

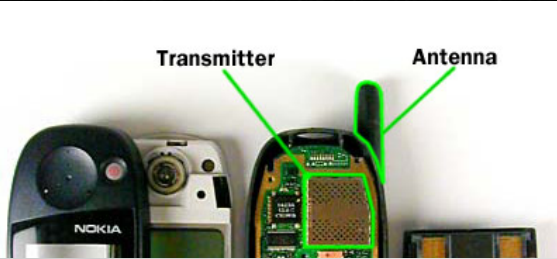
# Embedded and Nonclassical Systems

Prof. Bruce Jacob  
Electrical & Computer Engineering

# Today's Story

- **What are embedded systems?**  
*(more than just processor and/or software)*
- **What is the main problem?**  
*(difficult to verify that they work correctly)*
- **Why has it become a problem?**  
*(now in the era of non-classical systems)*
- **What is/are the solution/s? :)**

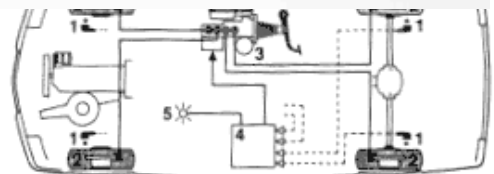


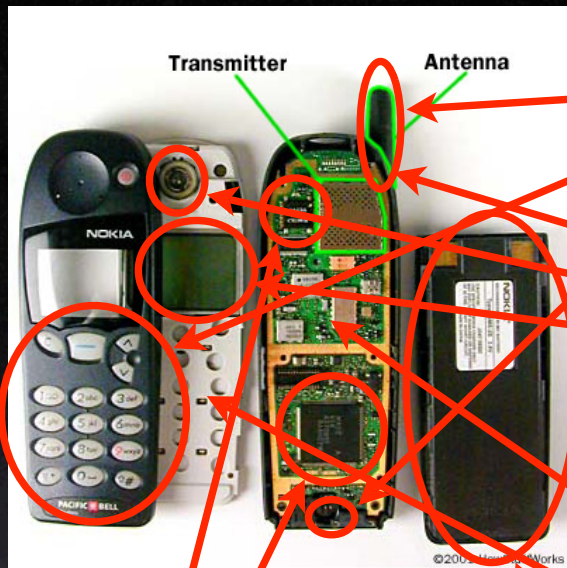


# EMBEDDED SYSTEMS



vacuumator unit with  
aster cylinder  
2U  
arming lamp





Transmitter

Antenna

Sensor/s  
(Multi-Mode)

Actuator/s  
(Multi-Mode)

# A DISSECTION

Microprocessor/s  
and dedicated  
software

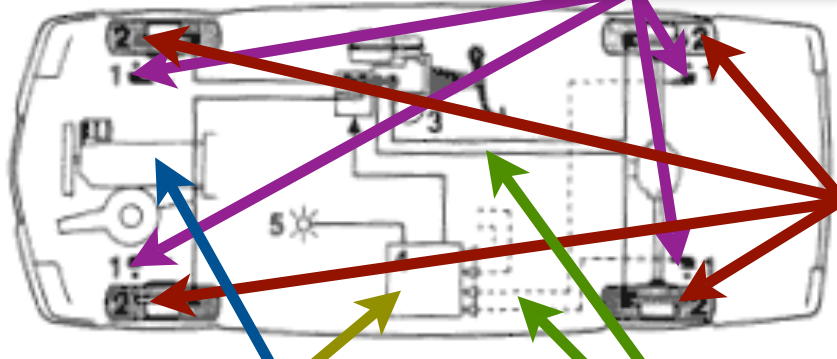
Communication  
Network/s  
(Multi-Mode)

Power Supply  
(Self-Sufficient)



Passenger car with ABS 3

- 1 Wheel-speed sensor
- 2 Wheel-brake cylinder
- 3 Hydraulic pressure modulator unit with master cylinder
- 4 ECU
- 5 Warning lamp



Sensor/s  
(Multi-Mode)

Actuator/s  
(Multi-Mode)

