ARM Processor Evolution:
Bringing High Performance to Mobile Devices

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August 18th, 2011

1980's mobile computing

HotChips 1981

- 4MHz Z80 Processor
- 64KB memory
- Floppy drives
- 5” screen
- 24.5 lbs
- $1,795
- 11,000 units sold

Osbourne 1 image courtesy of www.oldcomputers.net

Hot Chips 1983

- Motorola DynaTAC
- $3995
- 30 minutes talk time
- 10 hours charge time
- No texting or Bluetooth

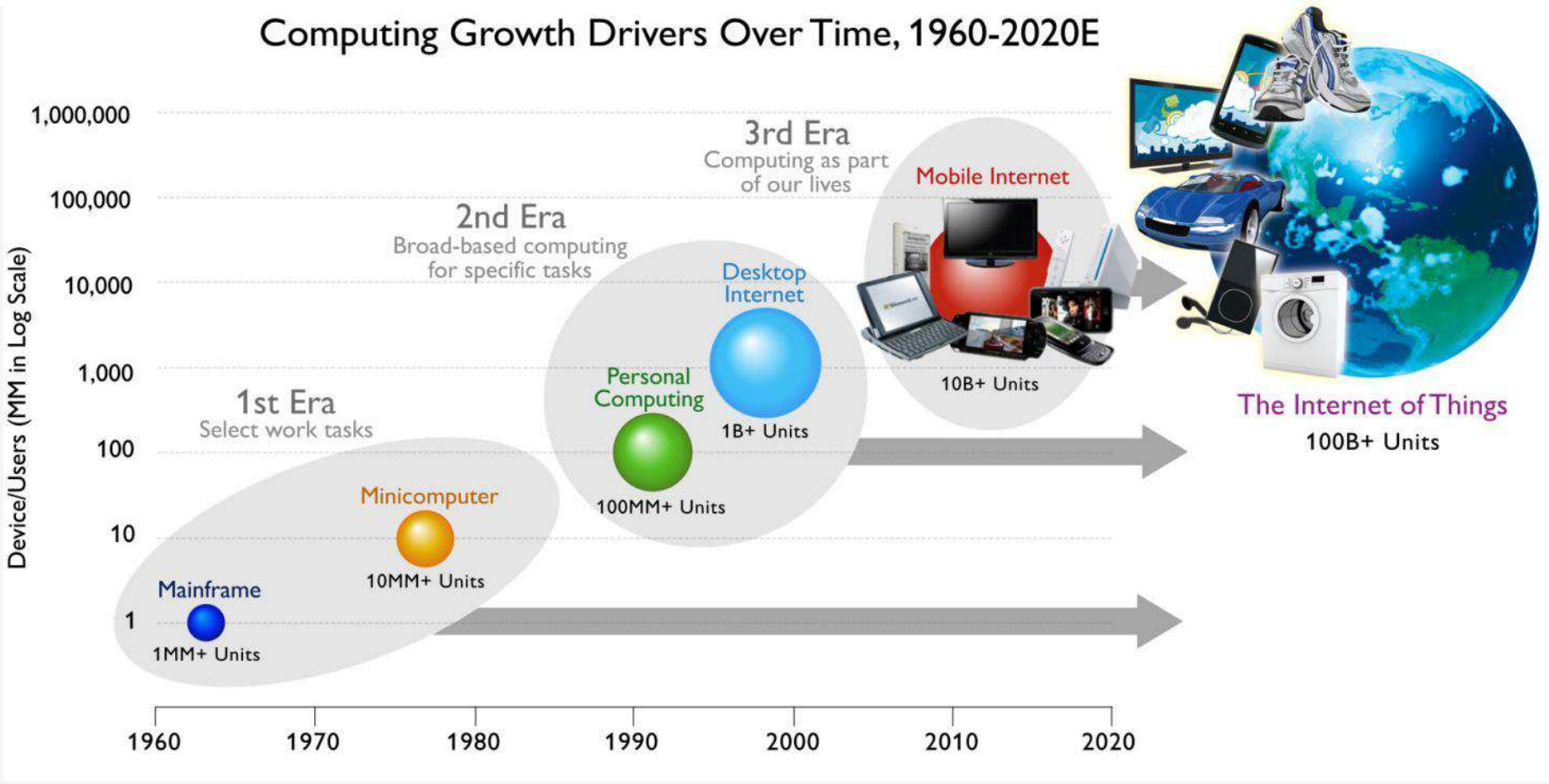
30 Years later…

- MacBook Air
- 1.7GHz Processor
- 8GB memory
- 256GB storage
- 13” screen
- 2.96 lbs
- $1,599

Your phone is a lot more useful too

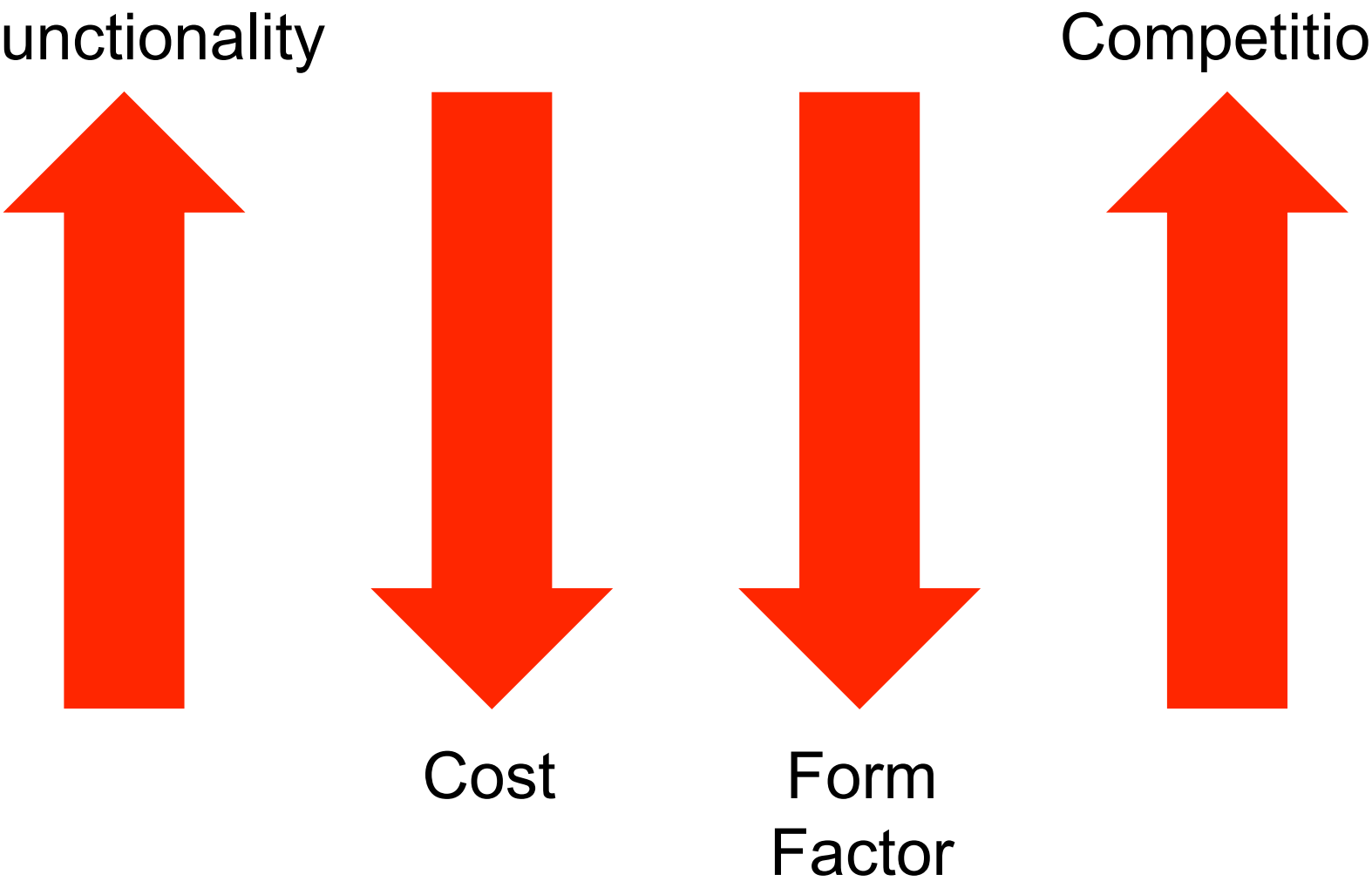
- Samsung Galaxy S-II
- Android 2.3
- 4.3” screen
- 32GB memory
- Web, weather, Angry Birds
- ~1/20th the DynaTAC cost

