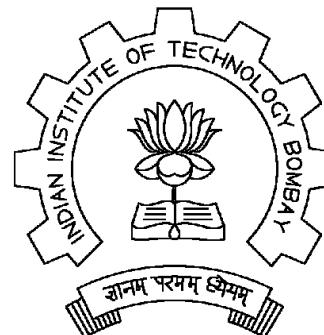


Embedded Systems (Software)

*Prof. Kavi Arya
Prof. Paritosh Pandya*

<https://cse-erts.github.io/cs684/>



Beware of the computer!



- From computers to **embedded & networked SoCs ... IoT**
- Complete change in device interaction
- Growing number of **critical applications**

Purpose of CS684 course



- **Create “fearless” engineers**
Willing to chase a problem wherever it goes
- **Solve societal problems**
Using technology
- **Learn System Design**
Model-based Design
Hardware/software co-design
State-of-the-art tools

FUTURE TRENDS:

Future of Work

- **Low-skill jobs being taken over by machines**
 - Manufacturing, software development, media, TV anchors,
...
- **High-skill jobs are also threatened**
 - Sales & marketing, para-legal work, software, education

AI is Disrupting Jobs

(ChatGPT AND GENERATIVE AI)

- **Glorious “search engine?”**
 - Based on training with large amounts of data
- **New skillsets demanded?**
 - Now: Prompt engg. (how to ask ChatGPT for a solution?)
 - Future: Problem articulation! System will solve!
 - Future opportunities are in creation of new knowledge
 - Original work (ie. solve problems not solved before)

WHAT WE NEED?

- **Engage with life:**
 - In entrepreneurial manner
 - Create new products, services, IP
 - Create startups to fulfil unmet market needs
- **Opportunities:**
 - MSME; Healthcare; Tourism; Agriculture; Transport; ...
- **Useful knowledge:**
 - Technology gives edge in market (Embedded Systems..)
 - Other skills: Critical thinking; Design; Finance; ...

Computing Trends:

Computing without Computers

(or, the changing nature of computers
or, where/what is hardware?)

Computing without Computers*

- **Change: How we design/ deliver compute power**
 - Reconfigurable computing and custom computing
 - i.e. sw → hw => speed up (no single processor to slow us)
 - Multi-core chips
 - **Low-cost printed circuits on flexible substrate**
e.g. Pragmatic IC (UK), etc.
- **Today: Computer chips surrounded by cores**
 - Graphics processing, AI/ML, display handling, network interfacing, audio, wireless comm., etc.
 - Supported by a range of functions embedded in hardware

Changes Happening



- **New ways of designing/delivering computer capability**
 - PCs -> mobile phones -> AR/VR goggles
- **Changing structure of electronics & computing industry**
 - Largest manufacturer of cameras?
- **Products we buy as well & how we buy & use them**
 - Tape-recorder -> Walkman -> digital players -> iPod -> iTunes...
 - Books -> ebooks -> audible.com ...
 - Compute: Mainframe -> minicomps -> PC->servers-> cloud -> SAAS
- **Changing how money is made from delivering value**
 - Products changing into services
 - Money: UPI stack (India), Crypto, ...
 - Potentially deep & far-ranging effects of energy use & sustainability