# A DISSECTION

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**



# 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



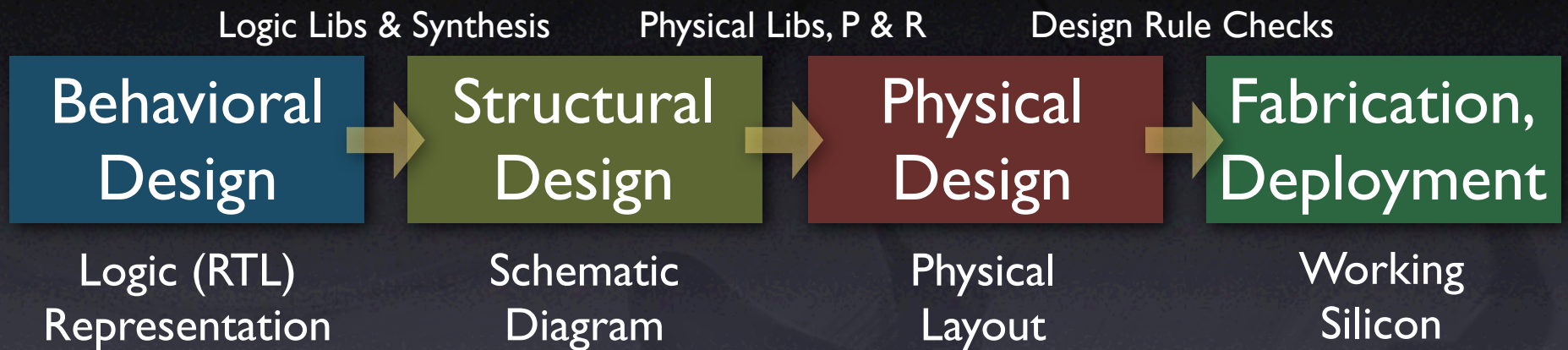


# THE PROBLEM

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

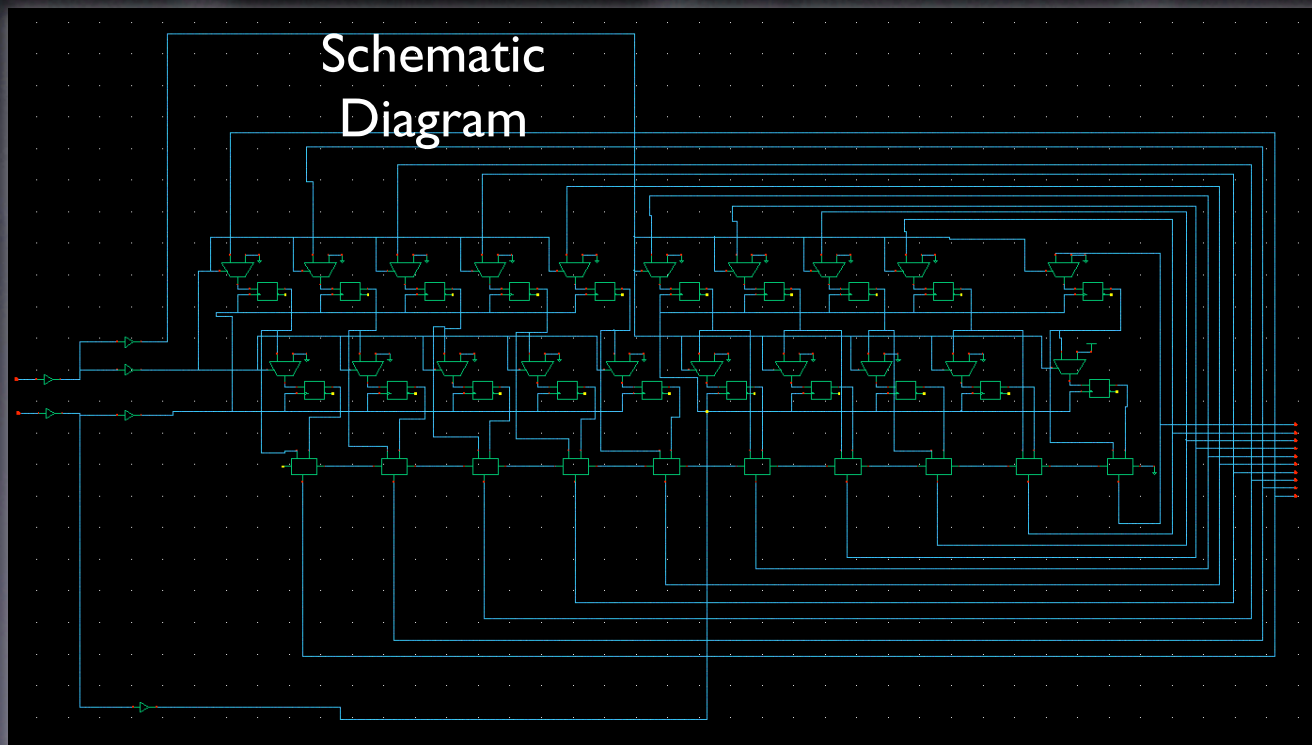
Fabrication,  
Deployment

Logic (RTL)  
Representation

```
module fibonacci(clk2, rst_1, out_w);  
  
input clk2, rst_1;  
output [7:0] out_w;  
  
reg [7:0] src1, out;  
wire [7:0] out_w = out;  
  
always @(posedge clk2)  
begin  
    if(!rst_1)  
    begin  
        src1 <= 1'd0;  
        out <= 1'd1;  
    end  
    else  
    begin  
        src1 <= out_w;  
        out <= src1 + out_w;  
    end  
end  
  
end  
  
endmodule
```