Connectivity driving computing



Source: Morgan Stanley, 2009

Evolutionary Pressures

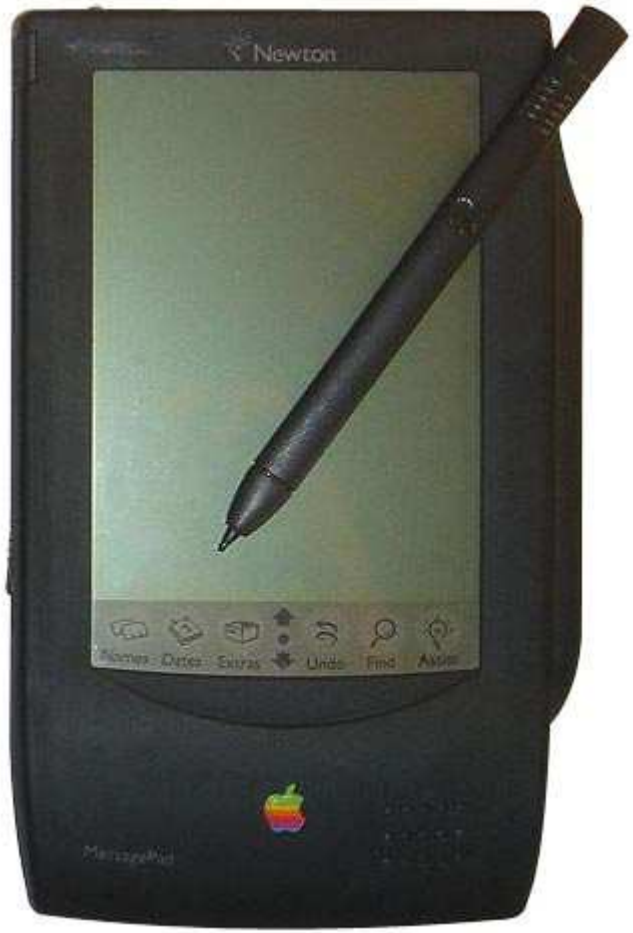


1990-2011

A long time ago in a village far away….

- Acorn, Apple and VLSI formed a joint venture
  - 13 engineers and a CEO
- ARM the company was born
  - 21 years old in November
- Goal to design low power *embedded* 32b processors
- But never to manufacture them

1993: An early mobile computer



- 1.4lb
- Personal Applications
- Expansion socket
- Stylus interface

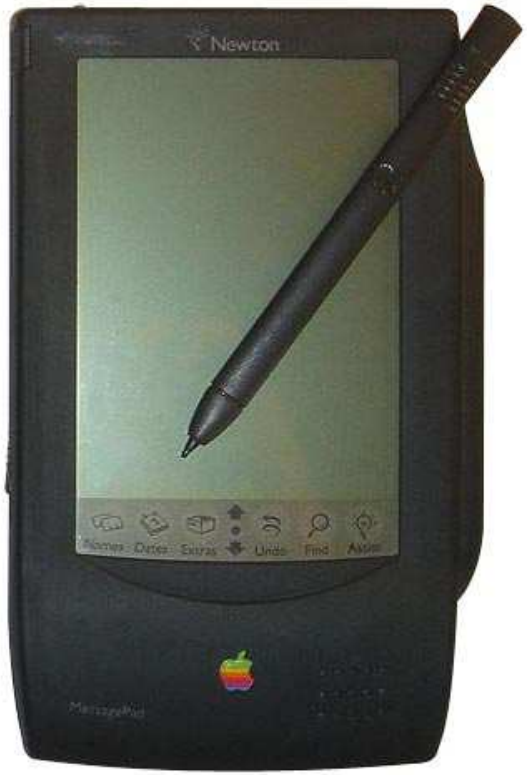
1992: ARM7TDMI – ‘thumb’

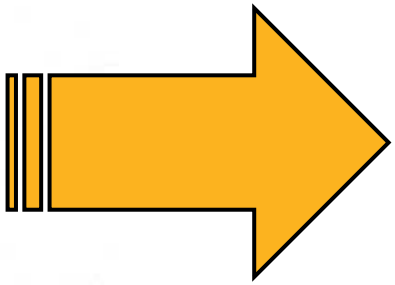
- A small, low power 32 bit core for wireless baseband
- 74,000 transistors, 40MHz, 4.2mm^2 on 0.5µm

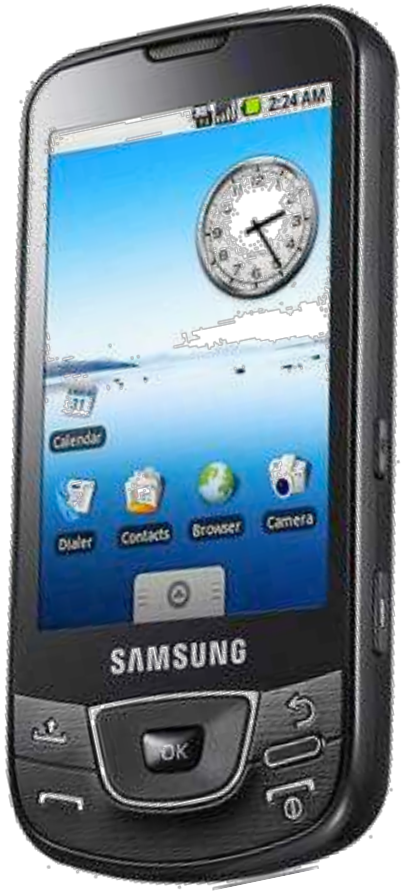
Early GSM phone

- 1 week battery life
- Contact list
- Calculator
- SMS
- Snake…
- Not exactly a mobile computer

