

Innovation & Wealth Creation from Technology

(With a Test Flavour)

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Deputy President IET

H.M. Government & Innovation

- May 03 DTI: 'Competitiveness Study', shows UK Industry must become more Innovative to remain competitive
- Dec 03 DTI: 'Innovation Report', Pref. by PM, elaborates on what that means
- Mar 05 DTI/HMT: 'Economics Paper 11' & July 05 HMT: 'Supporting Growth & Innovation'

... commits Gov. to driving UK R&D Spend to 2.5% of GDP (from 1.9%)

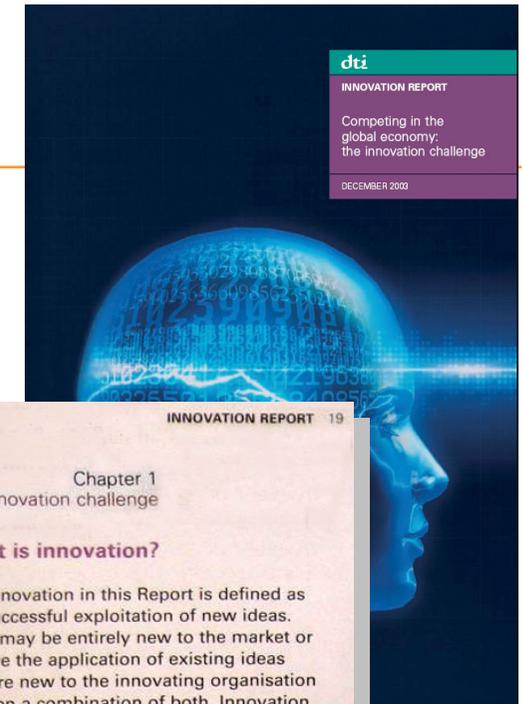
... When the Chancellor of The Exchequer and The Science Minister are aligned that presents an opportunity



So what is Innovation ?

- DTI defines Innovation as the successful exploitation of new ideas
- It **often** involves new technologies or the application of new technologies
- But **not always** ...

... Many (even most) of the Most-Innovative Products involve deployment of widely known technology in Innovative Ways!



INNOVATION REPORT 19

Chapter 1
The innovation challenge

What is innovation?

1.1. Innovation in this Report is defined as the successful exploitation of new ideas. Ideas may be entirely new to the market or involve the application of existing ideas that are new to the innovating organisation or often a combination of both. Innovation involves the creation of new designs, concepts and ways of doing things, their commercial exploitation, and subsequent diffusion through the rest of the economy and society. It is this last – diffusion – phase from which the bulk of the economic benefits flow. Most innovations are incremental – a succession of individually modest improvements to products or services over their life cycle. But a few will be dramatic, creating entirely new industries or markets.

1.2. Innovation involves experimentation and risk taking. Some attempts to innovate will fail, but across the economy the successes outweigh the failures. And the failures themselves generate new knowledge, which if evaluated correctly, can improve the chances for future success. The risk of failure justifies the potentially high returns from successes, which provide the incentive to innovate in the first place. Successful innovation-led companies have a number of common characteristics (Box 1.1).

Innovative Product ... The iPod

- Uses Known technology
 - Sound compression technology (mp3)
 - ARM based SoC technology
 - Operating System / GUI techniques
 - Micro Hard Disk / SSM
 - LCD and Touch interfaces
 - Standard Mobile Phone assembly technology
 - The Internet (for tune delivery)
- The product was a packaging exercise
- It displaces Walkman type product
- Increasingly displacing home Hi-Fi

... The real innovation however was iTunes which changes the Dynamic of Music Delivery



iTunes ...



Watch the iPod Ads.



iPod + iTunes
For Mac and Windows

Now with Podcasting

NEW 4.9



Free Download

Over half a billion songs sold and legally downloaded.

500,000,000

View the winners and the songs they downloaded.

Apple Financial Results Q3 - 2005

Download Podcast Now

Redeem song

SLURPEE



Next Free Single: 08/02

New 20GB iPod

2-inch color LCD display. Up to 15 hour battery life. Podcast ready. Just \$299.



The best digital jukebox, with the #1 music download store inside.

Setting a new milestone for the digital music business, the iTunes Music Store has sold more than 500 million songs, providing music fans with the best music download experience on Mac or PC. Now iTunes offers even more ways to discover and enjoy music.

Largest Legal Download Catalog. Select from more than 1.5 million tracks from all four major music companies and over 1,000 leading independent labels. Enjoy free 30-second previews of all songs and find hundreds of exclusive and pre-release tracks.

Podcasting. With iTunes 4.9 you can now browse, find, sample and subscribe to thousands of free podcasts — radio shows delivered over the Internet to your computer — then sync them to your iPod and listen anytime, anywhere.

Auto-Sync with iPod. With an iPod and iTunes, it's a cinch to sync: fast, simple and effortless. The new AutoSync option even automatically syncs just enough music for your iPod shuffle. Got photos? Now you can copy them to your iPod and view them on the go or on a big-screen TV.

Pop Music Wire/Cable on Your Home Stereo. With iTunes 4.9 you can now sync your iTunes library to your home stereo system.

The new iPod mini.

4GB and new 6GB models. Now starting at \$199.



iPod shuffle

1GB 240 songs now just \$129

512MB 120 songs just \$99.



Top 10 Songs

1. **Pon de Replay (Radio Edit)**
Rihanna
2. **Feel Good Inc. (Album Crossfade)**
Gorillaz
3. **Sugar, We're Goin Down**
Fall Out Boy
4. **You and Me**
Lifehouse
5. **Don't Cha (featuring Busta Rhymes)...**
The Pussycat Dolls & Busta Rhymes
6. **Just the Girl**
The Click Five
7. **Beverly Hills Weezer**

8. **Best of You**
Foo Fighters

- *iTunes takes Apple into the PC space*
- *Now bundled loaded on PCs*
- *Creates a new business space for Apple which to some degree competes or collaborates with Microsoft, Sony & Universal*

Innovative Product ... The GSM Phone

- GSM Telephone
 - Highly complex technology
 - Complex but user friendly handsets
 - Capital intensive infrastructure



... Stimulated move from Analogue to Digital
... Put Nokia ahead of Motorola
... Helped the growth of Vodaphone and France Telecom

GSM Phone ...

