EE1001 Introduction to Electrical Engineering

Medical Device Engineering

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Electrical Engineer
Boston Scientific Corp.
St. Paul, MN

16 Oct. 2014

Congratulations- You have all Chosen Wisely!

Boston Scientific

EE|Times Connecting the Global Electronics Community

Slideshow

10 Engineering Schools You Should Know But Don't

Zewde Yeraswork
2/24/2014 08:40 AM EST

School List:

- 1. Olin College of Engineering
- 2. Harvey Mudd College
- 3. Baskin School of Engineering at UC Santa Cruz
- 4. Samuel Ginn College of Engineering
- 5. California Polytechnic University
- 6. Rose-Hulman Institute of Technology
- 7. Valparaiso Technical Institute
- 8. New Mexico Institute of Mining and Technology
- 9. South Dakota State
- 10. University of Minnesota Duluth

Some Biomedical Electrical Engineering History

***46-** The first written document on **medical electricity**, Scribonius Largus recommended the use of torpedo fish for curing headaches and gouty arthritis. The electric fish remained the only means of producing electricity for electrotherapeutic experiments until the seventeenth century.*

***1781-** The first documented experiment in **neuromuscular electric stimulation** by Luigi Galvani, professor of anatomy at the University of Bologna. His assistant accidentally touched the femoral nerve of a dissected frog with a scalpel at the same time sparks discharged in a nearby machine and muscular contractions occurred.*

***1872-** T. Green described **cardio-respiratory resuscitation** using a battery of up to 200 cells generating about 300 volts. He applied this voltage between the neck and lower left ribs successfully on five patients who suffered sudden respiratory arrest and were without a pulse.*

***1887-** The **electrocardiogram (ECG)** signals from electric activity of the human heart first measured by Augustus Waller.*

***1899-** The first report on **cardiac defibrillation** by Jean Prevost and Frédéric Battelli. They found low-voltage electric shocks induced ventricular fibrillation whereas high-voltage shocks would defibrillate a fibrillating heart in animal experiments.*

***1930s-** Modern **ventricular defibrillation** started with the work of William Kouwenhoven and his colleagues who used 60 Hz current to defibrillate a dog heart.*

***1947-** The **first human defibrillation** was accomplished by Beck and his colleagues.*

***1952-** Modern **cardiac pacing** started when Paul Zoll performed pacing for a duration of 20 min.*

***1958-** Furman & Schwedel succeeded in supporting a patient for **96 days with cardiac pacing**.*

***1958-** First implantation of **cardiac pacemaker** from engineer Rune Elmqvist at Karolinska Institute in Stockholm by surgeon Åke Senning. [Note development of the implantable pacemaker made possible by the invention of the transistor in 1948.]*

***1980-** The first **Implanted Cardiac Defibrillator (ICD)** developed by Mirowski was implanted at Johns Hopkins Hospital.*

History adapted from web version of Malmivuo and Plonsey, “Bioelectromagnetism,” 1995.

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Stents

Balloons

Catheters / Guidewires

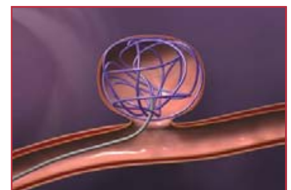
Embolic Protection

Ultrasound Imaging

Pacemakers / ICDs

Ablation

Peripheral Dilatation



Detachable Coils

Neurostimulation

Biopsy Systems

Embolics

Stone Retrieval

Lithotripsy Systems

Enteral Feeding

Portfolio of more than 13,000 products!

Boston Scientific- Cardiac Rhythm Management

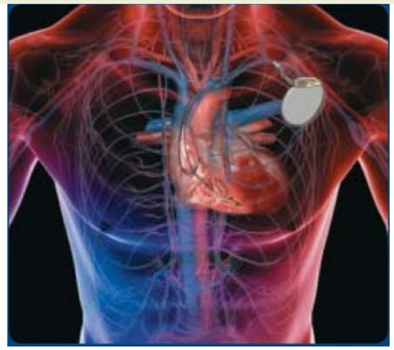
Boston Scientific

- Bradycardia -

Pacemaker Systems

Pacemaker

Brady Leads



- Tachycardia, Sudden Cardiac Arrest -

Implantable Cardioverter Defibrillators (ICD) Systems

ICD

Brady + Tachy Leads

- Heart Failure -

Cardiac Resynchronization Therapy (CRT) and Patient Management Systems

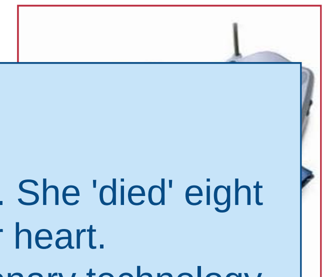
CRT-D

Remote Patient Management system

Brady + Tachy + CRT Leads

Boston Scientific- Cardiac Rhythm Management

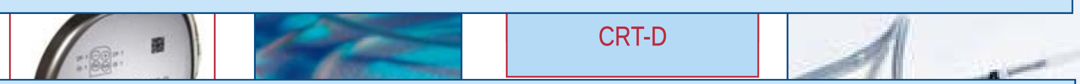
NYC autopsy: Heart problems caused Shay's Olympic trials death [HCM]
18 March 2008
NEW YORK (AP) - Elite runner Ryan Shay **died of an irregular heartbeat** due to an enlarged heart after collapsing during the U.S. men's marathon Olympic trials, the New York City medical examiner said…About 125 athletes under 35 involved in organized sports die of sudden death in the United States each year.



Sweet 16, the girl who died 8 times as a baby
25 June 2008
(The Daily Express) - …born with defective arteries and a hole in her heart. She 'died' eight times on the operating table during a five-hour procedure to try to repair her heart.
But after life-saving surgery to **install a pacemaker at 14 weeks**…revolutionary technology has allowed Kirsty, now 15, to lead a normal healthy life without the need for a heart transplant.

CRT-D

109-year-old Boston Scientific Ingenio patient sets record as oldest pacemaker recipient
2012



ICD

Leads

Boston Scientific- Cardiac Rhythm Management

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Implantable Cardiac Devices

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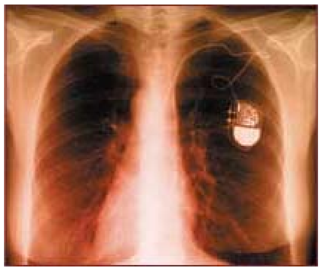

