Challenges in the Microelectronics Systems Industry (a personal view)

Warren East

PHEE
A forum for Academic Leaders in Electrical Engineering and Allied Technologies

Professors & Heads of Mechanical & Manufacturing Engineering

Academic Partners
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Challenges and Opportunities

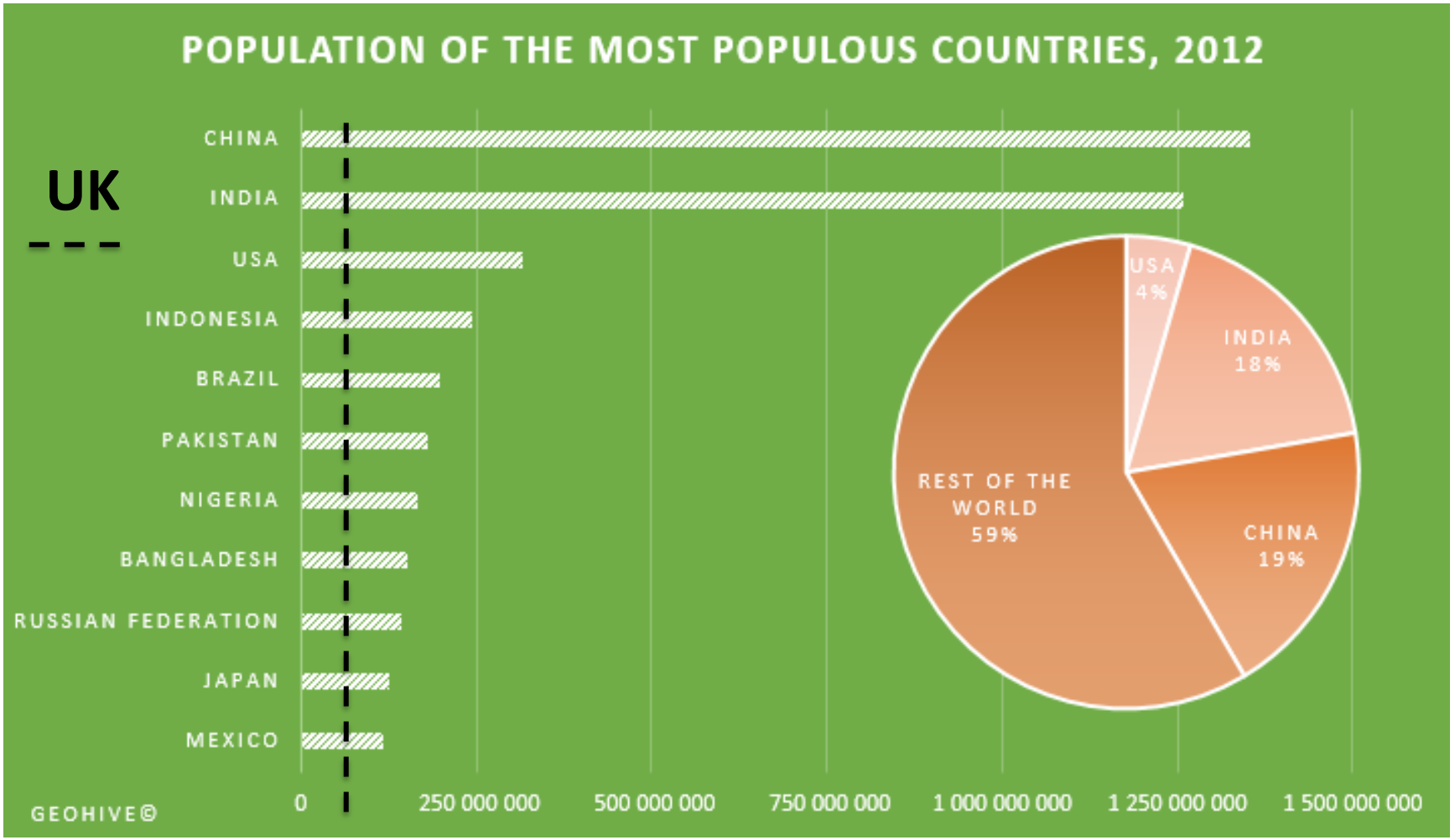
- Smart Electronic Systems – all around us
- Progress through bulk CMOS - Moore's law
- After Moore's law – Architecture and Materials
- Business challenges
- Opportunity
- The future

Acknowledgements

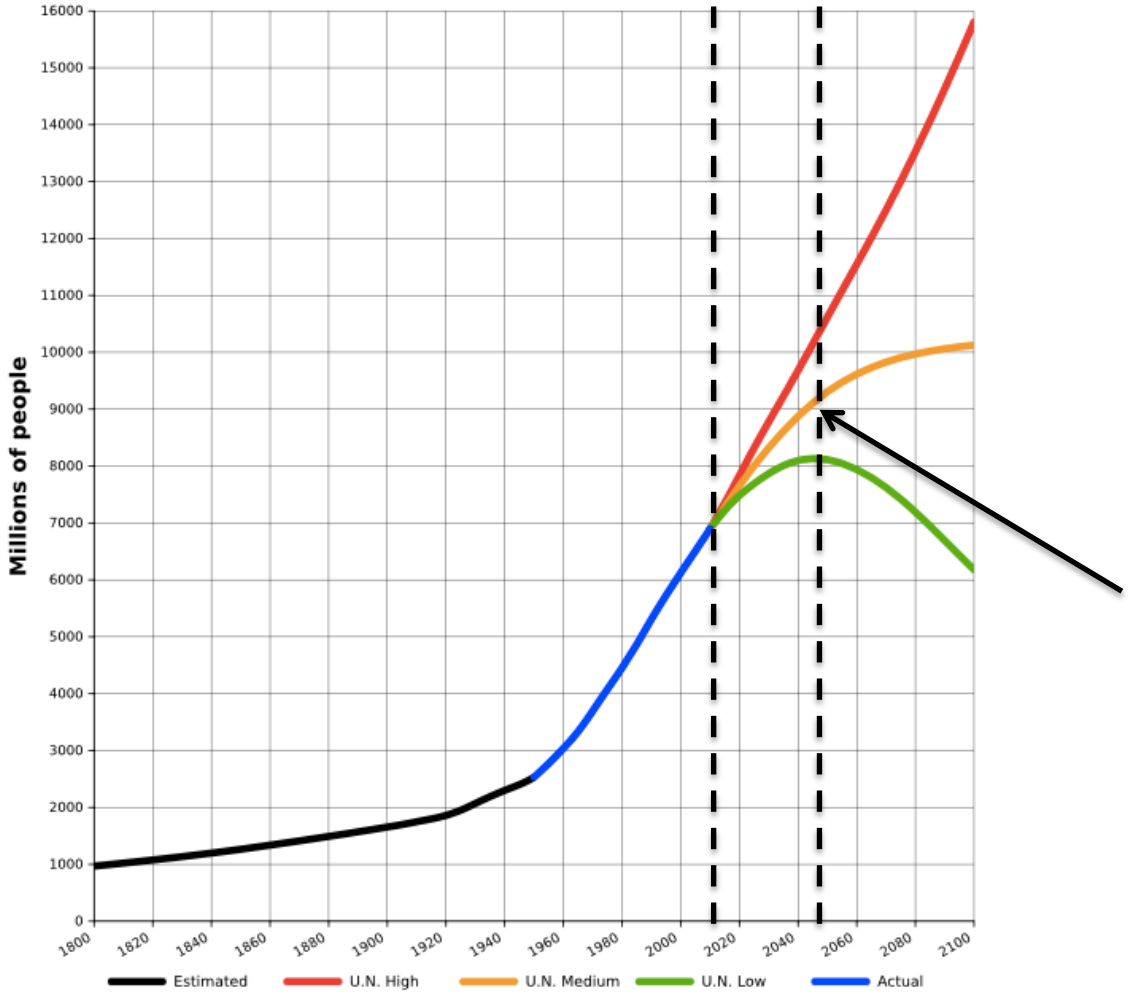
- ARM, Micron
- Image copyrights not otherwise highlighted
- Getty Images
- BBC
- HMC Consortium
- Fotalia
- Istockphoto
- Nanotech blogspot
- Stillhopefulmorn blogspot
- Nitronex

Front row at the Royal Wedding

Quite a small crowd



UN Population estimates



30 : 30

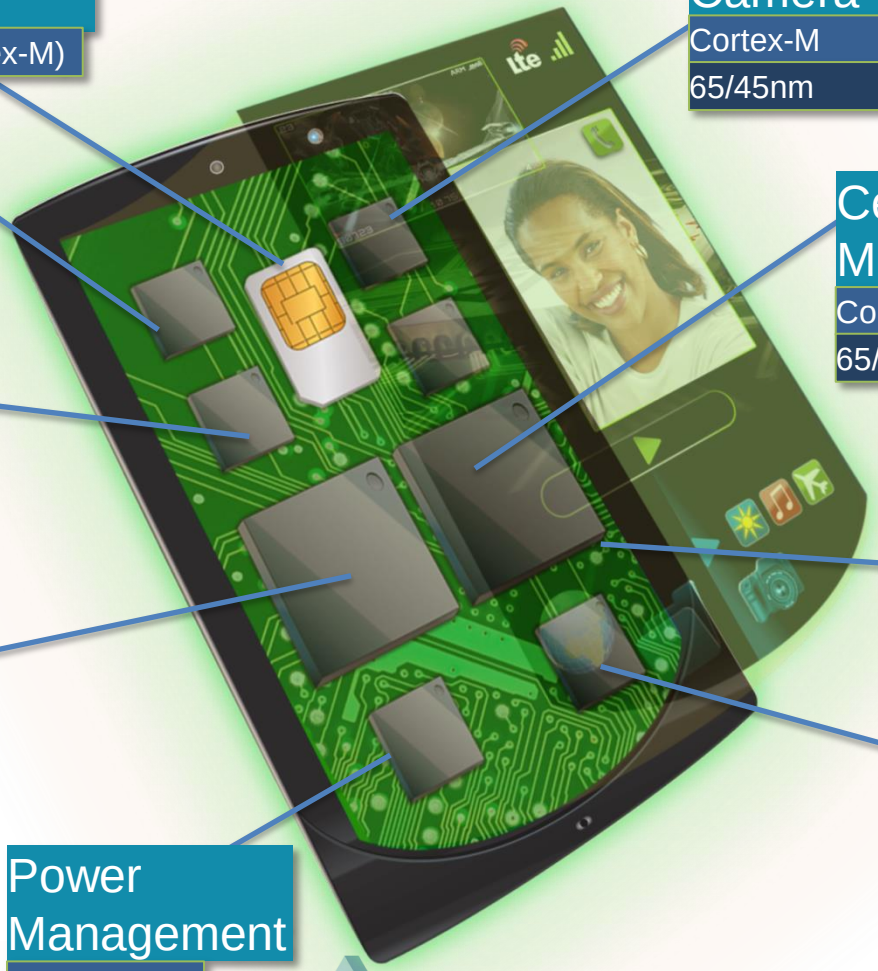
Medium case estimate
30% growth in 30 years

Smart Electronic Systems - all around us

In the fabric of our everyday life….