- *Lessons*

- *Standards are important*
- *Open architectures win against closed architectures*
- *GSM provided a better user experience than Analogue*

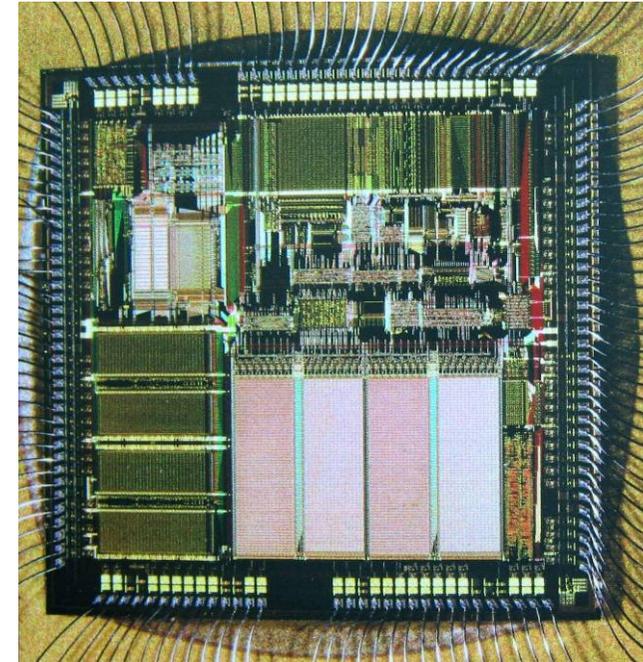
- *Meanwhile*

- *Qualcomm did well with CDMA*
- *3G coming*
- *New Businesses ARPU*
- *Phone services via the Internet have the opportunity to displace the Mobile Operators as they once displaced the National Carriers*

... The real innovation was creating a Global Standard

Innovative Product ... ARM CPU Cell

- Uses Known Technology
 - Was 'just another' CPU architecture ...
 - A good, simple (but basic) RISC implementation
 - With good simple (but basic) tools ... MIPS, ARC, 68K and x86 were around before it
 - Had no dominating technological characteristics except that it had been designed as an ASIC ...
 - Out of standard cells
 - On industry standard tools
 - On industry standard processes
 - But was small & was cheap



The First ARM ...

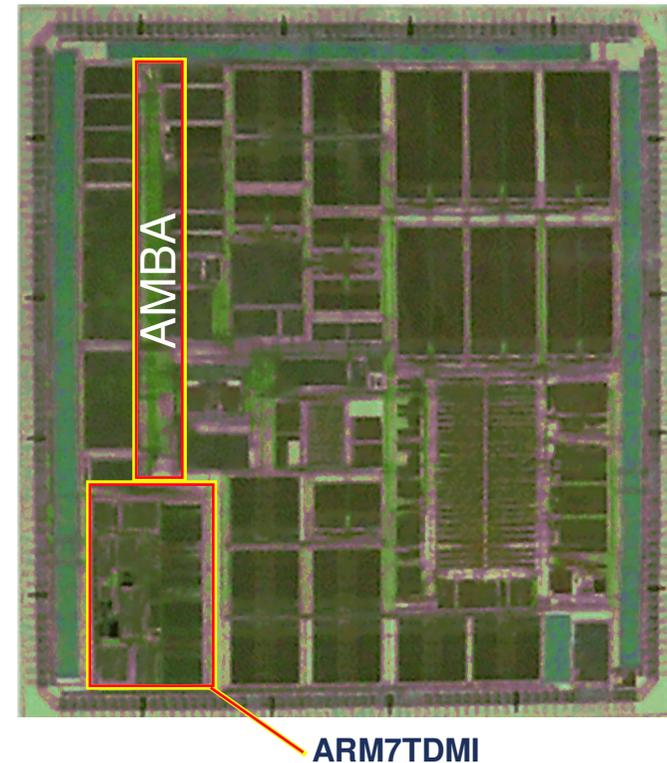
- ~39k transistors
- ~10 MIP
- 25mm² on 1.4um
- circa 1991

ARM CPU ...

- Addressed a market (Embedded Systems) which the 'big guys' saw was too small and specialised
- Replaced a lot of single-chip processor applications
- Enabled a new market for SoC
- Enabled the concept of the Virtual Component
 - Allowed design reuse
 - Allowed distributed design