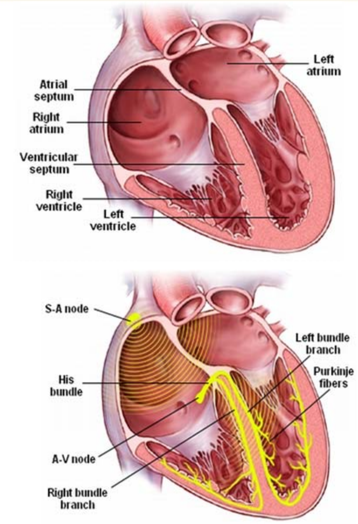

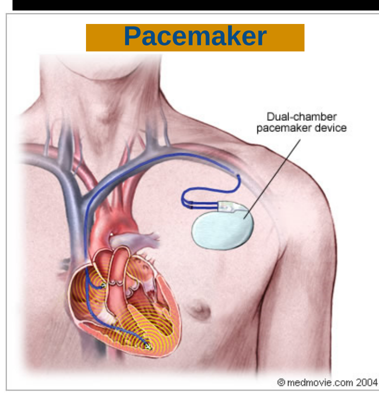

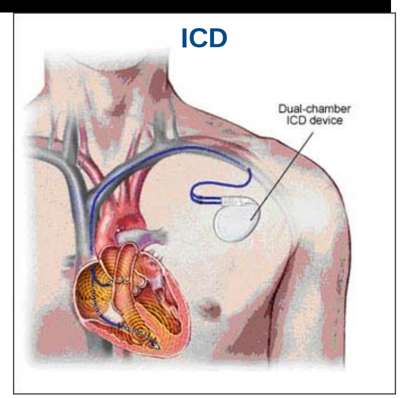

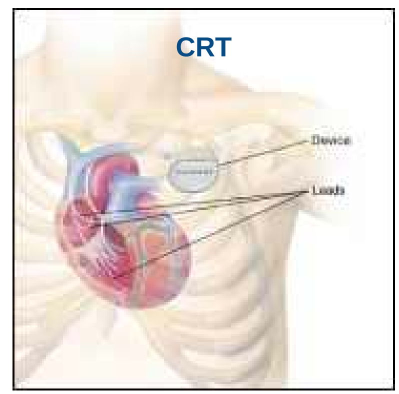

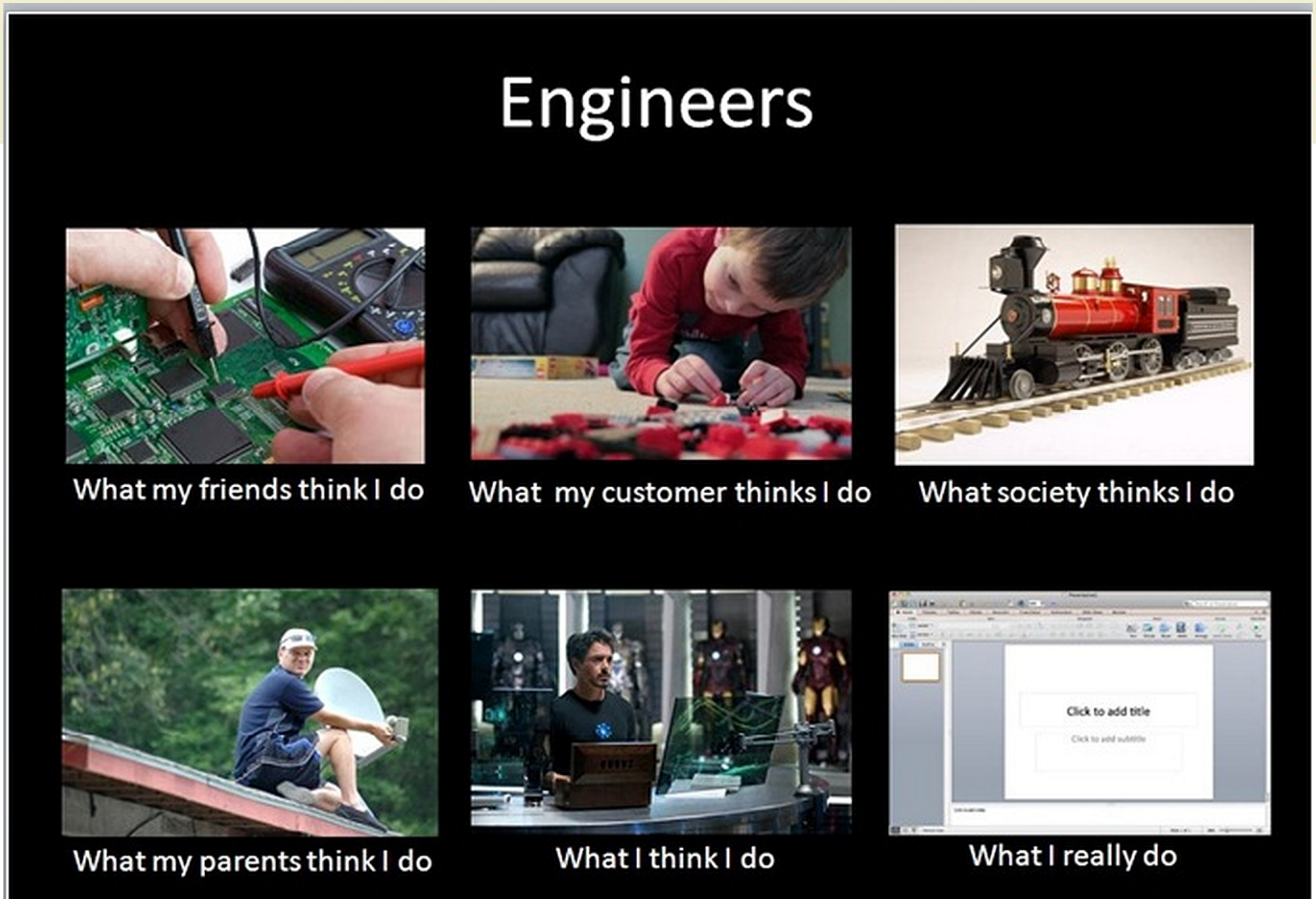

from EE Times Facebook page, March 2012

Things EEs should learn during college[1]…

Math/Science/Engineering fundamentals are essential…but also need:

- ❑ Verbal/written communications
- ❑ Project management
- ❑ Problem solving
- ❑ Test & Measurement
- ❑ Programming languages and design tools
- ❑ PCB Design
- ❑ Statistics

"…the field is so vast now that it is perhaps naive to suppose that one should be ready to do useful work upon graduation."

"I was so mad, frustrated, and confused as to how academia has cheated me the 5 years I spent doing…mathematical analysis on circuit diagrams."

"The degree means the engineer has the fundamental skills, ability, and confidence to learn how to do something and do it right and in a timely manner."

"people going into the sciences…frequently had hands-on experience as hobbyists and tinkerers."

[1]*Adapted from "7 More Things Colleges Should Teach EEs," Lou Frenzel– Electronic Design Blog, 8/25/13*

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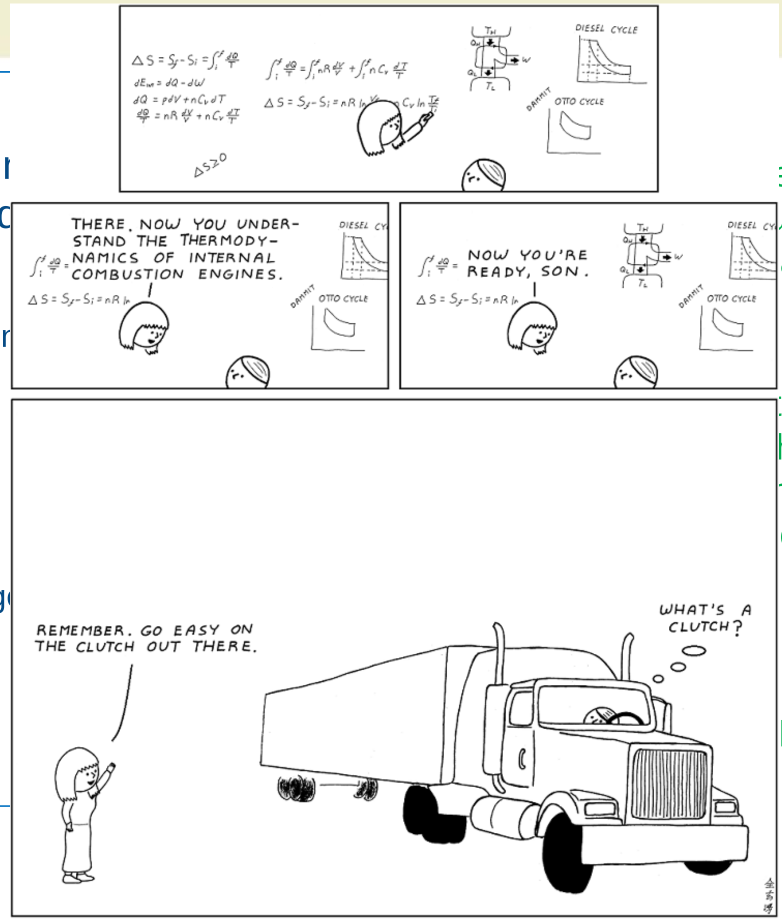

entering the real world after college

it's kinda like this

[1]*Adapted from “7 More Things Colleges Should Teach EEs,” Lou Frenzel– Electronic Design Blog, 8/25/13*

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The DiscoFish "Burning Man" vehicle was first built in 2002.

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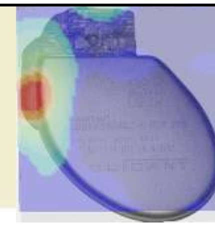
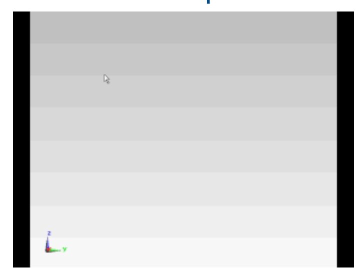
The daily engineering routine…



- Contrary to what you learn in class, the bulk of your day will NOT be solving circuit equations
  - Most time is spent in meetings discussing designs or on administrative tasks like ordering parts, documentation, training, etc.
- The delight of engineering: Pages of calculations predicting a result, the prediction turns out to be true, and when built it works![1]
  - A good day for an engineer is one where your lab measurements match simulation predictions…get used to having very few good days
- Design calculations and simulations are "necessary but insufficient" conditions[1]
  - "All simulations are wrong, but some are useful"



- An engineer's job is not done once the simulation runs
  - The theory may be incomplete, the models inaccurate, and external factors may confound correct operation[1]
- If a design does not work on paper, then it is irresponsible to expect that it will work in practice[1]

"Imagination is more important than knowledge" *Albert Einstein*

[1]*Adapted from "Perceptions and realities," Peter Hiscocks -- EDN, 9/14/2006*

The Cube office- get used to it!

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The Lab- your home away from home!