….. Now and even more in future

Smart Connected Device Processors



SIM
SecureCore (Cortex-M)

WiFi/ Bluetooth
Cortex-M
65/45nm

GPS
Cortex-M
65/45nm

Apps Processor
Cortex-A
Cortex-A
Cortex-M
Mali
32 → 14nm

Power Management
Cortex-M
180nm

Camera
Cortex-M
65/45nm

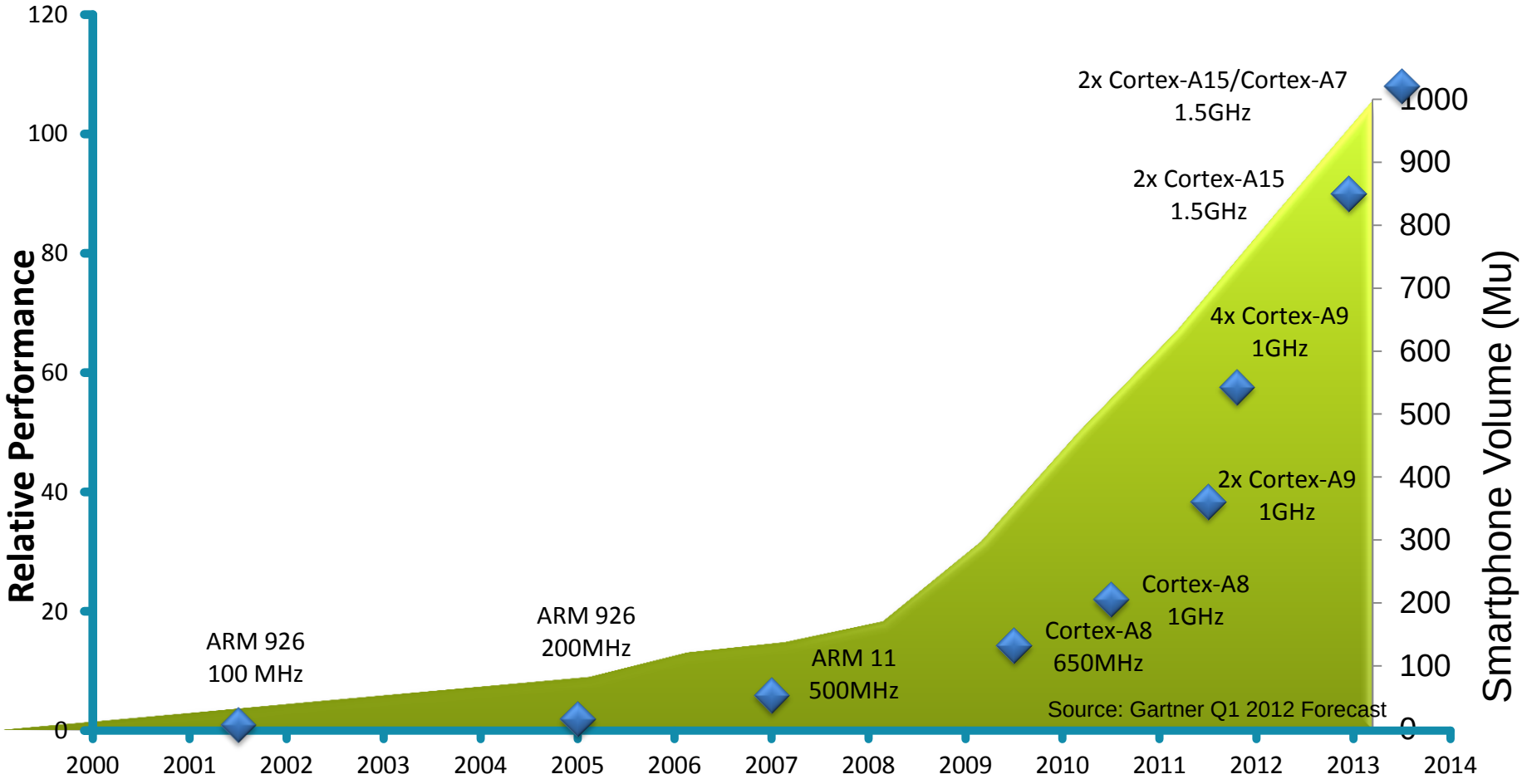
Cellular Modem
Cortex-R
65/45nm

Flash Controller
Cortex-M
130nm

Touchscreen Controller
Cortex-M
90nm

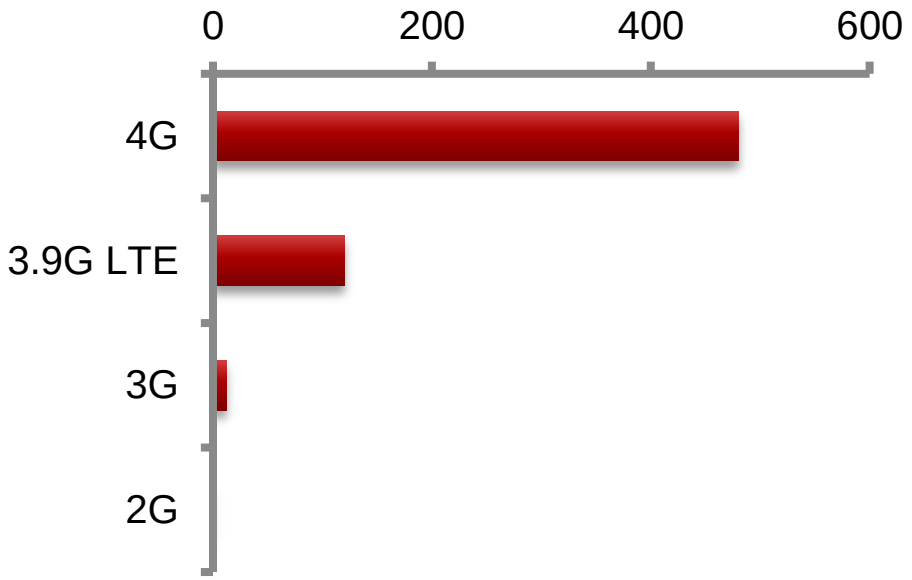
Function
ARM Processor
ARM Physical IP

Smart Device Acceleration



The Cost of Data Transmission

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



Fixed power budget

~ 6Wh

	Today	11% Growth
mWh	6,000	14,000
1 day	475mW	1095mW
3 day	159mW	365mW

Nature still the best engineer

4.5 kCal 30g

255 kCal 49g

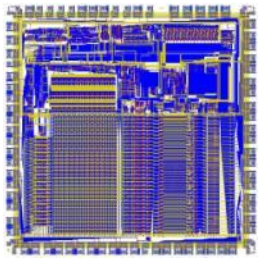
	Today	11% Growth
mWh	6,000	14,000
1 day	475mW	1095mW
3 day	159mW	365mW

Challenge: Implementation Complexity

- ARM7TDMI
  - 74K transistors
  - 4.2 mm^2 in 0.5µm technology
  - 3 corners, 1 voltage domain

- ARM Cortex-A9 MP Dual Core
  - >20M transistors
  - 3.4 mm^2 in 28nm technology
  - 12+ corners, 3 voltage domains

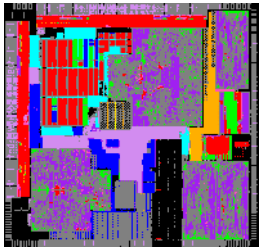
Challenge: Implementation Complexity



ARM1 (1985)

4 hours encoding

ARM Cortex-A9 (today)