... *The First Innovation was to make it equally Available to Everybody*

Mobile-Phone Processor.
1998 80mm², 0.6μm

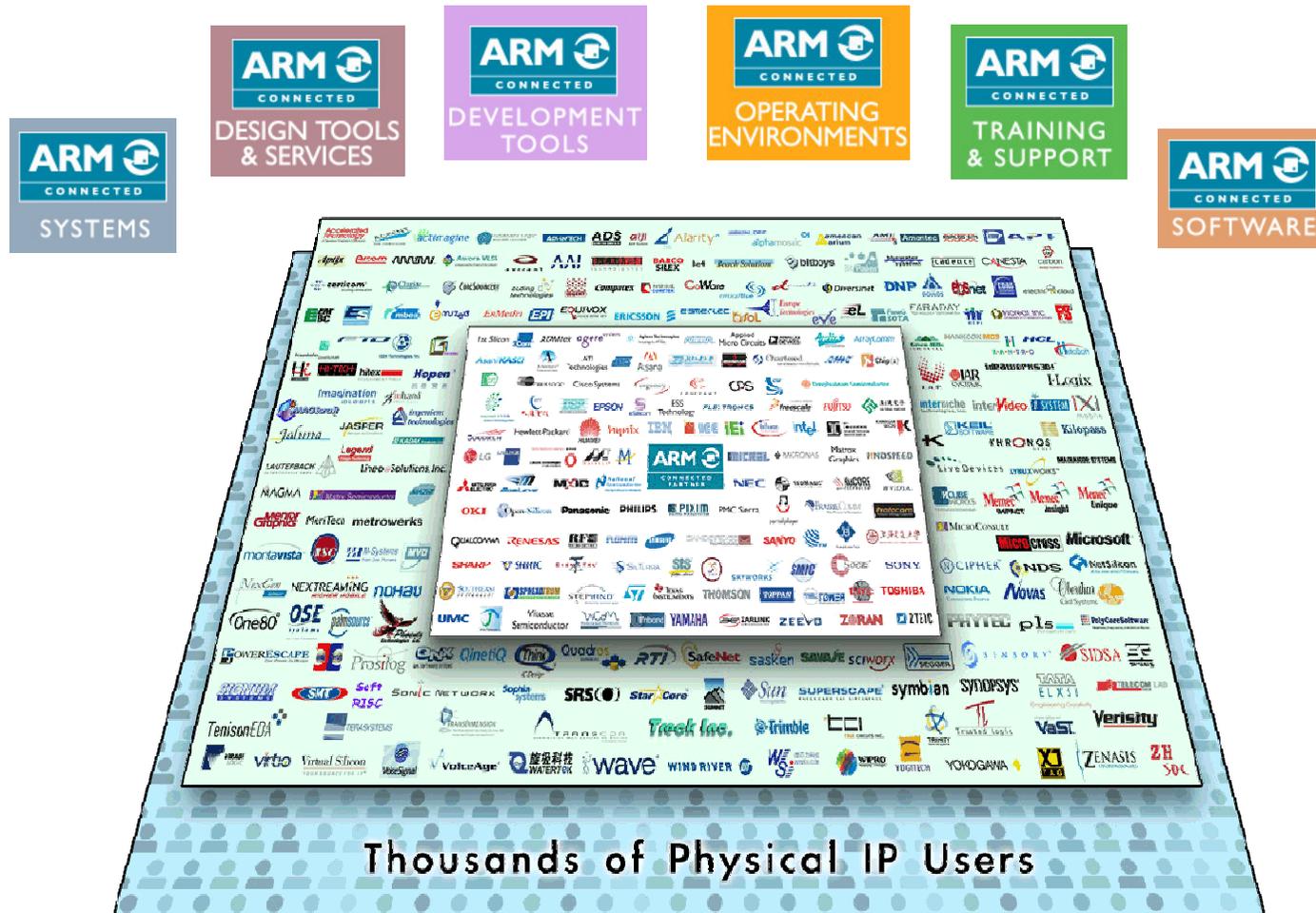


ARM in Embedded Systems Today ...



- 1990 Acorn ARM Units = 100K
- 2005 ARM Units 1.7B or 54 every sec

The Power of Partnership



- open standards, common vision, partner differentiation, local support

The Virtual Design Team

- Partnership ...
 - Share the Design Challenge
 - Allow 'groups' to excel in their own areas of expertise
- Cost and Return Sharing
 - Allows ARM's Partners to focus their R & D for more value add and less risk
 - Assures mutual incentive to succeed
 - More seamless hardware software interfaces
 - Phasing the cost of Intellectual Property by allowing the customer to negotiate his up-front payment vs his production payment – License vs royalty
- For the end customer – More choice – Better solutions

... The real ARM Innovation was the shared-cost Licensing and Royalty Business Model

Becoming a Serial Innovator

- Then we developed AMBA ...
 - then Memory Optimised Processors (Thumb),
 - then Sub-System Assemblies (PrimeXsys),
 - than Standard OS Ports,
 - then Drivers for Market Segments (Move, MBX and Jazelle)
 - then Secure Processors (Secure-Core and Trust-Zone),
 - then Data-Engines (OptimoDE)
 - then ...

... Based on 'standard' technology, these Innovations delivered Business advantages ... Increased Confidence for our Users

... They were driven by explicit needs of Real Customers

And Some Innovation is Technology

- Using 'standard' technology to implement the extraordinary.
- Developing processors which are optimised for Embedded Applications
 - Power management ... IEM
 - Processors with highest Power Efficiency
 - Operating Systems
 - Real Time De-bug
 - Methods
 - Cell-libraries ... (Artisan)
 - TrustZone

... Innovations delivering Technology advantages; enabling the development of products that could not be done elsewhere

So lets look at Innovation

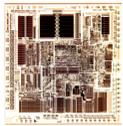
- So our retrospective 'analysis', tells us that Innovation is a powerful component of Successful Business ...
- But what is it ?
 - ... How do we recognise it ?
 - ... Can we make it happen on demand ? ..and..
 - ... Can it be tamed by Business Processes ?

... Some observations from my experience

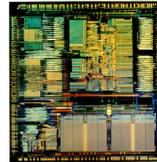


Scaling for Performance

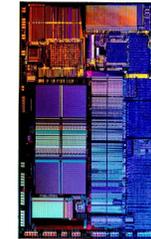
80s & 90s industry growth and scaling in computing power



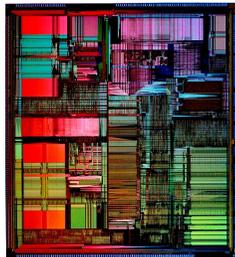
1982 - Intel 80286
134 thousand transistors
12MHz; 68.7 mm²



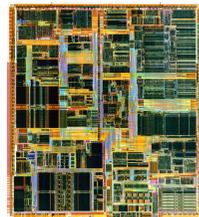
1985 - Intel 80386
275 thousand transistors
33MHz; 104 mm²



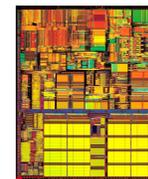
1989 - Intel 80386
1.2 million transistors
50MHz; 163 mm²



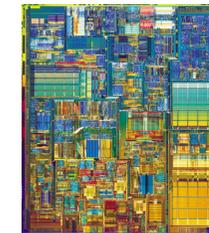
1993 - Intel Pentium
3.1 million transistors
66MHz; 264 mm²



1997 - Intel Pentium II
7.5 million transistors
300MHz; 209 mm²



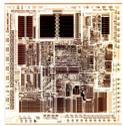
1999 - Intel Pentium III
28 million transistors
733MHz; 140 mm²



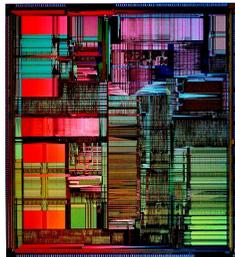
2000 - Intel Pentium 4
42 million transistors
1.5GHz; 224 mm²

Scaling for Performance

80s & 90s industry growth and scaling in computing power



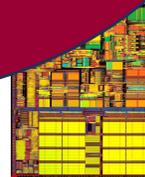
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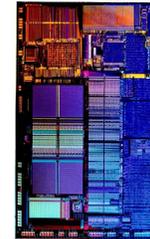
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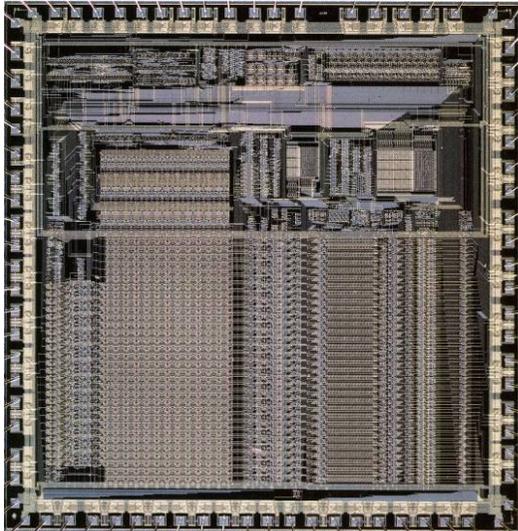