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Engineering Ethics

Integrity= *Doing what's right every time…even when no one is looking*

Your work & personal ethics are paramount

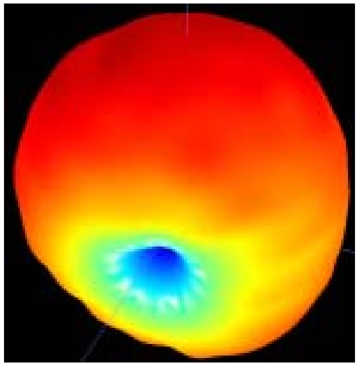
- Your decisions and quality of work will affect others
- If it doesn't look/work quite right, don't pass/ship it.
  - It will come back to haunt both you and your customers
  - For medical or high-reliability designs, someone's life can depend on your judgment call
  - Inevitably will not be enough time to do it right the first time, but always plenty of time to do it over again

Just say no to gifts, tickets, etc. from vendors and do not encourage this behavior by your own companies

- Regulations had to be enacted to deal with this in medical industry
- Avoid even the appearance of impropriety

Maintain a customer focus

- Know who customers of your work are
- Understand and empathize with your customers
- Do what's right for your customer, not what's easy



Engineering as a career

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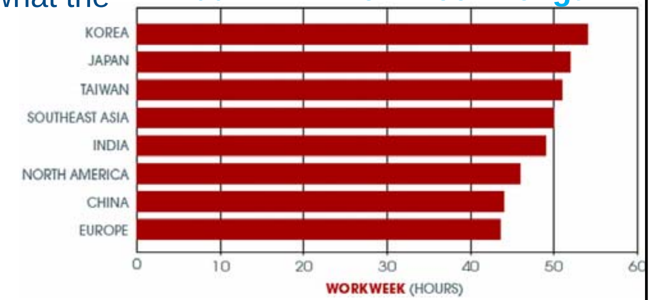
Engineers are professionals like doctors and (sorry to say) lawyers

- You will be master of your time- use it wisely
  - One FTE costs your employer ~$200K/year no matter what the level (your pay check is only part of this number!)
  - Consulting fees of $100 to $250/hr are typical
- In charge of reporting your own costs and time
- Salaried employees do not usually get overtime
  - Expect to work anywhere from 40-60 hours/week
  - Expect to work at home as well as the office
  - The hours you work are not usually considered- your performance is judged on your accomplishments
- Don't need to use vacation time for doctor, school, and other necessary reasons to miss work…but still need to complete your work even if gone
  - 2 weeks paid vacation/year 1st year
  - 3 weeks ~5th year
- Travel for work is work! Over the last 5 years colleagues and I have traveled to:
  - Lower 48 states, Alaska, Germany, Spain, France, Switzerland, Taiwan, China, Japan, Australia, Sweden, Argentina, England, Ireland, Israel, Belgium, Netherlands, Portugal, Italy, Canada, India, Iceland

2007 EDN Workweek Length



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2007 EDN Workweek Length

HOW MANY HOURS DURING THE TYPICAL WORKWEEK DO YOU SPEND: AT YOUR OFFICE?	
More than 60 hours	2.5%
56-60 hours	5.0%
51-55 hours	5.3%
46-50 hours	19.7%
41-45 hours	34.5%
36-40 hours	14.5%
31-35 hours	3.2%
26-30 hours	2.6%
21-25 hours	2.9%
16-20 hours	2.0%
15 or fewer hours	7.7%

WORKING AT HOME?	
More than 60 hours	0.9%
56-60 hours	0.7%
51-55 hours	0.4%
46-50 hours	1.0%
41-45 hours	1.2%
36-40 hours	1.7%
31-35 hours	0.8%
26-30 hours	1.9%
21-25 hours	2.4%
16-20 hours	6.1%
11-15 hours	6.9%
6-10 hours	16.5%
1-5 hours	35.5%
None	23.9%

Engineering problems in the real world…

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Defining / Identifying a problem is more difficult than solving a problem

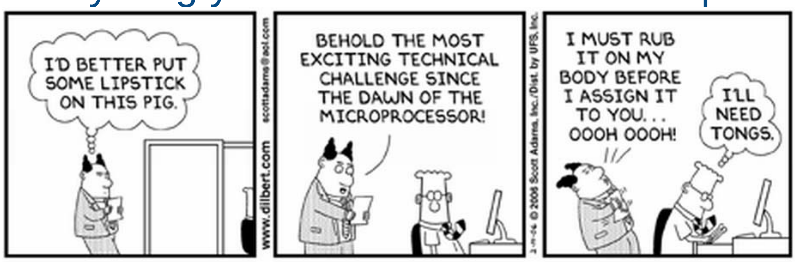
Don’t make solutions more complex than the original problem

- Simplifying converges on a solution
- Complexity diverges from a solution and creates new problems

Double check your work and don’t be offended when others do

- Catching errors early saves time, money, effort
  - In our business it saves lives
  - Finding issues early is ALWAYS better than seeing the consequences magnified later
- It allows you peace of mind as you see your product built and shipped to locations and customers all over the world

Not everything you work on will become a product



Design your products to be unconditionally safe

- Eventually they will be used in a manner you did not foresee

Engineering problems in the real world…

Boston Scientific

Defining / Identifying a problem is more difficult than solving a problem

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Vets install pacemaker in search-and-rescue dog

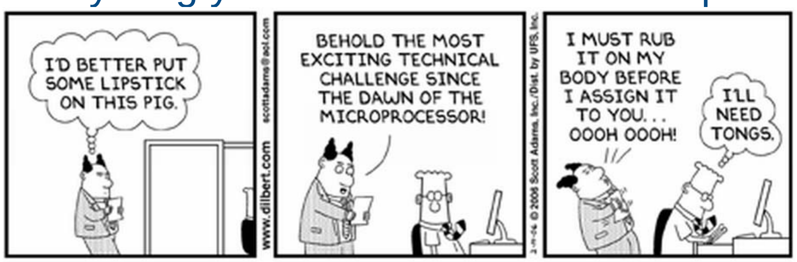
23 May 2008

COLUMBIA, Mo. (AP) - After years of helping authorities look for murder victims and survivors of natural disasters, a search-and-rescue dog named Molly has been rescued herself.

Surgeons at the University of Missouri College of Veterinary Medicine on Thursday installed a pacemaker in the 5-year-old chocolate Labrador retriever's heart. She needed the surgery after being diagnosed with a complete electrical heart blockage.

all over the world

Not everything you work on will become a product



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- Eventually

Engineering solutions

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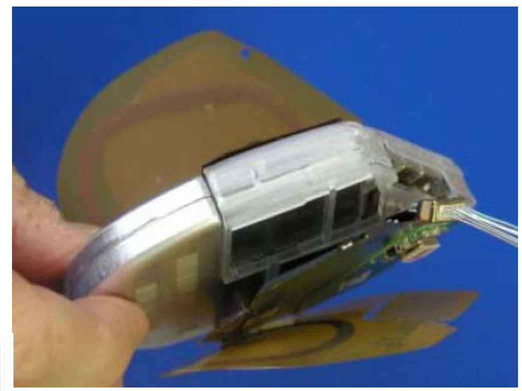
Engineering solutions are rarely “digital” but rather have a full “analog” spectrum of possibilities

- There usually is no single correct answer - most problems have multiple solutions
- The trick is to pick the solution path which will work best for your situation
- Some things to consider are:
  - Risk of totally new invention vs. modification of previous design
  - Cost, Time, Resources
  - The available resource capabilities
  - Complexity vs. reliability
  - Previous experience
- This is why engineers with experience are valuable



Engineering solutions

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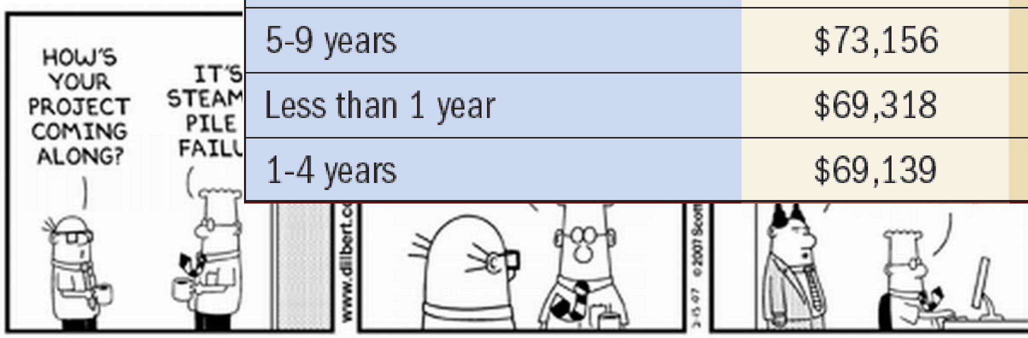
Average Salaries By Years Of Engineering Experience	Base salary	Total compensation
30-34 years	$108,137	$117,214
25-29 years	$106,136	$116,004
35-39 years	$105,664	$114,974
20-24 years	$101,106	$110,937
40 years or more	$93,217	$101,520
15-19 years	$92,483	$100,040
10-14 years	$90,015	$98,758
5-9 years	$73,156	$80,604
Less than 1 year	$69,318	$76,790
1-4 years	$69,139	$76,176