Tech & economic drivers of change

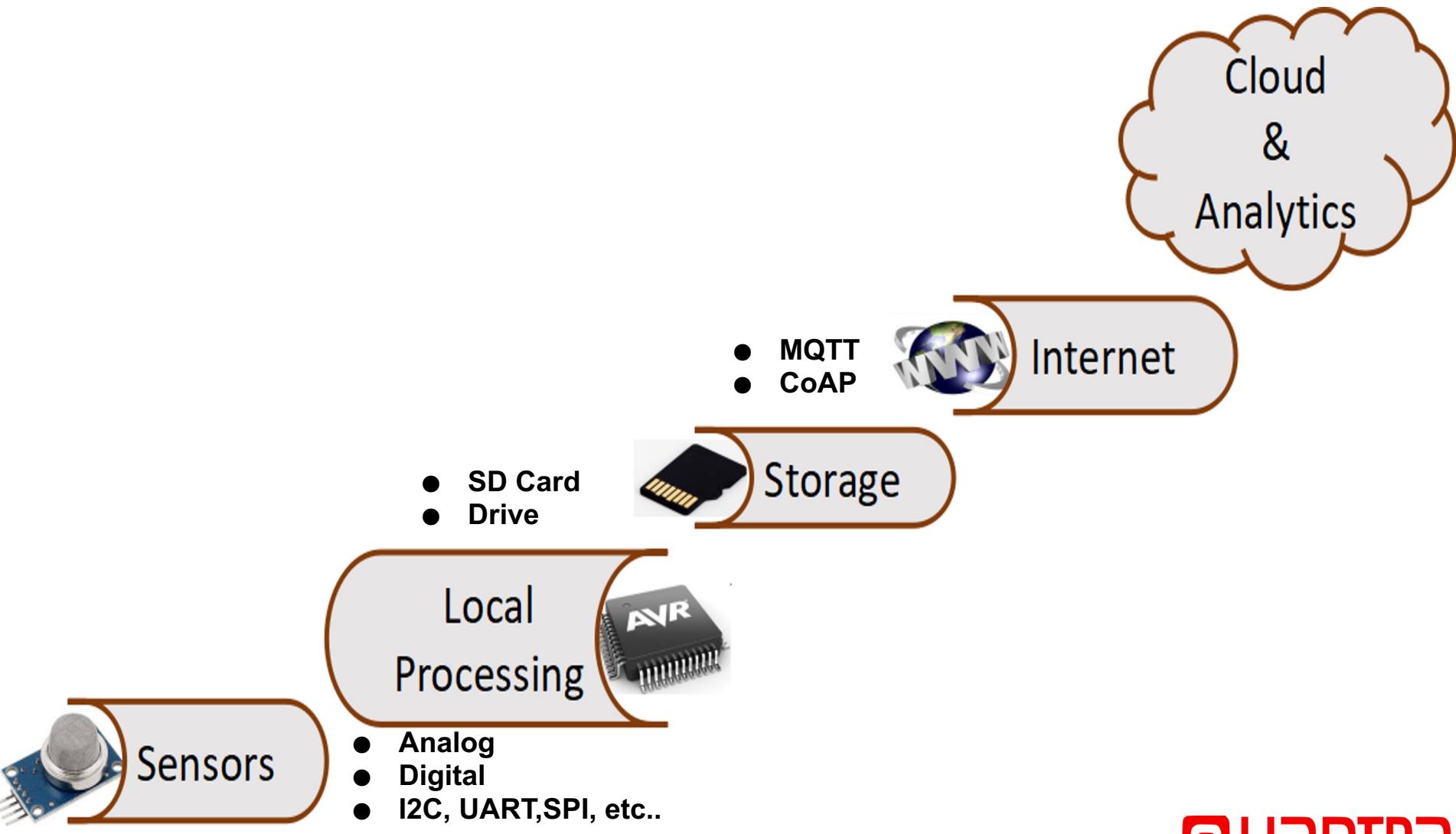
- **Nature of silicon industry**
 - Extraordinary consequences of Moore's Law.
- **Focus moving away from ASIC (appn sp. chip)**
 - Towards std chip products => lower prototype costs
- **Big winner: reconfigurable hardware**
 - In particular FPGA chips
 - reduce \$6M devp cost of new chip to a few \$ + days
- **More exciting is low cost “printable” ICs**
 - Pragmatic Semiconductors (UK), ...

Pragmatic Semiconductors (UK)

- Unique IC platform that doesn't rely on silicon
 - Ultra-thin, ultra-low-cost, flexible ICs
 - Thin-film semiconductors for flexible ICs “thinner than human hair”
- Cost:
 - Cheaper and faster to produce than silicon chips
- Ubiquitous:
 - Embed into anything => connectivity and intelligence
- Market
 - F&B, personal & home care, pharma/ healthcare, toys and games, ... supply chain traceability, authentication, smart shelves & customer engagement, ...
- New development paradigms:
 - Open-Source toolchains rapidly & cheaply prototype new ICs
=> Low-cost embedded systems for pennies

Internet of Things (IoT)

What is Internet of Things (IoT)?



The Shape of Things to Come... IoT



TESLA'S OVER-THE-AIR FIX: BEST EXAMPLE YET OF THE INTERNET OF THINGS?

WIRED



Image: jurvetson/Flickr

<http://bgr.com/2016/01/09/tesla-model-s-software-update-7-1-summon/>



Image Source: Green Car Reports

Tesla earlier today began pushing out version 7.1 of its software to Model S and Model X owners and, suffice it to say, it's a doozy of a software update.

While we'll get to the full changelog shortly, we first wanted to highlight a feature called *Summon* which enables users to park their cars without having to be inside it. Conversely, it also lets [Tesla](#) owners summon their cars that already happen to be parked.

Tesla Model S' new 'Summon' feature lets drivers park and retrieve their cars with no one inside

Tesla's Betting You'll Pay \$9,000 for a Software Upgrade

By David Ingold

June 10, 2016



On Thursday, Tesla Motors re-introduced the Model S60—a cheaper version of its all-electric sedan that was discontinued last April. The new S60 starts at \$66,000 and has a range of about 208 miles.