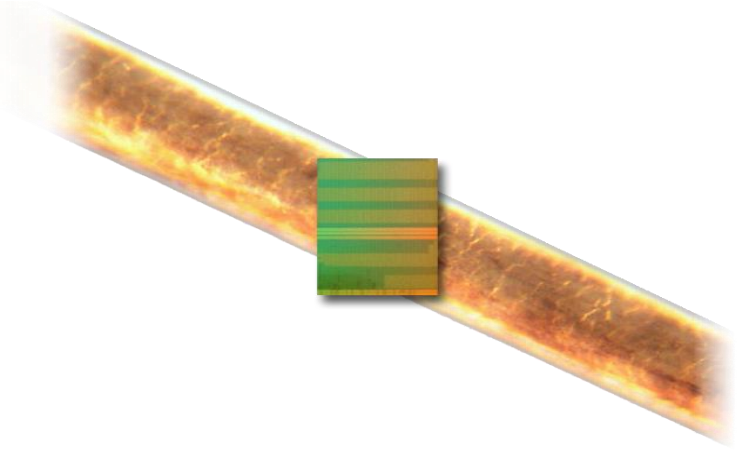
2min 55s encoding

Source: ARM estimates

Digital: Anywhere and Everywhere

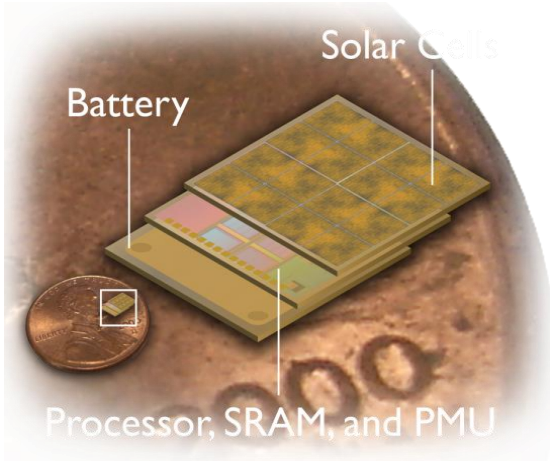
$0.1mm^2$

Processor Size



$0.1mm^2$

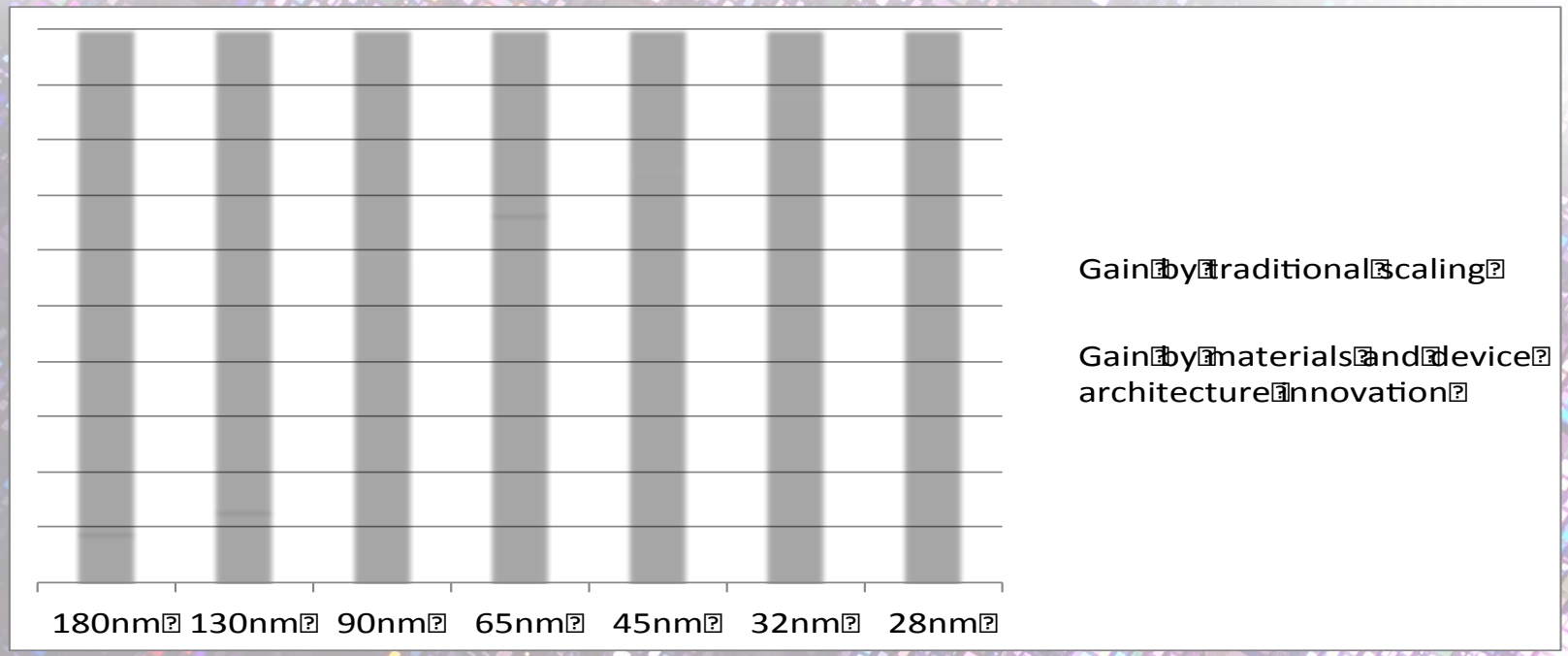
Solar Panel Size to Power Processor



Source: ARM, Ambiq Semiconductor

Can’t rely on Moore’s Law

Percentage of Performance Increase



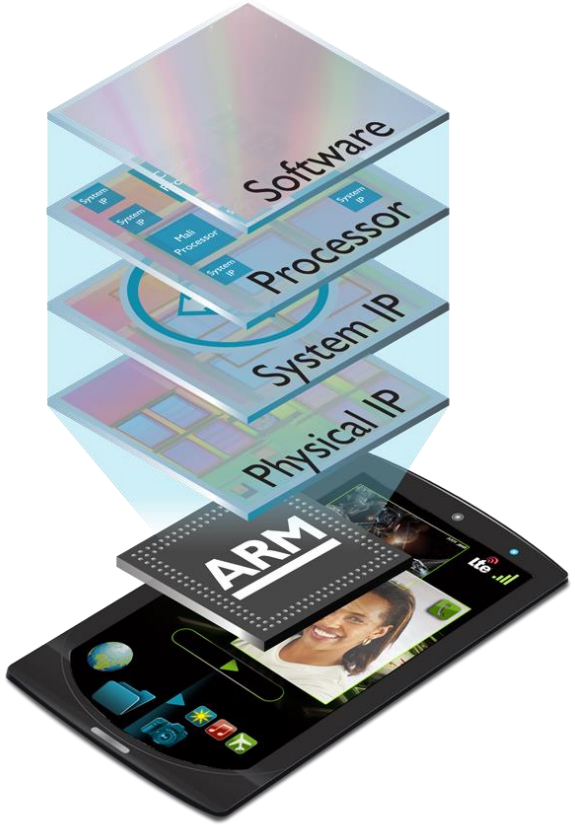
Source: IBM Microelectronics, IBM, IC Insights

It’s all about the System

Low power leadership requires a holistic approach

Integrating and optimizing solutions……

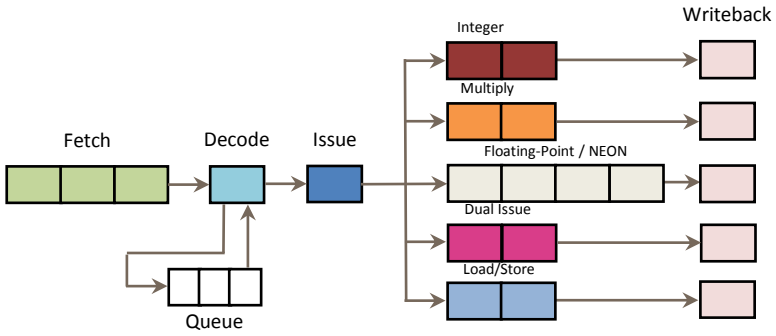
- Compression technologies to reduce memory power
- System caches and snoop filters in coherent interconnects
- Processor physical implementation solutions and advanced implementation flows
- Efficient micro-architecture design
- Intelligent software management of resources