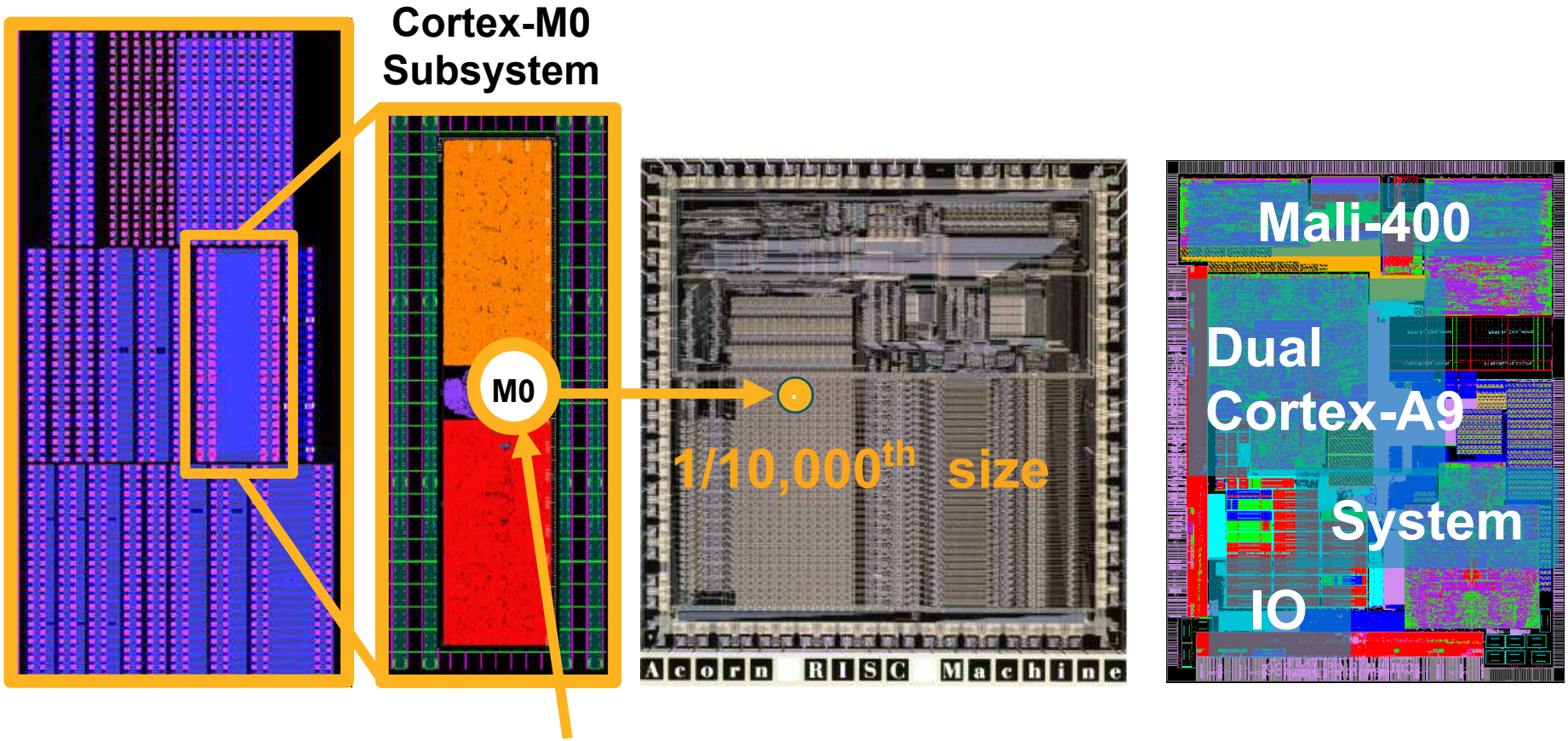
Evolution







Moore's law has helped a lot



Dec 2010

Cortex-M0
20nm 8k gates
0.07mm x 0.07mm

1985 ARM1
3μ 6k gates
7mm x 7mm

Cortex-A9 SOC
40nm 100M gates
7.4mm x 6.9mm

The next decade

There may be trouble ahead….

First the good news

In 2010 280M smartphones were shipped

Over 4 Billion people connected via mobile phones

LTE Deployment starting

During the 2010 Holiday period $230M was spent on EBay using smartphones

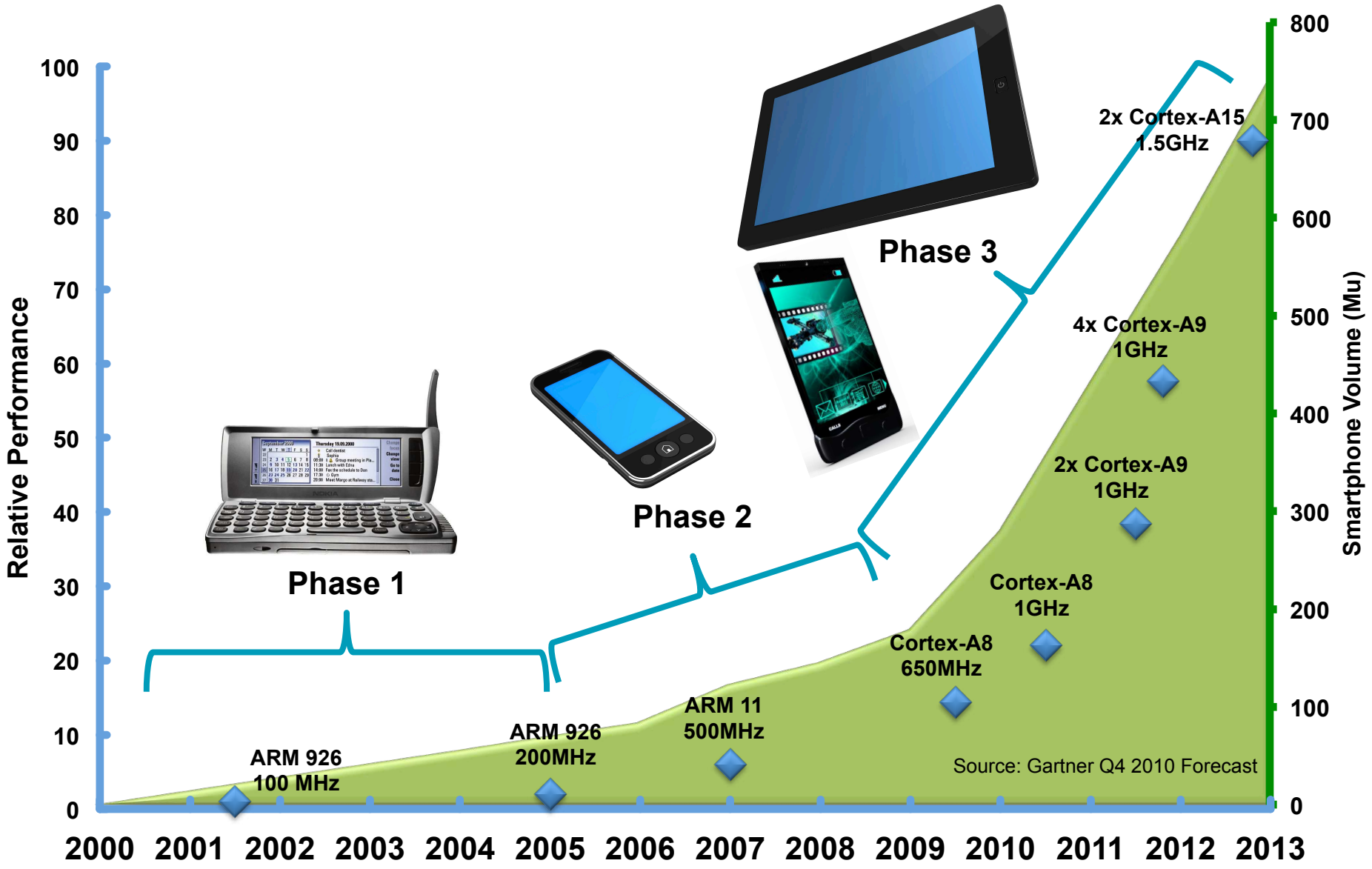
Smartphones will leapfrog over the PC in the developing world

Over 13 Billion smartphone apps downloaded in 2.5 years

BIG NUMBERS!

Smartphone data traffic will exceed PC traffic in 2014

Smartphone growing and growing



The “Superphone” for 2013

Device Vision

- Your primary internet access device
  - Always connected broadband
- Enough compute power to replace your laptop
- Your content with you
  - From HD to MP3 with cloud access

Enabling Technology

- Multi-core processor
- Multi-core graphics processor
- Multi-core coherency
- 28nm implementation
- Security solution

Visual Experience

- 12+MP Camera
- 1080p playback and capture
- 128 Gbyte of storage
  - **45 hours of 1080p video**
- HDMI video out

Applications

- Full browser with HTML v5 & Flash Player
- New UI paradigms
  - Voice, gestures, Augmented Reality supported by OpenCL
- Full ‘office’ support
- Vibrant applications market
- HD Gaming on device or screen

Another 1Bn sub $100 Computers

1+ Billion Opportunity

- Consumers, OEMs & MNO all want smartphones
- Emerging markets to bypass the PC
- Full internet connectivity
- Growth controlled by retail price, target $100-$200
- Requirement beyond ARM11™ performance

Device Features

- Full Android™ OS
- Access to full range of apps in Google Marketplace
- Full browser
- Flash Player 10 support
- Full HTML 5 support
- 3D UI accelerated with OpenGL® ES 2.0