Tesla Autopilot Drives Owner to Hospital During Pulmonary Embolism

by David Z. Morris @davidzmorris AUGUST 6, 2016, 2:16 PM EDT



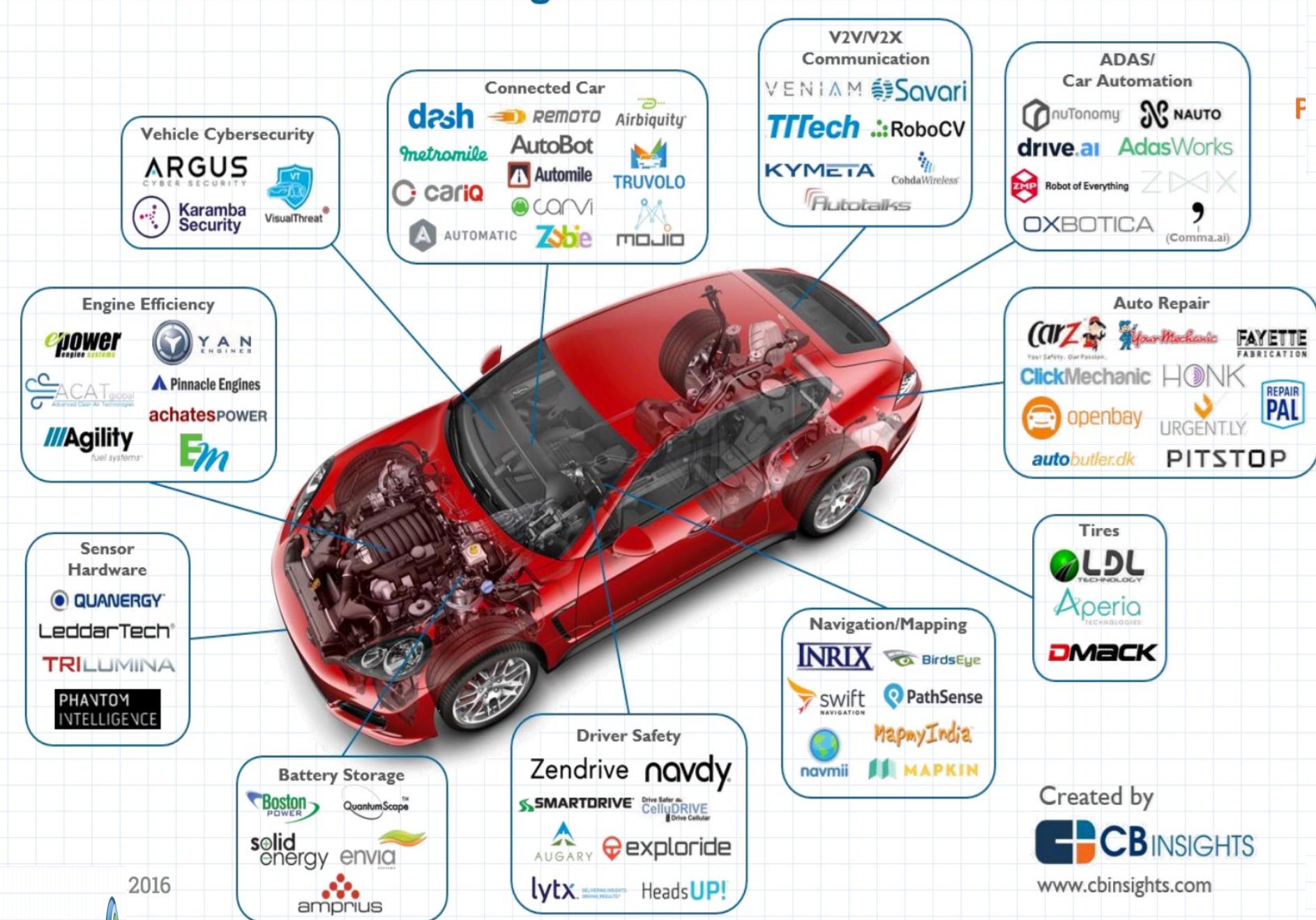
<http://fortune.com/2016/08/06/tesla-autopilot-hospital-rescue/>

A Model X navigated 20 miles of highway as its driver hovered near death.

Slate tells the harrowing story of Joshua Neally, a 37-year-old attorney in Springfield, Missouri who claims that his Tesla Model X's autopilot feature saved his life. Neally was driving home in late July when he suddenly felt something like "a steel pole through my chest."

Neally was in gathering highway traffic as the pain mounted rapidly. In the moment, Neally tells *Slate* he calculated he could reach the hospital faster by Autopilot than if he had stopped and called an ambulance. So he let his Model X take over for more than 20 miles, until reaching an off-ramp near a hospital in Branson. Neally steered the car the final stretch himself, and made his way

Unbundling The Automobile



Soon there will be no maids!! Then What?



