated to explore new areas, want to “make your mark” on a field, have “your own agenda” ... good signs
Are Advisors Important?

• From Carnegie-Mellon’s “How to Survive as a Graduate Student” talk by Brian Noble, et al

The three most important factors in your career are:

• Your Advisor
• Your Advisor
• Your Advisor

http://www.cs.cmu.edu/afs/cs/user/bnoble/Web/survival/slides.pdf
Selecting an Advisor

• Done at admissions (rarely), usually during the first year or two depending on many factors, some out of your (and the advisor’s) control

• Gathering information
  - Visit the school and talk with several faculty AND their graduate students
  - Where are their ex-students?
  - Do a literature search: read the papers!
Selecting an Advisor (Cont.)

- Academic age: Pre-Tenure
  - Plus: energy, enthusiasm, bright ideas, and has time for you
  - Minus: may not make tenure, may move to another school (see my c.v.), may be *too involved* in your project ... can be a real problem, relatively unknown (lacks connections), possibly unstable funding
Selecting an Advisor (Cont.)

• Academic age: senior professor
  - Plus: well-known, relatively stable funding, well-connected, has no time to look over your shoulder
  - Minus: less time for you, may manage group through postdocs or senior student(s); often incredibly busy with campus and outside commitments; is he/she burnt out? in good health?
Research Group Culture

• Organization:
  - Ph.D. students as “sub-group leaders” in charge of several M.S. students?
  - Check ratio of Ph.D./M.S. students
  - Postdocs? Industrial visitors?

• Range of projects: narrow or broad

• Funding sources: industry, government mix - consortium funds?
Risk Factors

• Start-up Companies
  - Does your advisor have a spin-off company? Does the company have any on-going ties with the university group? How are conflicts of interest handled?
  - Will your advisor go on leave to a start-up and leave you neglected or even an orphan?
  - Note: large groups can cover for a missing faculty member much better

• “Promotion”
  - Could your advisor end up Dept. Chair ... or Lab Director ... or Dean ... or the Faculty Director of a Nanofab?
Yes, I’ve Co-Founded a Start-Up

- Silicon Clocks, Inc., Fremont, California
- Based on UC Berkeley research on MEMS resonators for timing (i.e., clock) applications
- Founded 2004; funded Feb. 2006
- Acquired by Silicon Labs, April 2010

In Dec. 2009, I became Faculty Director of the SNF, an anchor node of the NNIN, and have spent many, many hours working to improve its performance. I will serve until 2014 and have reduced the size of my research group to accommodate the time commitment.
The Stanford Nanofabrication Facility

- 10,500 ft² of class 100 cleanroom space with separate floors for fan deck and support equipment.
- 100, 150, and 200 mm wafer processing
- 250 active users in any given month.
  - 175 Stanford academic users
  - 25 non-Stanford academic users
  - 50 industrial users.

- industrial users are primarily from small, local startups, but also several large companies (Intel, HP, IBM, Applied Materials, Bosch, and others).
SNF Milestones

1965
Integrated Circuits Lab is established in the McCullough Building.

1985
IC Lab moves to the newly completed CIS building (now the Paul G. Allen Building).

1994
Stanford is a founding member and co-prime institution (with Cornell) of the five university cooperative National Nanofabrication Users Network (NNUN).

2004
Stanford is a founding member and co-prime institution (with Cornell) of the 14-university cooperative National Nanotechnology Infrastructure Network (NNIN).

2010
The Stanford Nano Center opens with characterization tools and nano-patterning labs facilities complementary to SNF.

