R&D in Electrical & Computer Engineering

Prof. Bruce Jacob
Keystone Professor
Director of Computer Engineering

National Student Leadership Conference, Summer 2008
Today’s Outline

• Background (mine)

• Engineering careers in general

• Embedded systems issues
  — why does everything break?

• Computers & their memory systems
  — how do I make my computer faster?

• Design as modern engineering entrepreneurship
  — my take on *The World Is Flat* … and guitars
(Who Is This Old Guy?)

- **High school** (GA & FL): salutatorian, three-season athlete, into rock, law, sci-fi
- **College** (Harvard): astr/math, A/B student, one-season athlete, into music, food, art
- **Teaching** (Thayer): high-school math
- **Industry** (BT, PCM): software developer, system architect (employee #2)
- **Grad school** (Michigan): computer software and hardware ... research
Points to Take Home

- Engineering rocks
- Challenging & important problems exist
- Electrical engineering ≠ electrician
  Computer engineering ≠ programmer
- Anything that is in your head today can (should) be in your hands tomorrow
- People are willing to pay you to think
  (being smart is only a disadvantage now)
General Overview: Career Paths in (E&C) Engineering
Your Career Options

College => Industry
=> Grad School => Industry
=> Research
=> Academics

Paths I Will Discuss (briefly):
• Industry B.S. or M.S.***
• Industry/Research Ph.D.
• Academics Ph.D.***

*** Paths I have taken
Big Picture

In Computer & Electrical Engineering:

• **Industry** B.S. or M.S. **Develop**
• **Industry/Research** Ph.D. **Design**
• **Academics** Ph.D. **Research** **Teach**

Develop == Build
Design == Justify Your Choices

**Ph.Ds are paid to THINK**
**MSs and BSs are paid to DO**

*(mitigated by size of company)*
## Big Picture

<table>
<thead>
<tr>
<th></th>
<th>Industry/BS</th>
<th>Industry/PhD</th>
<th>Academia</th>
</tr>
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<tbody>
<tr>
<td><strong>Salary Range (0yrs–10yrs)</strong></td>
<td>$60K–120K</td>
<td>$90K–150K</td>
<td>$80K–150K</td>
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<tr>
<td><strong>Job Security</strong></td>
<td>Okay</td>
<td>Good</td>
<td>Great</td>
</tr>
<tr>
<td><strong>Freedom</strong></td>
<td>Little</td>
<td>Some</td>
<td>Lots</td>
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<tr>
<td><strong>Respect</strong></td>
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<tr>
<td><strong>Brief Job Description</strong></td>
<td>Develop</td>
<td>Design</td>
<td>Research &amp; Teach</td>
</tr>
<tr>
<td><strong>Perks of the Position</strong></td>
<td>Free coffee</td>
<td>Stock options</td>
<td>Talking to a captive audience</td>
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Start-Up Companies

• Enter at any level

• Flexible job description
  (room to move around)

• Flexible pay scales
  (SMALL possibility of LARGE pay-off)

• Collegiate atmosphere
  (working day == noon to 3am)

• Downside: RISK FACTOR
  (not advised for those w/ mortgage, children, etc. — mitigated by size & age of startup)
<table>
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Perhaps best of both worlds?
The Most Important Problem Today: Embedded Systems
EMBEDDED SYSTEMS
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A DISSECTION
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Microprocessor/s and dedicated software
A DISSECTION

Microprocessor/s and dedicated software

Power Supply (Self-Sufficient)
A DISSECTION

Sensor/s
(Multi-Mode)

Microprocessor/s
and dedicated
software

Power Supply
(Self-Sufficient)
A DISSECTION

Sensor/s (Multi-Mode)

Actuator/s (Multi-Mode)

Microprocessor/s and dedicated software

Power Supply (Self-Sufficient)
A DISSECTION

Sensor/s (Multi-Mode)

Actuator/s (Multi-Mode)