IoT & Analytics fueled by Technology Advancements

Cost of compute:

Reduced cost of compute driven by Moore's Law supports explosion of sensors and devices

Cloud infrastructure:

Scalable, reliable and services-based infrastructure lowers cost for companies of all sizes

Mega-trends support massive opportunity in the “Internet of Things”

Ubiquitous connectivity:

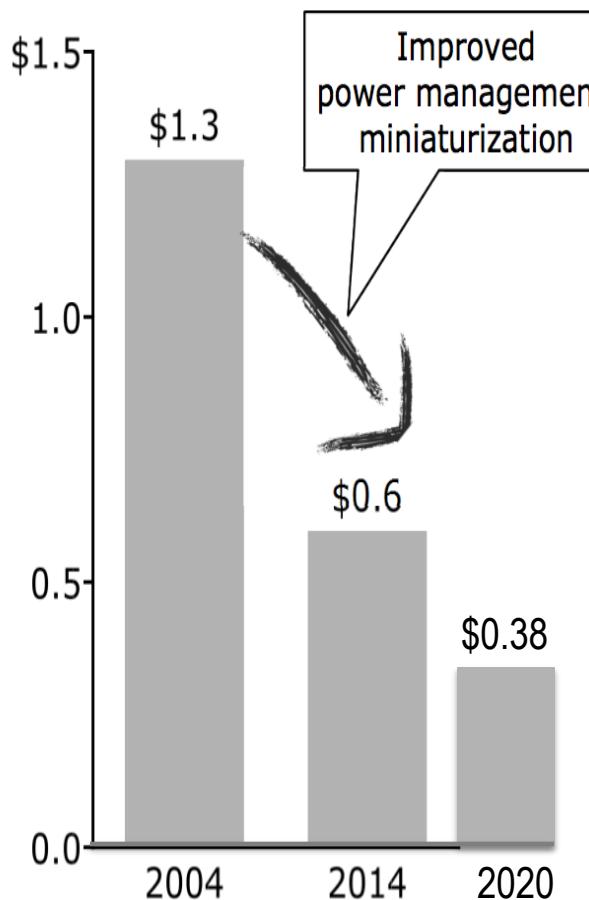
Low cost connectivity and bandwidth across the globe

Advanced analytics:

Emergence of new analytics methods strengthens ability to extract insight from data (machine learning, artificial intelligence, unstructured processing)