# A Tale of Two Design Flows



# A Tale of Two Design Flows

Logic Libs & Synthesis

Physical Libs, P & R

Design Rule Checks

Behavioral  
Design

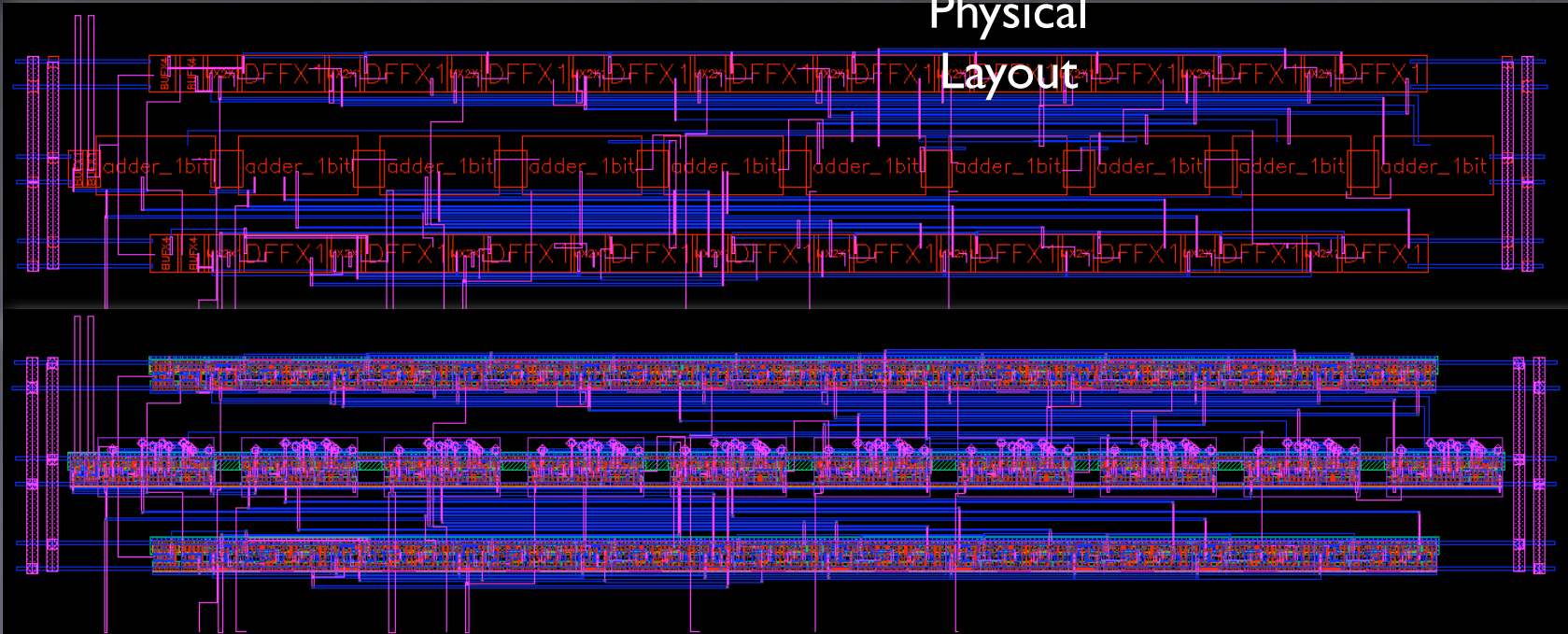
Structural  
Design

Physical  
Design

Fabrication,  
Deployment

Physical

Layout





# A Tale of Two Design Flows

Logic Libs & Synthesis

Physical Libs, P & R

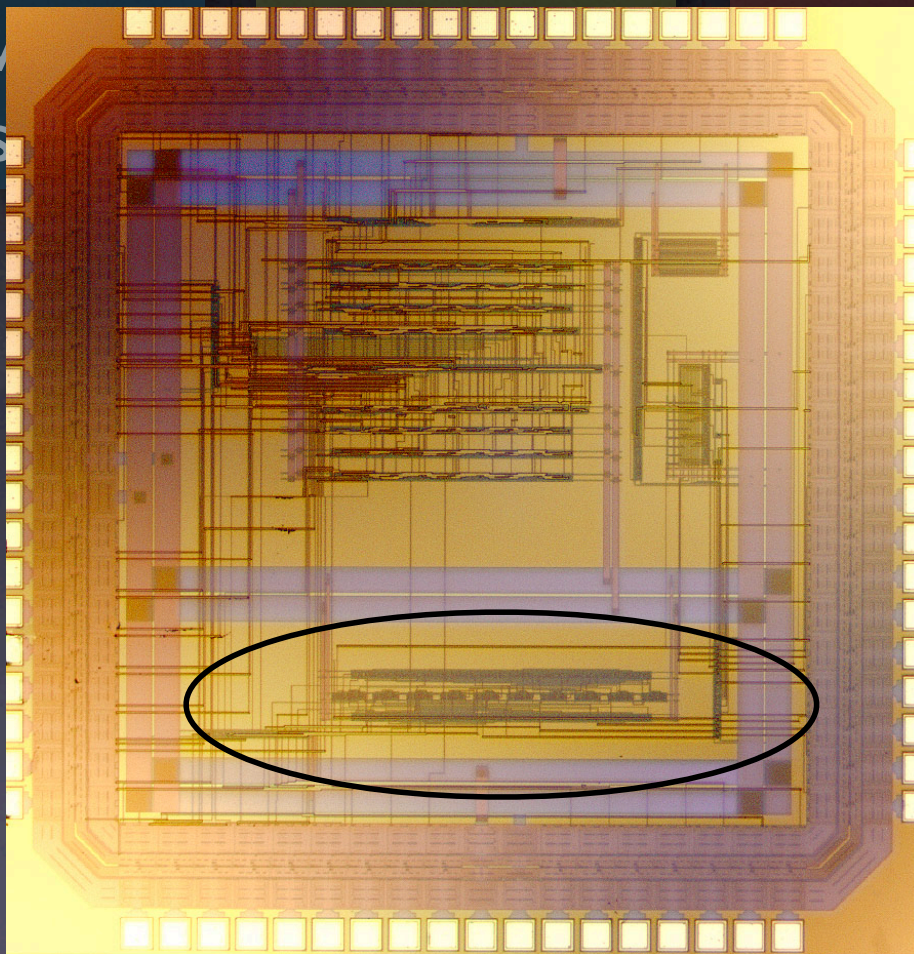
Design Rule Checks

Behavioral  
Design

Physical  
Design

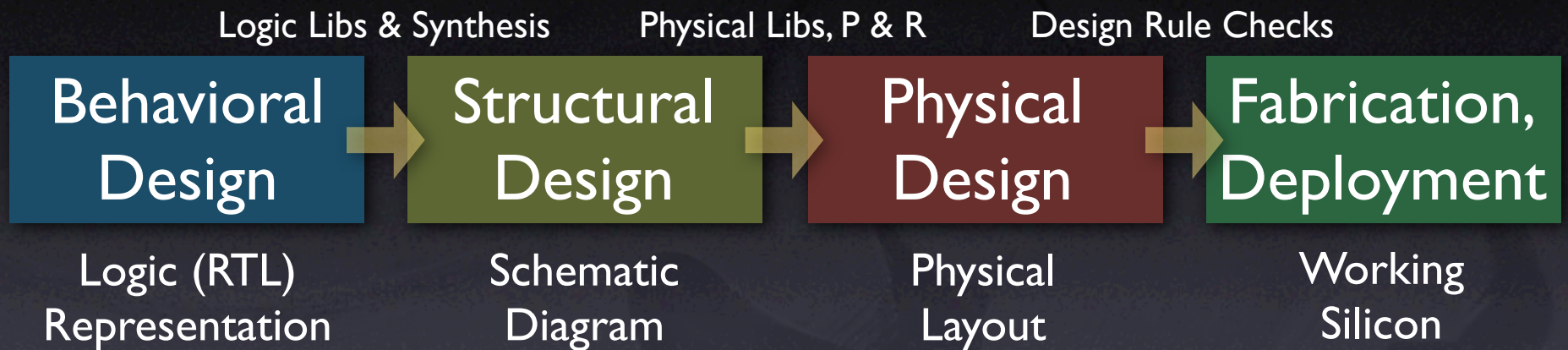
Fabrication,  
Deployment

Working  
Silicon





# A Tale of Two Design Flows



## **VLSI Limitation:**

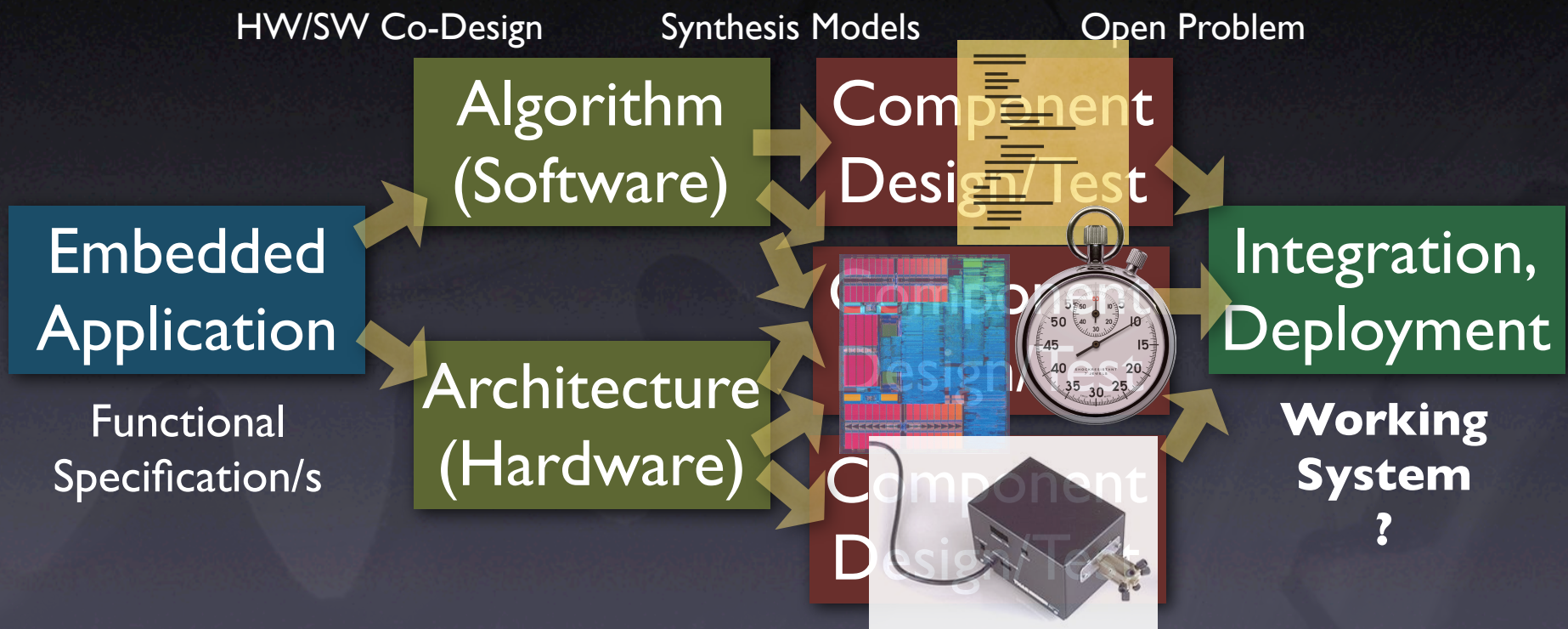
you can build **WIRES** or **TRANSISTORS**