Engineering with others

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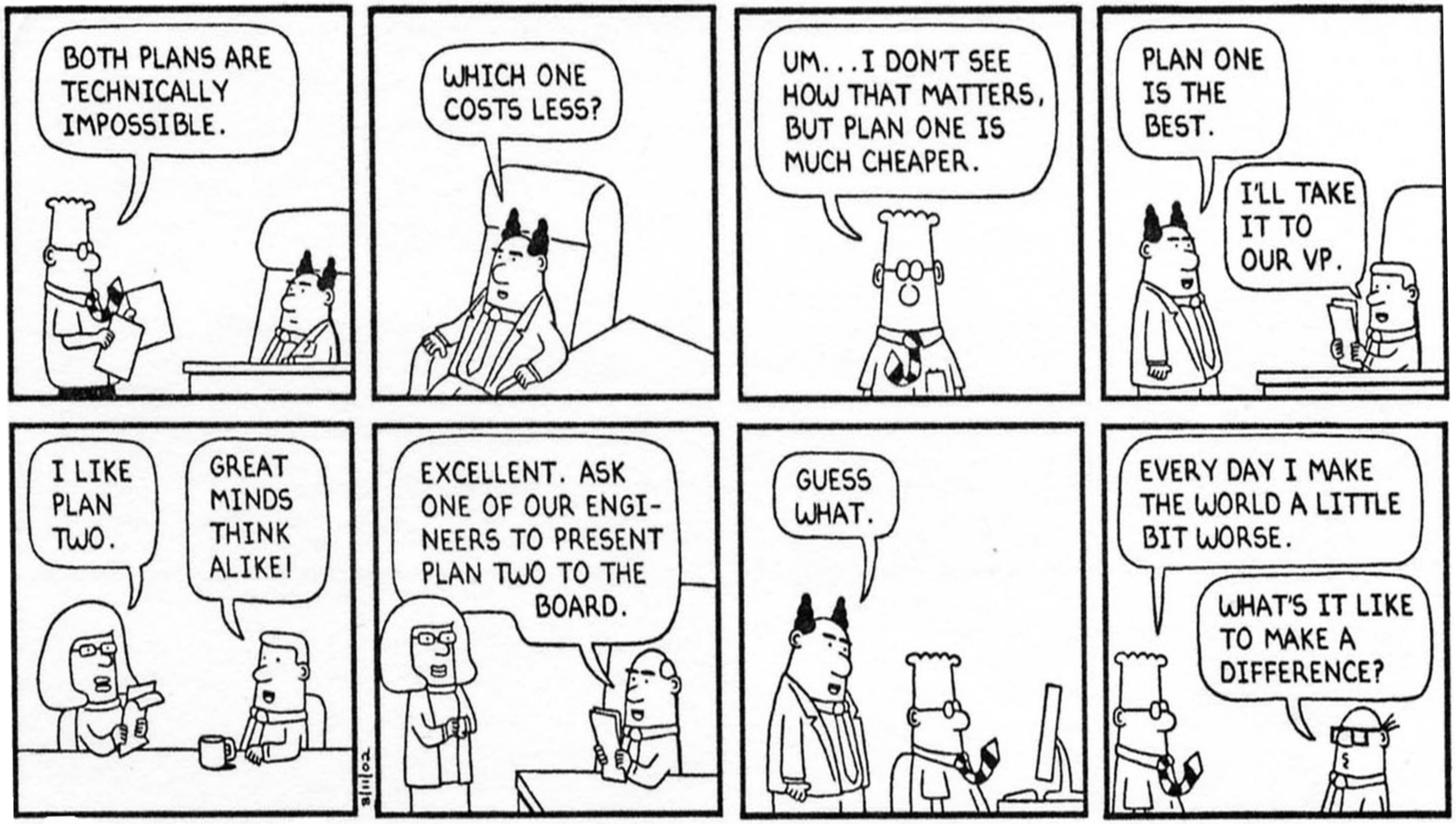
Can't we all just get along!

- Interpersonal skills are important (CareerBuilder.com 8/2011)
  - >60% of employers valued Emotional Intelligence higher than IQ
  - More likely to stay calm under pressure, Know how to resolve conflict effectively, Empathetic to their team members and react accordingly, Lead by example, Make more thoughtful business decisions
  - Valued traits: Admit/learn from mistakes, Keep emotions in check, Listen more than talk, Take criticism well, Show grace under pressure
- Effective engineers are able to work cross-functionally
  - You will typically be a member of a multi-disciplined team and will need to present your ideas and requirements to others
  - It is normal to "trade-off" requirements and specifications in order to come to an acceptable design solution
- Networking
  - Among students, teachers will help you find a job when you graduate
  - Cross-functionally outside your team exposes you to other career path possibilities
- Find yourself a mentor to discuss career moves with, help you understand your company's idiosyncrasies, help you broaden or deepen your technical knowledge

Engineering with others

Can't we all just get along!



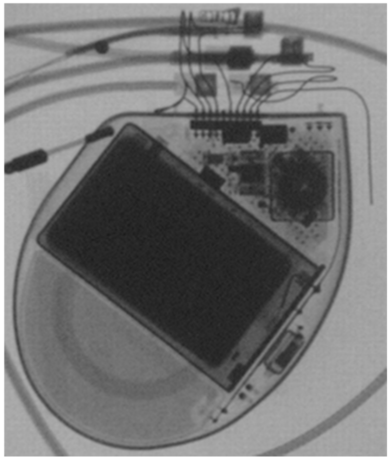
Engineering product planning

When defining a product today, the expected technologies available when its launched must be factored in

- Don’t include today's technology into tomorrow’s product or the product will be obsolete before starting production
- This means you need to foresee technology 4-6 yrs into future
- Its common to “design in” products/components that are not yet available themselves

Most companies have entire departments who plan product “portfolios”

- Maps showing all the product lines and their expected new product releases over the next 10 or more years in medical industry
- Show relationships across technologies and product lines
- Used to find future product gaps and highlight areas of investment



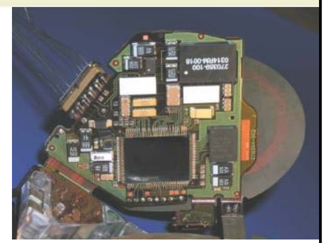
Products are often staged 1-2 yrs apart

Its common for 4-5 generations of products to be in development at one time

- You will work on multiple projects at the same time

Medical device life cycle

It takes time to bring new products to market

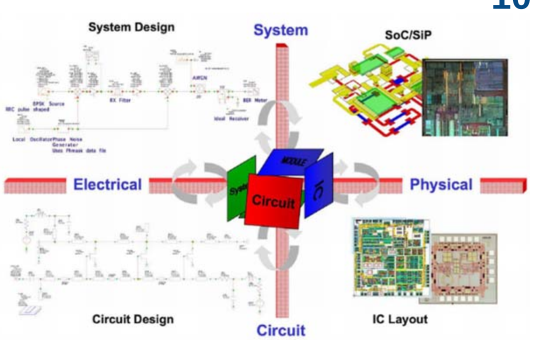


- Consumer electronics development cycle can be <1 year
- Medical products include stringent regulatory approval cycles & clinical testing
  - The bigger the company, usually the longer it takes

Example:

Example:	**1-2**	**yrs in definition of product, pre-clinicals**
	2-3	**yrs in design, testing**
	1	**yrs in regulatory/clinical approval**
	3-5	**yrs in production**
	5-10	**yrs in support**

10 - 20 year time before any product is ever "done"



So…always write everything down and never throw anything away - you may need it 10 - 20 years from now!

Engineering documentation

Keeping complete documentation is important

- Patents require invention disclosures, signatures and dates…not just a clever idea
- Usually ideas are kept in an official Lab Notebook
- Process: <u>Your Big Idea 0 years</u>

  Record of Invention +2 months

  Decision to Patent +6 months

  Draft Application +1 year

  Patent granted +5 years

  – Takes ~5 years from idea to a successful patent grant

  – "You know your idea is good when others take credit for it"

Medical devices require significant traceability

- Lot & serial number tracking are typical for all parts and equipment

Not enough to do the work- must be able to prove you have done it and document it so it can be repeated

(12) **United States Patent**
Batman et al.

(10) **Patent No.: US 6,635,167 B1**
(45) **Date of Patent: Oct. 21, 2003**

(54) **APPARATUS AND METHOD FOR DETERMINING THE CONCENTRATION OF A COMPONENT OF A SAMPLE**

(75) Inventors: **Carol Jane Batman**, Indianapolis, IN (US); **Greg Paul Carpenter**, Indianapolis, IN (US); **Robert Glenn Davies**, Carmel, IN (US); **Richard J. Kasle**, Indianapolis, IN (US); **Kurt Gerard Klem**, Indianapolis, IN (US); **Robert Anthony Parks**, Springport, IN (US); **Timothy L. Ranney**, Lebanon, IN (US); **William Brothers**, Lafayette, IN (US); **Christopher Louis Belisle**, Somerset, WI (US); **Michael Steven Ray**, Somerset, WI (US); **Leonard Allen Vetsch**, Elk Mound, WI (US); **Marvin W. Glass**, Fayetteville, TN (US); **Richard W. Wilson**, Noblesville, IN (US); **James R. Parker**, Carmel, IN (US); **Vladimir Svetnik**, Carmel, IN (US); **Lynne Denise Sly**, Fishers, IN (US); **Sandy Mark Richards**, Pershing, IN (US); **Nancy Kennedy Byrd**, Fishers, IN (US); **Patricia A. Hopkinson**, Lake Placid, NY (US)

(73) Assignee: **Roche Diagnostics Corporation**, Indianapolis, IN (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/555,659**
(22) PCT Filed: **Dec. 4, 1998**
(86) PCT No.: **PCT/US98/25863**
§ 371 (c)(1), (2), (4) Date: **Nov. 21, 2000**
(87) PCT Pub. No.: **WO99/28736**
PCT Pub. Date: **Jun. 10, 1999**

Related U.S. Application Data

(60) Provisional application No. 60/067,512, filed on Dec. 4, 1997.

(51) **Int. Cl.**[7] **G01N 27/28**; G01N 27/416; H01R 4/48
(52) **U.S. Cl.** .... **205/775**; 205/777.5; 204/400; 204/403.02; 204/406; 422/82.01; 324/431; 324/450; 439/786; 439/729; 439/759; 235/145 R
(58) **Field of Search** .... 204/400, 403.02, 204/408, 406; 422/82.01, 50, 62, 82.05; 324/426, 431, 450; 439/786, 729, 759, 816; 205/775; 235/145 R

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(List continued on next page.)

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(List continued on next page.)