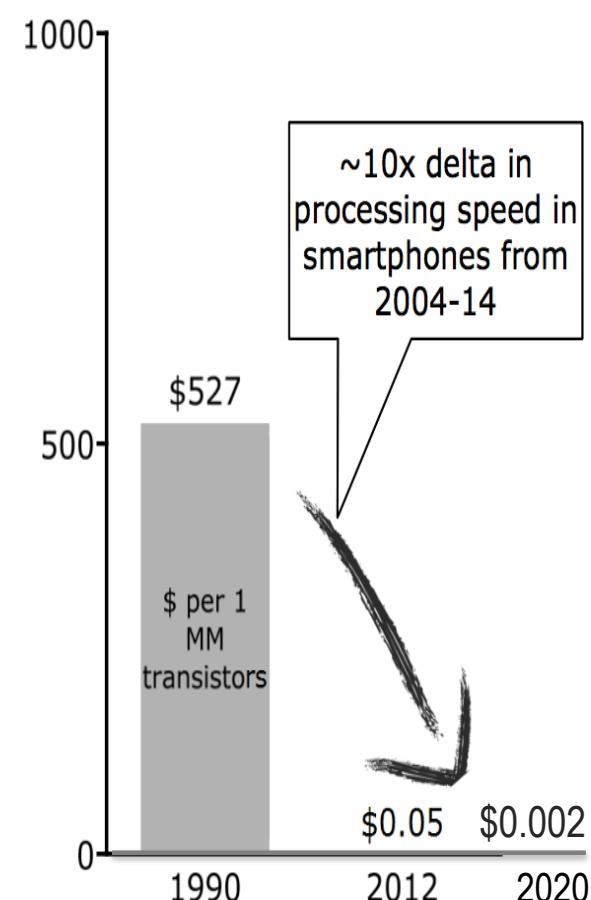
SENSOR PROLIFERATION

Sensor average sales price



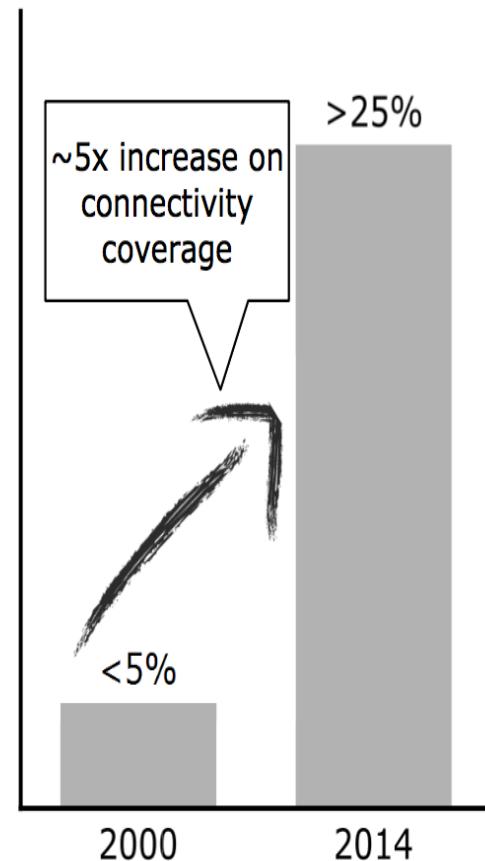
REDUCED COST AND BETTER PROCESSING

\$ per 1 million transistors



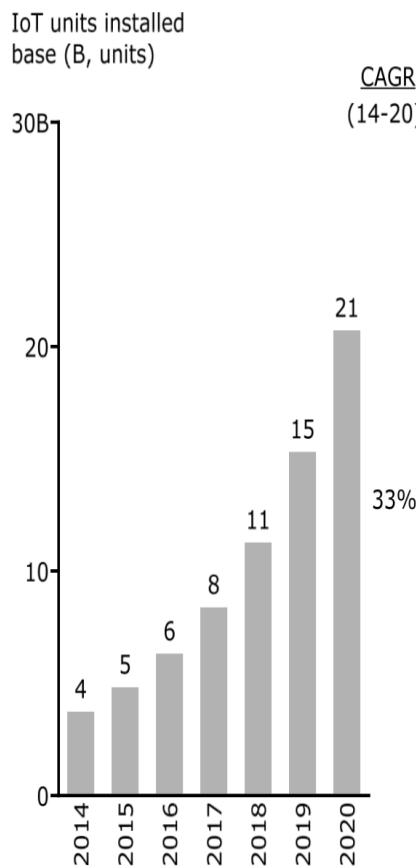
UBIQUITOUS CONNECTIVITY

GSM coverage (% of global)