## **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

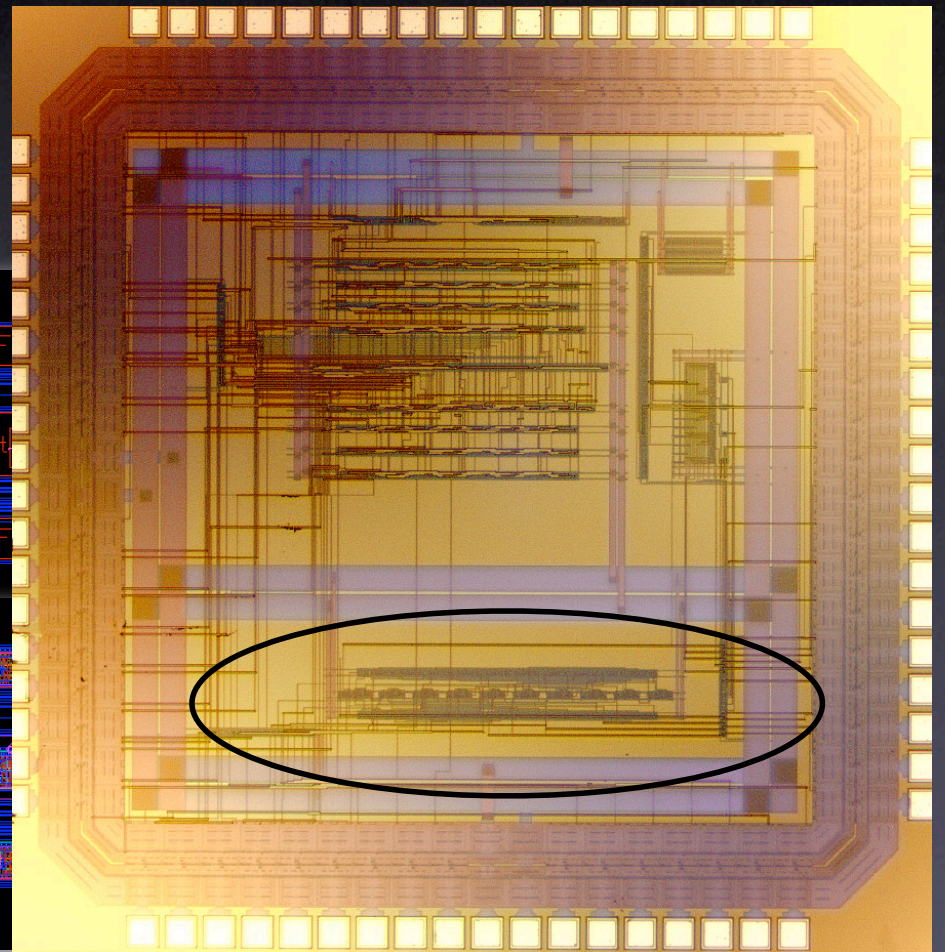
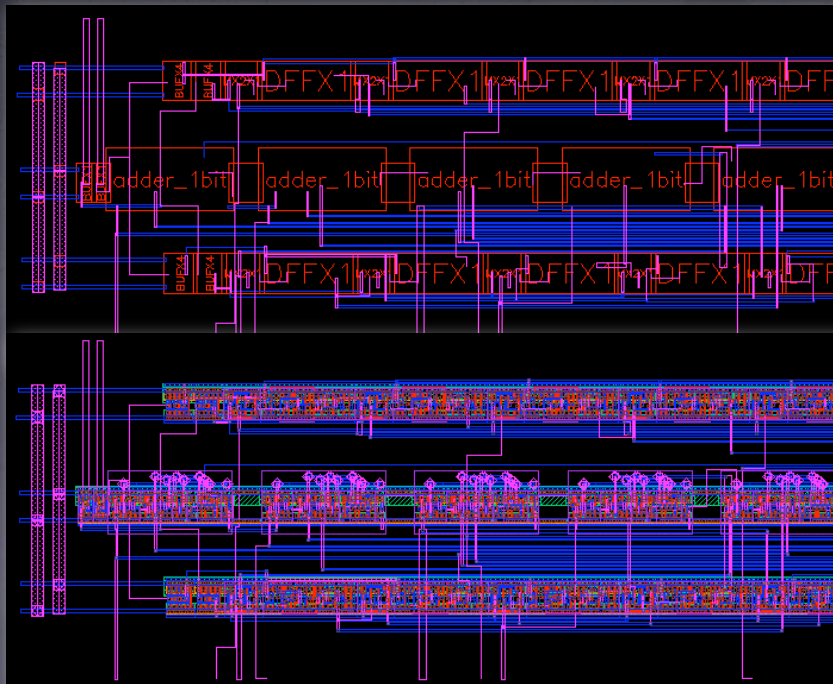


# NON-CLASSICAL SYSTEMS



# Classical Systems

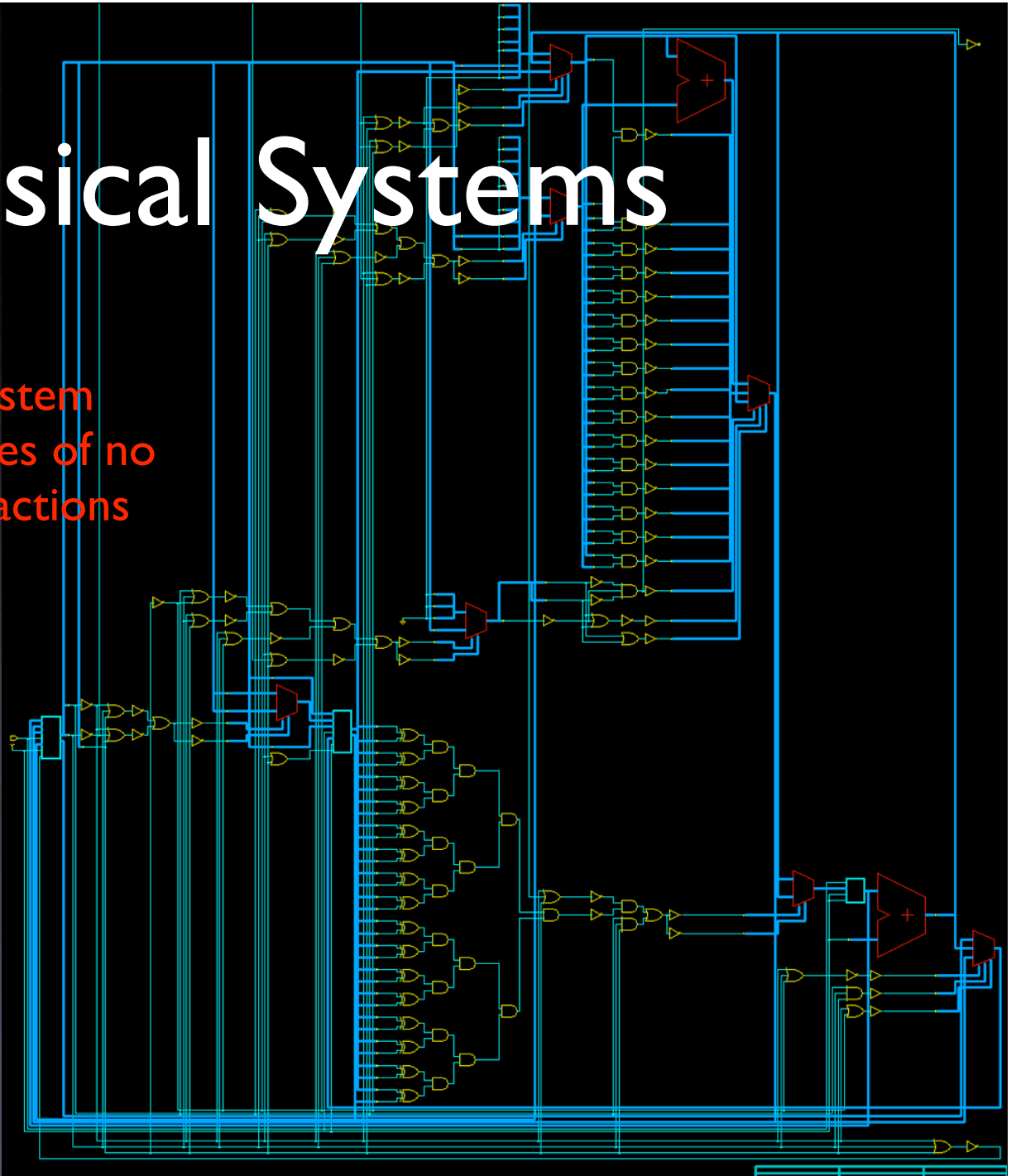
Analysis of this system  
requires guarantees of no  
out-of-band interactions