Primary Examiner—T. Tung
Assistant Examiner—Alex Noguerola
(74) *Attorney, Agent, or Firm*—Barnes & Thornburg

(57) **ABSTRACT**

An instrument (**20**) has a well (**28**a–b) for receiving a dry cell (**75**), an opening (**78**) through which a first connector (**74**) is exposed to the well (**28**a–b), and a boss (**76**) adjacent the opening (**78**). The boss (**76**) precludes the wrong terminal of the dry cell (**75**) from engaging the first connector (**74**) when the dry cell (**75**) is inserted into the well (**28**a–b) in incorrect orientation. A second connector (**80**) includes a base (**81**), a first leg (**82**) resiliently connected to and extending away from the base portion, a second leg (**84**) resiliently connected to and extending away from the first leg (**82**), and a third leg (**86**) resiliently connected to and extending away from the second leg (**84**) and toward the first leg (**82**). A display (**42**) for the instrument (**20**) has a lens (**90**) having a substantially transparent substrate with a polyurethane coating. The instrument housing has first and second portions. At least one locator pin (**30**) extends from one (**24**) of the housing portions and at least one complementary socket (**32**) extends from the other (**22**) of the housing portions for receiving the pin (**30**) to maintain the first (**22**) and second (**24**) portions in assembled orientation.

57 Claims, 65 Drawing Sheets

Boston Scientific has more than 15,000 patents

Engineering for life

Your engineering education impacts the rest of your life

- You'll see same equations for next 40 years, you better like them!

You're a geek, but that's OK! (according to US Department of Commerce, 2011)

- STEM careers projected to grow 17% over 2008 to 2018 (9.8% for non-STEM)
- STEM degree holders enjoy higher earnings in STEM or non-STEM jobs

You'll find getting a big paycheck will not make you happy in the long run

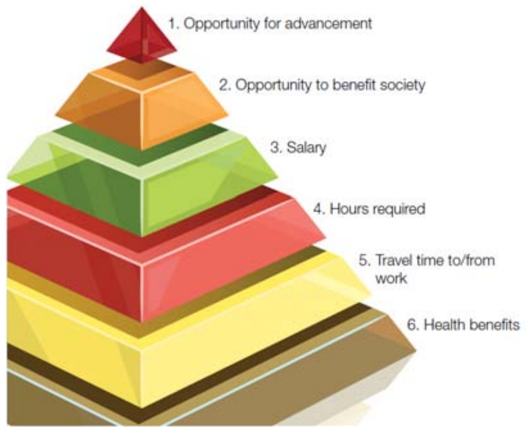
- Starting salary for BSEE is ~$55K, MSEE is ~$65K, PhD is ~$80K

What makes people get out of bed in the morning is a job which is:

- Challenging, rewarding, & part of a well balanced life
- One in which they feel they make a difference
- Opportunity for technical and personal growth

Stay in school- it's a jungle out there!

1986 Rodney Dangerfield, "Back To School"



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Yo

W

WOULD YOU RECOMMEND ENGINEERING AS A CAREER PATH TO A YOUNG PERSON LOOKING TO CHOOSE A PROFESSION?	
Yes	85.8%
No	14.2%

- Challenging, rewarding, & part of a well balanced life
- One in which they feel they make a difference
- Opportunity for technical and personal growth

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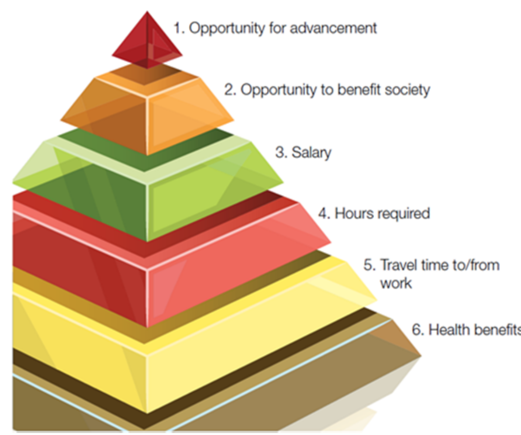
1986 Rodney Dangerfield, "Back To School"

FACTORS RECENT GRADUATES RATE MOST IMPORTANT IN CHOOSING THEIR FIRST JOB



Engineering education doesn't stop when you graduate

Boston Scientific

No matter the job, technology changes- don't get left behind!

- Continuing education keeps you on top of your field & builds confidence
  - Learn more = Earn more!
  - Examples are MS/PhD degrees, trade shows, seminars, MBA, conferences like IEEE, SPIE
- Employers typically pay for continuing education because they see benefits in a highly trained workforce
- Continuing education allows you to network with others in your field
- Learn from others around you
- **Learning from things that don't work can be more valuable than when everything goes according to plan**
- Read trade journals, books, internet to stay current:
  - IEEE Spectrum, IEEE Circuits & Systems, IEEE Trans on Circuits & Systems I, IEEE Eng. in Medicine & Biology, IEEE Trans on Biomedical Eng., IEEE JSSC, EDN, Electronic Design, RF Design, Microwave Journal, SPIE Optical Engineering, SPIE Journal of Biomedical Optics, Photonics Spectra
  - "Fields & Waves in Communication Electronics," Ramo; "Signals & Systems," Ziemer/Tranter; "Design of CMOS RFICs," Lee; "Analog IC Design," Johns & Martin
  - www.RFCafe.com, www.hp.woodshot.com, ieeexplore.ieee.org

Engineerin
graduate

Boston Scientific

DO YOU FEEL YOUR EDUCATION ADEQUATELY PREPARED YOU FOR THE JOBS YOU'VE HAD IN ENGINEERING?	
Yes	79.6%
No	20.4%

No matter … behind!

WHAT ARE SOME OF THE WAYS YOU CONTINUE YOUR ENGINEERING EDUCATION TODAY? (SELECT ALL THAT APPLY)	
In-classroom college courses	11.5%
Online college courses	15.3%
Seminars	51.9%
Webinars (online seminars)	61.8%
User group meetings	16.5%
Engineering association sponsored meetings	22.6%
Whitepapers	54.5%
Vendor-sponsored education (seminars, Webcasts, etc.)	38.7%
Trade show/conferences	41.6%
Engineering textbooks	46.1%
E-books (online textbook downloads)	31.5%
In-house educational programs sponsored by your company	22.1%
Online discussion forums	18.8%
Engineering/technology publications	72.8%
Other	4.5%

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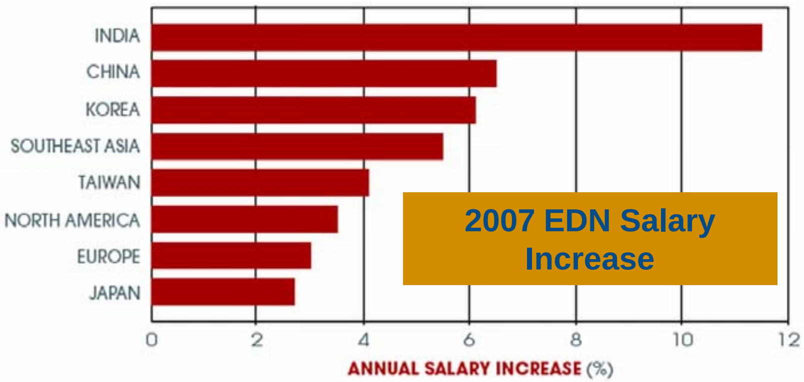
  - "Fiel … Ziemer/Tranter; "Des
  - www

You are never done being graded!

Typically every year you have a performance review…

Rating	Description
Outstanding	Clearly and consistently both exceeds objectives and demonstrates exceptional accomplishments Sought after for their skills, expertise and results Recognized as exceptional by others - both within and outside their group
Valued	Achieves objectives and demonstrates competency in critical performance dimensions Meets high standards of performance, and at times may go beyond acceptable but demanding performance standards Recognized as adding value, especially in key areas of resp
Improvement Required	Achieves some, but not all, objectives of the job with a reasonable degree of proficiency Need for further development and improvement is clearly recognized by their management Improvement in performance is required

	Performance Rating		
Position to MRP	**Improvement Required**	**Valued**	**Outstanding**
Above	0%	1.0 – 4.0 %	5.0 – 9.0%
At or Below	0 – 1.0 %	2.0 – 5.0 %	6.0 – 10.0%



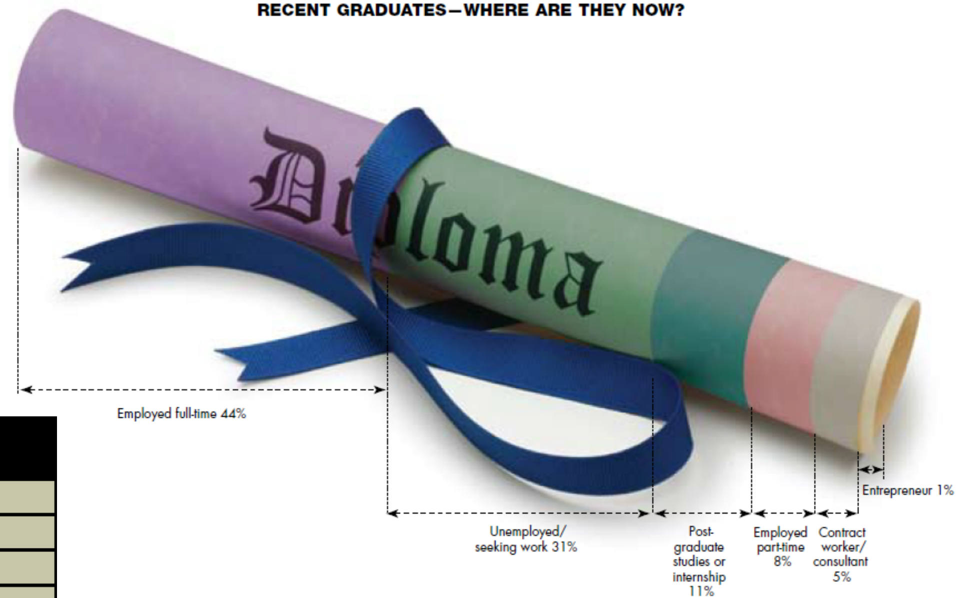
Your first “Real” job…

Boston Scientific

LANDING THE OFFER

Before graduation	40%
Within one month of graduating	21%
Within 6 months of graduating	20%
Within a year of graduating	6%
It took more than a year	7%
It’s been over a year; still no luck	7%

RECENT GRADUATES—WHERE ARE THEY NOW?