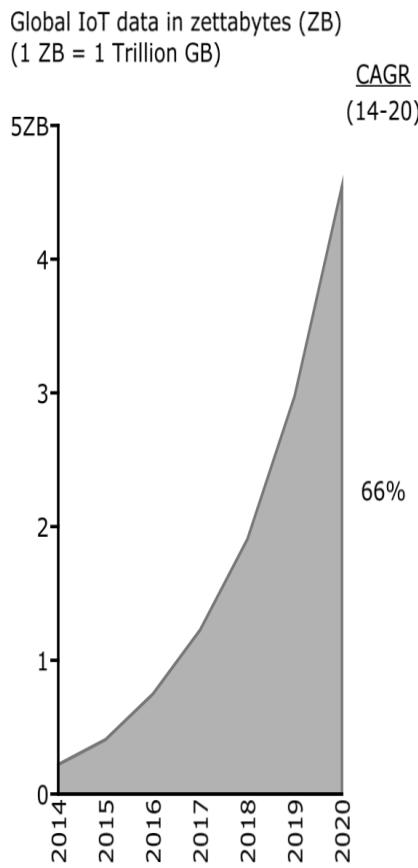


IOT/Analytics => massive amounts of data /traffic

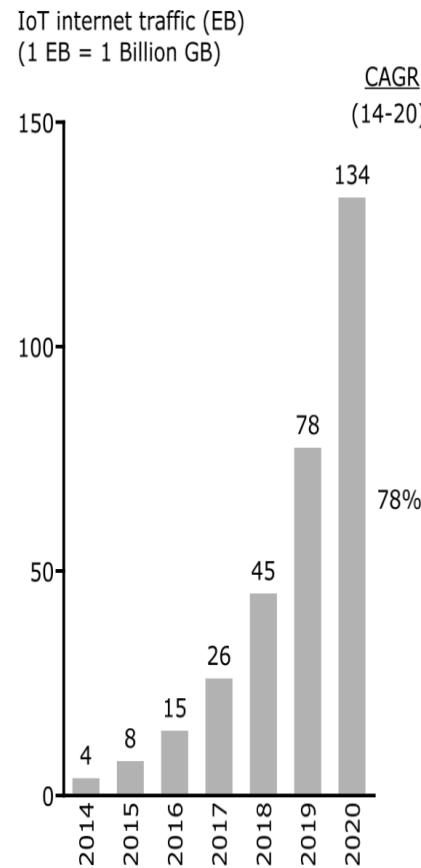
**~20B IOT ENABLED
DEVICES...**



**...CREATING ~5ZB OF
DATA...**

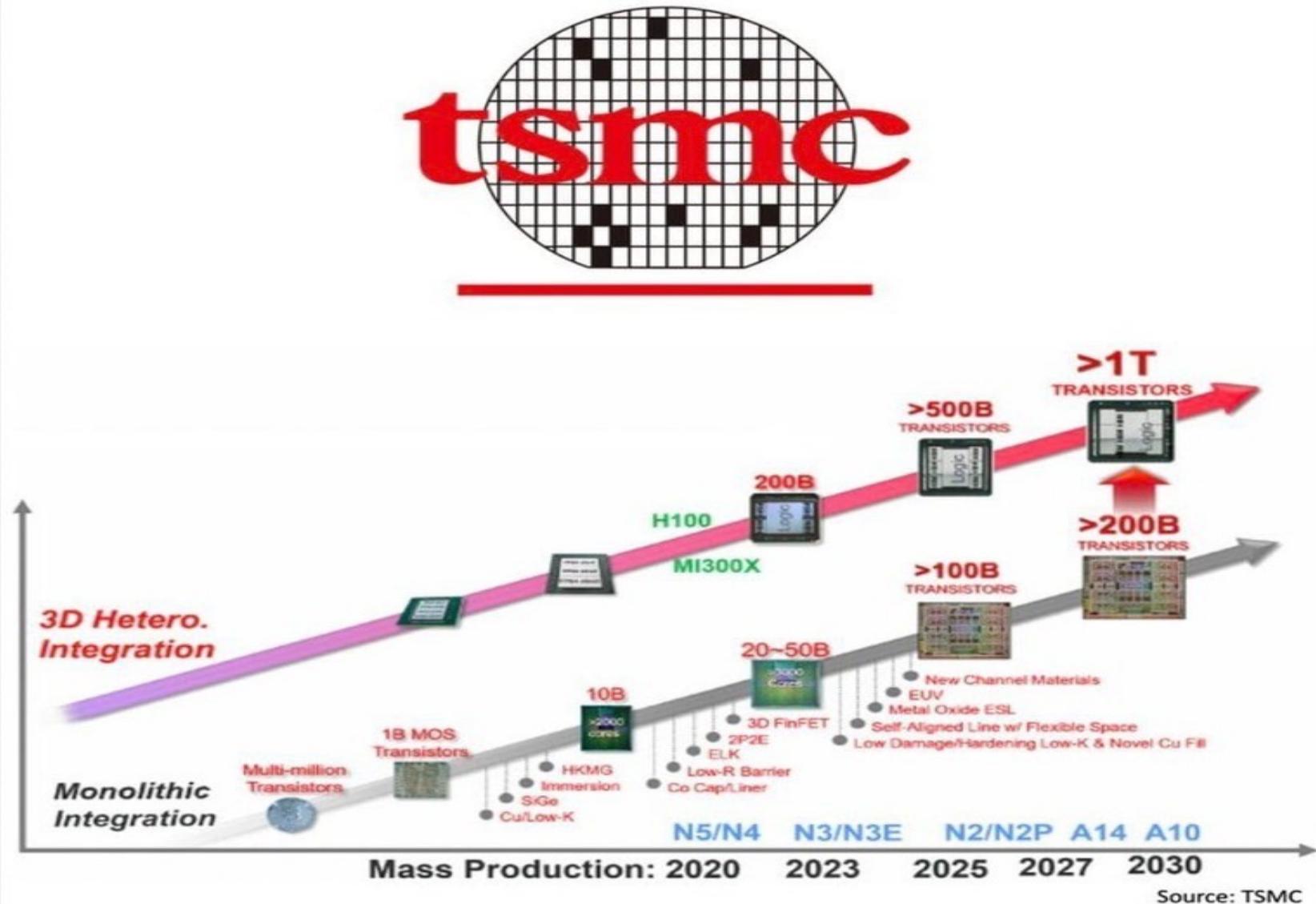


**... AND ~134 EB OF
INTERNET TRAFFIC**



1 ZB =
 10^9 TB

TSMC Says It Expects to Produce **1nm** Transistors by 2030 and expects to have **1 trillion transistors** on a single package by then as well



Relevant across all Industry Segments

- **Personal (devices worn by consumers)**
 - Use cases: Wellness/ fitness monitoring, smart baby monitor, etc.
- **Home (devices in homes)**
 - Use cases: Home automation, energy mngmt, connected security, etc.
- **Automotive (In cars/ light trucks interacting w/consumers)**
 - Use cases: In-vehicle infotainment (IVI), Advanced Driver Assistance Systems (ADAS), remote access, telematics, etc.
- **Healthcare**
 - Systems/ devices for patient, provider, payer value chain
 - Use cases: Trial monitoring, personalized medicine, etc.
- **Building, Retail, Infrastructure, ...**
- **Smarts: building, agri, healthcare, logistics, ...**

IOT for cost savings + revenue generation

- Increase **reliability** of operations
- Increase **QoS** or product
- Increase **asset productivity**
- Increase **workforce productivity**
- Increase **customer satisfaction** to reduce costs
- Improve **time to market**
- **Reduce waste/cost of materials**
- **New insights...**

IOT Issues

- **Cost & complexity:**
 - “Smart” lamps, thermostats, bulbs, ...
- **Environmental Cost:**
 - e-Waste, batteries, products with limited lifespan,...
- **CyberSecurity:**
 - Fails due to shoddy engineering
 - Tesla-S buffer overflow; Amazon Ring camera
- **Privacy:**
 - “Free” => usage data being monetized
- **Battery life:**
 - Wireless communication is very expensive!
- **Network:**
 - COTS internet-enabled solns use 3G/4G/5G, WiFi, BLE
 - Except for BLE, unacceptably power hungry at the edge