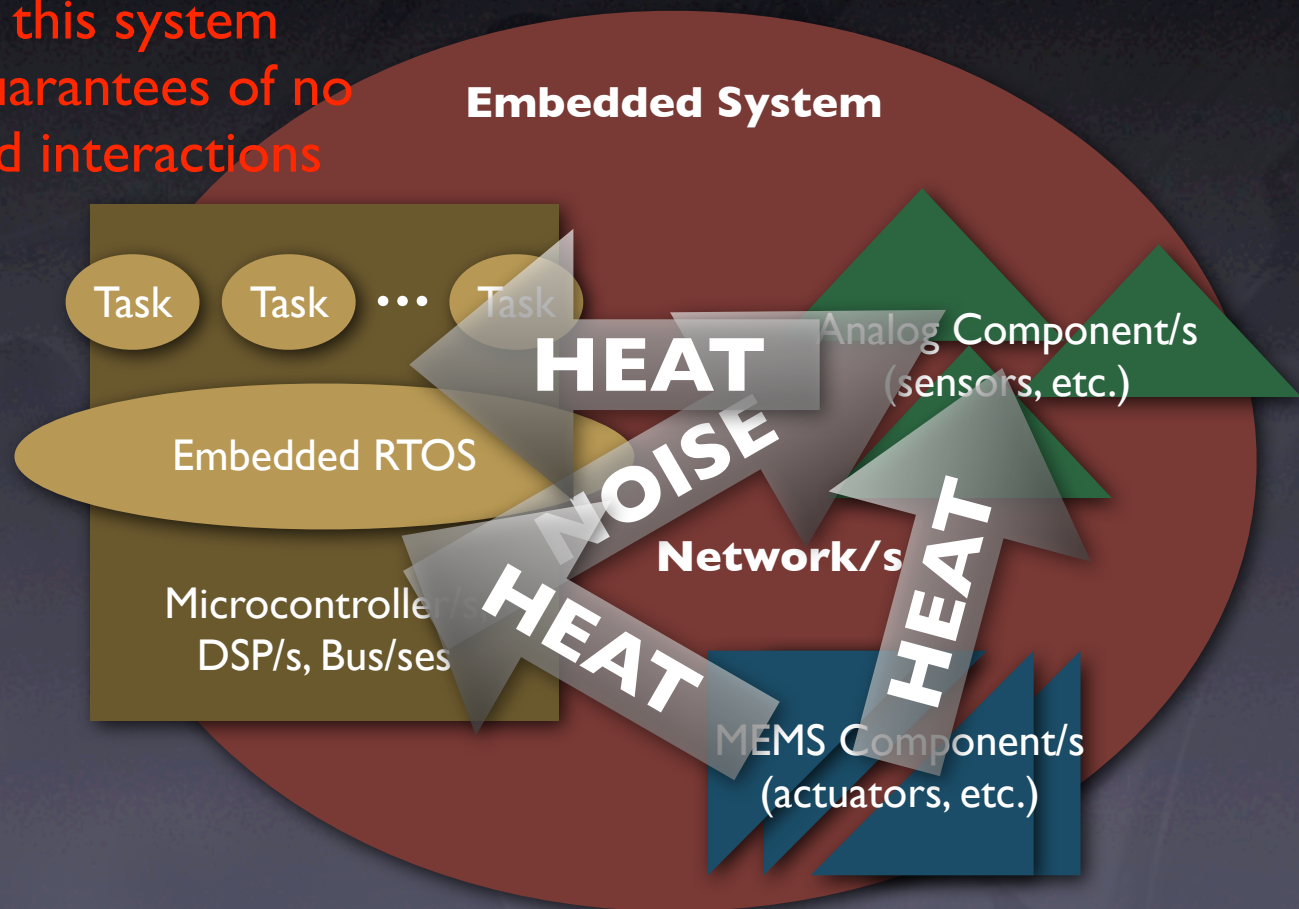
# Classical Systems

Analysis of this system  
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# A Classical System?