Access to full range of apps in Android Marketplace

A whole lot of software

Application diversity delivers the personalized compute experience

Apps &
App Stores
100,000's of Apps
15+ Billion Downloads

Full connectivity to the Internet and the Cloud

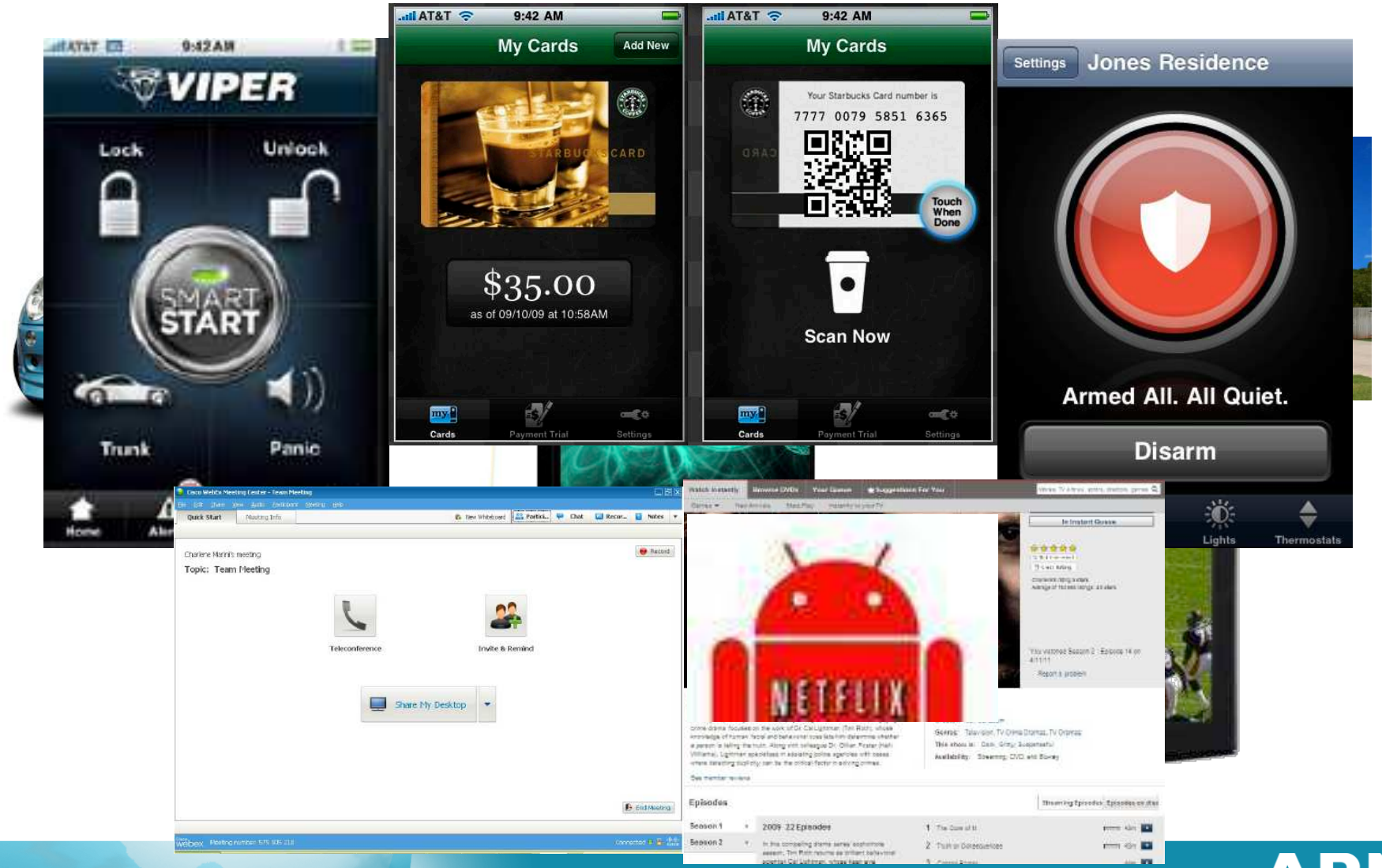
Web
Technology
support for all
standards

Flash Player 10 | AIR | <HTML> v5 | Webkit | Internet Explorer | Google Chrome | Mozilla Firefox

Diversity and rapid mobile OS innovation

Operating Systems
innovating on
a 6-12 month period

The center of your world



TrustZone in 3 Steps

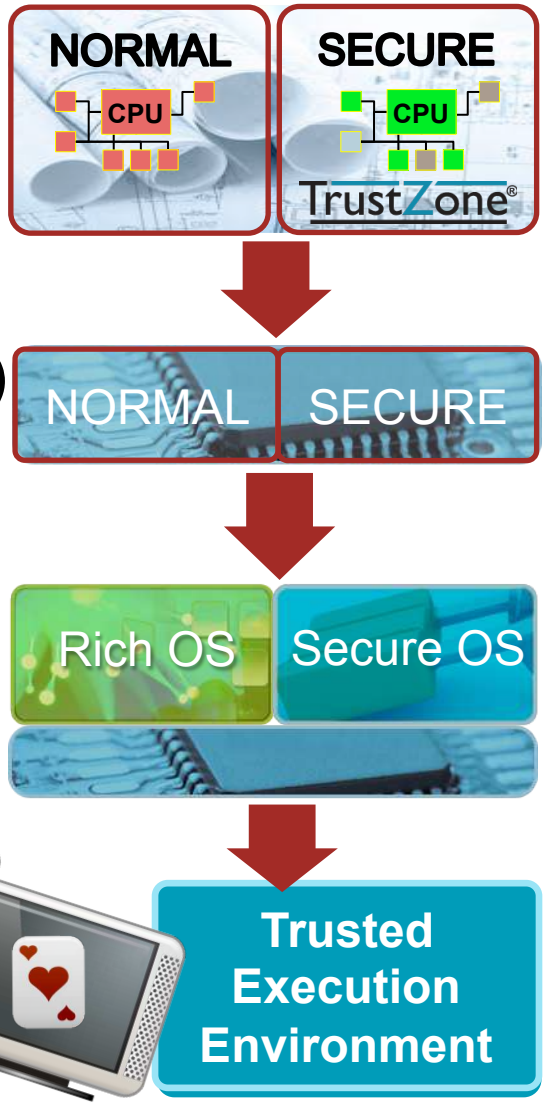
1. Define secure hardware architecture
   - Two separate domains:- **normal** and **secure**
   - Extends across system:-

     Processor, display, keypad, memory, clock, radios

2. Implement in silicon system on chip (SoC)
   - Physically enforcing secure/normal separation

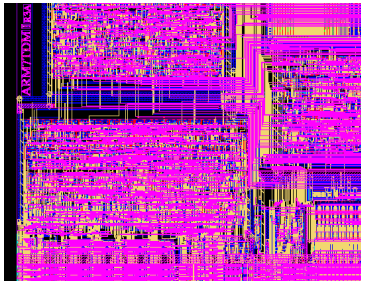
3. Combine SoC with Secure OS
   - Separate but connected to main operating system

Result: A **T**rusted **E**xecution **E**nvironment
   - Ready to develop and deploy trusted services