FACTORS RECENT GRADUATES RATE MOST IMPORTANT IN CHOOSING THEIR FIRST JOB
1. Opportunity for advancement
2. Opportunity to benefit society
3. Salary
4. Hours required
5. Travel time to/from work
6. Health benefits
7. Vacation time
8. Bonuses
9. 401(k) matching
10. Relocation opportunity
11. Tuition reimbursement
12. Pension plan
13. Stock options

Electronic Design Magazine 2011 Annual Salary Survey Report

Setting Salary Expectations

Boston Scientific

AVERAGE STARTING INCOME OF RECENT GRADS BY COMPANY SIZE	
Small firm (fewer than 100 employees)	$33,647
Medium-size company (100 to 999 employees)	$38,405
Large organization (More than 1000 employees)	$44,808

Average Salaries By Geographic Region	Base salary	Total compensation
Pacific	$115,003	$126,269
New England	$105,900	$115,893
West South Central	$105,792	$115,473
Mid-Atlantic	$99,881	$108,409
South Atlantic	$98,255	$107,124
East South Central	$98,767	$106,058
East North Central	$91,831	$99,542
Mountain	$90,938	$99,180
West North Central	$90,065	$97,584

Average Salaries By Industry	Base salary	Total compensation
ICs and semiconductors	$130,634	$145,831
Software	$111,500	$123,414
Computer systems/boards/ peripherals/software	$111,889	$122,297
Government/Military	$110,598	$116,377
Medical electronics	$100,611	$109,484
Avionics/marine/space	$101,909	$108,664
Communications systems/ equipment	$97,603	$106,794
Automotive electronics	$97,940	$106,540
Test and measurement equipment	$98,189	$105,274
Other (please specify)	$92,586	$102,117
Research & development	$91,632	$101,063
Components and subassemblies	$90,304	$99,954
Industrial controls systems/equip-ment	$90,400	$99,289
Consumer electronics	$87,401	$96,306
Consultant	$85,372	$92,465
Contract design or manufacturing	$83,045	$88,506

Setting Salary Expectations

BSEE degrees are top earners!

	STARTING MEDIAN PAY	MID-CAREER MEDIAN PAY
Petroleum Engineering	$97,900	$155,000
Chemical Engineering	$64,500	$109,000
Electrical Engineering (EE)	$61,300	$103,000
Materials Science & Engineering	$60,400	$103,000
Aerospace Engineering	$60,700	$102,000
Computer Engineering (CE)	$61,800	$101,000
Physics	$49,800	$101,000
Applied Mathematics	$52,600	$98,600

Computer Science (CS)	$56,600	$97,900
Nuclear Engineering	$65,100	$97,800
Biomedical Engineering (BME)	$53,800	$97,800
Economics	$47,300	$94,700
Mechanical Engineering (ME)	$58,400	$94,500
Statistics	$49,000	$93,800
Industrial Engineering (IE)	$57,400	$93,100
Civil Engineering (CE)	$53,100	$90,200
Mathematics	$47,000	$89,900
Environmental Engineering	$51,700	$88,600
Management Information Systems (MIS)	$51,000	$88,200
Software Engineering	$54,900	$87,800
Finance	$46,500	$87,300
Government	$41,400	$87,300
Construction Management	$50,200	$85,200
Supply Chain Management	$50,200	$84,700
Biochemistry (BCH)	$41,700	$84,700
Industrial Design (ID)	$44,400	$84,400
Electrical Engineering Technology (EET)	$55,100	$84,300
Food Science	$43,300	$83,700
International Business	$41,600	$83,700
Civil Engineering Technology (CET)	$46,600	$83,300
Geology	$45,300	$83,300
Computer Information Systems (CIS)	$47,900	$83,100
Mechanical Engineering Technology (MET)	$51,600	$81,200
Molecular Biology	$40,500	$81,200
Chemistry	$42,000	$80,900
Film Production	$41,600	$80,700

2011-2012 PayScale College Salary Report, downloaded *8/2011*

Setting Salary Expectations continued…

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Political Science (PolySci)	$39,900	$80,100
Biotechnology	$40,800	$79,900
International Relations	$40,500	$79,400
Occupational Health and Safety	$46,400	$79,000
American Studies	$43,400	$78,600
Information Technology (IT)	$48,300	$78,500
Industrial Technology (IT)	$48,100	$78,400
Information Systems (IS)	$48,300	$78,100
Telecommunications	$37,300	$78,100
Urban Planning	$41,500	$78,000
Accounting	$44,700	$75,700
Philosophy	$39,800	$75,600
Zoology	$38,000	$75,200
Advertising	$37,700	$74,700
Architecture	$41,500	$74,400
Marketing & Communications	$38,200	$73,500
Literature	$39,100	$73,200
Fashion Design	$36,300	$72,400
Global & International Studies	$37,800	$72,000
Biology	$37,900	$71,900
Environmental Science	$40,200	$71,200
Linguistics	$39,800	$70,700
Business	$41,000	$70,500
Microbiology	$38,500	$70,100
Nursing	$52,700	$69,300
History	$37,800	$69,000
Public Administration	$40,400	$68,900
Hotel Management	$36,100	$68,700

Forestry	$41,500	$67,200
Communications	$38,000	$66,900
Landscape Architecture	$41,900	$66,700
Geography	$39,600	$66,700
Journalism	$36,100	$66,400
Health Sciences	$35,800	$66,200
English	$37,100	$65,800
Public Relations (PR)	$35,500	$65,700
French	$38,400	$65,500
Sports Management	$35,400	$65,100
Liberal Arts	$37,800	$63,200
Anthropology	$35,600	$63,200
Human Resources (HR)	$37,900	$62,600
Organizational Management (OM)	$42,300	$61,900
Agriculture	$38,600	$61,500
Psychology	$35,000	$61,300
Medical Technology	$45,100	$60,900
Health Care Administration	$36,700	$60,900
Sociology	$36,100	$60,500
Radio & Television	$35,000	$60,000
Hospitality & Tourism	$35,900	$59,500
Visual Communication	$35,600	$59,000
Criminal Justice	$35,300	$58,900
Fine Arts	$35,900	$58,600
Spanish	$36,400	$58,400
Interior Design	$34,300	$58,200
Humanities	$34,900	$57,800
Horticulture	$39,600	$57,300

2011-2012 PayScale College Salary Report, downloaded *8/2011*

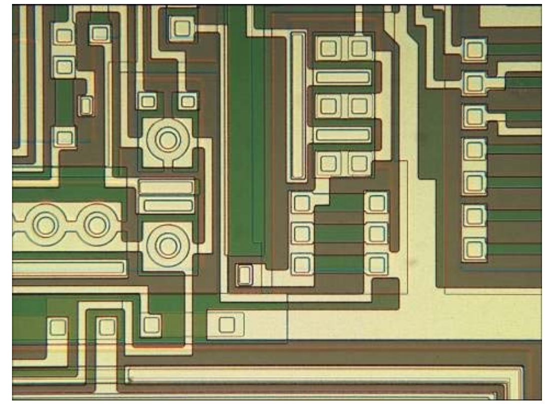
Setting Salary Expectations continued…

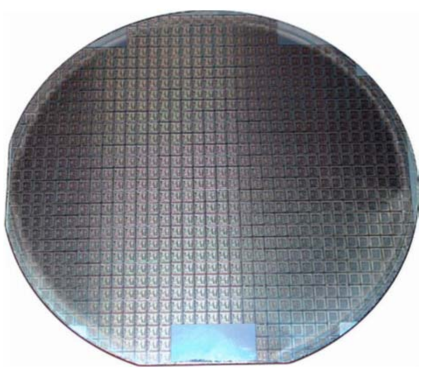
Theater	$34,700	$57,300
Music	$36,800	$57,200
Graphic Design	$35,600	$56,500
Fashion Merchandising	$36,800	$56,300
Dietetics	$41,500	$56,100
Education	$36,800	$54,700
Kinesiology	$34,200	$54,600
Photography	$32,900	$54,500
Nutrition	$38,600	$54,400
Interdisciplinary Studies (IS)	$36,300	$54,400
Exercise Science	$33,100	$54,400
Social Science	$36,600	$54,300
Drama	$37,800	$54,200
Multimedia and Web Design	$40,400	$53,900
Animal Science	$33,800	$53,700
Paralegal/Law	$35,300	$53,500
Art History	$38,300	$53,300
Art	$35,300	$52,400
Theology	$35,600	$52,000
Public Health (PH)	$35,500	$51,700
Athletic Training	$34,600	$50,200
Religious Studies	$32,900	$49,700
Recreation & Leisure Studies	$34,500	$49,100
Special Education	$34,300	$47,800
Culinary Arts	$29,900	$46,800
Social Work (SW)	$32,200	$44,300
Elementary Education	$32,400	$44,000
Child and Family Studies	$29,600	$40,500

2011-2012 PayScale College Salary Report, downloaded *8/2011*

Typical Engineering Levels*

Program Management	Functional Management	Technical Ladder
Vice President, Program Mgmt	Vice President	Corporate Distinguished Fellow
Director, Program Mgmt	Director	Senior Fellow
Senior Project Manager (Manager 2, Project Mgmt)	Manager 2	Fellow
Project Manager (Manager 1, Project Mgmt)	Manager 1	Principal Engineer / Scientist
Associate Project Manager (Supervisor, Project Mgmt)	Supervisor	Senior Engineer / Scientist
		Engineer 2 / Scientist 2
		Engineer 1 / Scientist 1 (Associate level)





"Technology is dominated by 2 types of people:

Those who *manage* what they do not *understand*
and
Those who *understand* what they do not *manage*."