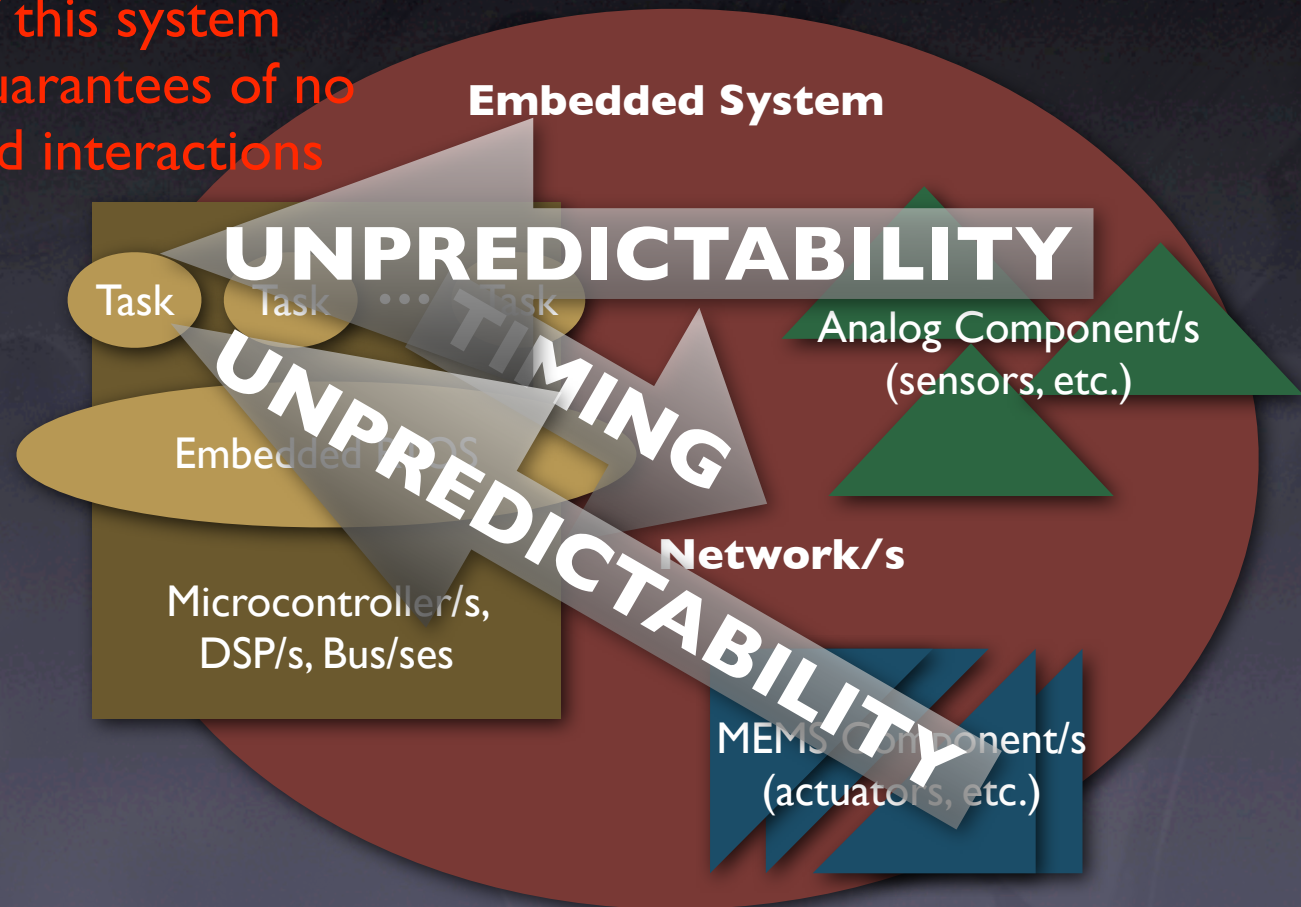
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# A Classical System?

Analysis of this system  
requires guarantees of no  
out-of-band interactions



# THE SOLUTION I





**EXTREMELY  
ACCURATE MODELS**

# Existing: SimBed

- Extremely accurate software model of embedded hardware
- Runs unmodified RTOS and application binaries
- Models performance and energy consumption
- Allows arbitrary probing & debugging of system