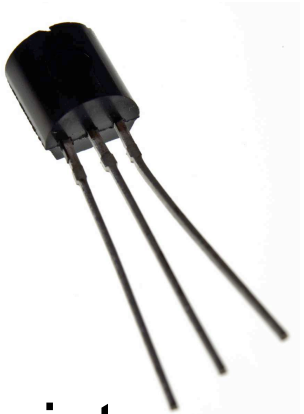
But there are challenges

Modems



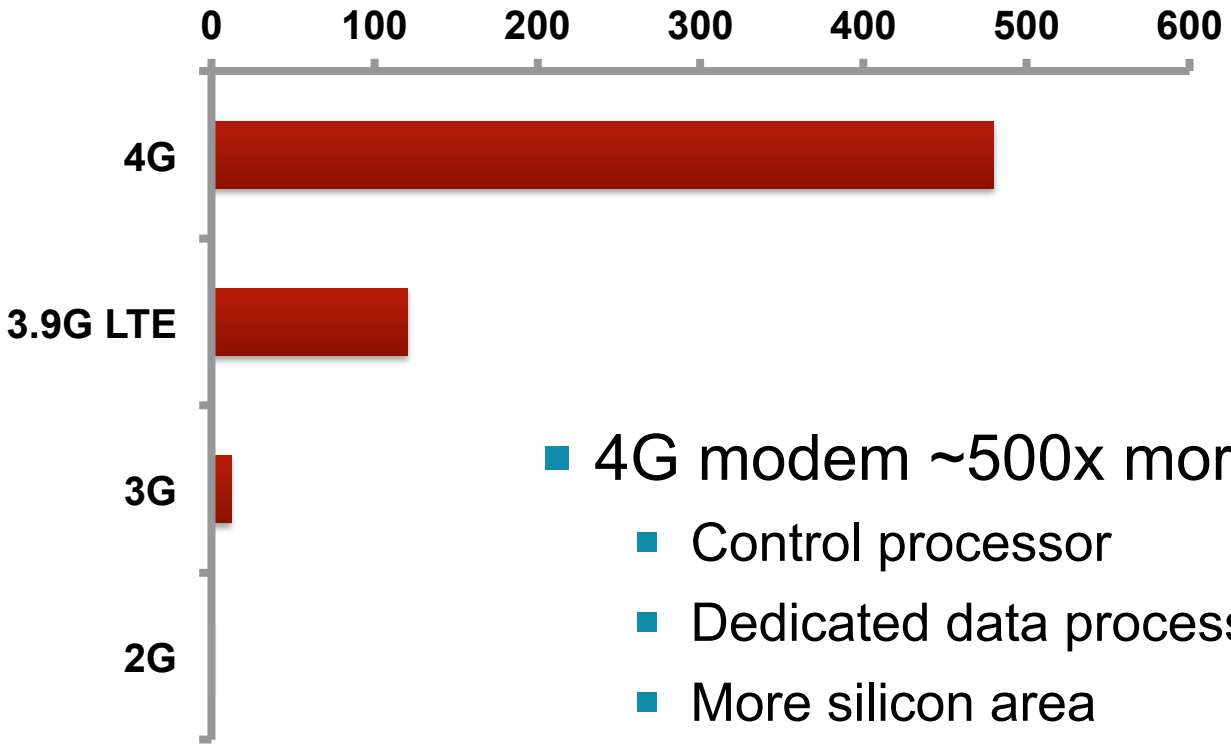
Implementation

Battery scaling



Transistor scaling

Modem relative performance



- 4G modem ~500x more complex than 2G
  - Control processor
  - Dedicated data processing engines
  - More silicon area
  - More power consumed

Batteries haven't helped

- Historical 11% capacity growth
  - Not well matched to Moore's Law
- Continued innovation required just to maintain 11%
  - New Si alloy materials or anode Carbon Nano Tubes may help

4.5 kCal
30g

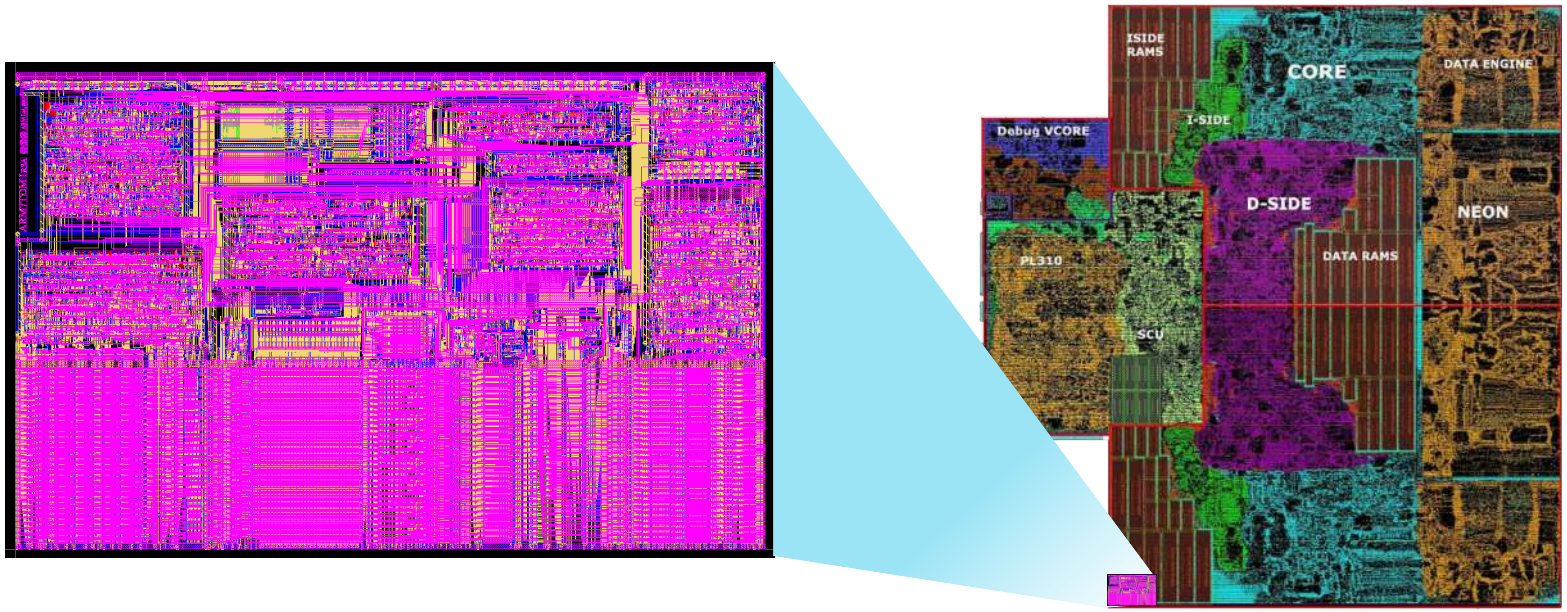
255 kCal
49g

x2.2
Capacity

		2011	2020
Capacity	mWH	5,700	13,135
Power Budget mW	1-day life	475	1,059
	3-day life	159	365