Moving to Heterogeneous Multi-core

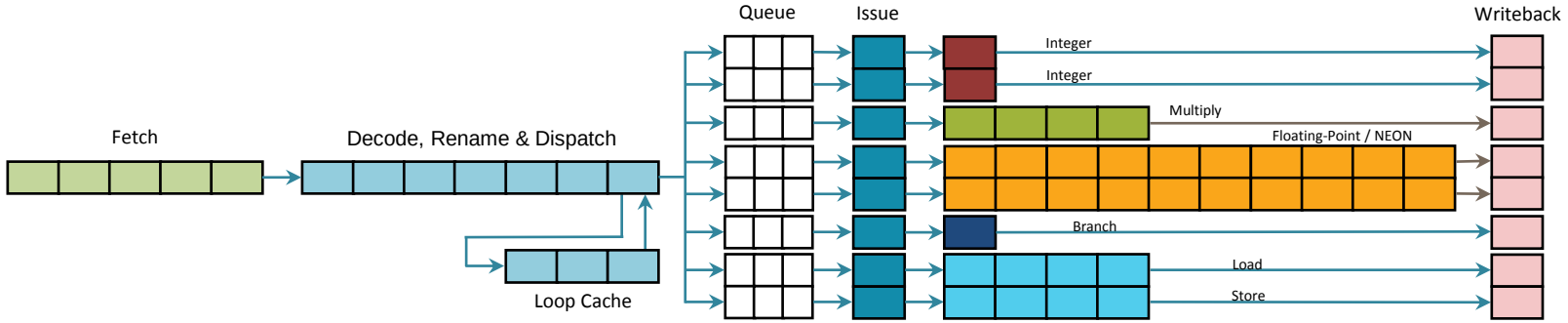
Little: ARM Cortex-A7 Pipeline

- Focused on energy efficiency
- 8-11 Stages, in-order, limited dual-issue

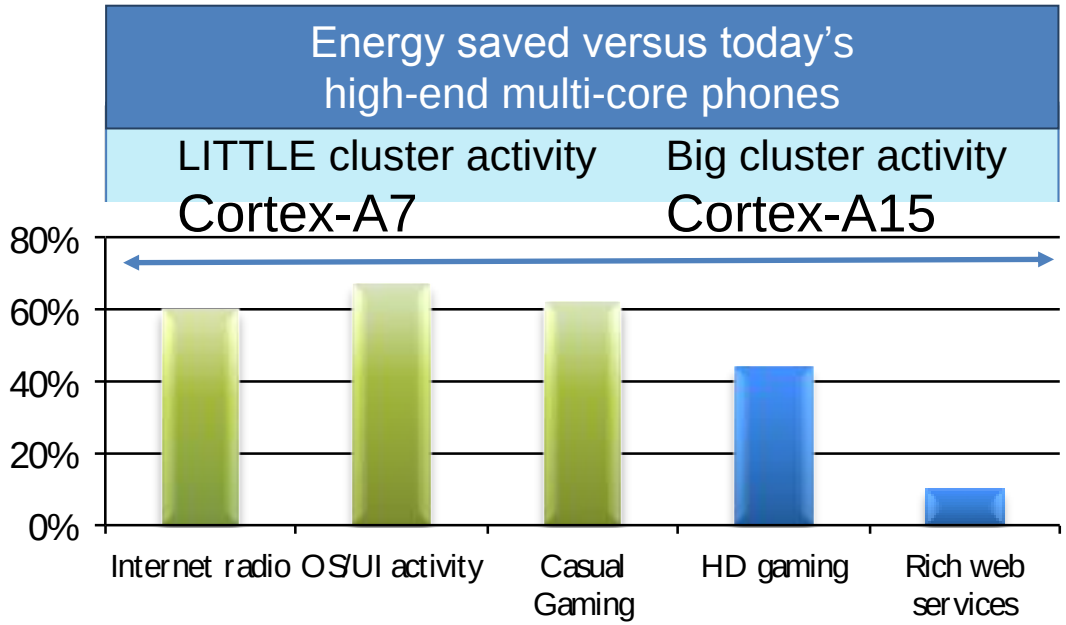


Big: ARM Cortex-A15 Pipeline

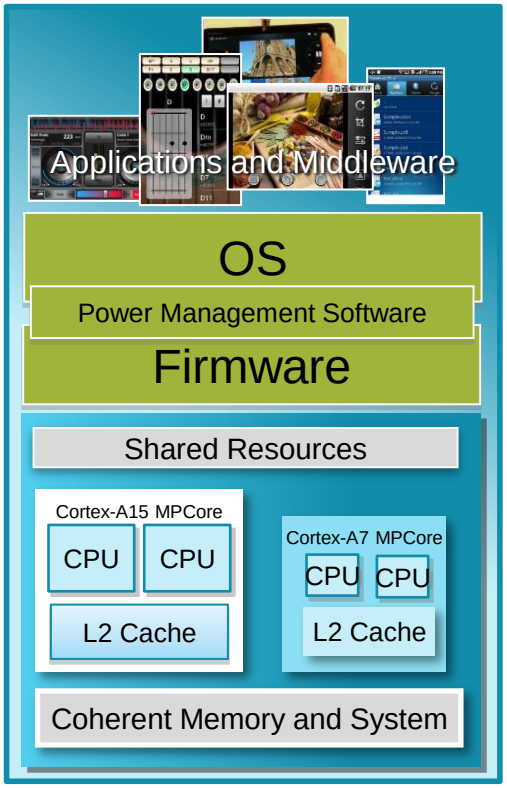
- Focused on efficient peak performance
- 15+ Stages, out-of-order, multi-issue



The right Processor for each job

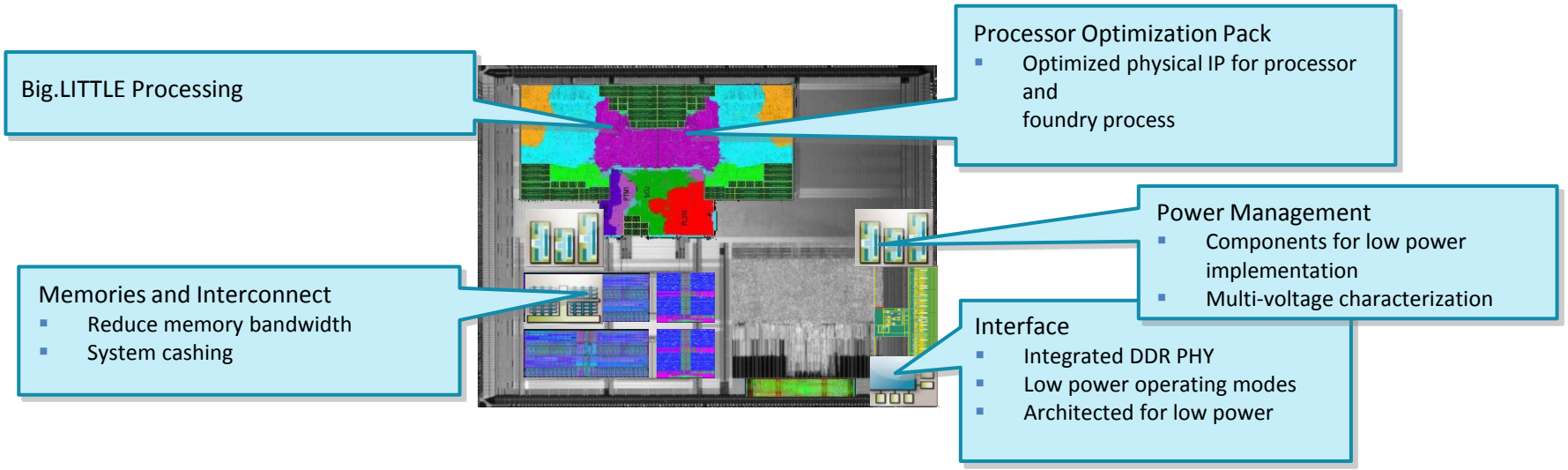


* Dual Cortex-A15 + Dual Cortex-A7 big.LITTLE system estimate in 32/28nm compared with a dual-Cortex-A9 system estimate in 40nm



Energy Efficient Chip Design

- Designing systems-on-chip for low-power
  - Smart interconnect and system components balance the demands of multiple asymmetric processors with widely differing memory requirements
  - Smart physical IP implementation for desired balance of power, area, size and yield