Task

Task

Task

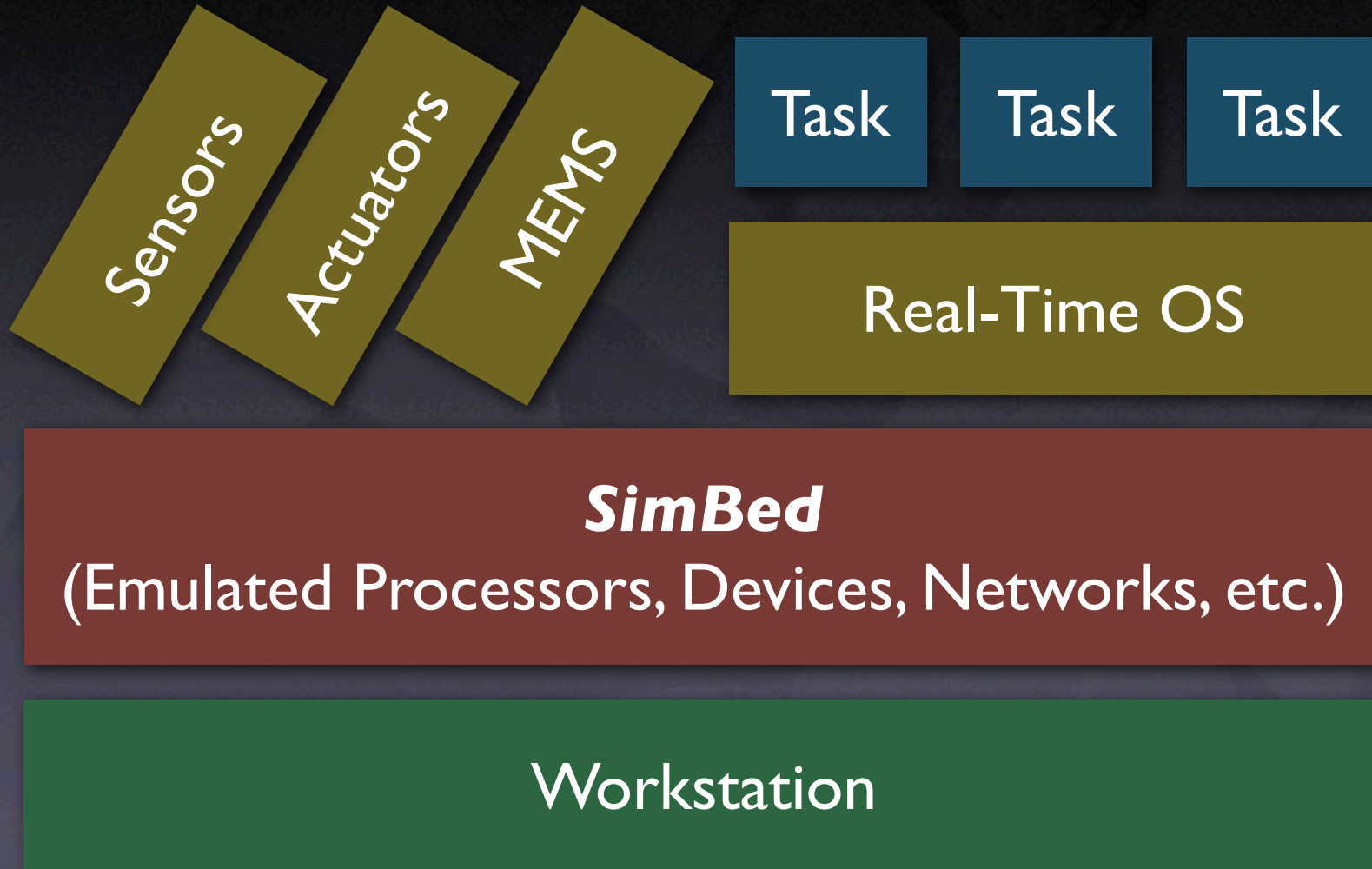
Real-Time OS

***SimBed***  
(Emulated Hardware)

Workstation



# ... Expanded



# But Wait, There's More

## OUT-OF-BAND EFFECTS:

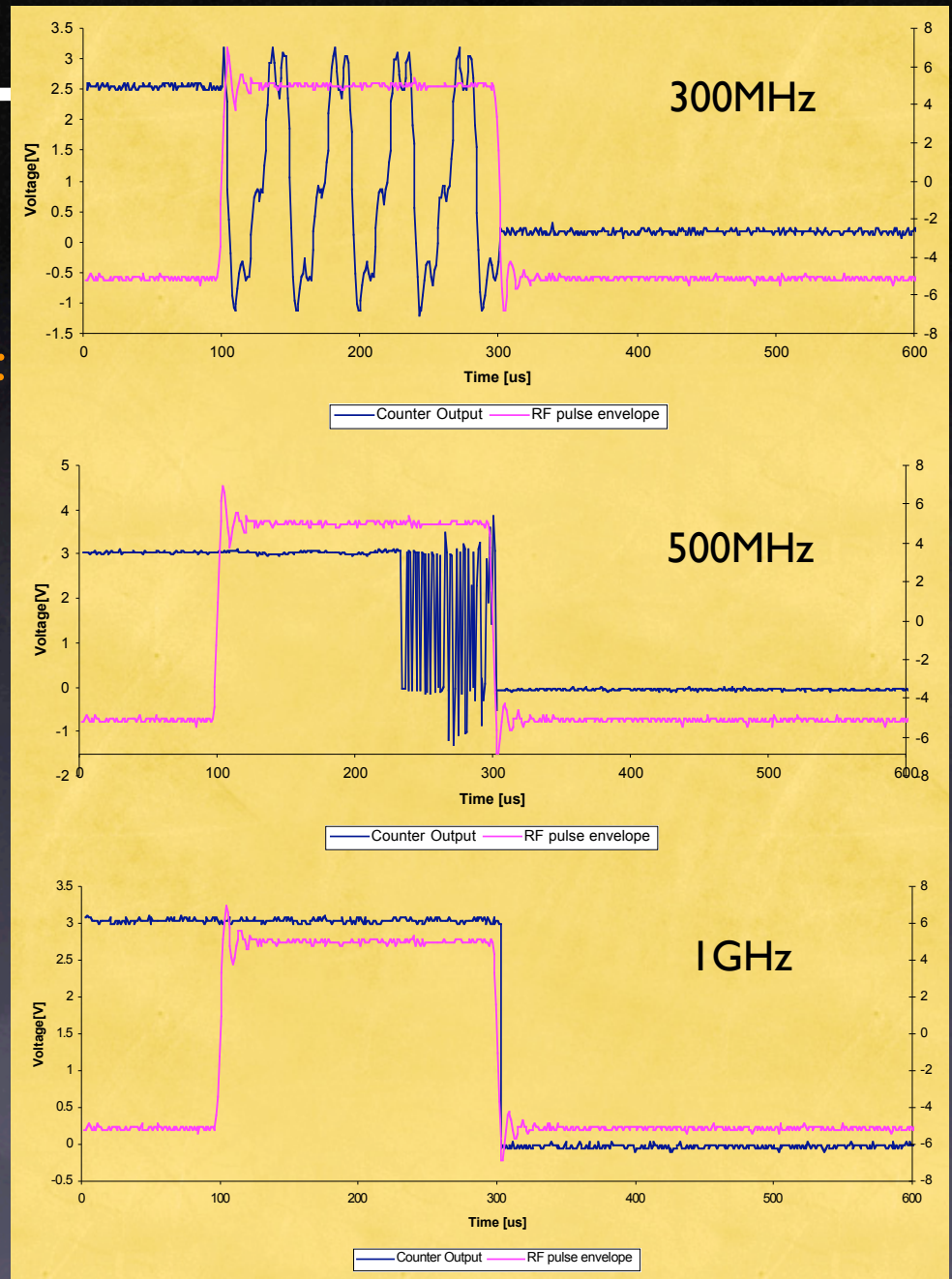
- Electromagnetic Interference
- Thermal Interference
- Mechanical Interference
- etc. . . .



