R&D in Electrical & Computer Engineering

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Career Day — Baltimore Polytechnic Institute — April 2010

Today's Outline

1. Engineering careers in general
2. Embedded systems issues
   — *why does everything break?*
3. Computers & their memory systems
   — *how do I make my computer faster?*
4. 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 engineer ≠ electrician
  Computer engineer ≠ 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 <u>now</u>)

I of IV

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

	Industry/BS	Industry/PhD	Academia
Salary Range (0yrs–10yrs)	$60K–120K	$90K–150K	$80K–150K
Job Security	Okay	Good	Great
Freedom	Little	Some	Lots
Respect	Lots	Lots	Little
Visibility	None	Little	Lots
Brief Job Description	Develop	Design	Research & Teach
Perks of the Position	Free coffee	Stock options	Talking to a captive audience

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)

Big(ger) Picture

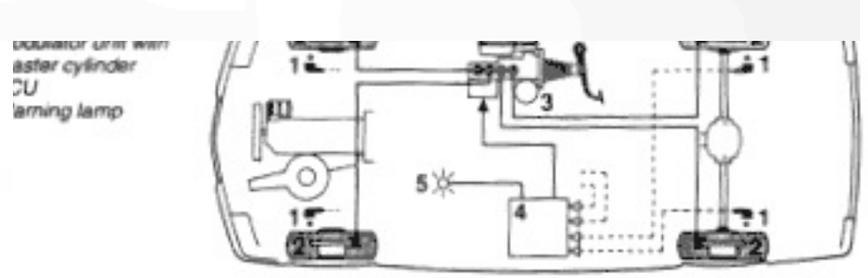
	Start-Up Company
Salary Range (0yrs–10yrs)	$50K–$120K or more
Job Security	None (… to Lots)
Freedom	Lots
Respect	Lots
Visibility	None
Brief Job Description	Design, Build, Test, Maintain, Deal w/ Customer, whatever
Perks of the Position	Cool atmosphere, intriguing problems, stock options?

Perhaps best of both worlds?

II of IV

The Most Important Problem Today: Embedded Systems

EMBEDDED SYSTEMS



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

Examples Abound …

REUTERS

NEWS AND FINANCIAL INTELLIGENCE FROM THE WORLD LEADER

TOP NEWS

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

PressPass · Information for Journalists

Microsoft Technology Hits the Road in BMW 7 Series

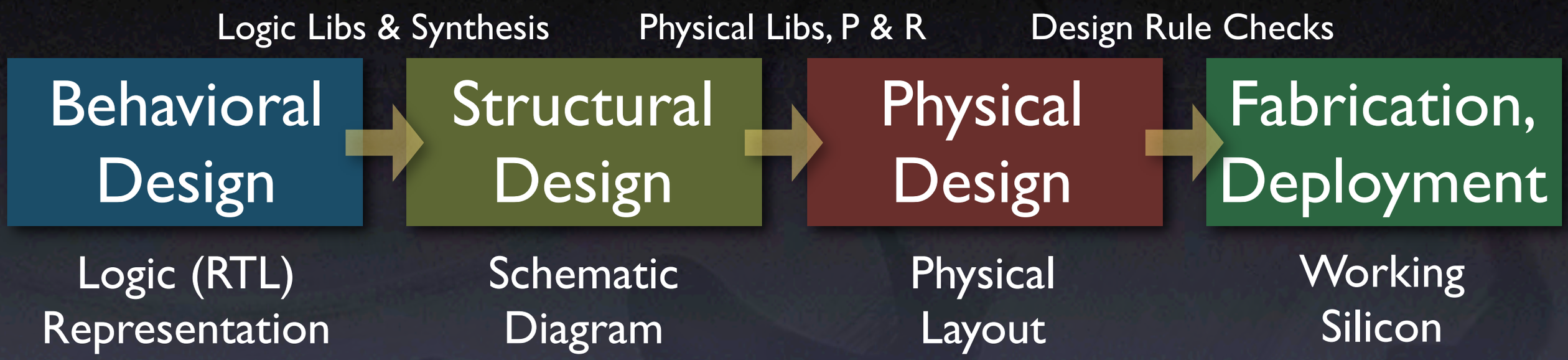
Microsoft Navigates the Automotive Industry, Enhances the Driver Experience

REDMOND, Wash. -- March 4, 2002

Problem: Components

may be verifiable, but the System is not

A Tale of Two Design Flows



VLSI Design Flow:
characterized by strict design rules, verifiable physical design

A Tale of Two Design Flows

Logic Libs & Synthesis | Physical Libs, P & R | Design Rule Checks

Behavioral Design → Structural Design → Physical Design → Fabrication, Deployment

Logic (RTL) Representation

```
module fibonacci(clk2, rst_l, out_w);

input clk2, rst_l;
output   [7:0] out_w;

reg      [7:0] src1, out;
wire     [7:0] out_w = out;

always @(posedge clk2)
begin
        if(!rst_l)
        begin
                src1 <= 1'd0;
                 out <= 1'd1;
        end
        else
        begin
                src1 <= out_w;
                out <= src1 + out_w;
        end
end

endmodule
```