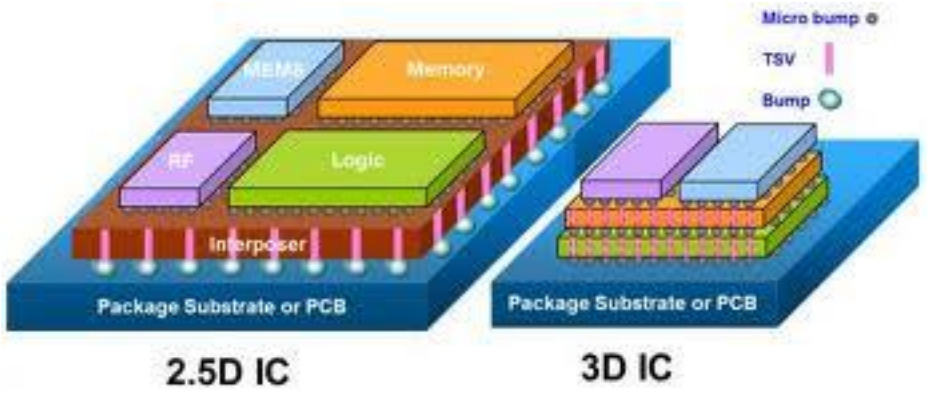


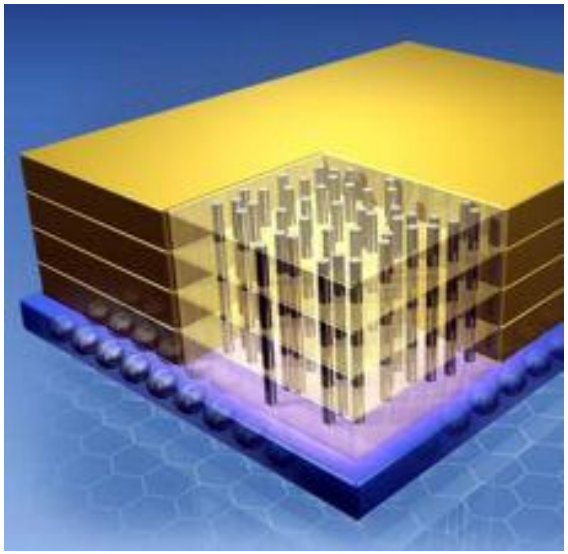
Beyond architecture and system design

- Packaging
- Structures
- Materials

Beyond architecture and system design

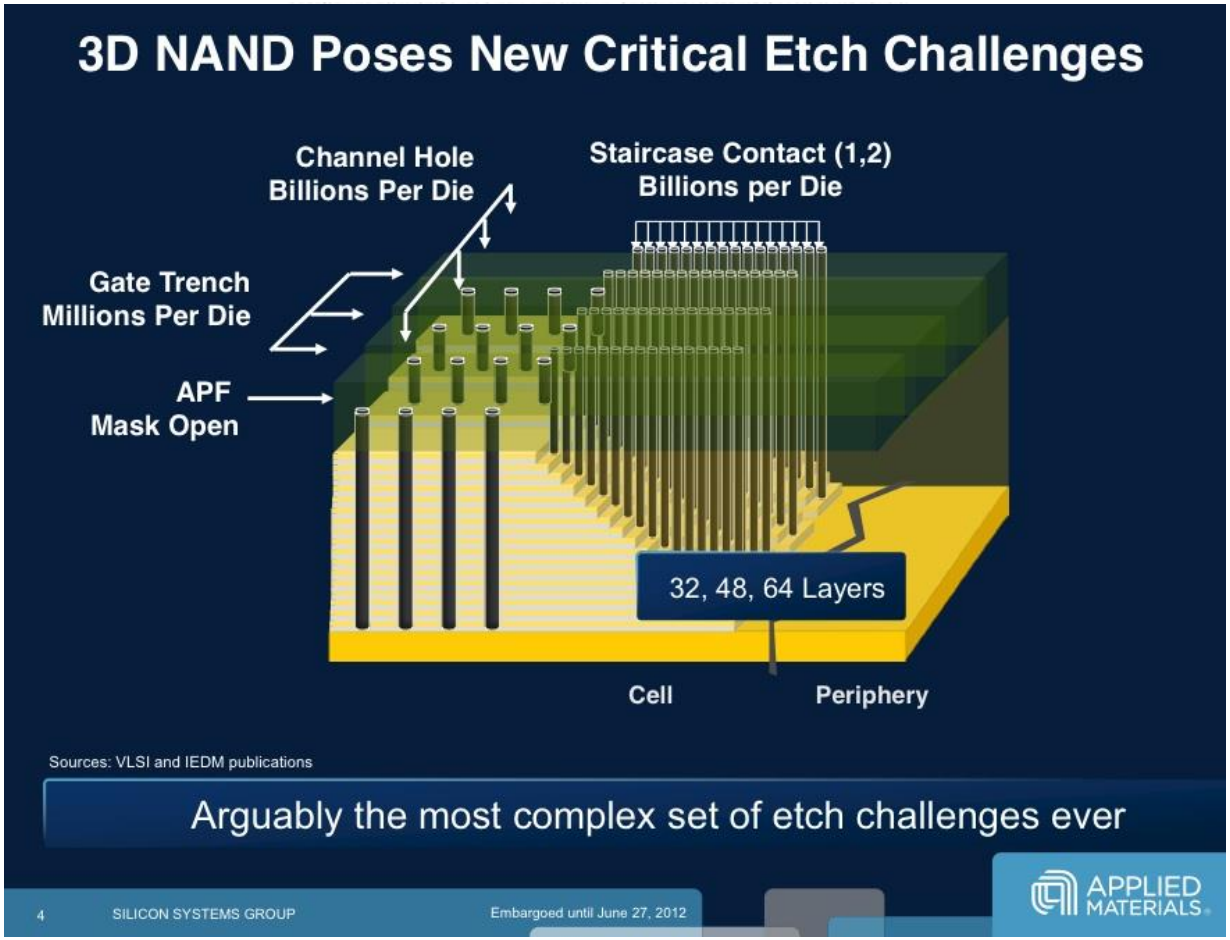
- **Packaging**
- Structures
- Materials





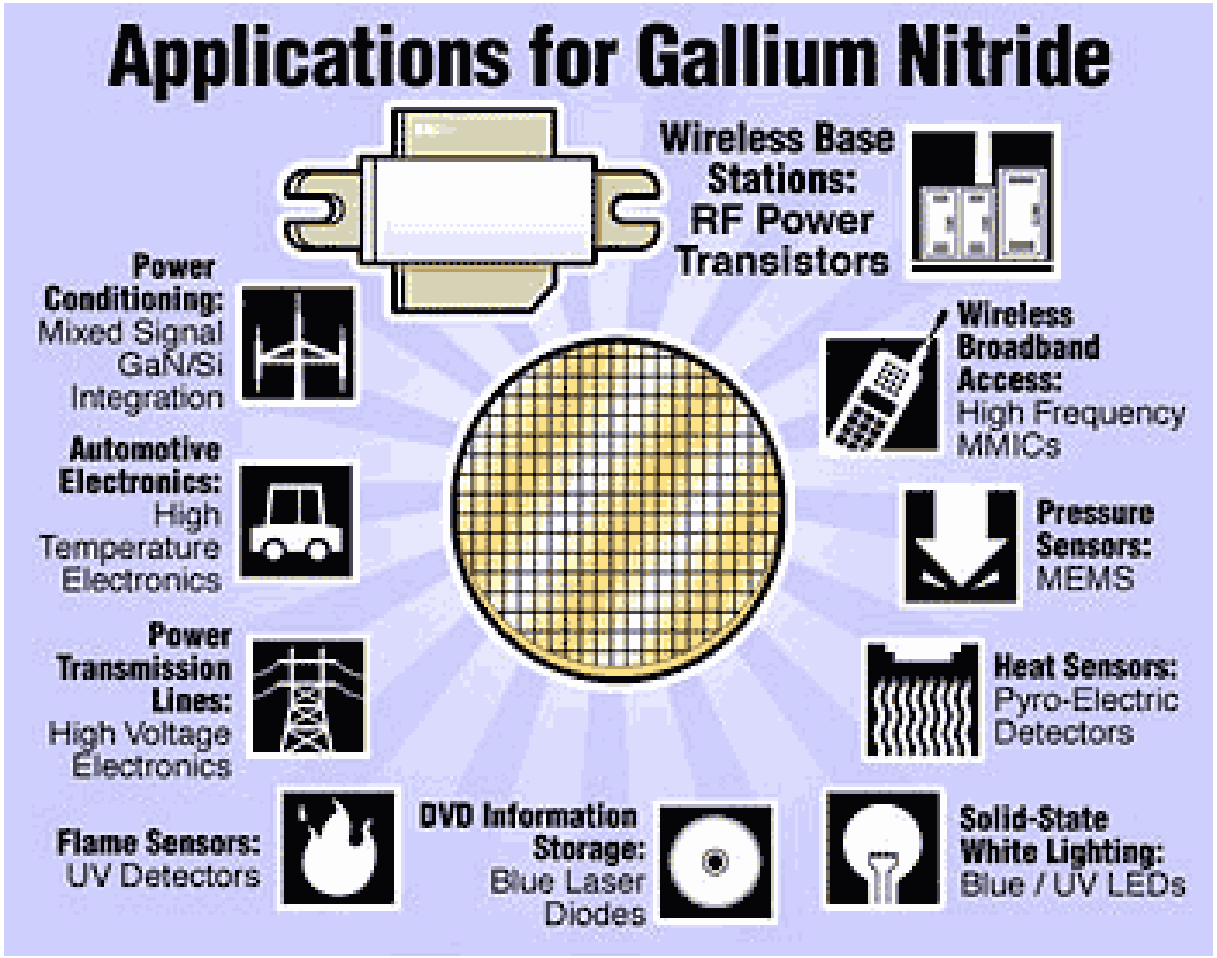
Beyond architecture and system design

- Packaging
- **Structures**
- Materials



Beyond architecture and system design

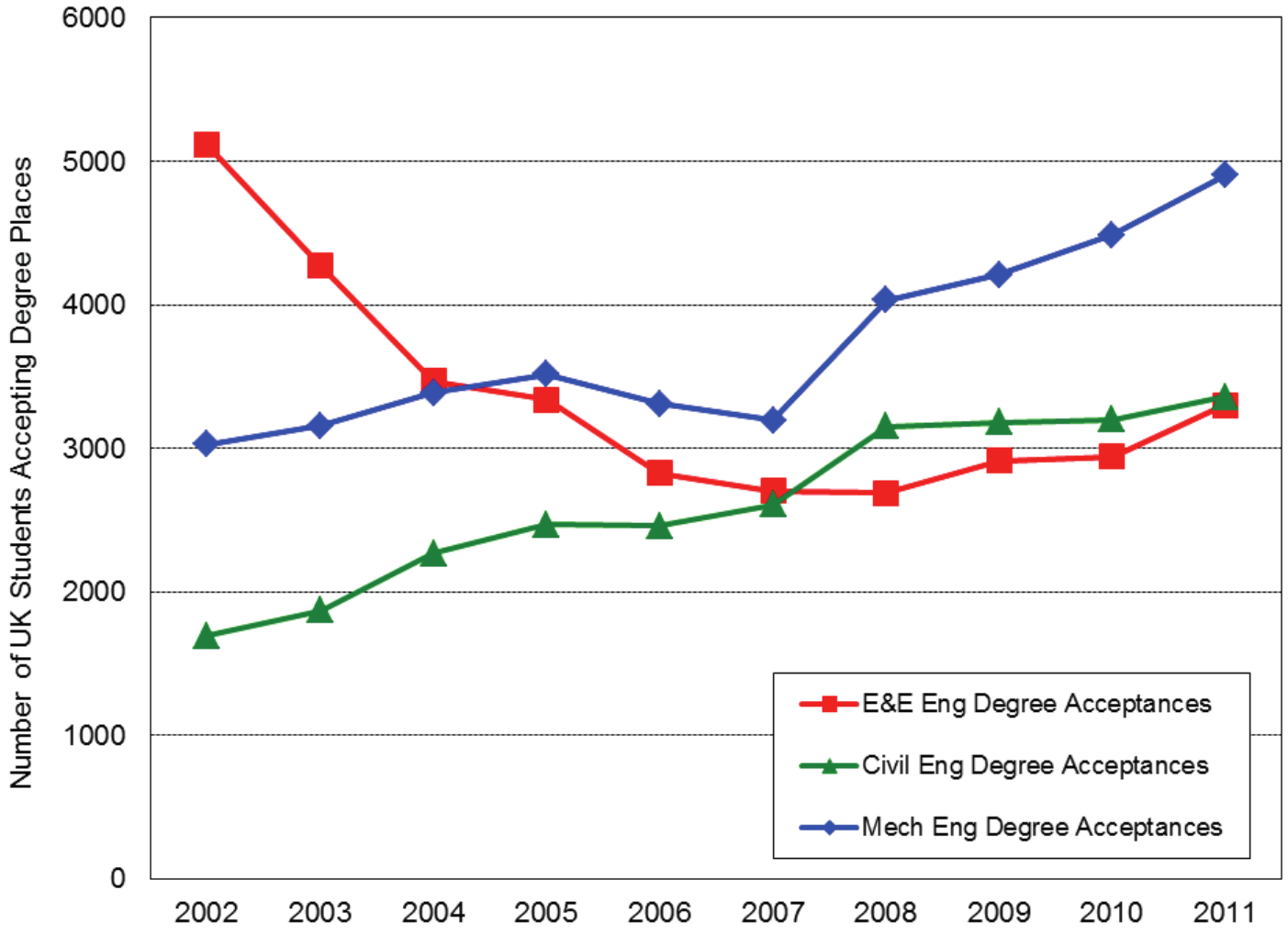
- Packaging
- Structures
- **Materials**