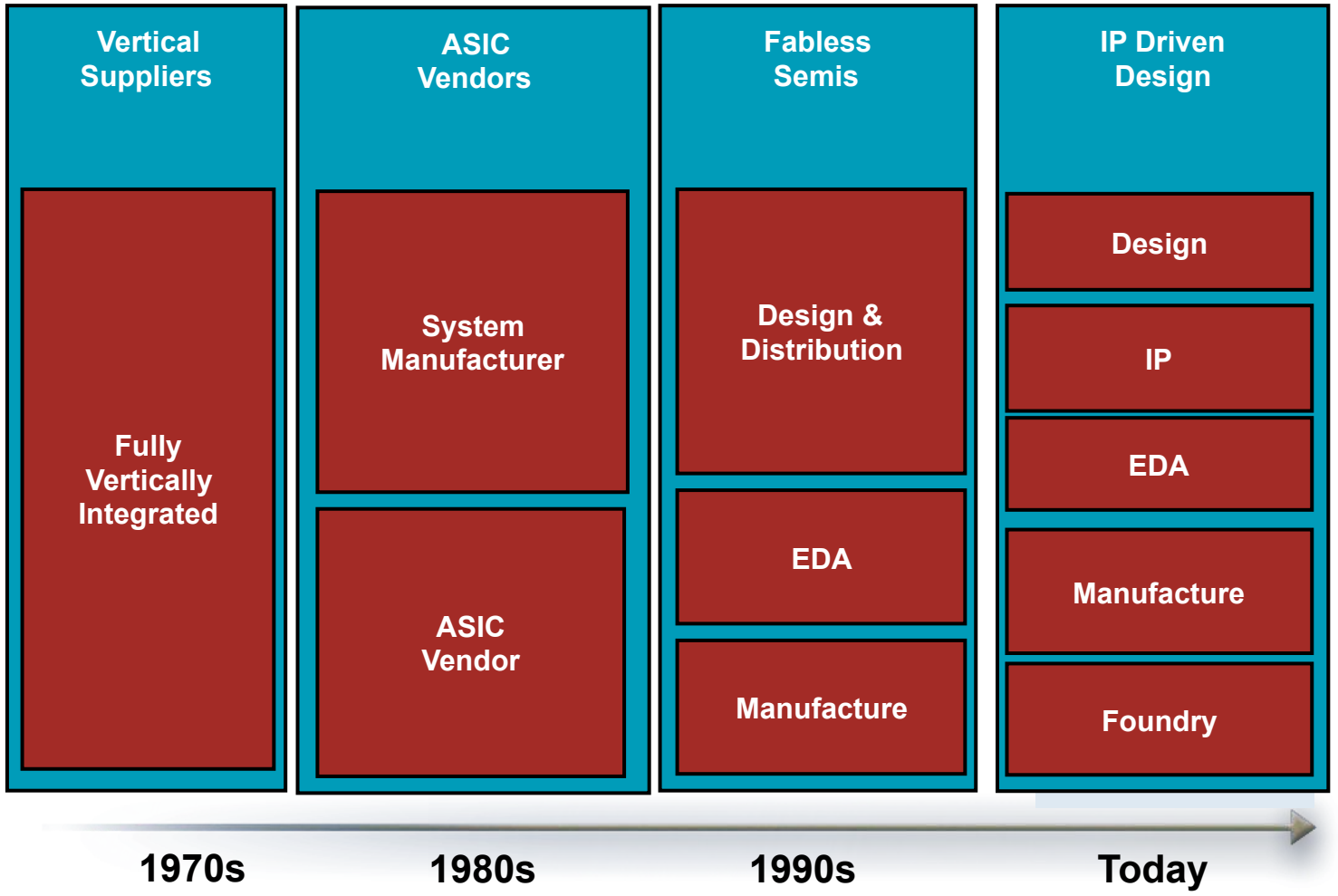
Assuming 12 hours of use per day

Challenge: Implementation Complexity

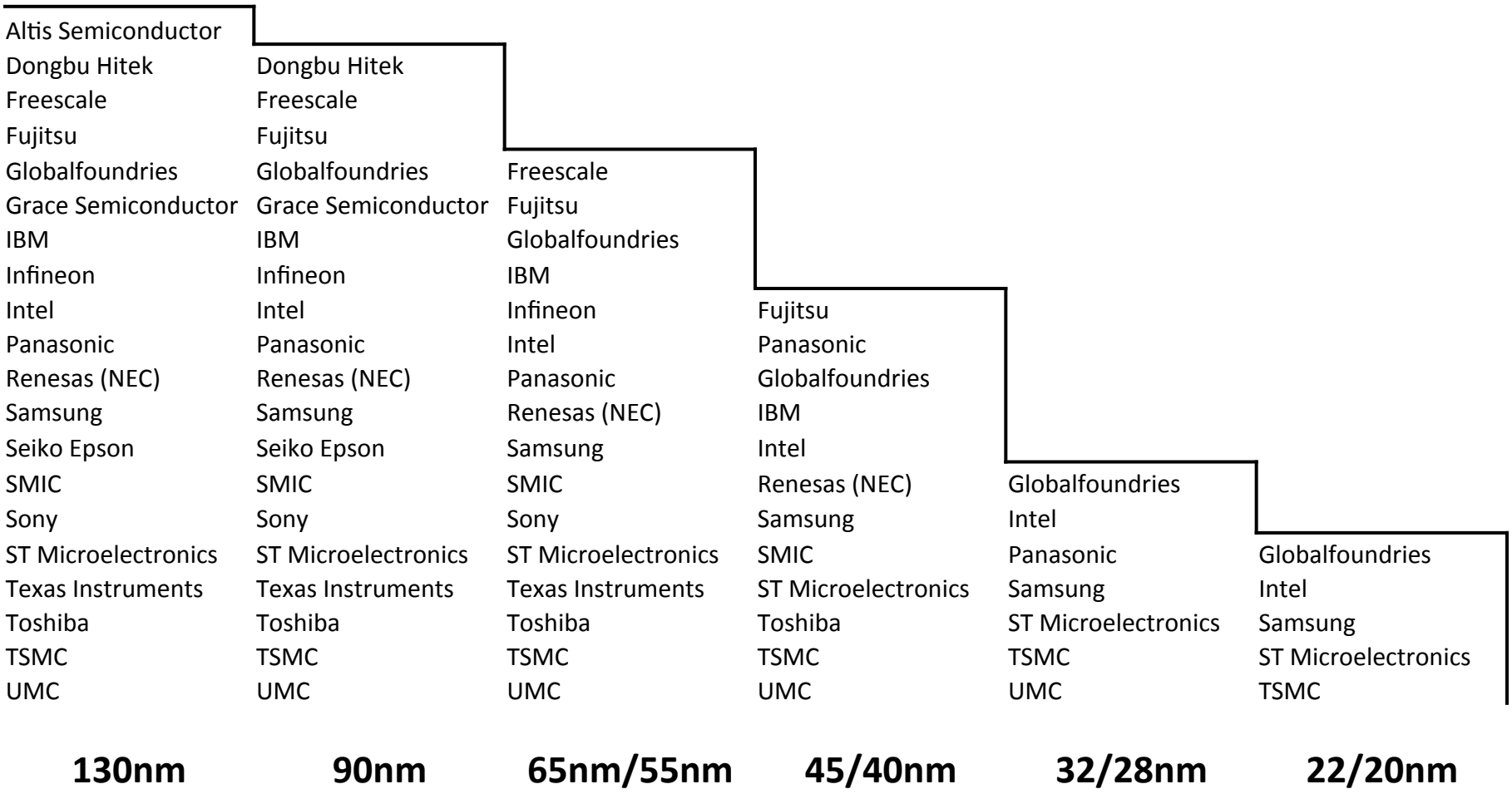


- **ARM7TDMI**
  - 74K transistors
  - 4.2 mm^2 in 0.5µm technology
  - Largely hand-designed
  - 3 corners, 1 voltage domain
- **Cortex-A9 MP Dual Core**
  - >20M transistors
  - 3.4 mm^2 in 28nm technology
  - Complex timing sign-off
  - 12+ corners, 3 voltage domains
  - DFM, Variation modeling, …