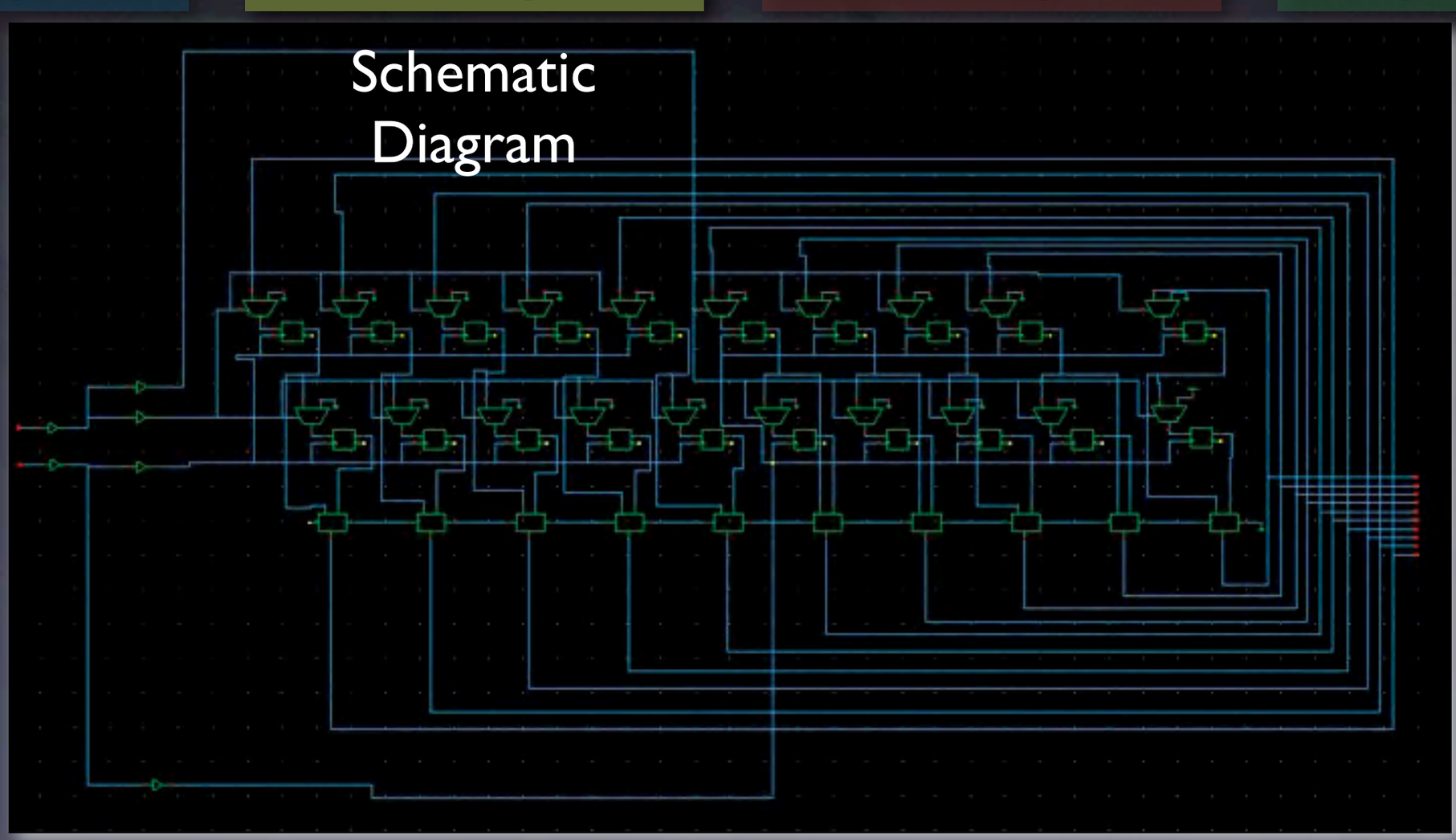
A Tale of Two Design Flows

Logic Libs & Synthesis

Physical Libs, P & R

Design Rule Checks

Behavioral Design → Structural Design → Physical Design → Fabrication, Deployment



A Tale of Two Design Flows

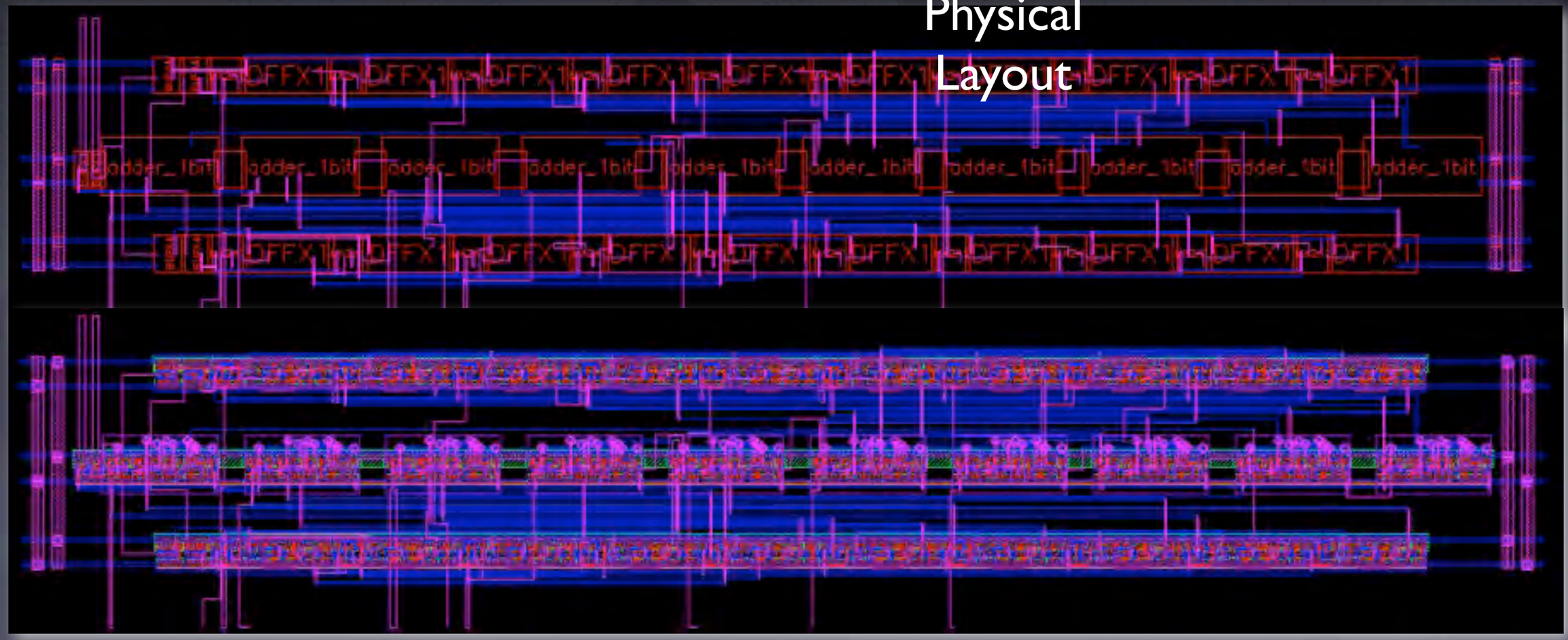
Logic Libs & Synthesis

Physical Libs, P & R

Design Rule Checks

Behavioral Design → Structural Design → Physical Design → Fabrication, Deployment