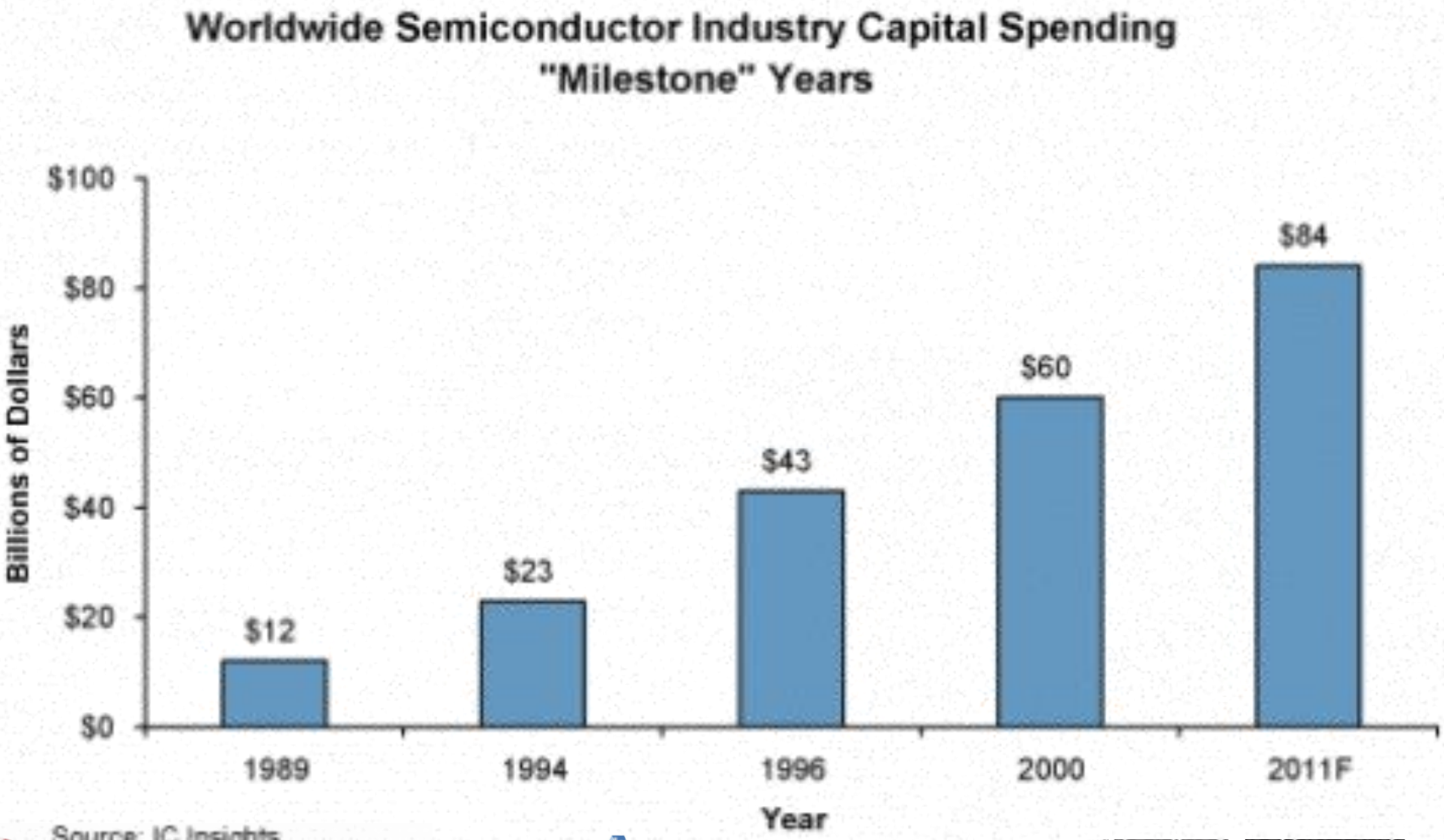
A few Business Challenges

- Getting the skills
- Dichotomy of Innovation & Scale
- Collaboration and Competition

Skills

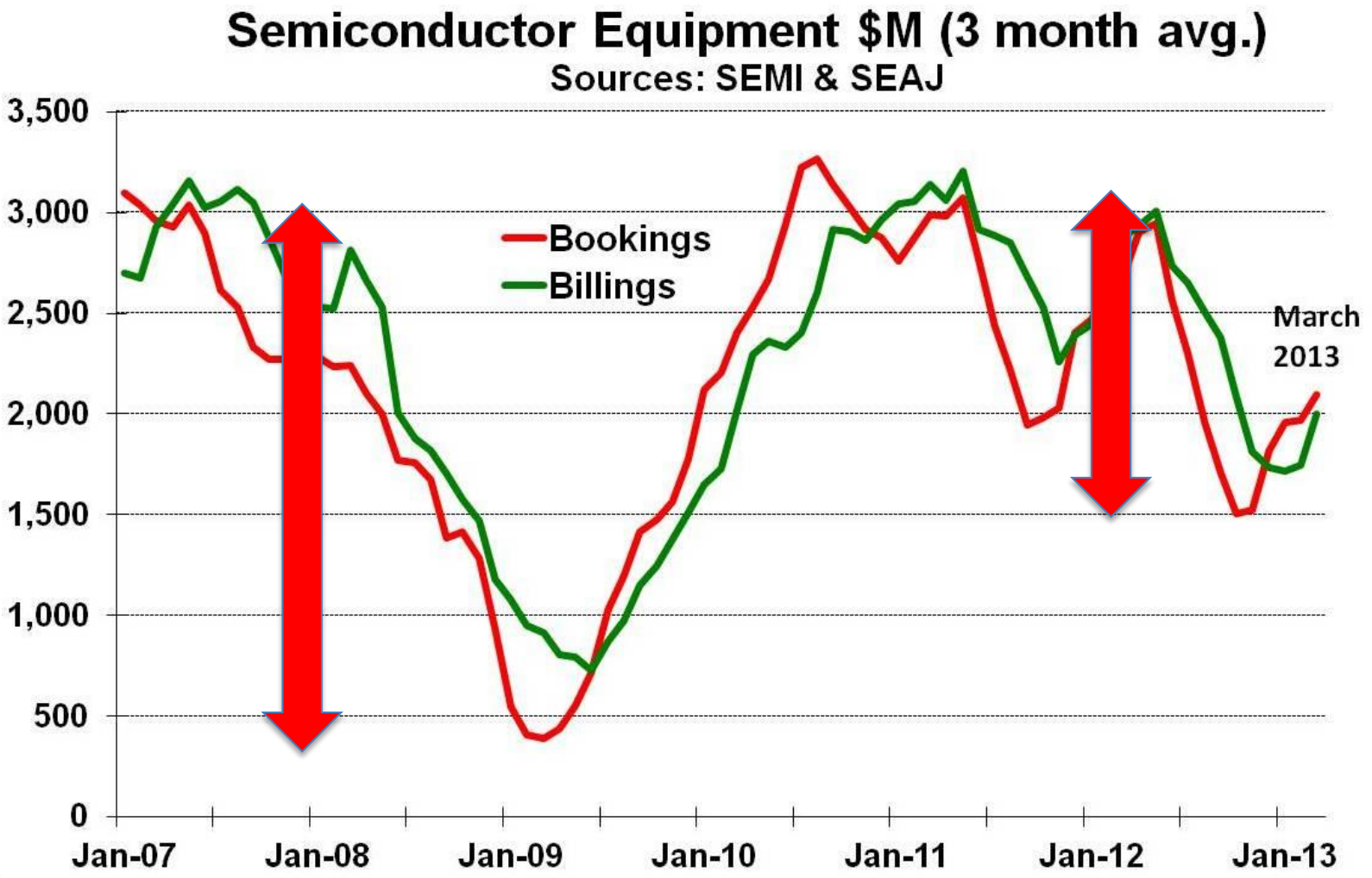

6000
5000
4000
3000
2000
1000
0
Number of UK Students Accepting Degree Places
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
E&E Eng Degree Acceptances
Civil Eng Degree Acceptances
Mech Eng Degree Acceptances

Semiconductor Investment



Source: IC Insights

Investment volatility



Not for the faint hearted…

2013F Rank	Company	2010 ($M)	2011 ($M)	11/10 % Change	2012 ($M)	12/11 % Change	2013F ($M)	13/12 % Change
1	Intel	5,207	10,764	107%	11,000	2%	13,000	18%
2	Samsung	10,948	11,755	7%	12,225	4%	12,000	-2%
3	TSMC	5,936	7,333	24%	8,324	14%	9,000	8%
4	GlobalFoundries	2,750	5,400	96%	3,000	-44%	3,500	17%
5	SK Hynix	3,028	3,165	5%	3,655	15%	3,200	-12%
6	Micron	2,495	2,913	17%	1,773	-39%	2,225	25%
7	Toshiba	1,762	1,935	10%	1,637	-15%	1,600	-2%
8	UMC	1,854	1,585	-15%	1,723	9%	1,500	-13%
9	SanDisk	1,052	1,368	30%	988	-28%	1,000	1%
10	Sony	460	1,805	292%	1,100	-39%	775	-30%
—	Top 10 Total	35,492	48,023	35%	45,425	-5%	47,800	5%
—	Others	18,303	18,042	-1%	13,150	-27%	12,035	-8%
—	Total Cap Spending	53,795	66,065	23%	58,575	-11%	59,835	2%

*Includes company's share of joint-venture spending.

Source: IC Insights, Company Reports

UK Industry structure

- ***Electronic Systems Enterprises***

Table 6: Overtly ES Enterprises (P+S) ...