2000 - Intel Pentium 4
42 million transistors
1.5GHz; 224 mm²

Performance at
expense of power
and thermal
challenges

Move to multi-
processor

Scaling for Power and Area (Cost) Too



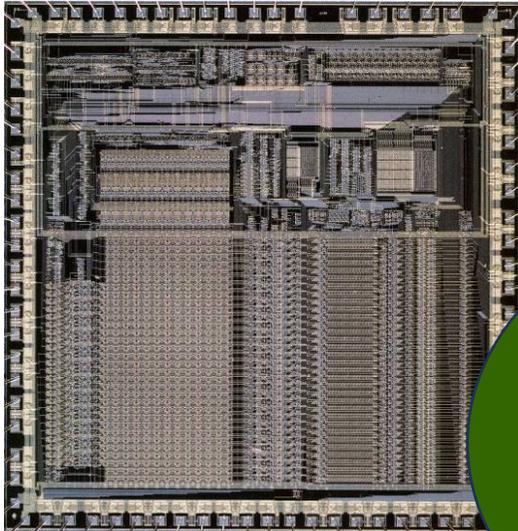
- ARM1 (1986)

- 3.0 μ m (2 Layer Metal)
- 25K Transistors
- 6MHz
- 20mW/MHz
- 50mm²

- ARM7TDMI[®] (2006)

- 65nm (4 Layer Metal)
- 100K Transistors
- ~180MHz
- 0.025mW/MHz
- <0.1mm²

Scaling for Power and Area (Cost) Too



Relative size
today!

800 x power
efficiency
550 x area
efficiency

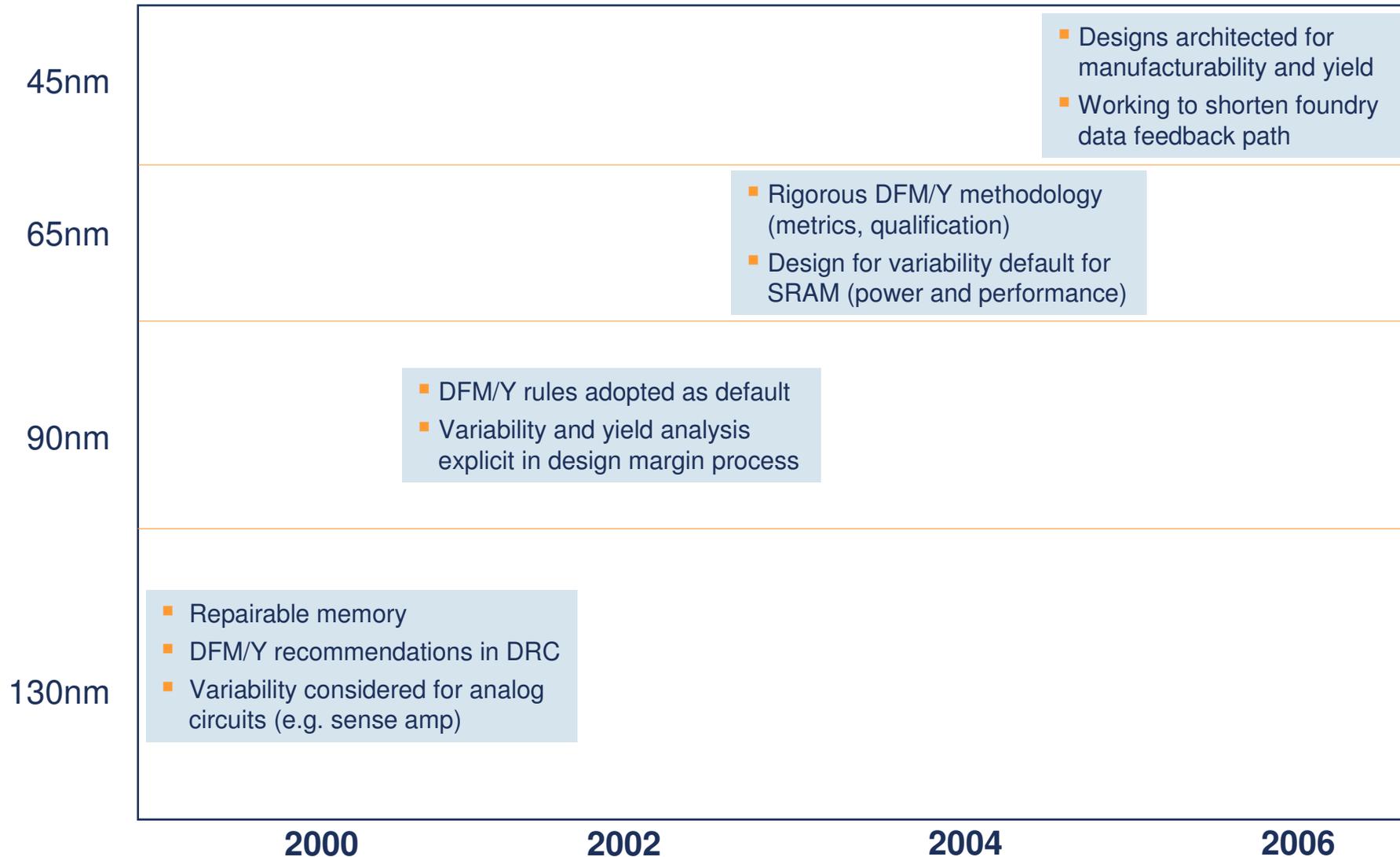
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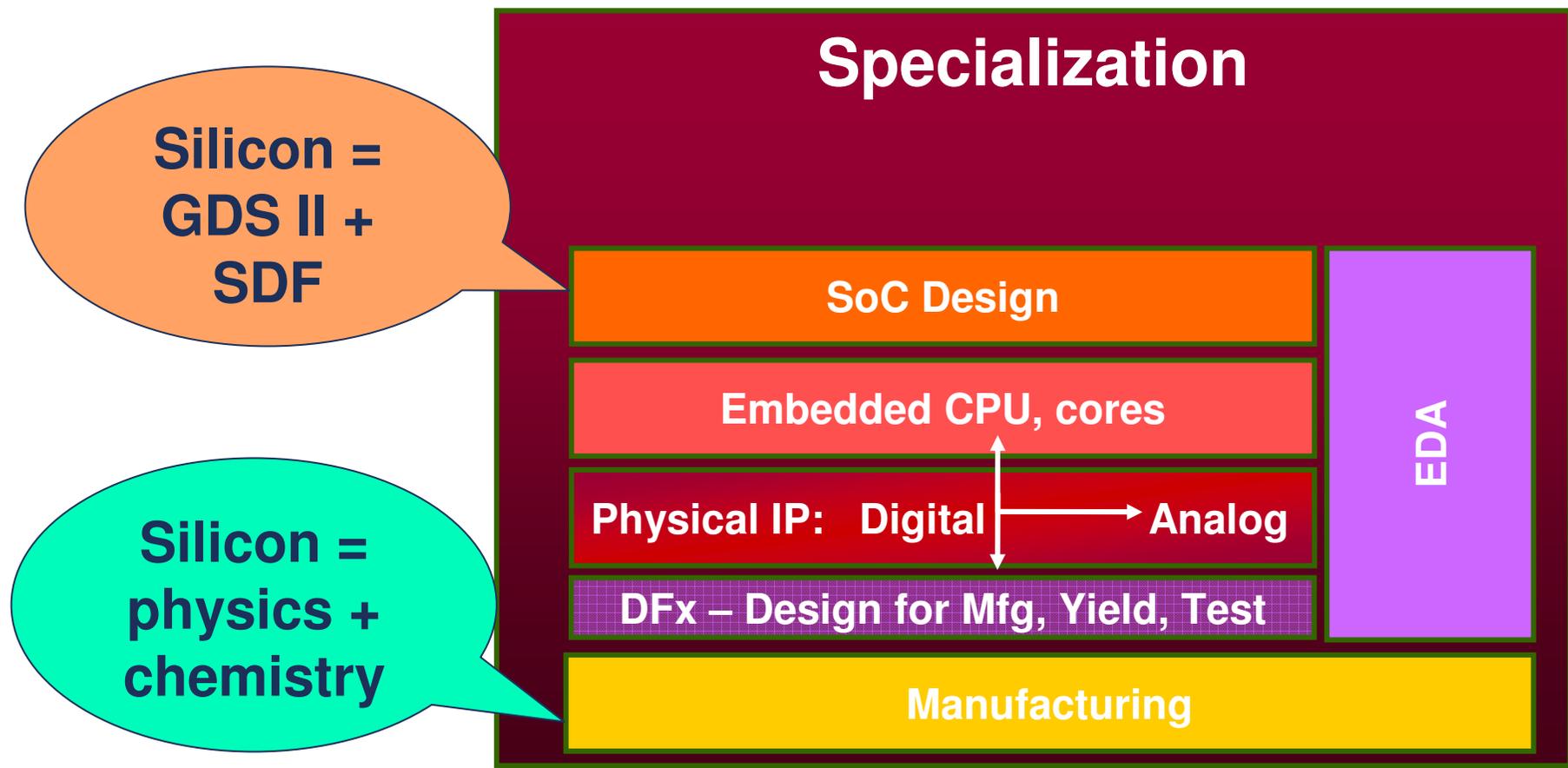
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DFY across process generations