2010
Stanford is awarded a National Science Foundation ARI-R2 grant for renovation and expansion of the SNF during 2010 - 2013.
My Experience

- B.S. physics from Harvey Mudd College
- Applied to: Berkeley, Stanford, UCLA, USC ... for a M.S. degree in communication theory with intention to work for Hewlett-Packard (I interned there)
- Chose Berkeley over Stanford by calling “Mudders” who’d gone to each school; offered a one-year fellowship
- TA’ed a lab class (electronics for non-majors ... E40) and found out I loved teaching
- Discovered that the professor I wanted to work with had terminal cancer, took a class from Richard S. Muller in device physics, was invited into his group
- Changed my mind about the Ph.D. and switched into solid-state devices and decided to go for prelim exam ... and passed!
My Academic Geneology

- Richard S. Muller, Ph.D., Caltech 1962
  Professor, UC Berkeley 1962 -

- R. David Middlebrook, Ph.D. Stanford 1955
  Professor, Caltech, 1960 -

- Joseph M. Pettit, Ph.D., Stanford 1942
  (Dean of Engineering, Stanford, 1958-1972,
  President of Georgia Tech, 1972-1986)

- Frederick E. Terman, Ph.D., MIT 1920
  (Dean of Engineering, Stanford, 1944-1958)

- Vannevar Bush, Ph.D., MIT 1916
  (Chairman, NACA 1939-1941, Director, OSRD, 1941-1945,
  helped establish the U.S. National Science Foundation)

- Arthur E. Kennelly, Chief Electrical Asst.,
  Edison Lab, Menlo Park, NJ, 1887-94 (no Ph.D.)
  later Professor at Harvard and MIT

- Thomas A. Edison (1847-1931) ... no degree!
Richard S. Muller
Ph.D. (Caltech, 1962)

Born in New Jersey and educated in New Jersey and California
- Mechanical Engineer (Stevens Institute of Technology, 1955)
- M.S. in Electrical Engineering (Caltech, 1957)
- Ph.D. in Electrical Engineering (Caltech, 1962)

• Professor at the University of California at Berkeley (1962 - )
• Co-wrote *Device Electronics for Integrated Circuits* with Ted Kamins of HP Labs
• Co-founded BSAC with Prof. White and helped found the MEMS field
• Received many awards: UC Berkeley Citation (1994), IEEE Cledo Brunetti Award with Roger Howe (1998), IEEE Millennium Medal (2000), NAE, Life Fellow of IEEE, IEEE/ASME Journal of MEMS Editor in Chief, ...
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Where to Go?

• The graduate school rankings: a first cut with the usual qualifications

• Narrowing down your list:
  - Your specific interests
  - Geography and connections to specific industry (e.g., the Ohio EE grad schools (e.g., Case, OSU, Cincinnati) and their strong ties to Midwest high-tech industry)

• Going international
  - Many grad programs are now in English in Asia and Europe and they’re looking for Americans* … but can’t get them

*Defined as “graduates of U.S. schools”
# Schools of Engineering

## The Top Schools

<table>
<thead>
<tr>
<th>Rank</th>
<th>School</th>
<th>Overall Score</th>
<th>Peer Assessment (0 highest)</th>
<th>Recruiters Assessment (0 highest)</th>
<th>'06 Average Quantitative GRE Score</th>
<th>'06 Acceptance Rate</th>
<th>% of 06 Ph.D. Students/ Faculty</th>
<th>% 06 Faculty Membership in National Academy of Engineering</th>
<th>'06 Engineering School Expenditures (In millions)</th>
<th>'06 Research Expenditures per Faculty (In thousands)</th>
<th>Ph.D.’s Granted 2005-2006</th>
<th>% of 06 Total Graduate Enrollment</th>
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2007 US News Graduate Schools of Engineering rankings
## 2006 Ranking of World Universities*