EntSize	ES Enterprises	Dist'n	Employment	Dist'n	Wages (£m)	Dist'n
0-4	22,450	74.8%	30,021	6.9%	1,285	7.5%
5-9	2,894	9.6%	16,520	3.8%	707	4.1%
10-19	2,000	6.7%	23,994	5.5%	978	5.7%
20-49	1,388	4.6%	37,738	8.7%	1,537	8.9%
50-249	1,050	3.5%	92,740	21.3%	3,581	20.8%
250+	250	0.8%	234,441	53.8%	9,106	53.0%
	30,031	100.0%	435,454	100.0%	17,195	100.0%

- **Electronic Systems employs 435k people in 30k ES Enterprises**
- **~50% of employment is in 250 companies with ave. size of 1,180**
  - Nationally only 22% of employment is in 250+ category
  - These are very successful ES businesses!
- **~80% of ES Enterprises are <10 employees**
  - These a tremendous growth opportunity for the ES Sector

Dichotomy of Innovation & Scale

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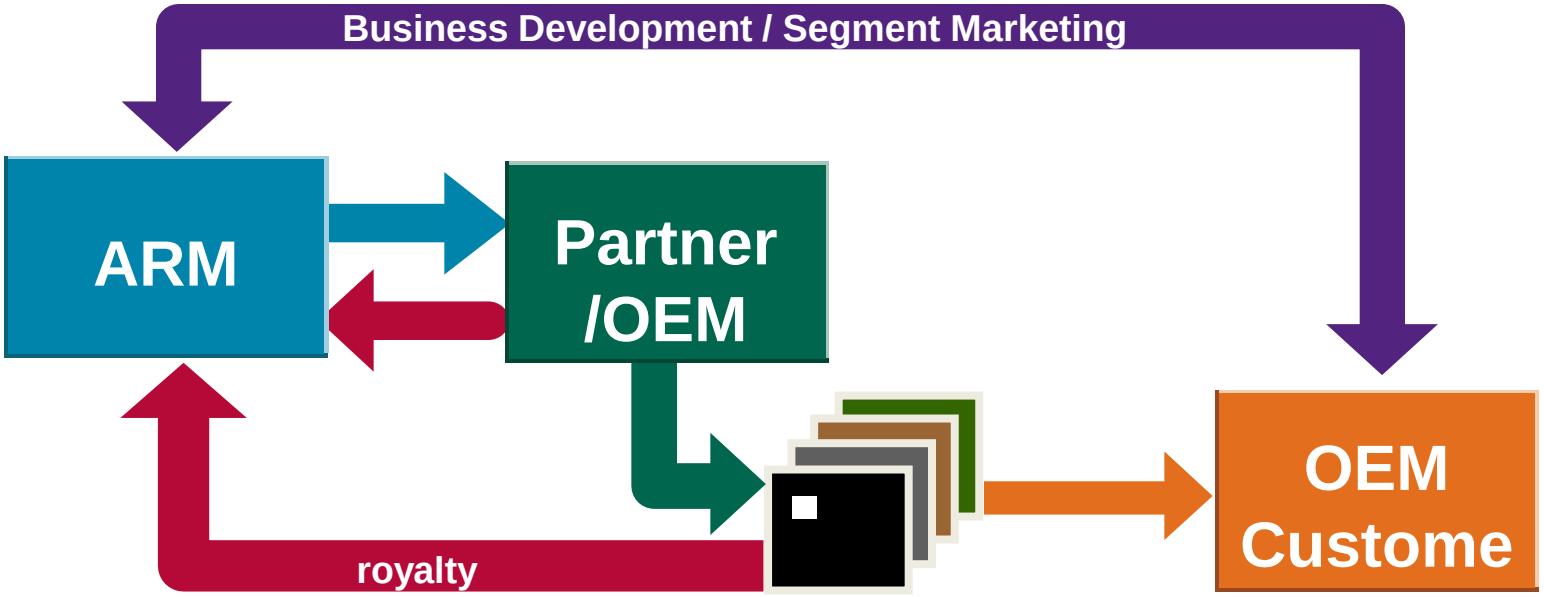
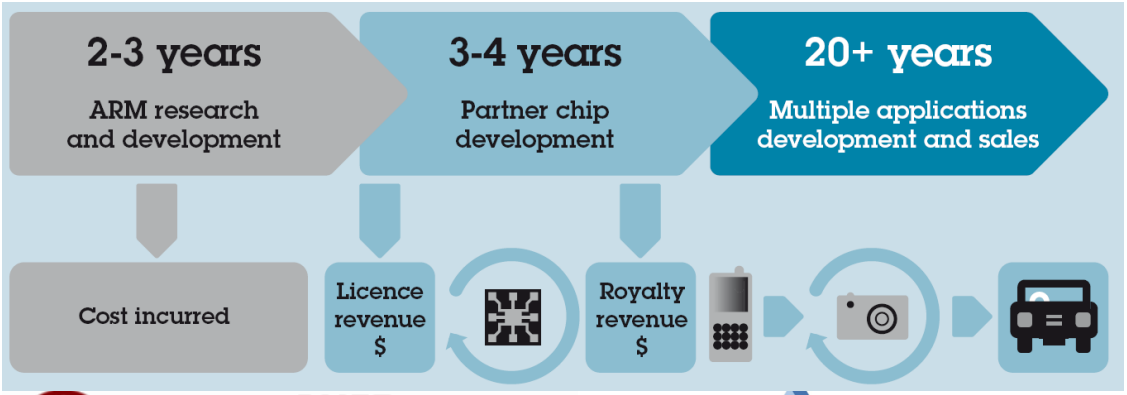
ARM's Licensing Model





Base of circa 100 licenses
Grows by 80-100 every year

Approx 330 potential shipping SC partners

9 bn ARM-based chips in 2012
25% CAGR over last 5 years

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Industry collaboration essential

Connectivity

Choice

Interoperability

Trust

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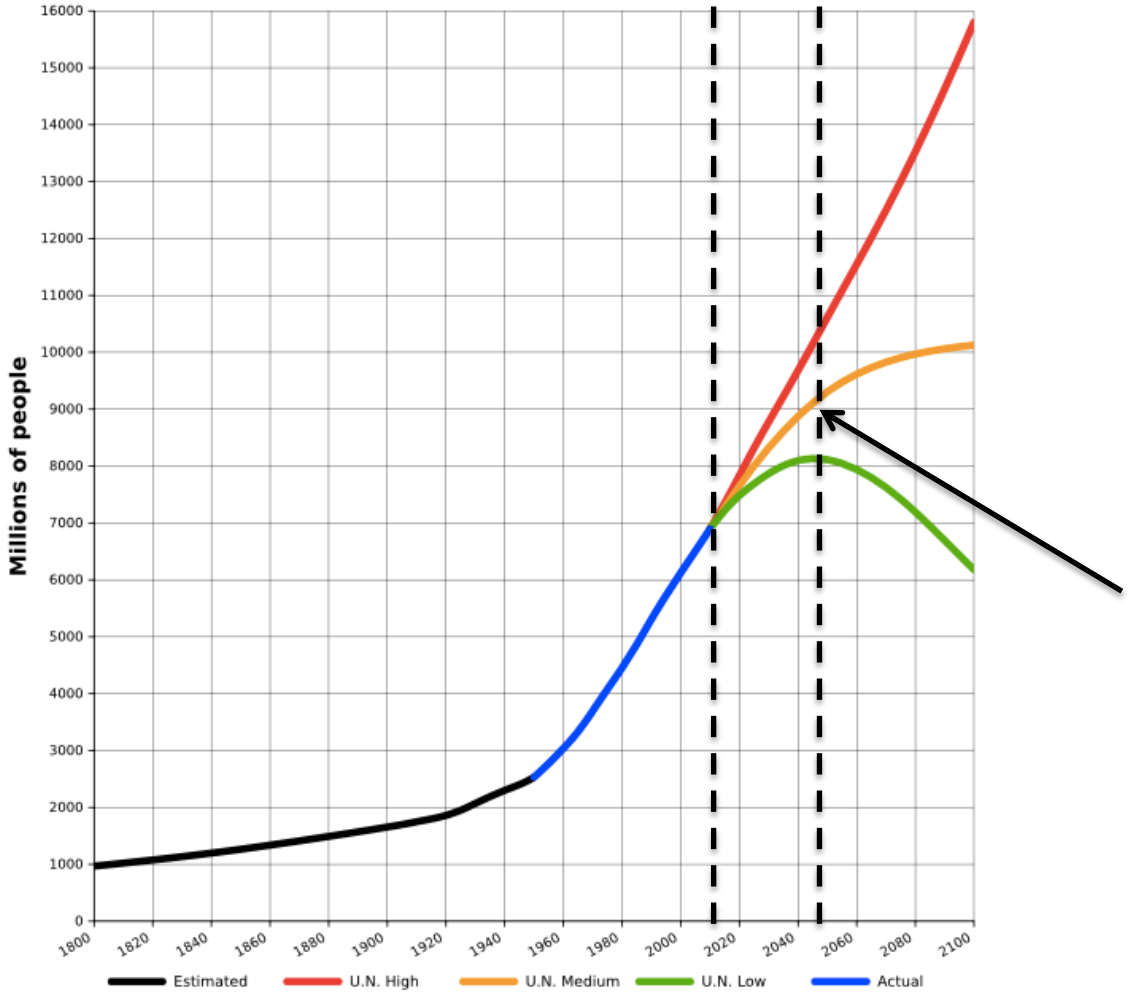
UN Population estimates