Physical Layout



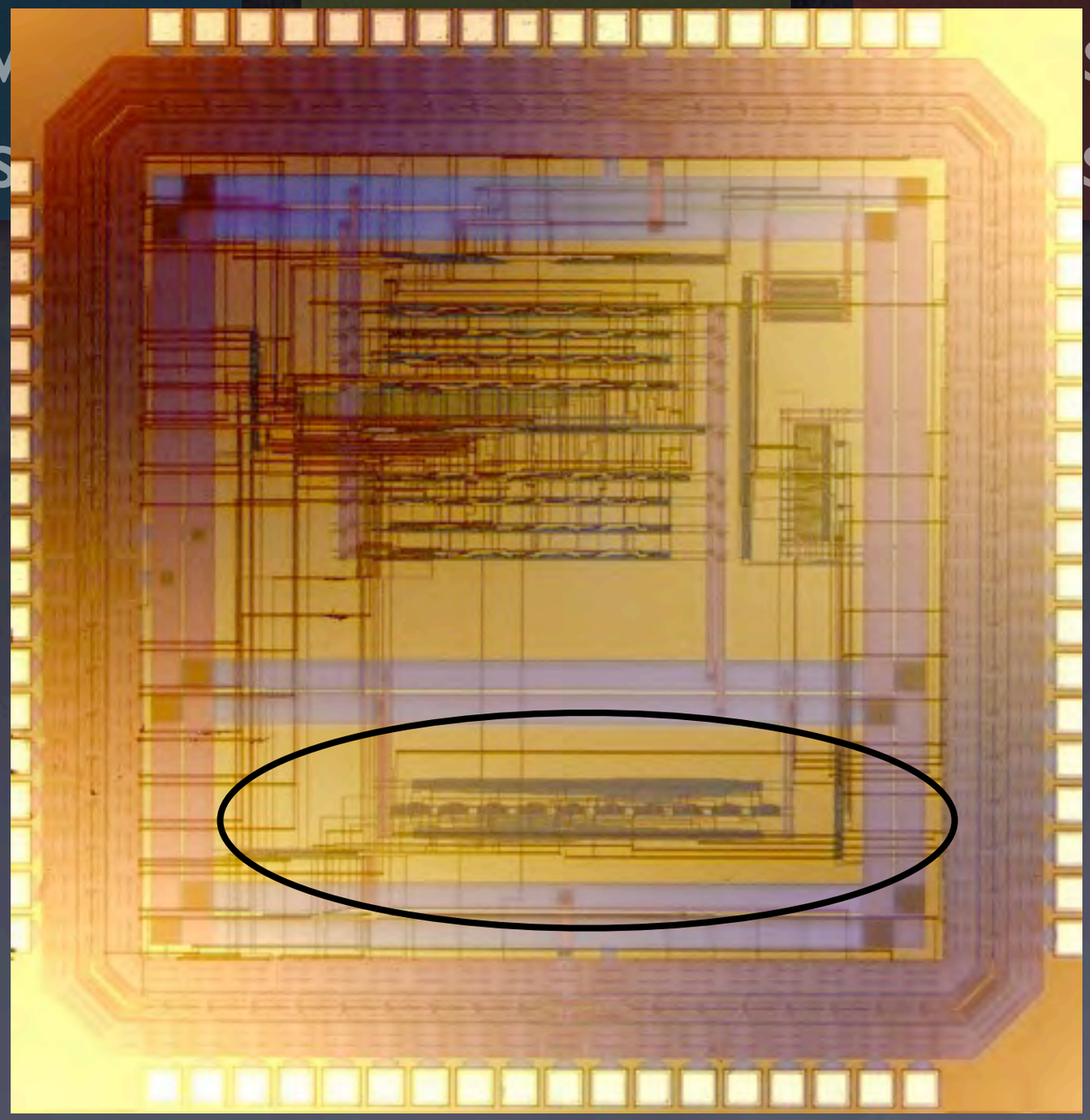
A Tale of Two Design Flows

Logic Libs & Synthesis

Physical Libs, P & R

Design Rule Checks

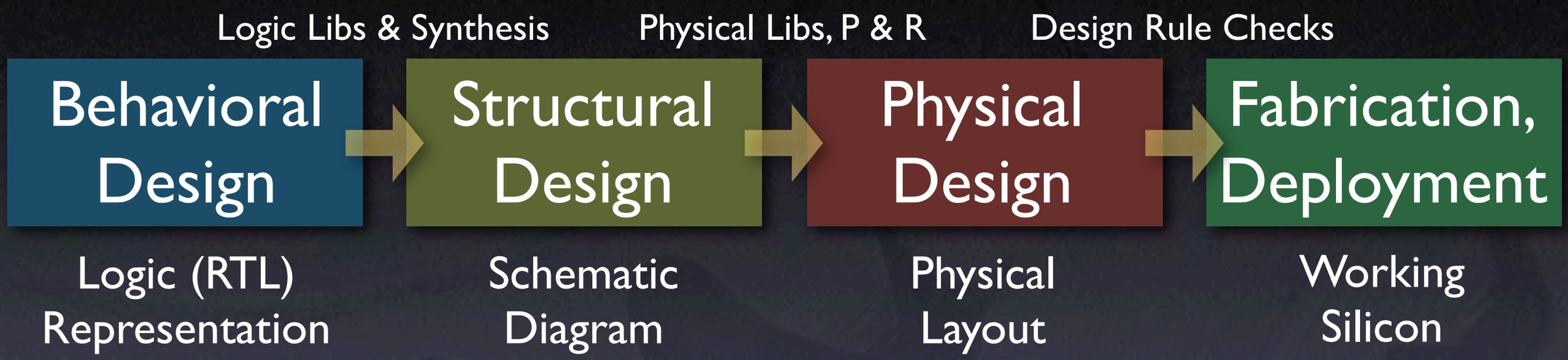
Behav… Des… …sical …sign



Fabrication, Deployment

Working Silicon

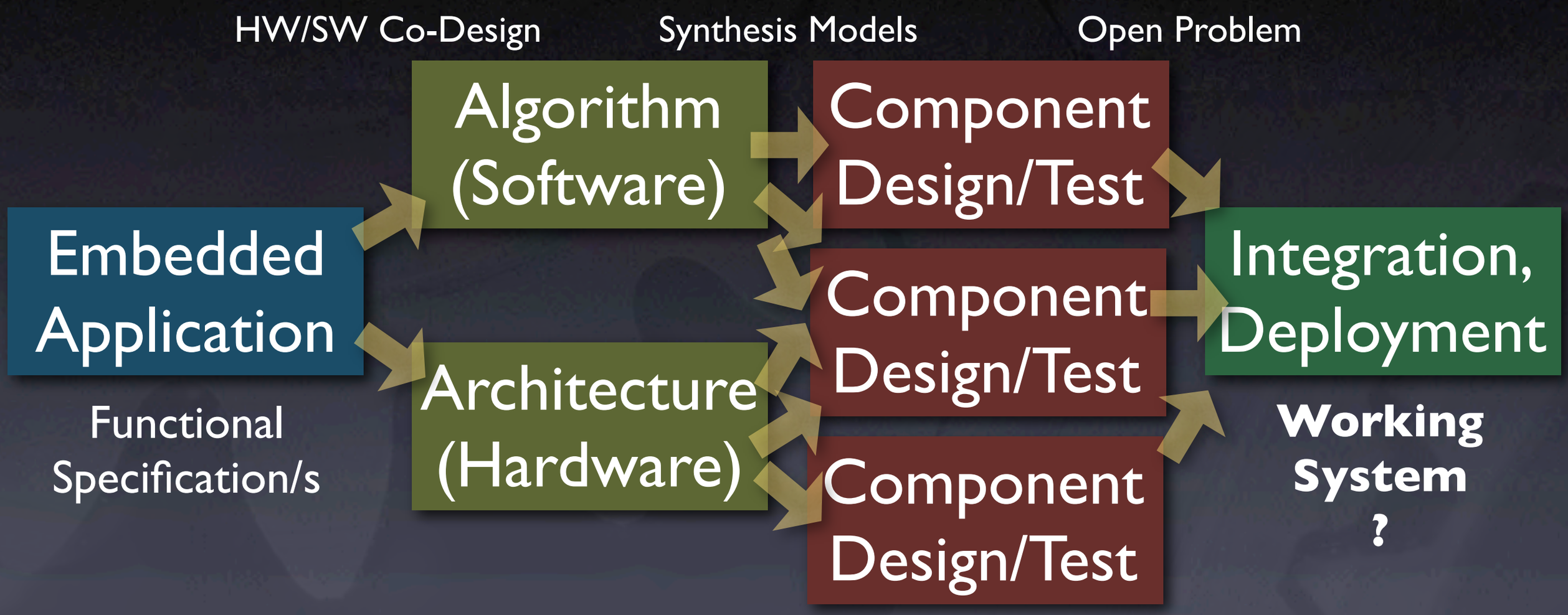
A Tale of Two Design Flows



VLSI Limitation:
you can build *WIRES* or *TRANSISTORS*

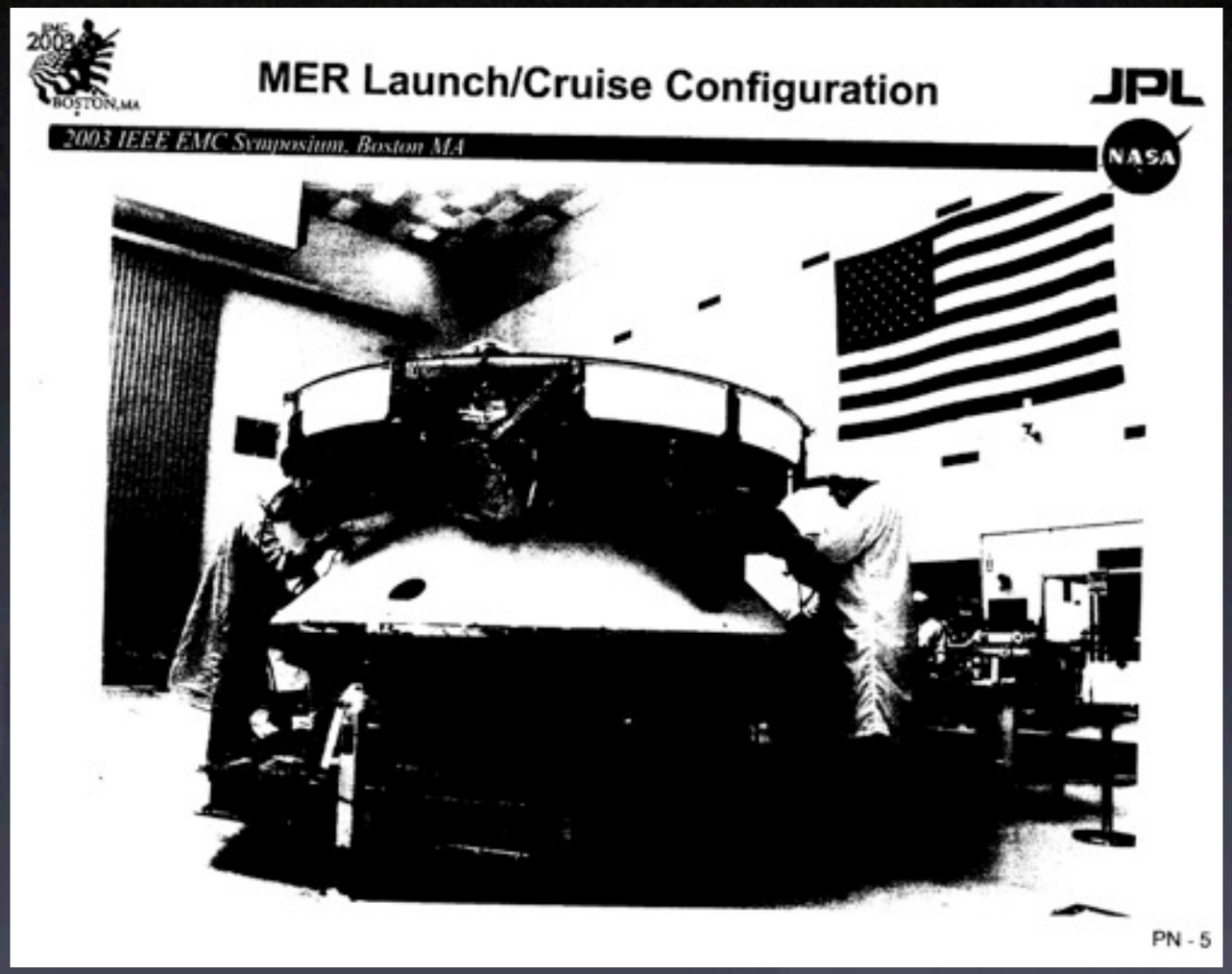
VLSI Design Flow:
characterized by strict design rules, verifiable physical design

A Tale of Two Design Flows



Embedded Design Flow:
characterized by nonexistent design rules,
ad hoc methods for system-level verification

Examples Abound …



"System Level EMC Testing of Spacecraft," Narvaez, *EMC* 2003.

Jet Propulsion Laboratory, California Institute of Technology

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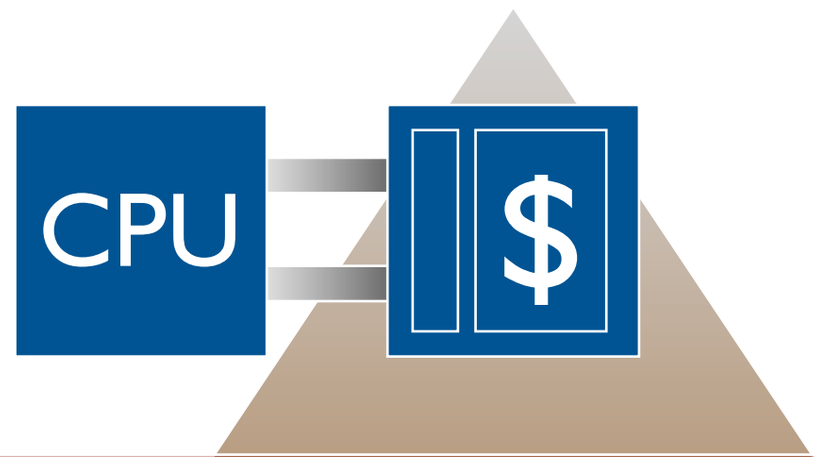
What I'm Known for:

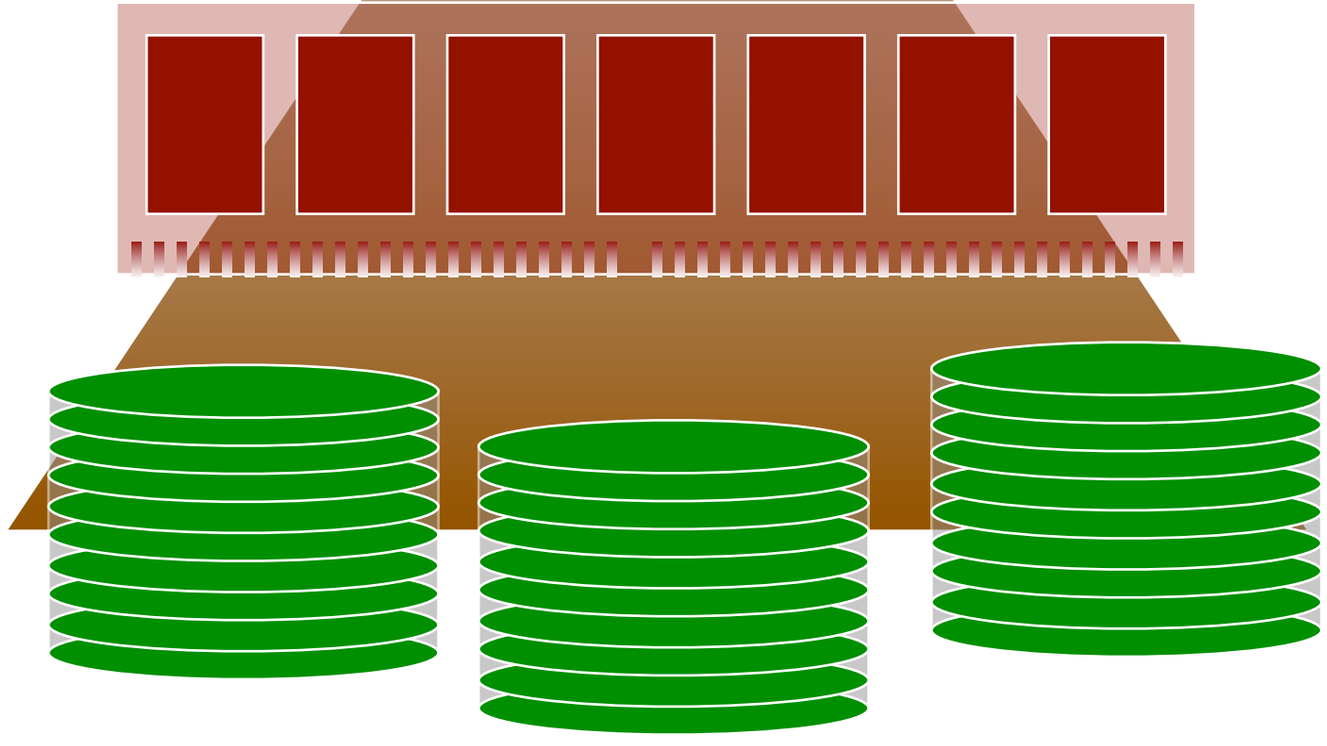
Computers and Memory Systems

Perspective

~10 Billion/s ⟶



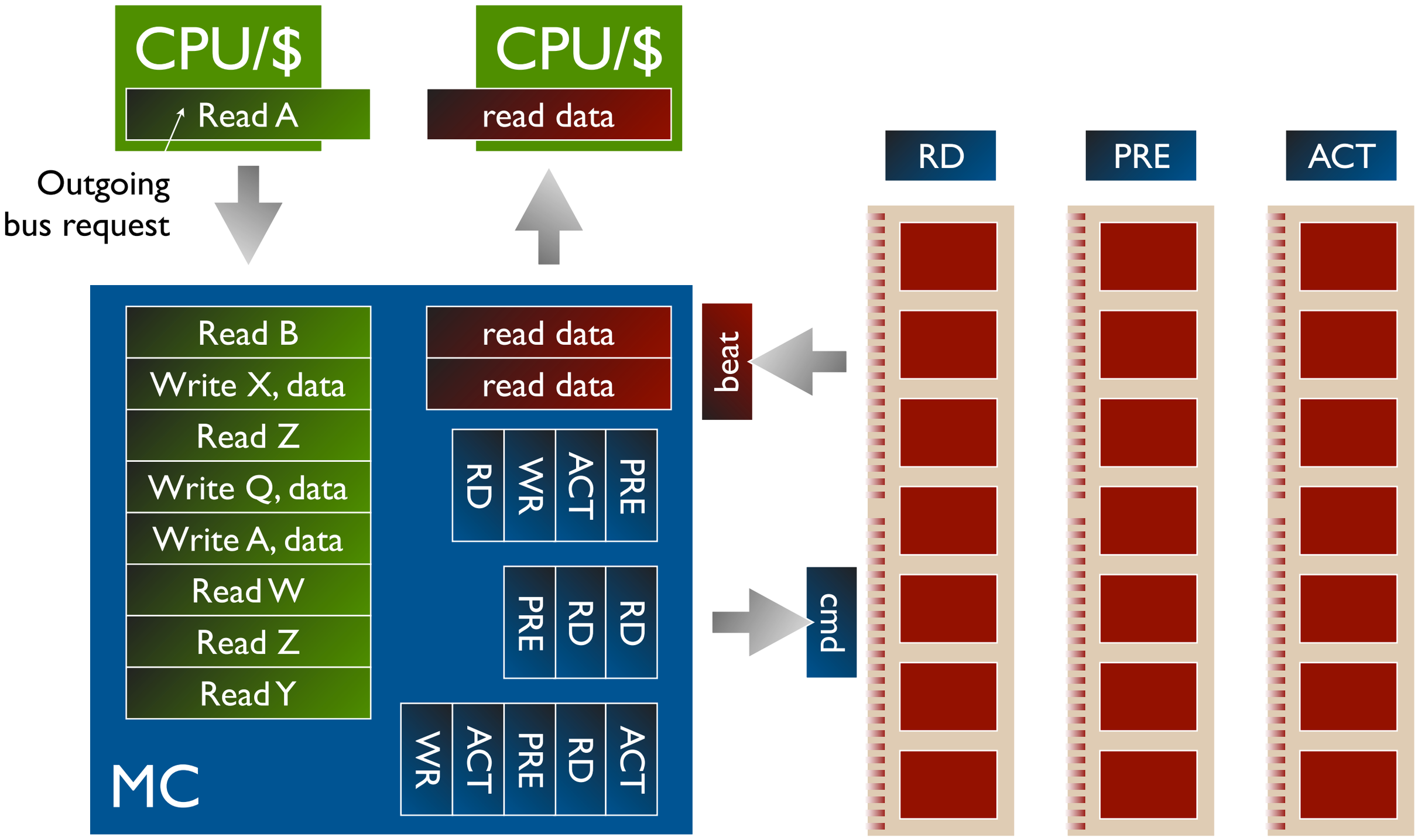
~10 Million/s ⟶



~100 per sec ⟶

< 1Billion/s

Primer


CPU/$
Read A
CPU/$
read data
Outgoing
bus request
Read B
Write X, data
Read Z
Write Q, data
Write A, data
Read W
Read Z
Read Y
read data
read data
RD
WR
ACT
PRE
PRE
RD
RD
WR
ACT
PRE
RD
ACT
MC
beat
cmd
RD
PRE
ACT