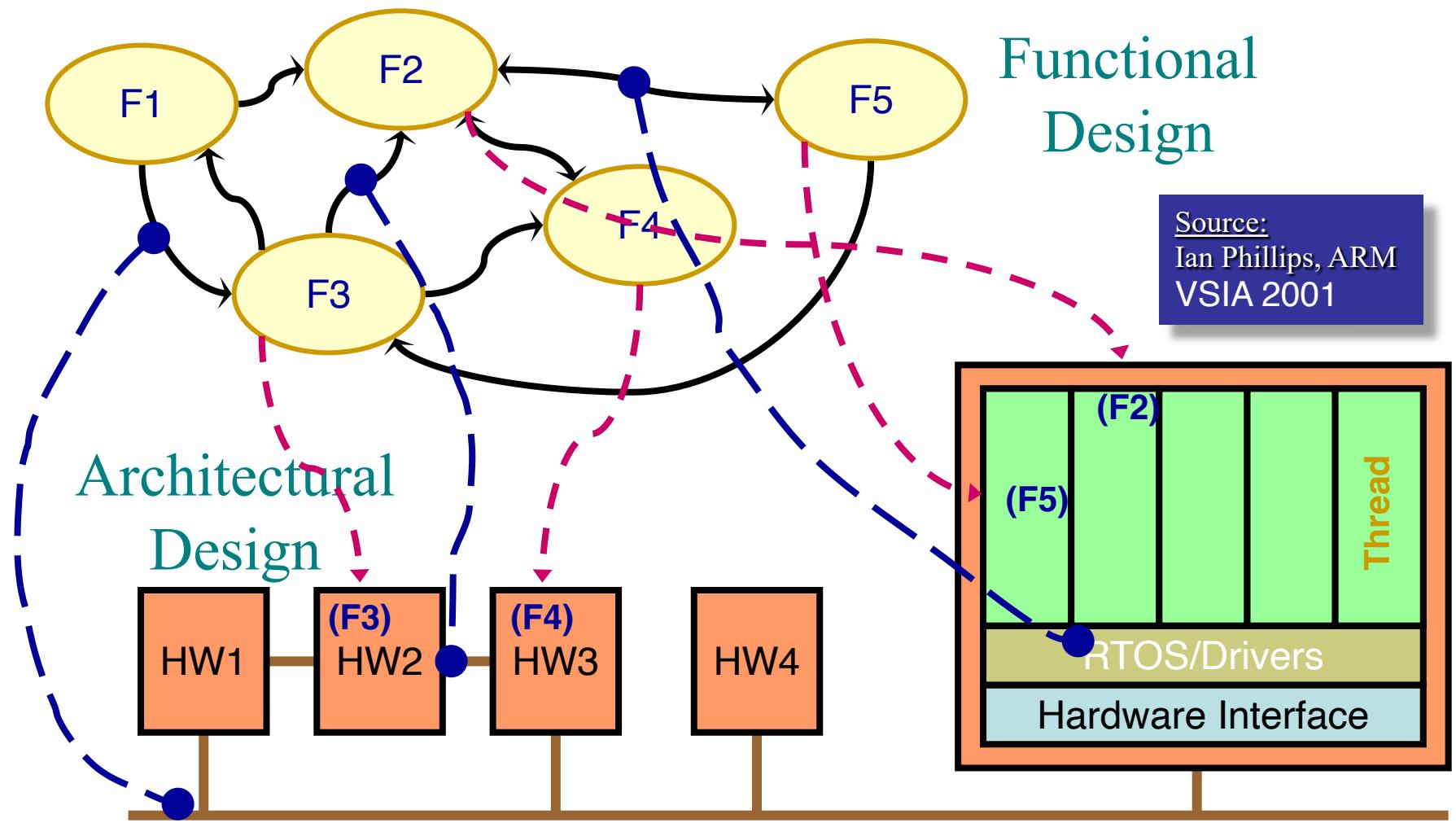
IoT brings Disruption

- Disruption good for entrepreneurs
- Entrepreneurs embedded in opportunity
- We need to train students with skills
- **HOW ??**

Design Issues

(How do we build these systems?)

Functional Design & Mapping



Guidelines (CS684)

- **Compulsory Labs** (Self-study or live class):
 - 7 labs (introduction to Embedded Systems)
 - Introduction to Embedded Systems/ IoT System Building
- **Evaluation**
 - 5% Quiz
 - 20% Assignments
 - 15% Labs
 - 30% Project (seeded pre-midsem, impl. post-midsem)
 - 20% Midsem
 - 10% Endsem

**Note: Percentages may be
tweaked as we progress**

Course Details (No Audit)