# But Wait, T

## OUT-OF-BAND EFFECTS:

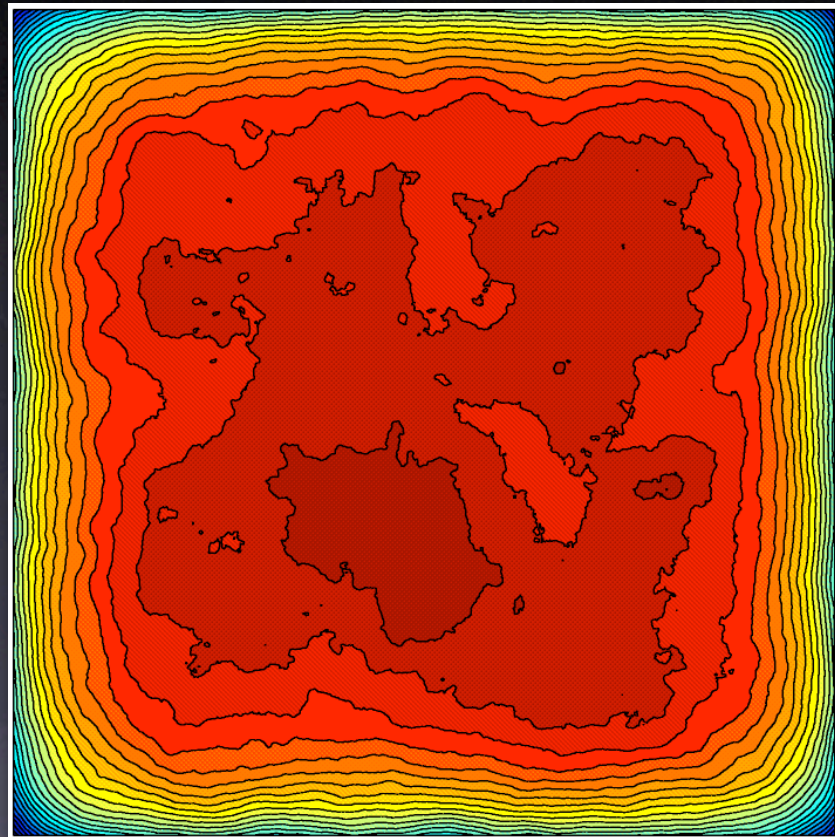
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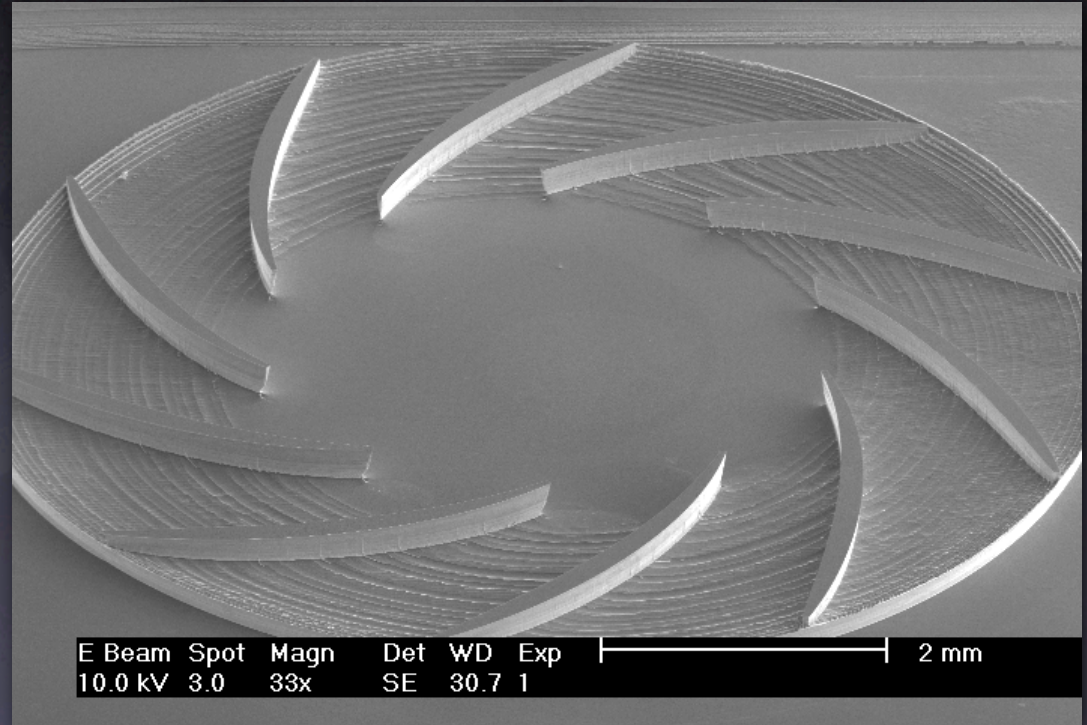
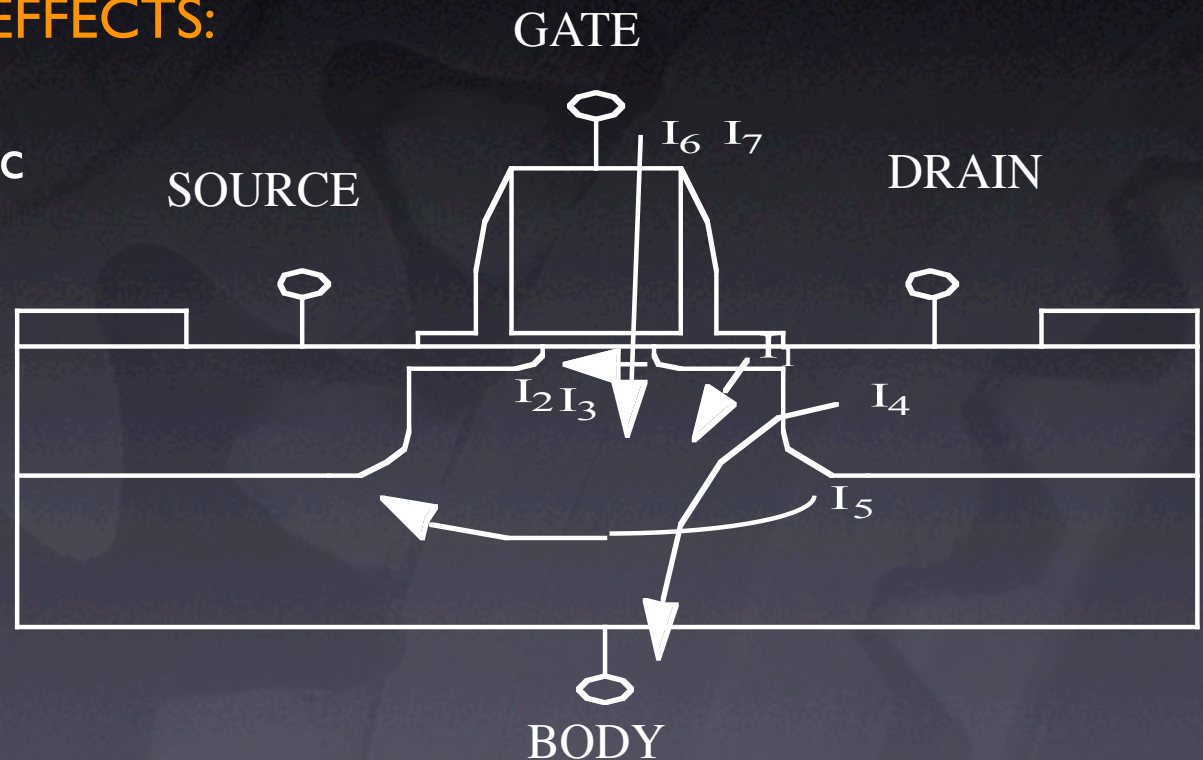


Image: Morgan, Waits, Kastantin and Ghodssi, University of Maryland, Feb. 2003

# But Wait, There's More

## OUT-OF-BAND EFFECTS:

- Electromagnetic Interference
- Thermal Interference
- Mechanical Interference
- etc. ...



**Device Physics?**



# 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

# What is Required?

- *(most importantly)* Foresee all possibilities

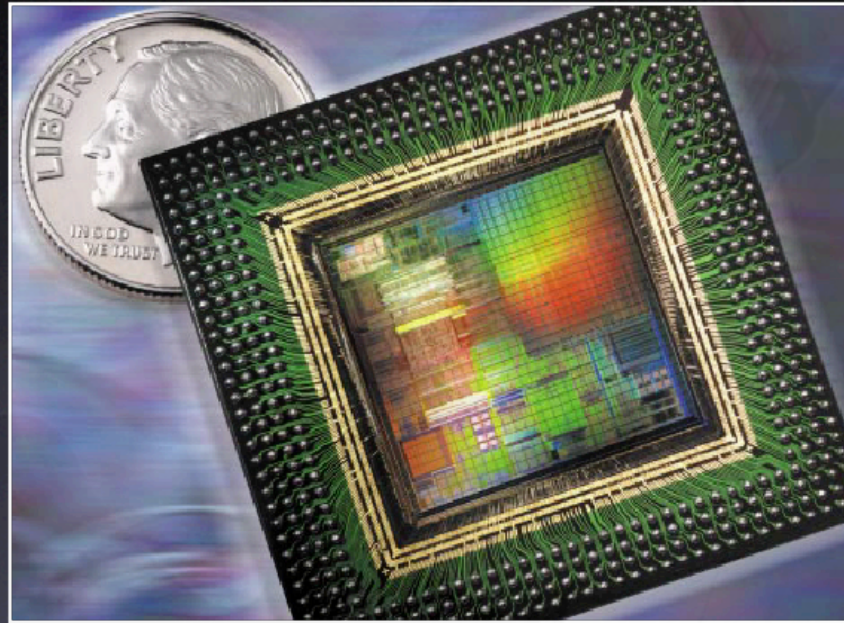


THE SOLUTION

II

Come up with a totally  
new understanding





<http://www.ece.umd.edu/~blj/embedded>