30 : 30

Medium case estimate
30% growth in 30 years

Food: we are running out of room

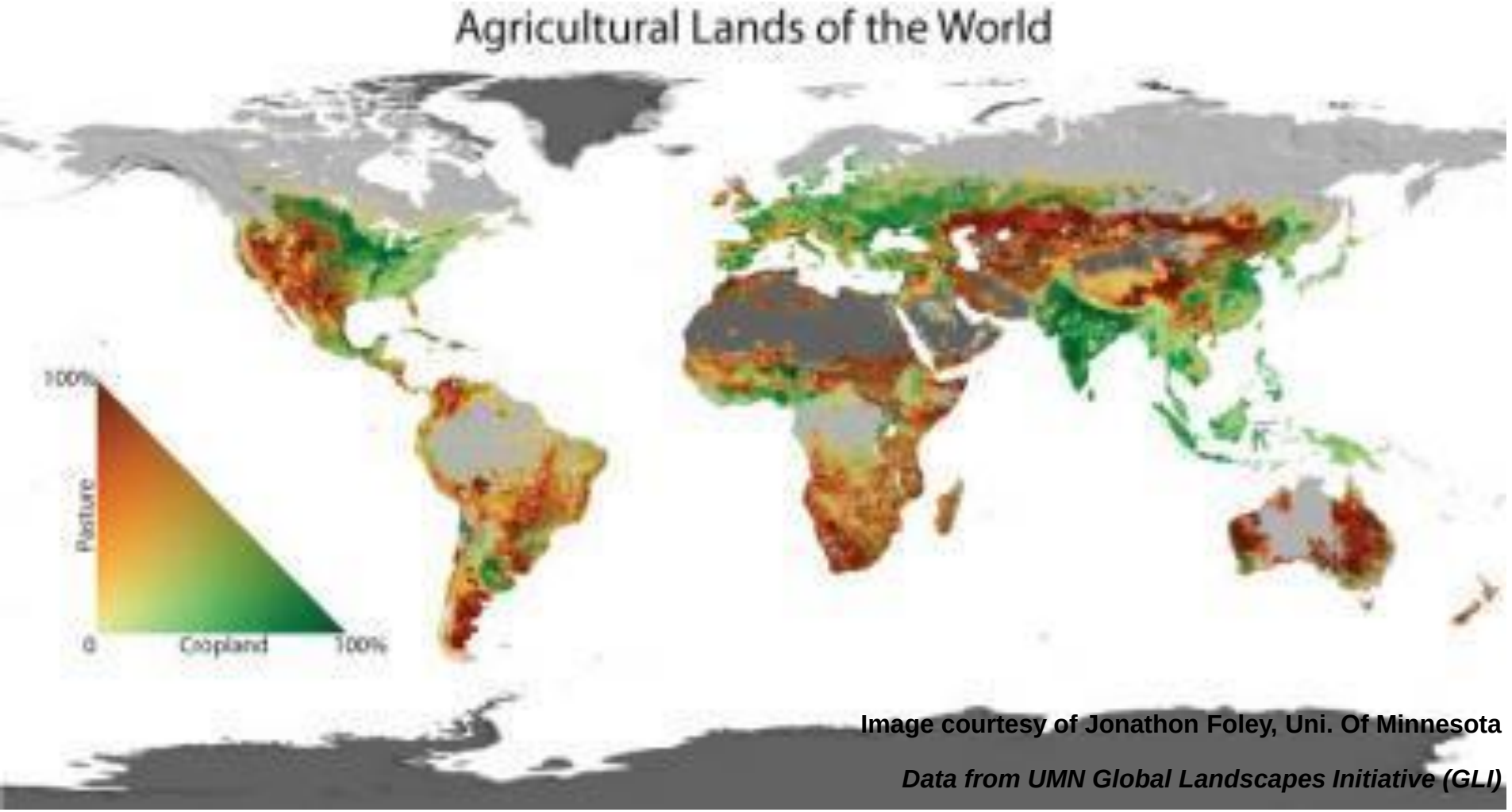
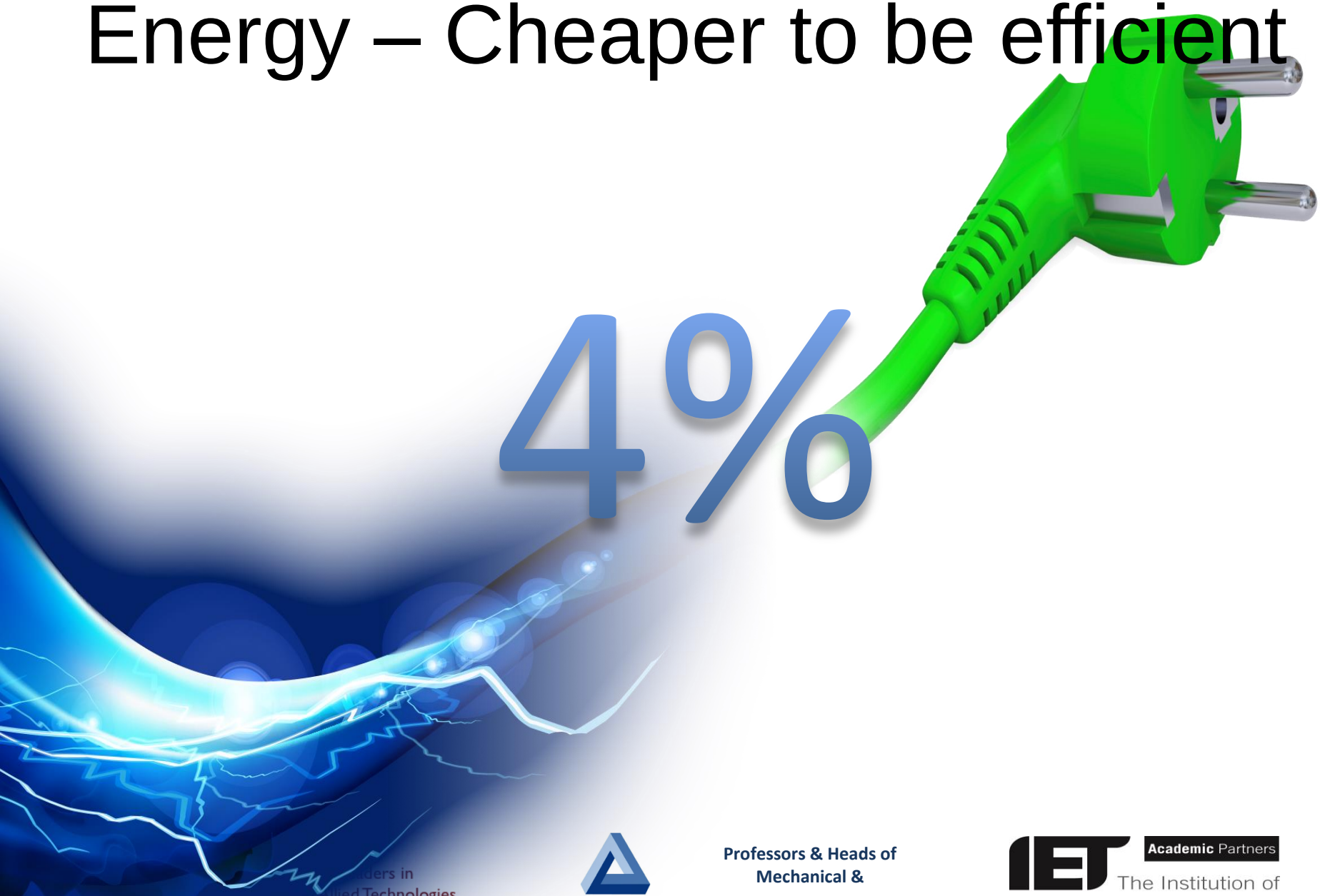


Image courtesy of Jonathon Foley, Uni. Of Minnesota

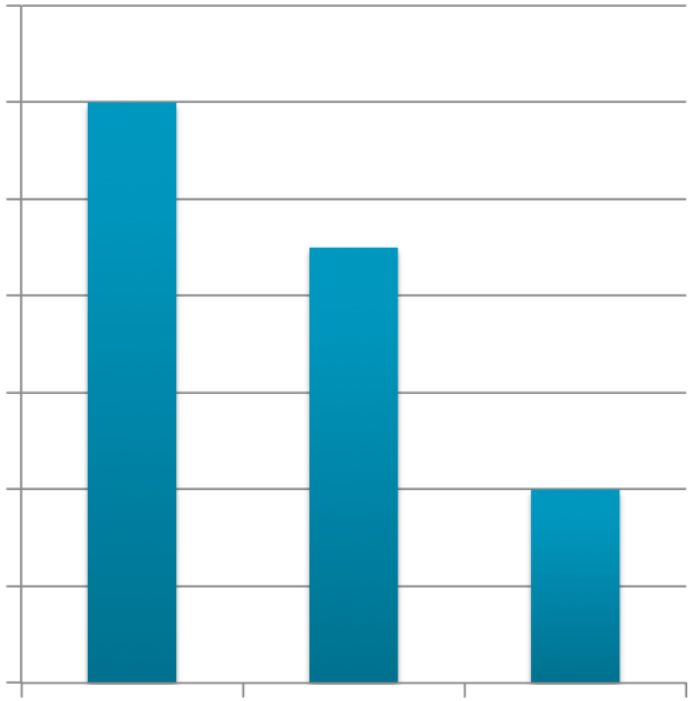
Data from UMN Global Landscapes Initiative (GLI)

Water is our rarest commodity

Energy – Cheaper to be efficient



Ageing population, growing problem



Source: World Population Ageing 1950-2050, United Nations

What is already out there?

ONFARM GROW INFORMED

EnLight ADVANCED LIGHTING TECHNOLOGY

Syrinix Leading Pipeline Protection

SCANADU

Scanadu Scout™

Precision Agriculture

Streetlight Efficiency

Leak Detection

Chronic Disease Management

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Future

What

- Continued Innovation in Electronic Systems
- New materials and microstructures
- More software for flexibility and cost

How

- Skills and retraining required
- Multidisciplinary Engineering collaboration
- Collaboration between businesses
- Standardisation & reuse
- Global outlook

Why

- Huge opportunity for this technology to address big societal challenges and make the world better