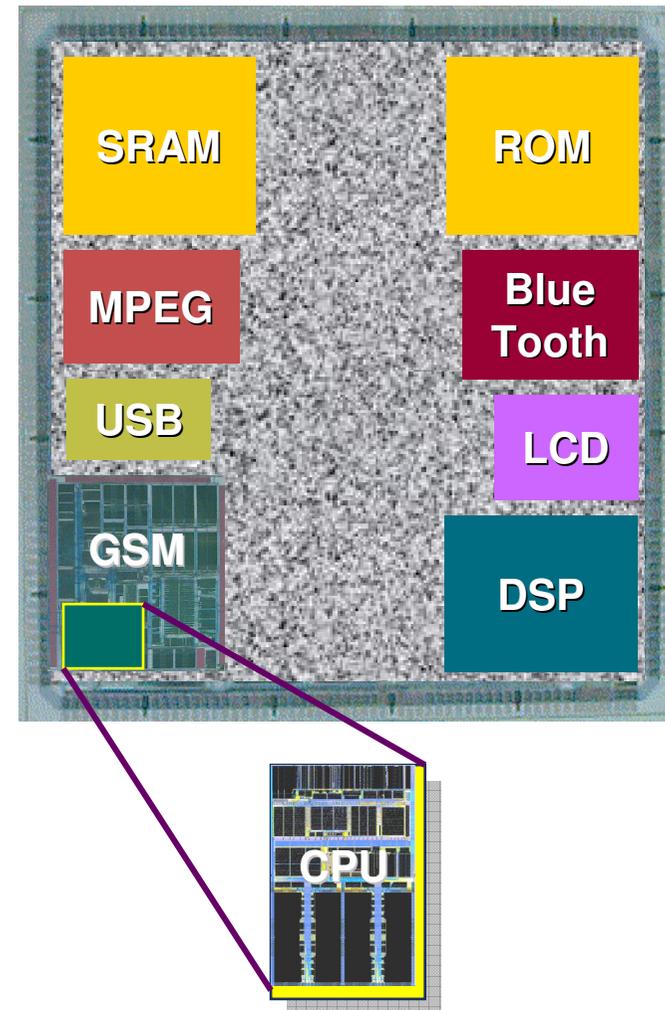
DFx – where does it fit?