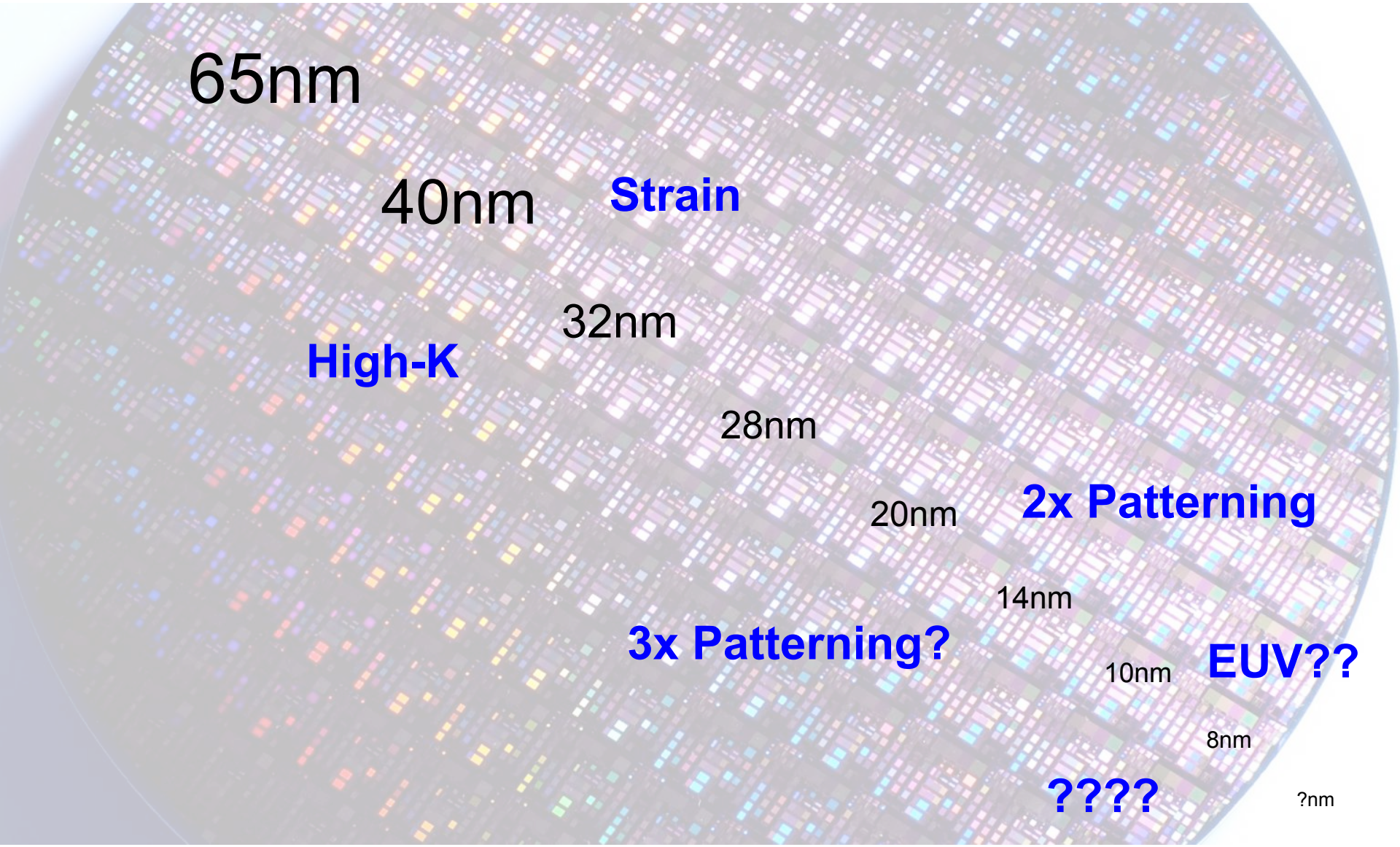
Disaggregation – pros and cons



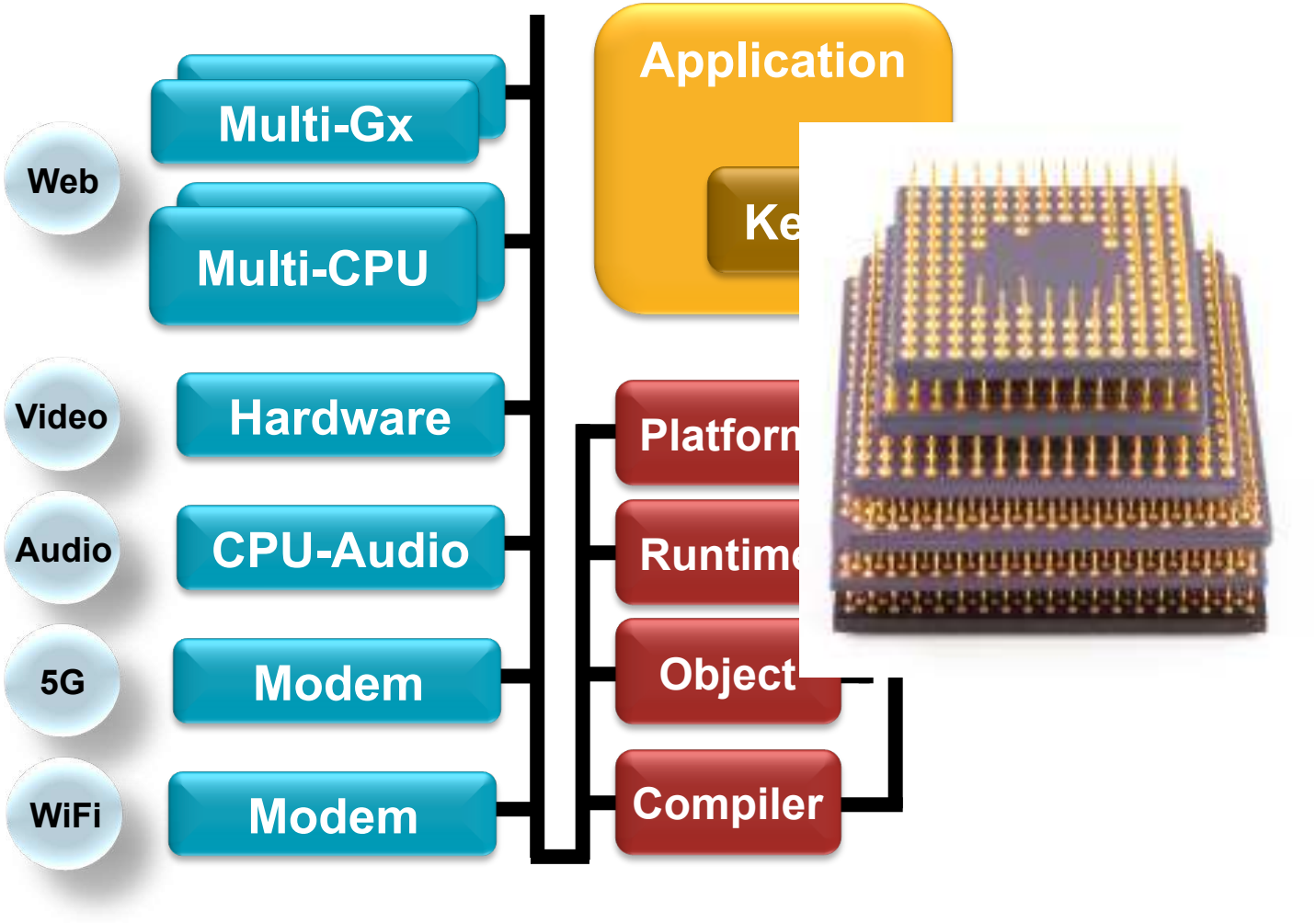
Fabs: not as popular as they used to be



Device Scaling



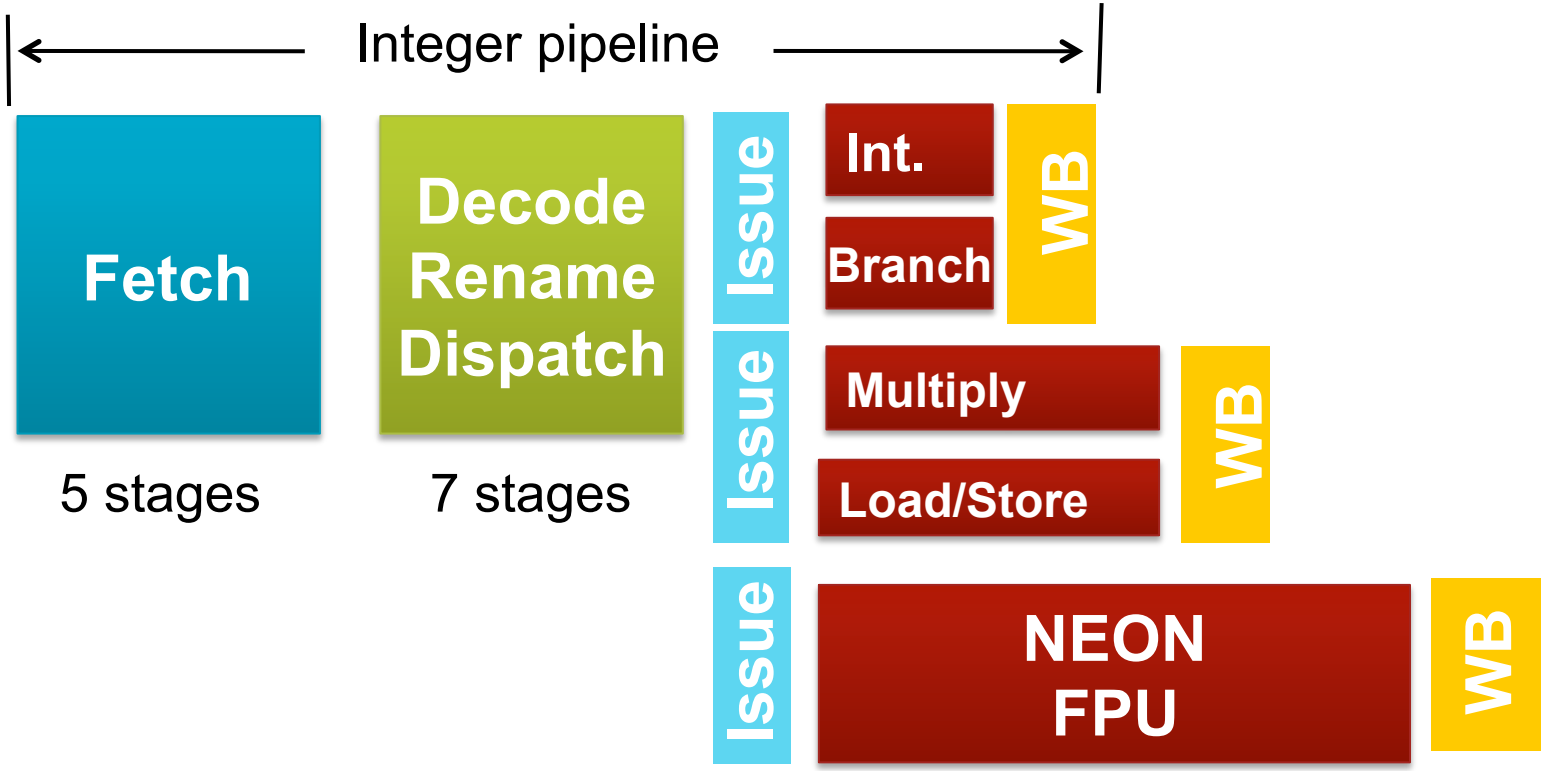
Think different!