| World Rank | Institution                  | Region       | Regional Rank | Country | National Rank | Score on Alumni | Score on Award | Score on HiCi | Score on N&S | Score on SCI | Score on Size | Total Score |
|------------|------------------------------|--------------|---------------|---------|---------------|----------------|----------------|---------------|--------------|--------------|---------------|-------------|-------------|
| 1          | Harvard Univ                 | Americas     | 1             | USA     | 1             | 100            | 100            | 100           | 100          | 100          | 73.6          | 100         |
| 2          | Univ Cambridge               | Europe       | 1             | UK      | 1             | 96.3           | 91.5           | 53.8          | 59.5         | 67.1         | 66.5          | 72.6        |
| 3          | Stanford Univ                | Americas     | 2             | USA     | 2             | 39.7           | 70.7           | 88.4          | 70           | 71.4         | 65.3          | 72.5        |
| 4          | Univ California - Berkeley  | Americas     | 3             | USA     | 3             | 70.6           | 74.5           | 70.5          | 72.2         | 71.9         | 53.1          | 72.1        |
| 5          | Massachusetts Inst Tech (MIT)| Americas     | 4             | USA     | 4             | 72.9           | 80.6           | 66.6          | 66.4         | 62.2         | 53.6          | 69.7        |
| 6          | California Inst Tech        | Americas     | 5             | USA     | 5             | 57.1           | 69.1           | 59.1          | 64.5         | 50.1         | 100           | 66          |
| 7          | Columbia Univ                | Americas     | 6             | USA     | 6             | 78.2           | 59.4           | 56            | 53.6         | 69.8         | 45.8          | 61.8        |
| 8          | Princeton Univ               | Americas     | 7             | USA     | 7             | 61.1           | 75.3           | 59.6          | 43.5         | 47.3         | 58            | 58.6        |
| 9          | Univ Chicago                | Americas     | 7             | USA     | 7             | 72.9           | 80.2           | 49.9          | 43.7         | 54.1         | 41.8          | 58.6        |
| 10         | Univ Oxford                 | Europe       | 2             | UK      | 2             | 62             | 57.9           | 48            | 54.3         | 66           | 46            | 57.6        |
| 11         | Yale Univ                   | Americas     | 9             | USA     | 9             | 50.3           | 43.6           | 59.1          | 56.6         | 63           | 49.3          | 55.9        |
| 12         | Cornell Univ                | Americas     | 10            | USA     | 10            | 44.9           | 51.3           | 56            | 48.4         | 65.2         | 40.1          | 54.1        |
| 13         | Univ California - San Diego | Americas     | 11            | USA     | 11            | 17.1           | 34             | 59.6          | 54.8         | 65.6         | 47.1          | 50.5        |
| 14         | Univ California - Los Angeles| Americas     | 12            | USA     | 12            | 26.4           | 32.1           | 57.6          | 47.5         | 77.3         | 34.9          | 50.4        |
| 15         | Univ Pennsylvania           | Americas     | 13            | USA     | 13            | 34.2           | 34.4           | 57            | 41.7         | 73.6         | 40            | 50.1        |
| 16         | Univ Wisconsin - Madison    | Americas     | 14            | USA     | 14            | 41.5           | 35.5           | 53.3          | 45.1         | 68.3         | 29.3          | 48.8        |
| 17         | Univ Washington - Seattle   | Americas     | 15            | USA     | 15            | 27.7           | 31.8           | 53.3          | 47.6         | 75.5         | 27.8          | 48.5        |
| 18         | Univ California - San Francisco| Americas     | 16            | USA     | 16            | 0              | 36.8           | 55.5          | 54.8         | 61.1         | 48.2          | 47.7        |
| 19         | Tokyo Univ                  | Asia/Pac     | 1             | Japan    | 1             | 34.8           | 14.1           | 41.4          | 51.5         | 85.5         | 35.2          | 46.7        |
| 20         | Johns Hopkins Univ          | Americas     | 17            | USA     | 17            | 49.5           | 27.8           | 40.7          | 52.2         | 68.8         | 25.3          | 46.6        |
| 21         | Univ Michigan - Ann Arbor   | Americas     | 18            | USA     | 18            | 41.5           | 0              | 61.5          | 41.6         | 76.9         | 31.2          | 44.5        |
| 22         | Kyoto Univ                  | Asia/Pac     | 2             | Japan    | 2             | 38.3           | 33.4           | 36.9          | 36.2         | 72.4         | 31.7          | 43.9        |
| 23         | Imperial Coll London        | Europe       | 3             | UK       | 3             | 20.1           | 37.4           | 40            | 39.7         | 64.2         | 40.2          | 43.4        |
| 24         | Univ Toronto                | Americas     | 19            | Canada   | 1             | 27.1           | 19.3           | 38.5          | 36.5         | 78.3         | 44.8          | 42.8        |
| 25         | Univ Illinois - Urbana Champaign | Americas     | 20            | USA     | 19            | 40.1           | 36.6           | 45.5          | 33.6         | 57.7         | 26.3          | 42.5        |