Physical IP provides link between silicon & design
-- and DFX makes it all possible



DFT for soft core IP

- IP provider's objectives:
 - To ease core integration into an SoC
 - To enable higher quality of test
- DFT methodology:
 - Wrappers for test isolation
 - Standardisation – IEEE 1500 and 1450.6
 - Working with EDA vendors on reference methodology flows
 - Provide extra types of test: transition delay, path delay, IDDQ
 - Standardised deliverables

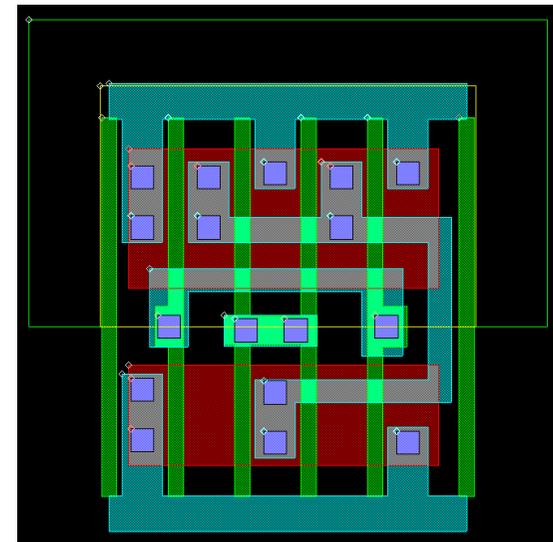
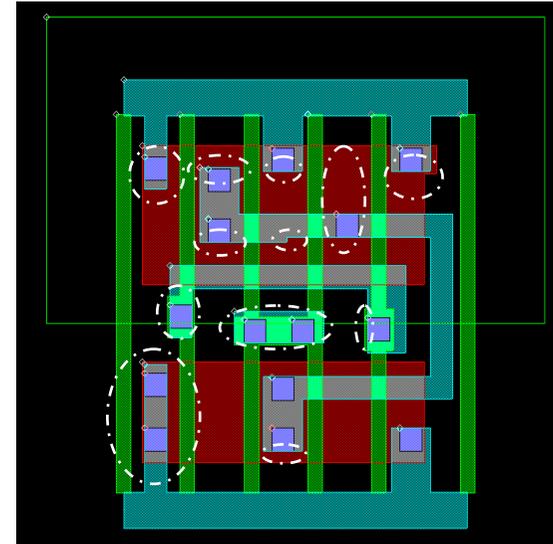


DFT – the future

- Support for 45nm and below
 - Bridging faults
 - New memory algorithms
 - New classes of faults
- Devices may have to be shipped with some level of defects
 - But what level will be acceptable?
- Wear-out mechanisms; high energy particles
 - Need for in-life testing
- How to keep cost of test (and repair) at reasonable levels?
- Support for DVS (Dynamic Voltage Scaling) systems
- Larger SoCs – continue with standardisation effort to make the DFT flow as smooth as possible

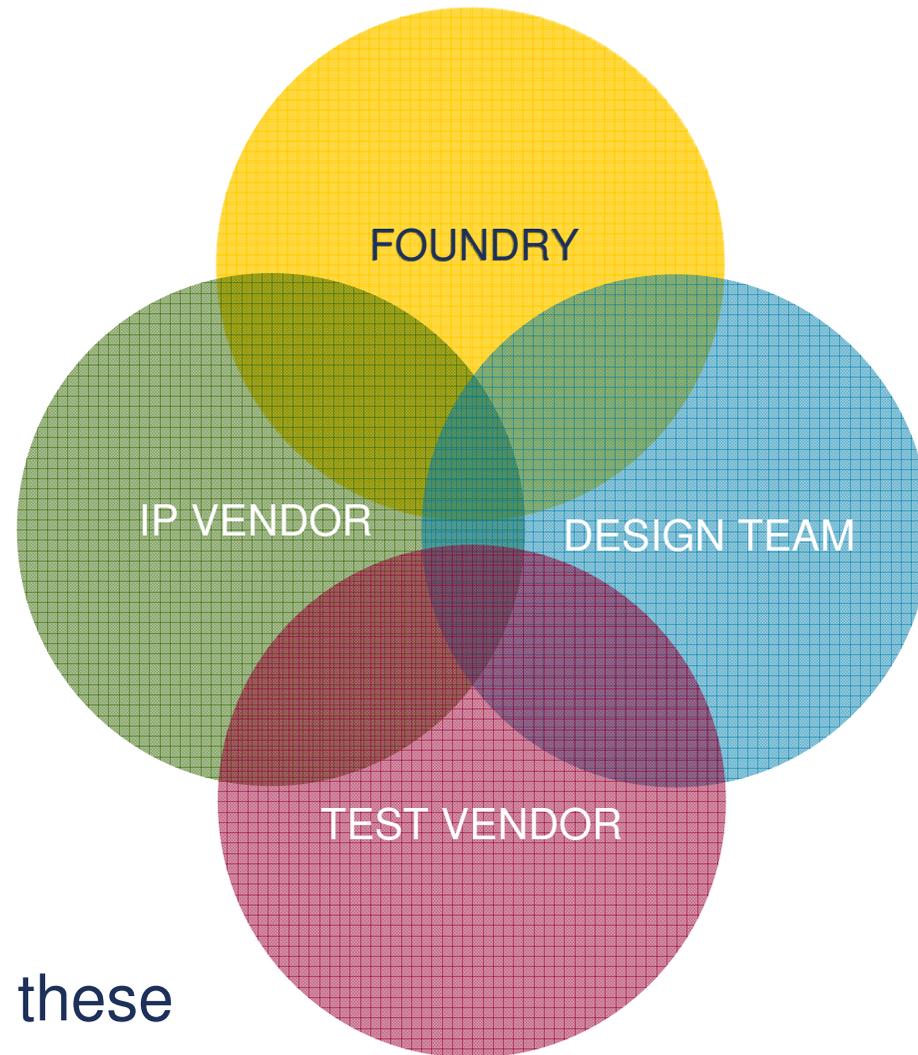
What is DFY?

- Design for Manufacturability
 - Things that need to be done to achieve working silicon
- Design for Yield
 - Things that can be done to increase amount of working silicon
- Examples of DFY
 - Layout design rules (e.g. line spacing)
 - Mask fixes (e.g. optical proximity correction)
 - Design margining (e.g. Monte Carlo simulation)
 - Defect avoidance (e.g. critical area optimization)
 - Plus lots more...