Communication Network/s (Multi-Mode)

Power Supply (Self-Sufficient)

Microprocessor/s and dedicated software

Transmitter

Antenna
A DISSECTION

- Actuator/s (Multi-Mode)
- Sensor/s (Multi-Mode)
- Communication Network/s (Multi-Mode)
- Power Supply (Self-Sufficient)
- Microprocessor/s and dedicated software
A DISSECTION

Sensor/s (Multi-Mode)

Actuator/s (Multi-Mode)

Microprocessor/s and dedicated software

Power Supply (Self-Sufficient)

Communication Network/s (Multi-Mode)
Characteristics

• Dedicated function (not general-purpose)
• Interact with environment (real-time)
• Resource-constrained (power, space, cost)
• Safety-critical (loss of life, property, etc.)
• Increasing pressure on time-to-market

THIS IS A BAD MIX
Official Trapped in Car After Computer Fails
Mon May 12, 2003 09:44 AM ET

BANGKOK (Reuters) - Security guards smashed their way into an official limousine with sledgehammers on Monday to rescue Thailand's finance minister after his car's computer failed.

Suchart Jaovisidha and his driver were trapped inside the BMW for more than 10 minutes before guards broke a window. All doors and windows had locked automatically when the computer crashed, and the air-conditioning stopped, officials said.

'We could hardly breathe for over 10 minutes,' Suchart told reporters. 'It took my guard a long time to realize that we really wanted the window smashed so that we could crawl out. It was a harrowing experience.'
Examples Abound ...

Microsoft Technology Hits the Road in BMW 7 Series

Microsoft Navigates the Automotive Industry, Enhances the Driver Experience

REDMOND, Wash. -- March 4, 2002
COMPONENTS MAY BE VERIFIABLE, BUT THE SYSTEM IS NOT
TWO SOLUTIONS
I. Modeling ... What is Required?

- Expertise in **design**: VLSI, PCB, system
- Expertise in **tools**: CAD, codesign, compiler
- Expertise in digital, mixed-mode, MEMS, ...
- Expertise in controls, networks
- Expertise in real-time systems software
- Proven ability to make things that work
1. Modeling ...

What is Required?

- *(most importantly)* Foresee all possibilities
2. Come up with a totally new understanding
What I’m Known for:
Computers and Memory Systems
Perspective

- ~10 Billion/s
- ~10 Million/s
- ~100 per sec
- < 1 Billion/s
Napkin Math: Palm HD

- $1920 \times 1080 \times 36b \times 60fps = 560\text{MB/s}$
  ($\sim 1\text{GB/s incl. ovhd}$)

- $3 \times 4 \text{ DDR800} = 1.2\text{GB/s, 600mW}$

- Power budget = 500mW $\textbf{total}$ (DRAM 10–20%)
Limit: Cost

- CPUs: die area (& power)
  Systems: **pins & power**
  (desktop: power is **cost**
   embedded: power is **limit**)

- FB-DIMM (Intel’s solution
to the capacity problem)
obscured former at cost
doing to latter … **R.I.P. FBD**

- Whither PERFORMANCE
  w/o limits? **10x at least**
Questions?

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More on Start-Ups: The Importance of (High-Tech) Design
Important development in last decade:

Manufacturing as a Service
The Basic Idea

You → Design Blueprint → Factory

Manufactured Device
The Basic Idea

Design Blueprints → Factories → Manufactured Device → Assembly

You
Some Blueprints
Some (other) Blueprints
Pros & Cons

- Idea already proven in marketplace (shareware, boutique electronics)
- Low risk/reward ratio
- Win/win situation (even company failure is good résumé material)
- Start soon

- Can’t possibly compete with big companies
- Might fail
- Can’t afford it
- Window of opportunity?

Bottom line: a path well worth exploring
Points to Take Home

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• Challenging & important problems exist
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google bruce jacob
(btw, the one on wikipedia is my dad)