* Compiled by Shanghai Jiao Tong University
## 2006 Ranking of World Engineering Schools*

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<thead>
<tr>
<th>World Rank in ENG</th>
<th>ARWU 2006 Rank</th>
<th>Institution*</th>
<th>Country</th>
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* Compiled by Shanghai Jiao Tong University
A Few Top EE Grad Schools (US)

1. MIT
2. Stanford
3. UC Berkeley
4. Illinois
5. Michigan
6. Georgia Tech
7. Caltech
8. Cornell
9. UT Austin
10. Carnegie Mellon
11. Purdue

For MEMS, strength in Mechanical Engineering, Materials Science, Chemical Engineering, and Bioengineering are also very important.

There are at least another 12 U.S. schools where you could earn a Ph.D. in MEMS and have your initial career trajectory more or less the same ...

USN&WR EE Grad School Rankings
Beyond the Rankings

• The Ivys
  - Harvard (big push in engineering), Princeton, Penn, Columbia, Yale, Duke ... especially for an academic career but industry has heard of these schools, too

• Look at the up-and-coming campuses in the top state university systems:
  - UT Dallas and UT Arlington: pushing nano
  - UC San Diego, Santa Barbara, Irvine, and Santa Cruz
  - University of Florida: new fab early 2008

• Look at schools in high-tech areas with strong industry ties
  - Arizona State in Tempe (Phoenix)
  - Univ. of Washington
How Can You Distinguish Yourself?

1. Your undergrad degree ... and work experience
2. US undergrad education and background (even without residency or citizenship) is a major plus
3. Internships, undergrad research opportunities
   - National labs, research universities, companies
   - Letters from these places are important!
4. Projects: these lead to content-rich letters of recommendation, which are critically important
5. Family background: engineering? farming? college/university education?
6. Work experience: 1-2 years after B.S. is not unusual for engineering applicants
Outline

• Graduate school in engineering
  - What is it like?
  - Knowing that, why apply?
  - How to get in, how to survive?

• Graduate schools in EE and MEMS

• Life as an engineering professor
To Be an Engineering Professor

• Getting hired: the postdoc (or industrial equivalent) as a preliminary step is becoming a the norm in the MEMS/nano fields
• The tenure track: (slightly) less stressful in engineering vs. sciences; depends on the schol
• Fund raising: more challenging since early 2000’s
  - NSF engineering research budget is 1/3 of what it was when I started at CMU in 1985 (real dollars)
  - DoD funding: feast or famine ... and long-term decline
  - Industry funding: near-term development orientation is an issue, but can be very productive
What Do Professors Do?

- Come up with new research directions
- Raise money to support these ideas
- Come up with curriculum innovations (courses, books, web-based instruction, ...)
- Lead shared research facilities (e.g., the SNF)
- Do “outside stuff”
  - Present papers, give talks (about 10/year)
  - Consulting, expert witness in patents, ...
  - Government service (examples from my own experience and other Berkeley and Stanford faculty)
  - Start new companies
- Teach (!)
The Pluses

• Flexibility to pursue new ideas by yourself or through collaboration within your university or with other schools or companies

• No boss! Dept. Chairs and Deans have some, but usually quite limited authority over professors, especially after tenure

• Interacting with new classes of undergraduates, new generations of graduate students, postdocs, and staff (technical and administrative)

• The long-term ties to your own Ph.D. alumni
The Academic Family

Frank J. Zendejas, Ph.D. “hooding” at College of Engineering commencement, UC Berkeley, May 2006

Dr. Zendejas joined the large-area photovoltaic technology group at Sandia National Labs in Livermore, Calif.

I first met Frank in 1998 as a summer intern in my group from CSU-Fresno