Components of Yield

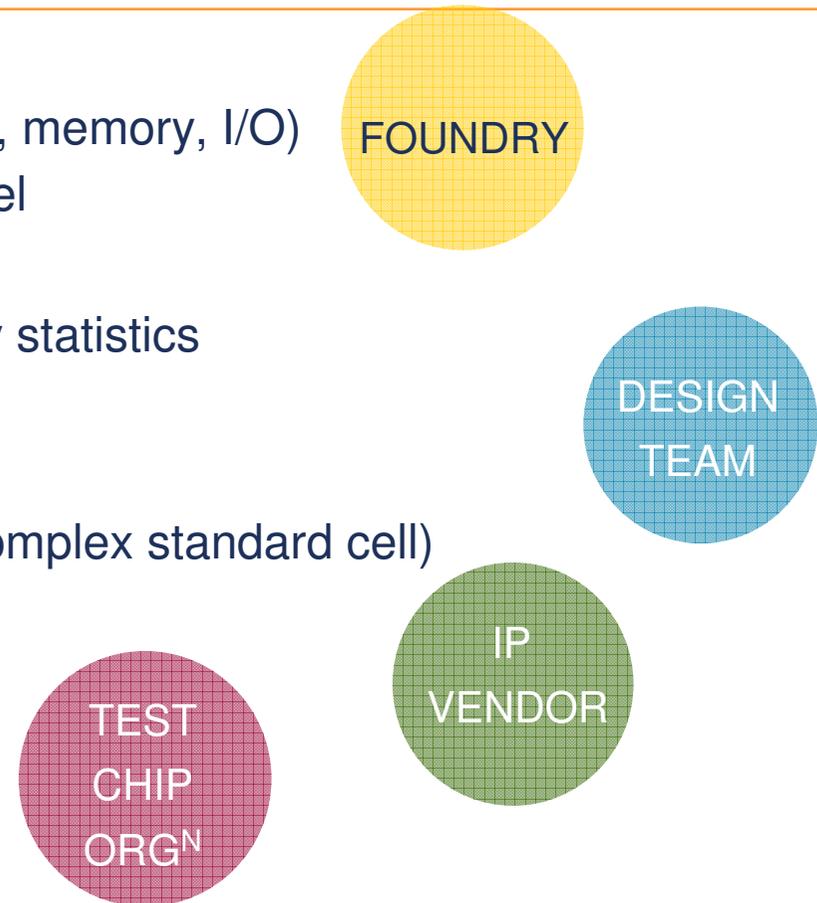
- Systemic problems
- Parametric variations
- Defect-related yield
- Design-related yield
- Test-related yield



- DFY concerned with all of these
- Need to be able to compare effects to enable good tradeoffs

What data is needed?

- Foundries/Test Houses:
 - Relative fail rates of different tests (logic, memory, I/O)
 - Diagnostic data, increasingly at gate level
- Design team (chip, core)
 - Critical timing paths, cell usage/criticality statistics
- Physical IP vendor
 - DFM conformance level by cell
 - Intra-cell path criticality (e.g. memory, complex standard cell)
 - SRAM data
- Test chip organizations
 - Failure rates for various structures
- Challenge: Putting it all together



Practical DFX

- Practical (=good) DFX requires only a good methodology and adequate data
- Example: Same layout optimised by several OPC methods – same areas highlighted as hotspots each time
- So we can solve the DFX problem through reasonable communication between parts of the connected community – without anyone revealing their crown jewels

Current status

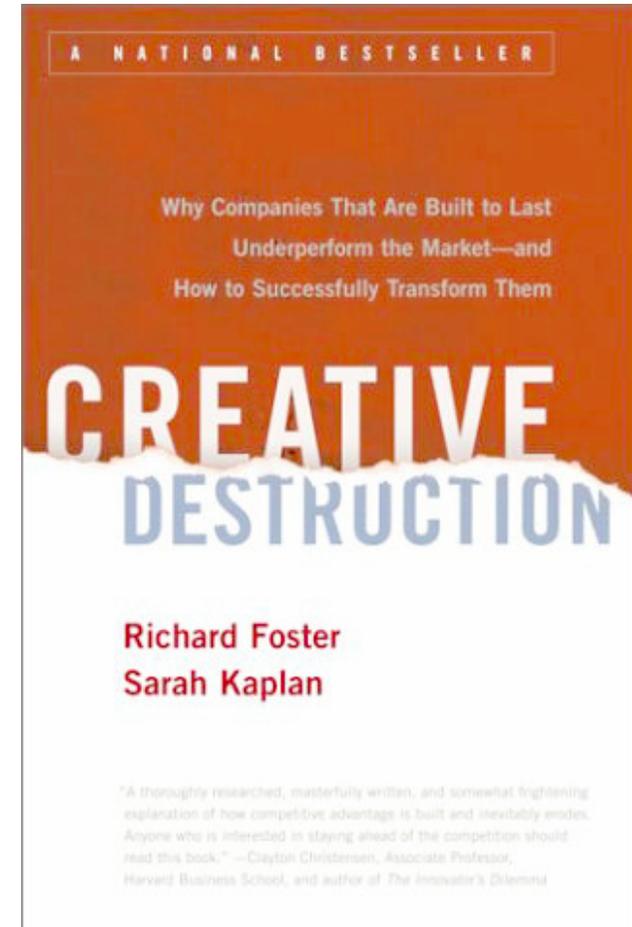
- ARM is focusing on what is needed to get working silicon
- ARM always looking to do more to optimize yield, manufacturability
- Things ARM can do alone
 - Follow foundry guidelines and establish good layout practices
 - Incorporate design margin and variability tolerant design
 - Build yield optimized cells (via doubling, extra spacing)
 - Develop metrics based on above
- Things ARM needs to work with partners to achieve
 - Anything requiring fab process details (OPC, metal etch, exposure, etc.)
 - Anything requiring huge numbers of silicon measurements
 - variability statistics, modified SPICE models
 - Precisely quantify yield or yield improvements
 - Fix systematic foundry yield issues

Sustaining Competitive Advantage

- An Innovation is not forever ...
- Innovations are seldom Patentable
- Innovations de-value very quickly as others follows your lead
- A Healthy Company needs a Regular Influx of Innovations

... *Sometimes you have to discard what has served you well ... and commit to the new and the unknown !*