Advanced Processing

Cortex-A15 for High-end, power-efficient processing

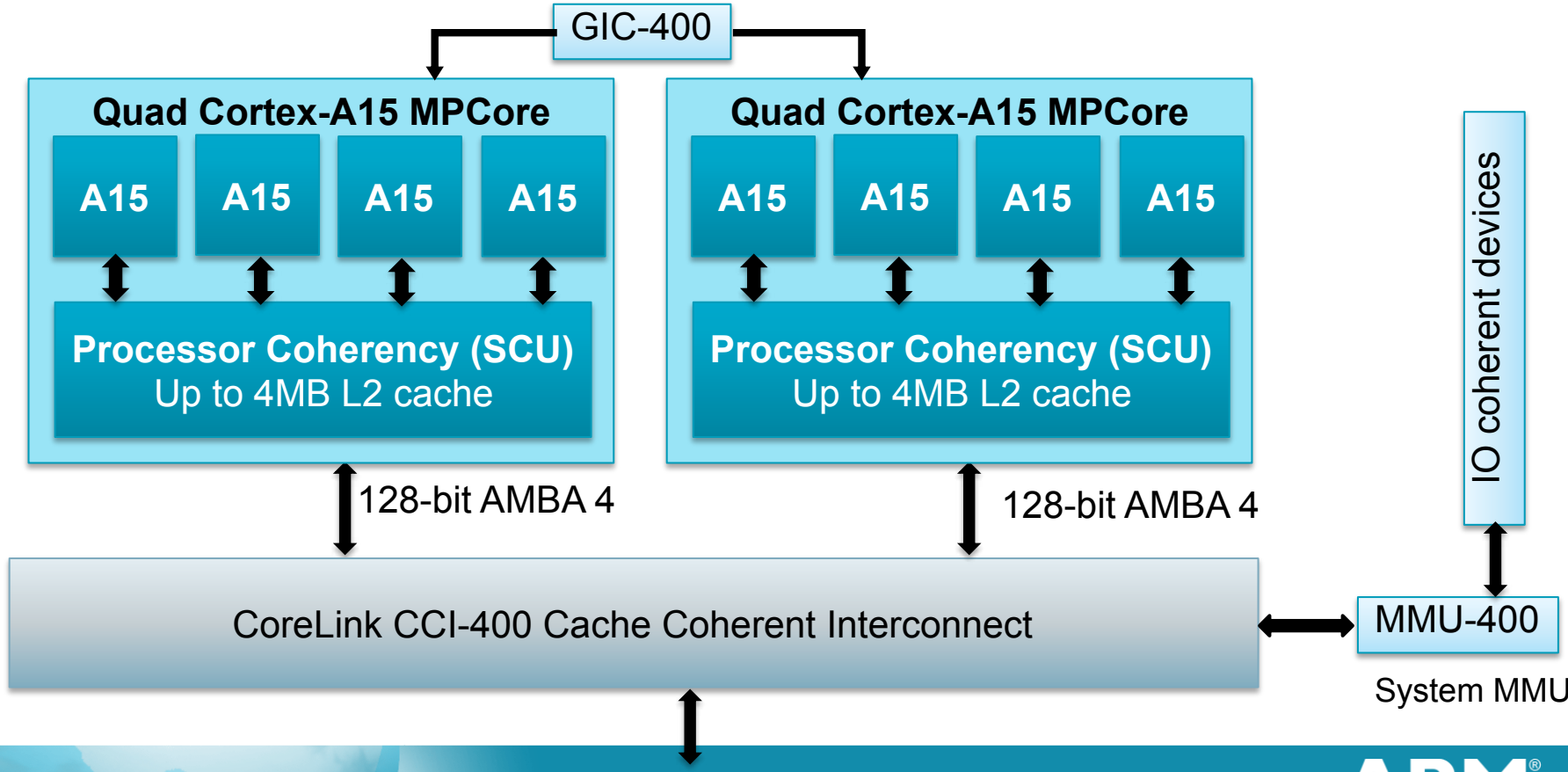
- 15-Stage Integer Pipeline
- 2 extra cycles for multiply, load/store
- 2-10 extra cycles for complex media instructions



Cortex-A15 System Scalability

Introduces Cache Coherent Interconnect

- Processor to Processor Coherency and I/O coherency
- Memory and synchronization barriers
- Virtualization support with distributed virtual memory signaling



Fully coherent SoCs

2011 Devices

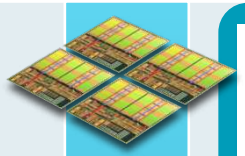
- Full coherency within CPU cluster
- Limited I/O coherency
- Software managed coherency for SoC

2013 Devices

- Full coherency for multiple CPU clusters
- I/O coherency with graphics and other
- Simpler software programming model

2015 Devices

- Full coherency on CPU, GPU and other
- True General Purpose Compute



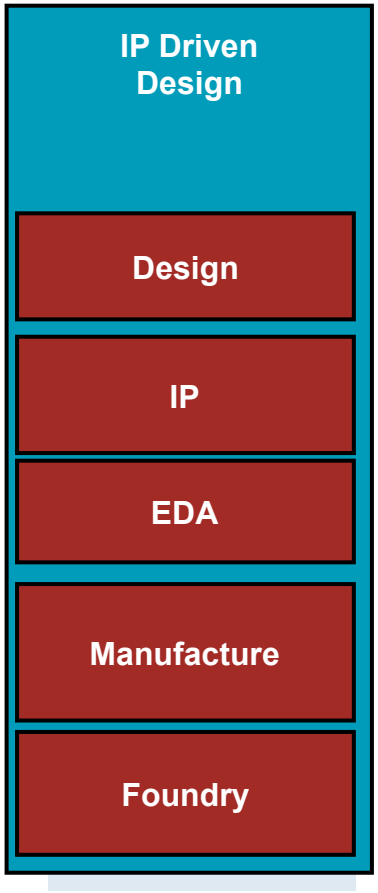
Greater Performance and interaction
Lower energy per transaction

Applications Processor	Graphics and Video	
2x or 4x Cortex-A9	Mali-400	Video
Fully Coherent	Non-coherent or Software Managed	

Applications Processor	CI	Graphics and Video	
>4x Cortex-A15		Mali-T604	Video
Fully Coherent		**I/O Coherent**	

Applications Processor	CI	Graphics and Video	
Next generation Compute cluster		Next Gen	Video
Fully Coherent			

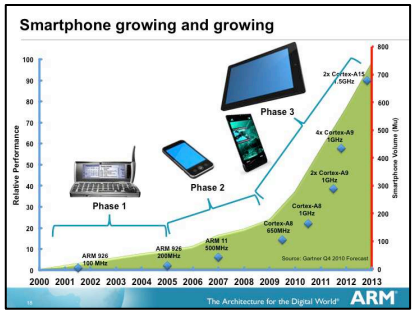
The holistic SoC Designer

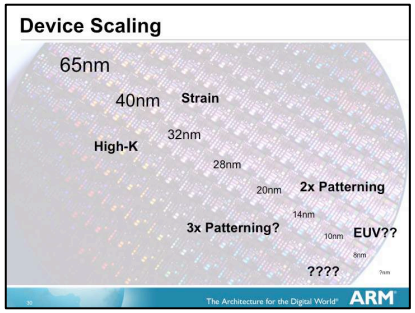


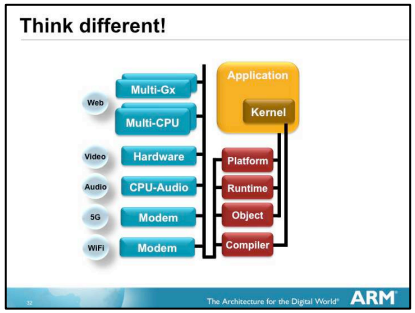
Architecture

Implementation

Conclusion







- 30 years have delivered incredible gains
  - Mobile computing now ubiquitous
  - Smartphones, Superphones, Tablets
- Silicon scaling has driven PPA gains
  - But it has to end somewhere, so get ready!
- The future is Hetrogeneous
  - Multi-core CPU, multi-CPU, dedicated engines
- A new battery would help too!

Thank you.