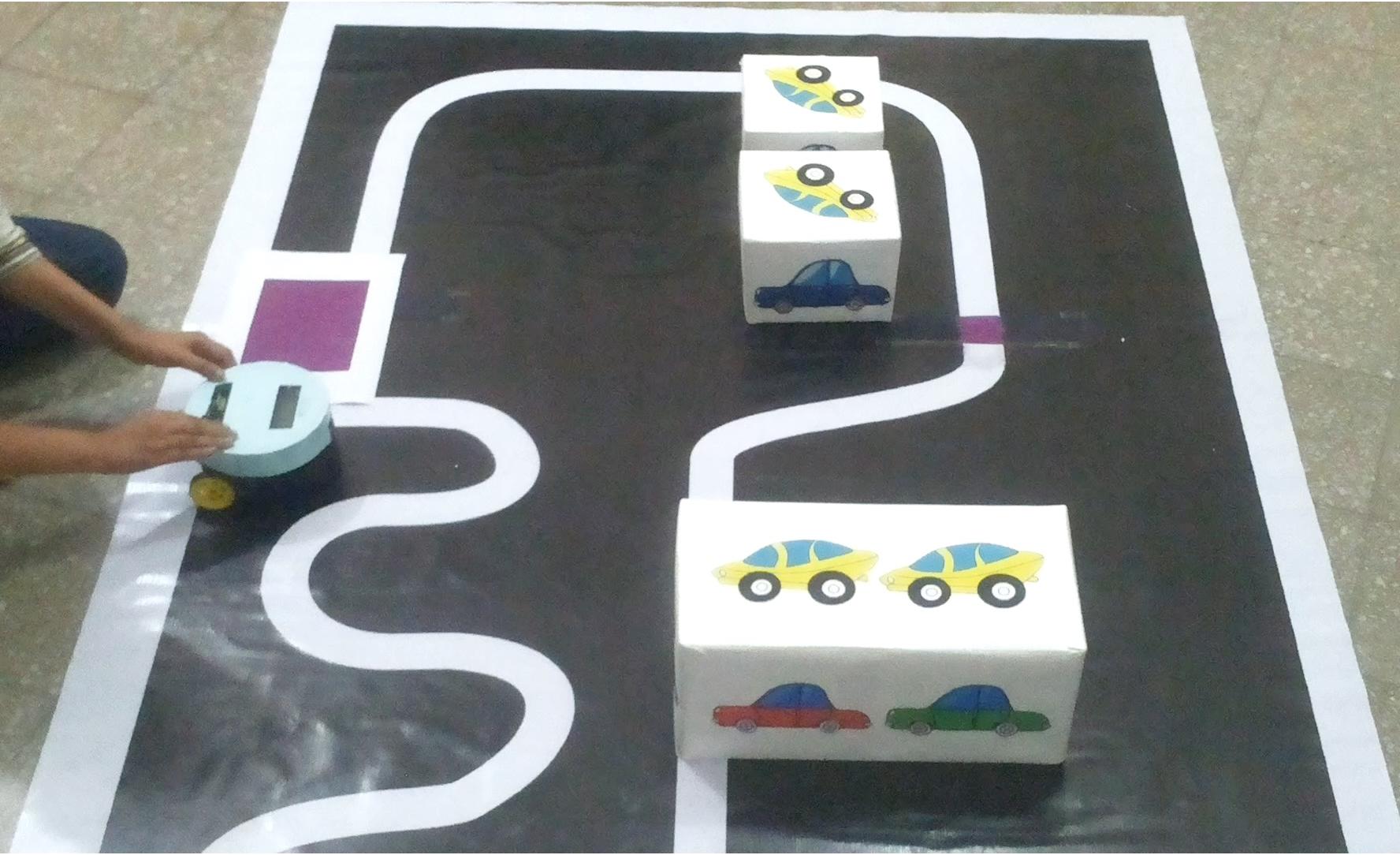
- **Mail ids:**
 - Faculty: kavi@cse.iitb.ac.in
- **Assignments**
 - On Moodle - subscribe to 'CS 684' on Moodle
 - <http://moodle.iitb.ac.in>
- **TAs:**
 - Rutuja (lead TA), Ruchi, Isha, Shyama, ...
 - Rutuja Ekatpure (Lead TA) rutuja_e@iitb.ac.in
- **Online Forum:**
 - Moodle
 - Piazza for discussions (details on website)
- **Website:**
 - <https://cse-erts.github.io/cs684/>

Course Content & Goal:

Introduction: Embedded Systems & IoT			
Model Based Design	<ul style="list-style-type: none">• Finite State Machines• Statecharts• Lustre/Heptagon	Lustre/ Heptagon	<ul style="list-style-type: none">• Finite State Automata• Higher Order Functions• Uni-mode and Multi-mode controllers
Device Drivers	<ul style="list-style-type: none">• I/O device• Motor/ PWM• Sensor interfacing	RTOS	<ul style="list-style-type: none">• Introduction• Scheduling Theory

Project

(in competition mode):



Conclusion

- We have simultaneous optimisations of competing design metrics: speed, size, power, complexity, etc.
- We need a “Renaissance Engineer”
 - Holistic view of design process & comfortable with technologies ranging from hw, sw to formal methods
- Maturation of system-building tools
 - Enables unified view of hardware/ software co-design.
- Design focus at higher levels of abstraction => Abstract specs refined into programs -> (gates and logic)
- **There is no fundamental difference of between what hardware and software can implement.**