Putt's Law and the Successful Technocrat, A. Putt, 1981

** See end of presentation for more details…***

Some Engineering Careers*

Boston Scientific

- ***Applications***
- ***Electronic***
- ***Failure Analysis***
- ***Field Clinical***
- ***Industrial***
- ***Manufacturing***
- ***Quality***
- ***Materials***
- ***Process***
- ***Product Performance***
- ***R&D/Systems***
- ***Reliability***
- ***Software/Firmware***
- ***Supplier***

**** See end of presentation for more details…***

What Employers look for…

Boston Scientific

Impact

- Positive first impression, command attention and respect, show confidence & interest

Business/Technical Skills

- Technical/Professional knowledge and skills
- Ability to use technical / business / professional information
- Customer orientation

Leadership

- Guiding individuals or groups towards task and goal accomplishments

Communication

- Understanding others and expressing yourself

Interpersonal skills

- Team orientation, interact and collaborate effectively with a variety of people
- Building trust

What Employers look for…

Decision making

- Identifying problems, evaluating relevant facts, generating ideas / alternatives, reaching sound conclusions, and taking appropriate actions
- Analysis, judgment, problem solving and decisiveness

Initiative / Effort

- Self-starter rather than passive acceptance
- Willing to take calculated risks
- Adaptability
- Quality and results orientation

Planning / Organizing

- Setting a course of action to accomplish a goal
- Planning allocation of resources
- Managing work, using time wisely

Motivational Fit

- Organizations corporate and individuals personal needs both met

Make yourself more "employable"

Boston Scientific

Internships, co-op positions & other practical experiences are extremely important

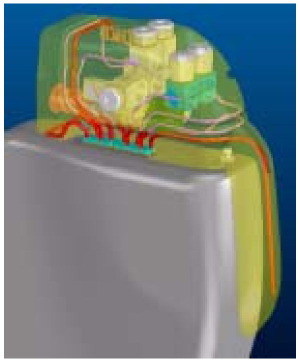
- Experience in what you want and (more importantly) don't want to do
- Helps with education by focusing future course work
- Separates you from applicants with no experience

GPA & School engineering program reputation

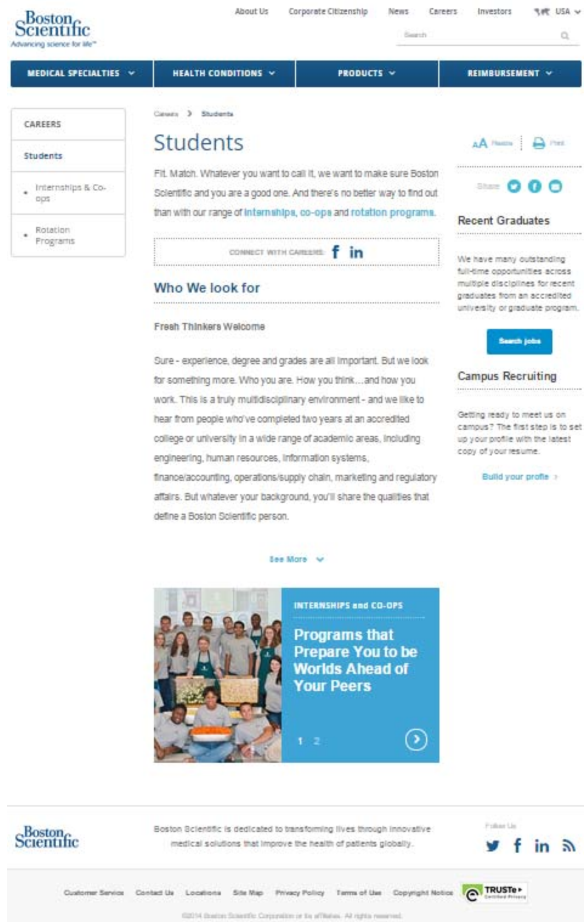
- GPA used as a filter for entry level positions for lack of other clear predictor
- Both become less important over time as experience builds

Clubs, organizations, extracurricular activities

- Have something more fun to discuss than work!
- Hobbies related to your desired career indicate a passion for your field
- A way to demonstrate leadership prior to entering the workforce
- Networking w/others will expose you to more opportunity



Boston Scientific Campus Recruiting- Internships



http://www.bostonscientific.com/en-US/careers/students.html

Boston Scientific | CRV Cardiology, Rhythm and Vascular

Thank You!

Back-up information slides

Boston Scientific

- Reference –

Some typical career details and job descriptions

Typical Engineering Responsibilities

Boston Scientific

Key Engineer Responsibilities

- *Designs, develops, debugs, modifies, and tests electrical circuits and systems by using current tools, analysis techniques, and technologies.*
- *Documents electrical development by writing documents, reports, memos, change requests. Methods used are determined by approved procedures and standards.*
- *Tracks electrical development effort by creating and maintaining records in the approved tracking management tool.*
- *Solves engineering problems by analyzing the situation and recommending corrective or alternative actions.*
- *Analyzes, evaluates, verifies, requirements, circuits, and systems by using engineering practices.*
- *Investigates, researches, selects electronic circuits, components, tools, equipment and practices.*

Job Description: Associate Engineer

Boston Scientific

JOB CODE / TITLE: Engineer, Electronic *LEVEL: Entry/Associate*

JOB SKILLS

- ***Experience/Education-*** ***Bachelor's degree plus 0-2 years of related work experience*** *with a basic understanding of specified functional area, or an equivalent combination of education and work experience.*
- ***Technical/Business Knowledge (Job Skills)-*** *Basic technical knowledge of concepts, practices and procedures. Limited understanding of business unit/group function. Will perform this job in a quality system environment. Failure to adequately perform tasks can result in noncompliance with governmental regulations.*
- ***Cognitive Skills-*** *Learns to use professional concepts and company policies and procedures to solve routine problems. Works on problems of limited scope. Minimal independent decision making.*
- ***Influence/Leadership-*** *Begins developing a network of internal resources to facilitate completion of tasks. Individual influence is typically exerted at the peer level.*
- ***Planning/Organization-*** *Completes daily work to meet established schedule with guidance from supervisor on prioritization of tasks.*
- ***Decision Making/Impact-*** *May exercise authority within pre-established limits and approval. Failure to achieve results can normally be overcome without serious effect on schedules and programs.*
- ***Supervision Received-*** *Work is closely supervised. Follows specific, detailed instructions*
- ***Supervision Provided-*** *N/A*

Job Description: Engineer

Boston Scientific

JOB CODE / TITLE: Engineer, Electronic *LEVEL: Intermediate*

JOB SKILLS

- ***Experience/Education-*** ***Bachelor's degree plus 2-5 years of related work experience*** *with a good understanding of specified functional area, or* ***Master's degree with 0-2 years of related work experience****, or an equivalent combination of education and work experience.*
- ***Technical/Business Knowledge (Job Skills)-*** *Working technical knowledge and application of concepts, practices and procedures. General understanding of business unit/group function. Will perform this job in a quality system environment. Failure to adequately perform tasks can result in noncompliance with governmental regulations.*
- ***Cognitive Skills-*** *Works on problems of moderate scope where analysis of situations or data requires a review of identifiable factors. Exercises judgment within defined procedures and practices to determine appropriate action. Has a broad knowledge of technical alternatives and an understanding of their impact on the systems environment.*
- ***Influence/Leadership-*** *Cultivates a wide range of internal networks and begins to develop an extensive external network of resources to facilitate completion of tasks. May lead a project team of moderate scope. Provides guidance to less experienced staff. Acts as a mentor to lower level individual contributors. Influence exerted at peer level and occasionally at first levels of management.*
- ***Planning/Organization-*** *Plans, organizes, and prioritizes own daily work routine to meet schedule.*
- ***Decision Making/Impact-*** *Exercises authority and judgment within defined limits to determine appropriate action. Failure to achieve results or erroneous decisions or recommendations may cause delays in program schedules and may result in the allocation of additional resources.*
- ***Supervision Received-*** *Works under general supervision. Follows established procedures. Work is reviewed for soundness of technical judgment, overall adequacy and accuracy.*
- ***Supervision Provided-*** *May provide limited work direction and guidance to exempt and/or skilled nonexempt levels of employees; may be asked to evaluate performance of and assist in career development planning for subordinates.*

Job Title: Electrical Engineer

As a electrical engineer, you could work in a variety of departments on these types of projects:

Analog or digital design, Logic synthesis, Simulation of low-power CMOS ASICs for implantable pacemakers and defibrillators

Your development tasks may require you to:

Design analog and digital test hardware, develop software test programs, participate in the development and enhancement of tests for new and released products, establish design for testability features

Electrical Engineering Roles

Product Development Team Member- Performs system integration testing, works with hardware, firmware, and software to understand the root cause of failures and recommend corrective design changes

Manufacturing Process Engineer- Provides engineering support for a pacemaker and defibrillator manufacturing process, drives electrical test and design revisions to enhance manufacturability and product performance

Advanced Manufacturing Engineer- Evaluates corrective action to improve yields for all products

Reliability Engineer- Identifies potential product failure mechanisms, develops methods to assure failure mechanisms are eliminated or prevented in current products and future designs

Research Engineer- Designs systems and devices for acquiring data, signal processing, and therapy control; responsible for areas such as sensing amplifier, automatic gain control, A/D, D/A, control systems, microprocessor implementation and interfacing, telemetry, and simulation

Job Title: Product Development Engineer

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PURPOSE STATEMENT- Responsible for providing electrical and electronic engineering support and expertise in the definition, design, development and test of products.