Napkin Math: Palm HD

- 1920 x 1080 x 36b x 60fps = 560MB/s (~1GB/s incl. ovhd)
- 3 x4 DDR800 = 1.2GB/s, 600mW
- Power budget = 500mW **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) observed former at cost of latter … *R.I.P. FBD*

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

Questions?

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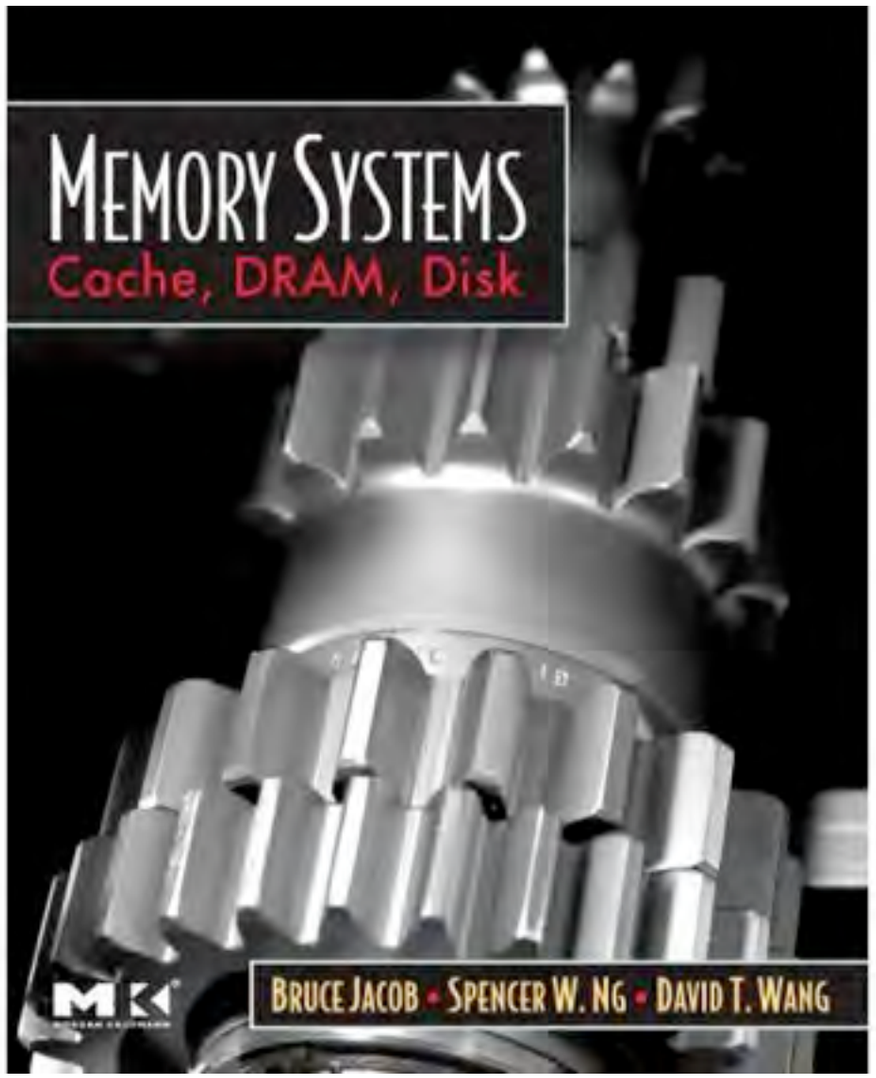

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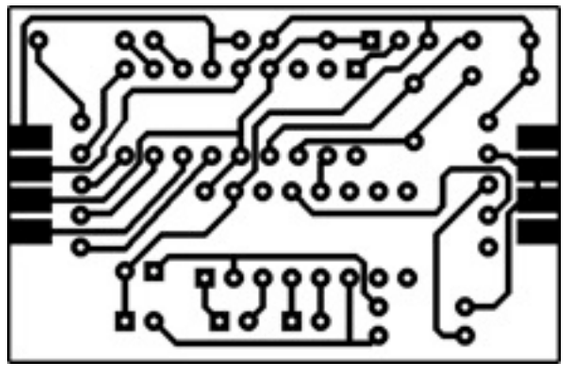
More on Start-Ups: The Importance of (High-Tech) Design

Important development in last decade:

Manufacturing as a Service

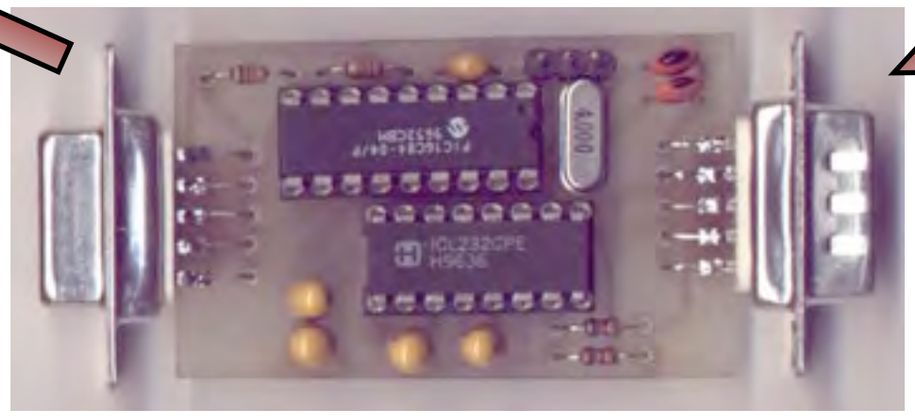
The Basic Idea



Design Blueprint

You

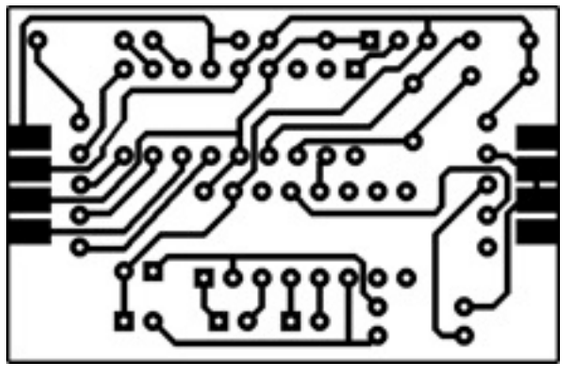
Factory



Manufactured Device

The Basic Idea

You



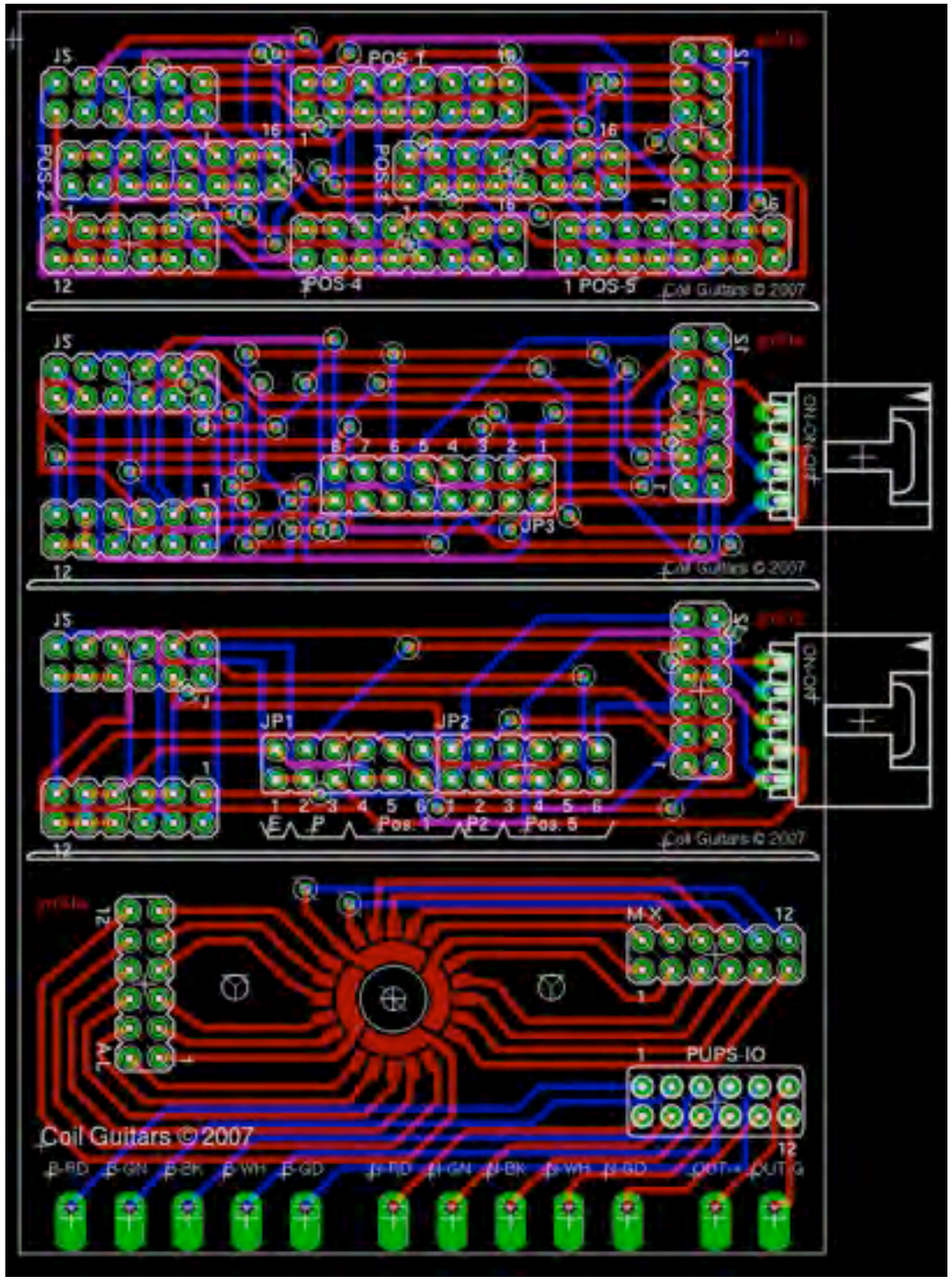
Design Blueprints

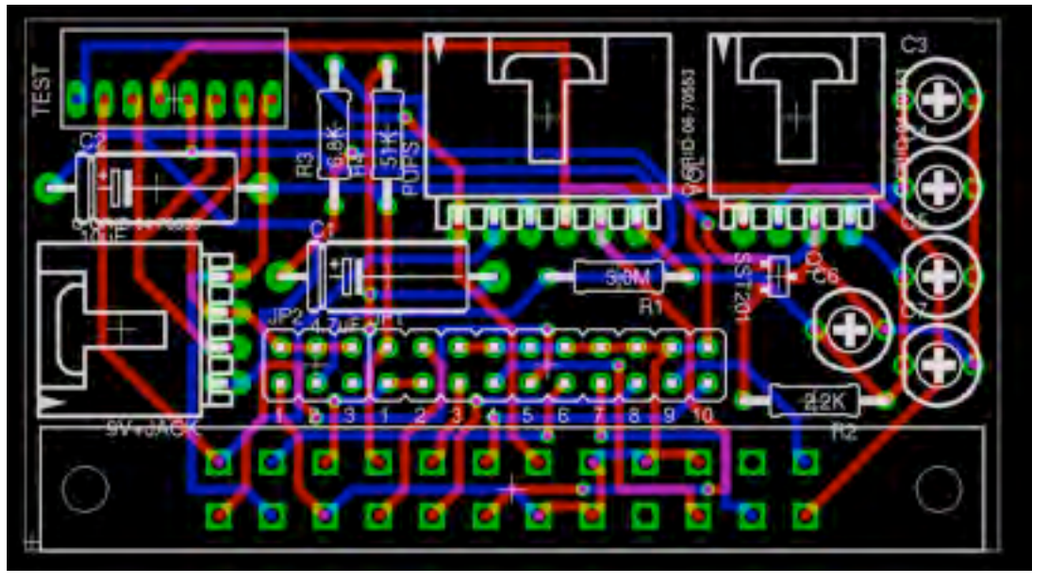
Factories

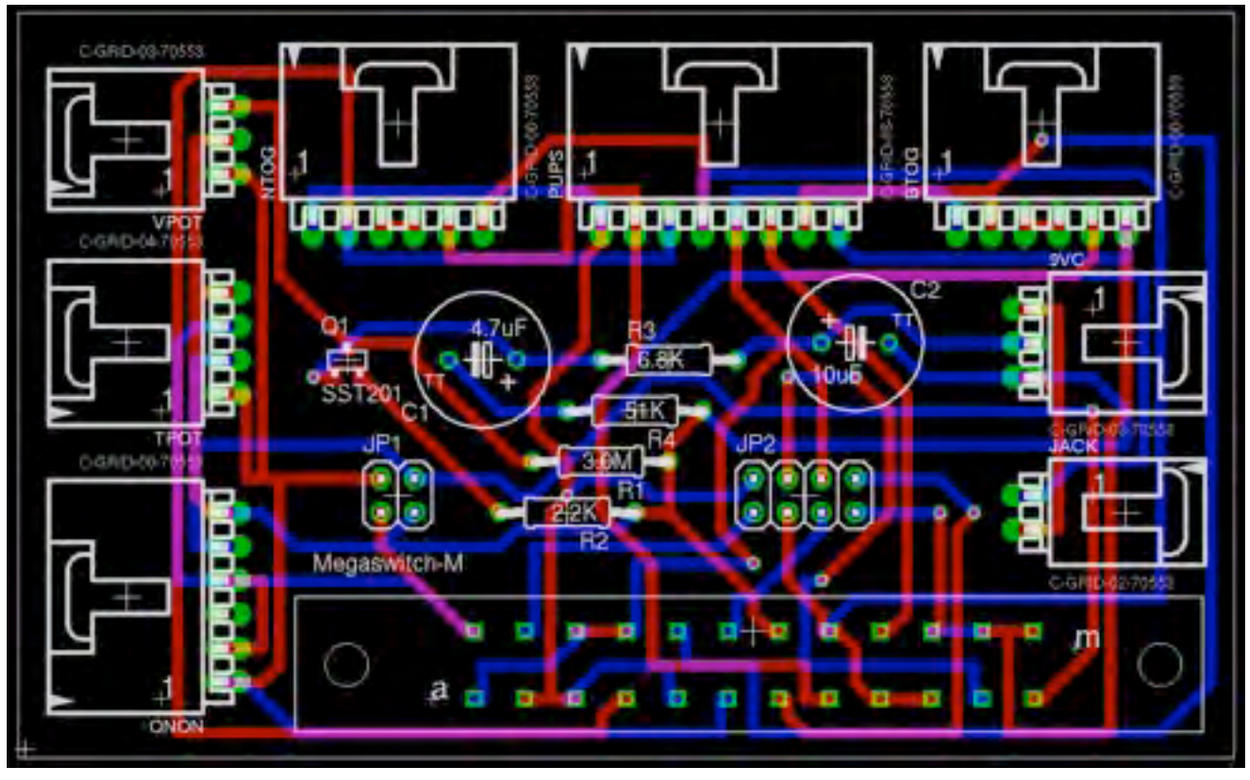
Manufactured Device

Assembly