... *“Creative Destruction”*

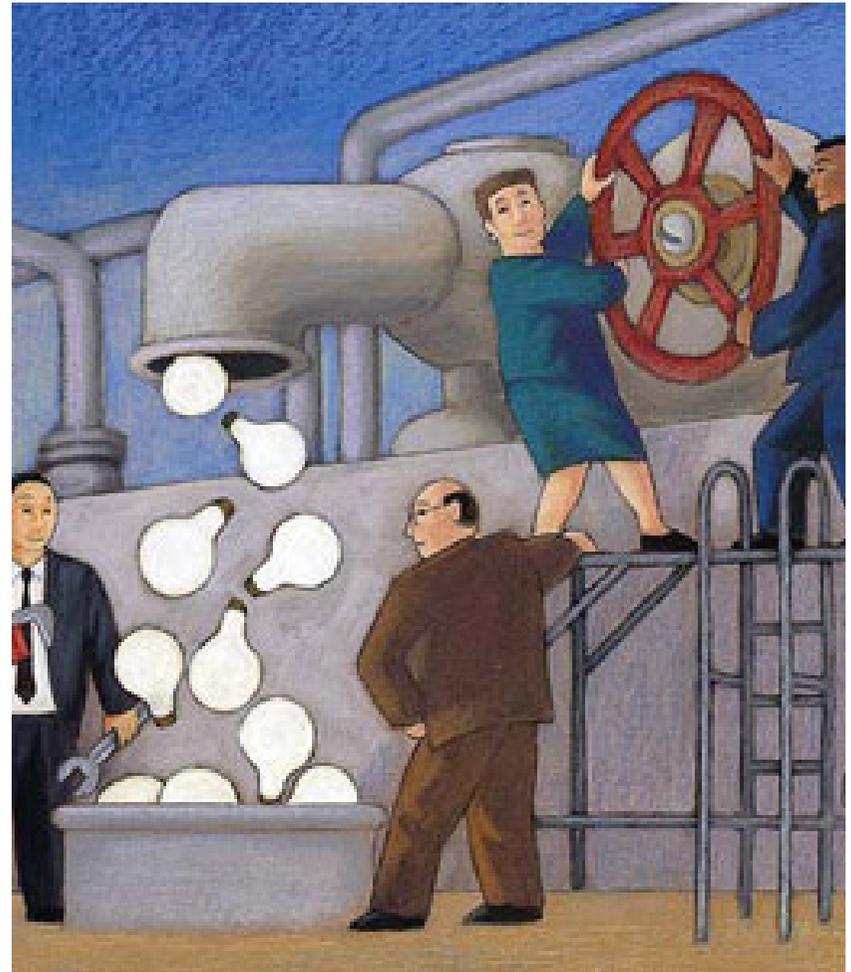


Evolving IP Business Model



A Culture for Innovation

- New project approval / proposals
- You're not working hard enough unless you're making mistakes
- Thinking time
 - Refresh after burn-out
- Capacity for follow-up
- Contemplating “Creative Destruction” ...
- Stock markets are Risk Averse
- It gets harder the bigger you are
- Competitions – e.g. Imperial



Where / How Does Innovation Occur

- Good University Research points the way to the future
- History can help you find some rules, cycles
- People who are networked and have more free time are likely to spot opportunity
- Use and correlate all your sources of information
- Spot the growth opportunity before your competitors
- Be prepared to fail but not destroy the company
- Plan and Iterate
 - Learn by doing
- Read and Learn



Applications and services

- Messaging
- PIM (diary, contacts)
- Entertainment
 - Audio, games
- Information services
- M-Commerce
 - DRM
 - Security
- Enterprise
- Longer term
 - Health monitoring / care



World of 2015 and Beyond



- Digitization and non-intrusive technology creates new markets for semiconductor products
- Trends
 - Consumer products have shorter shelf life
 - Increasing Complexity
 - Standard products
 - Design for re-use
 - High volumes needed to recover development cost
- Semiconductor company challenges
 - Ramp-to-volume, system design, software complexity

2020: Products for the Infirm

- Clothing measures skin temperature, controls insulation

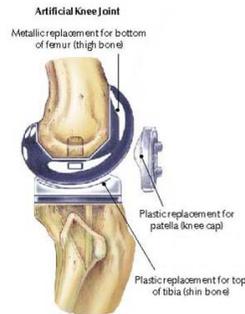


Mini Logger
Temp monitor



Chilli Heated Clothing

- Active wrist, elbow, knee joints to increase strength



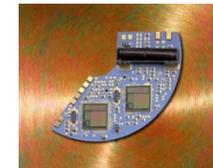
Active Joint Brace wins MIT \$50K

- Implanted automatic drug delivery

Insulin Delivery

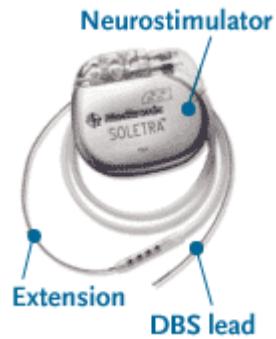


Medtronic
Replacement Pancreas

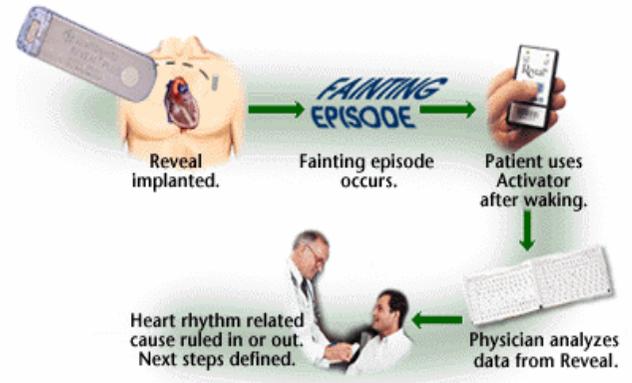


2020: Products for the Infirm

- Biometrics - time to visit the doctor again



Controls Parkinson's Disease



Heart monitoring

- Replacement of senses



Cochlear Ear
Advanced Bionics

2020: Products for Kids

- Active clothing / skin? that changes colour / tone for mood?

“In his latest column for Business 2.0, “Wearable Tech,” Rafe Needleman tells us that clothes that can change colors electronically are soon coming to our closets.”

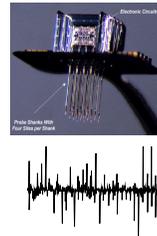


*DNA Screen
On offer in a
Cambridge shop*

- Eye mounted displays for view ahead with maps, directions



- Allow online **Google** searching by thought



2020: Products for Kids

- Five-sense Virtual Reality gaming and experiences



- Holographic projection conference calling with friends



3D freescan image



POC 3D display

Summary

- Business is always challenging
- Great teams can do amazing things
 - However a company is as weak as its “weakest link”
 - Opportunity comes from fitting technology to explicit customer needs
- Services & applications are as important as product
 - Open standards win against proprietary standards
- Plan and iterate (learning by doing)
- Be realistic about people and competition
- Have a Global Picture / Vision that is scaleable
- Think beyond the possible and back off to reality
- We have exciting new challenges but also great opportunities
- Have Fun!