KEY RESPONSIBILITIES- Designs, develops, debugs, modifies, and tests electrical circuits and systems by using current tools, analysis techniques, and technologies. Documents electrical development by writing documents, reports, memos, and change requests. Methods used are determined by approved procedures and standards. Tracks electrical development effort by creating and maintaining records in the approved tracking management tool. Analyzes, evaluates, verifies, requirements, circuits, and systems by using engineering practices. Investigates, researches, selects electronic circuits, components, tools, equipment and practices.

Job Title: Biomedical Engineer

Boston Scientific

Biomedical engineers identify new sensors or algorithms to improve current therapy and to treat new patient indications. As a biomedical engineer, you will also generate clinical and preclinical protocols and collect and analyze acquired physiologic signals. A solid knowledge of statistics and the ability to interact with patients, physicians, and other clinical support staff are a big asset in this job

Biomedical Engineering Roles

Advanced Technology Engineer:

- Performs research aimed at directly transferable concepts to new products
- May develop polymers, metals, and coatings
- May participate in the development of mechanical test methods and modeling capabilities, as well as biomechanics studies aimed at determining the in-vivo conditions under which devices operate

Applied Research Engineer:

- Performs fundamental research directed at cardiac arrhythmia detections and therapy
- Handles many projects including sensing algorithms, waveforms, sensors, electrodes, and modeling

Job Title: R&D Engineer

Boston Scientific

PURPOSE STATEMENT- Responsible for providing engineering support in the creation and the development of new medical device products (invasive and non-invasive).

KEY RESPONSIBILITIES- Researches, develops, designs, and evaluates mechanical and electro-mechanical materials, components, assemblies, processes and/or equipment. Conducts feasibility studies to verify capability and functionality. Develops new concepts from initial design to market release. Directs support personnel and coordinates project activities. Write and submit intellectual property (patents). Maintains detailed documentation throughout all phases of research and development. Investigates and evaluates existing technologies. Reviews or coordinates vendor activities to support development.

Job Title: Software Engineer

Boston Scientific

As a software engineer, you will:

- Develop fault-tolerant, real-time, mission-critical embedded software for implantable pacemakers and defibrillators
- Develop graphical user interface software for external medical instrumentation

Your development tasks may require you to:

- Develop new and enhance existing software products
- Analyze and resolve system and software issues
- Develop and improve R&D software tools, processes, procedures, techniques, and methodologies throughout the software life cycle
- Work with OOA OOD tools to develop reusable feature components
- Work with various dedicated teams to develop new techniques and gather feedback to improve them

Your verification duties may be to:

- Verify software
- Prepare plans
- Analyze requirements
- Develop test protocols and test code
- Debug and execute the tests and analyze test results

Your test system duties may require you to:

- Maintain software
- Troubleshoot systems and software enhancements to the test tool systems
- Work with dedicated product development teams to develop new advanced test tool systems

Job Title: Product Development Software Engineer

Boston Scientific

PURPOSE STATEMENT- Develops software systems, applications, firmware, and/or provides software systems testing and validation in support of R&D and/or Manufacturing Process Engineering. Performs any of the following: Applications: Responsible for analyzing, designing, programming, debugging, and modification of local, network/internet-related computer programs for commercial or end user applications (i.e. materials management, financial management, HRIS, or desktop applications products). May interface with users to define system requirements and/or necessary modifications. Product Applications: Responsible for analyzing, designing, programming, debugging, and modification of real-time applications. Requires knowledge of real-time operating systems and software. Work often involves knowledge of modeling and simulation software. May interface with users to define system requirements and/or necessary modifications. Firmware: Responsible for the analysis, design, programming, debugging and modification of firmware applications. Work often involves analog and digital hardware and software operating systems. Position requires knowledge and exposure to hardware design. Internal Systems: Responsible for designing, developing, troubleshooting and debugging software programs for internal technical end users. May include software tools, utilities, databases and internet-related tools, etc. Position requires knowledge of hardware compatibility and/or hardware design. Programmers who are developing applications for technical end users should be matched here. Systems Verification: Responsible for developing, applying and maintaining quality standards for software products.

KEY RESPONSIBILITIES- Designs, develops, debugs, modifies, tests software programs by using current programming languages, methodologies and technologies. Documents software development and/or test development by writing documents, reports, memos, and change requests. Methods used are determined by approved procedures and standards. Tracks software development effort by creating and maintaining records in the approved tracking management tool. Analyzes, evaluates, verifies requirements, software and systems by using software engineering practices. Investigates, researches, selects software designs, operating systems and/or practices. Continuously improves process and work methodologies by interfacing with peers/cross-functional groups and analyzing activities to improve workflow and work processes.

Job Title: Manufacturing Engineer

PURPOSE STATEMENT- Provides support to the Manufacturing organization to facilitate efficient operations within the production area, to optimize existing processes, and to ensure that production goals are met. Monitors performance of equipment, machines and tools and corrects equipment problems or process parameters that produce non-conforming products, low yields or product quality issues. Interfaces with Quality and Research and Development organizations to integrate new products or processes into the existing manufacturing area.

KEY RESPONSIBILITIES- Initiates and completes technical activities leading to new or improved products or process, for current programs, next generation programs and to meet strategic goals and objectives of the company. Prepares reports, publishes, and makes presentations to communicate findings. Analyzes and solves problems from basic engineering principles, theories and concepts through to a wide range of complex and advanced problems which require novel and new innovative approaches or a major breakthrough in technology. Understands engineering principles theories, concepts, practices and techniques. Develops knowledge in a field to become a recognized leader or authority in an area of specialization and applies this knowledge in leadership roles in the company. Incorporates business policies and procedures into task completion. Understands the business needs of the company, and has knowledge of the customer needs of our business. Understands the business cycle and foresight of emerging technologies trends. Cultivates internal and external network of resources to complete tasks. Serves has a resource in the selection orientation and training of new engineers and employees. May lead a project team, determining goals and objectives for the projects. Mentors employees by sharing technical expertise and providing feedback and guidance. Interacts cross functionally and with internal and external customers. Serves as a consultant for engineering or scientific interpretations and advice on significant matters. Acts as a spokesperson to customers on business unit current and future capabilities.

Job Title: Quality/Process Engineer

PURPOSE STATEMENT- Provide Process/Quality Engineering support to manufacturing, helping to ensure delivery of highest quality product to the customer. Provide Process/Quality Engineering support to product development teams, helping to ensure development of highest quality new products.

KEY RESPONSIBILITIES- Learns to identify Manufacturing process defects (scrap, nonconforming material, customer complaints) by dispositioning non-conforming material, assisting in identification of primary root causes and understanding corrective and preventative actions. May be responsible for working with process owner to bound product stops and document release criteria. Gains understanding of product quality plans, documents and systems by reviewing product specifications, quality specifications, and working with quality systems. May be responsible for learning risk analyses and FMEAs. Learns Process Monitoring Systems by becoming familiar with systems applications and critical process steps; and through familiarization with methods used to reduce process variation. Becomes familiar with Product/Process improvement efforts by understanding current quality metric data and learning the various analysis methods used to enhance sustaining product design and new product development. Learns Quality Tools & Training Materials by gaining knowledge of prevalent tools used and by reviewing & utilizing available training materials.

Presenter Bio

Greg P. Carpenter, Boston Scientific Corporation, St. Paul, MN, USA

Greg Carpenter (BS'87) is an electrical engineer with 25 years of medical industry experience. He is a research fellow at the Cardiac Rhythm Management division of Boston Scientific/Guidant Corporation since 2001. His current research interests include MRI compatibility of implanted devices, implanted and near patient sensors, energy harvesting and wireless telemetry design for medical systems. He has done research, design, and product development for various medical diagnostic instrumentation platforms including blood glucose and coagulation monitoring while at Roche Diagnostics/Boehringer Mannheim Corporation from 1991-2000. Prior to this, he worked on design and development of miniaturized industrial and medical sensors from 1988-1991 at HEI, Inc. He holds 10 patents, has 1 publication and is a member of IEEE and ISMRM (when he remembers to pay the dues!)

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