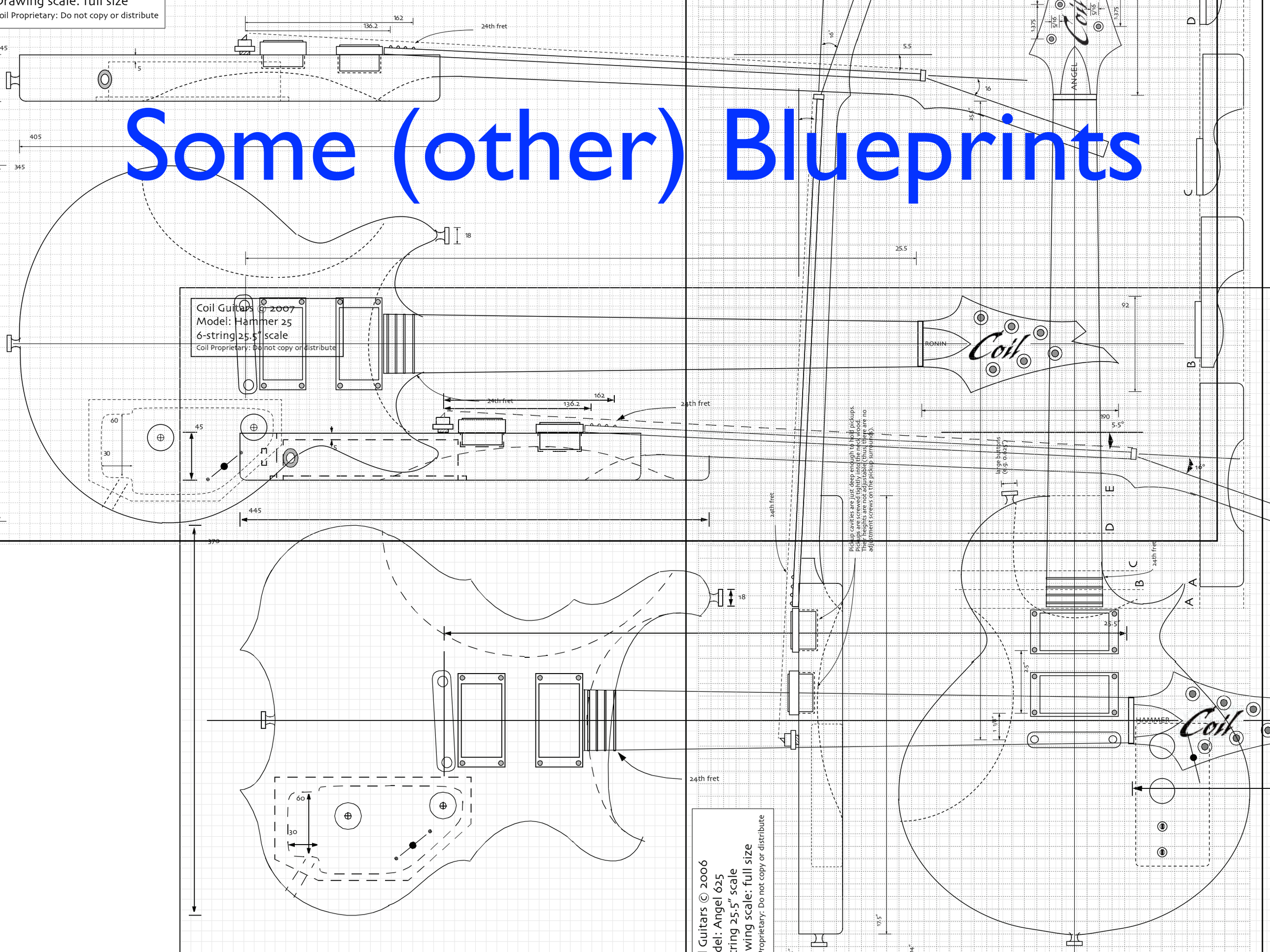
Some Blueprints







Some (other) Blueprints



Pros & Cons

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

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

Bottom line: a path well worth exploring

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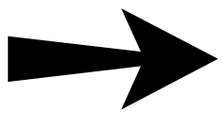

google bruce jacob
(btw, the one on wikipedia is my dad)