Cortex
Intelligent Processors by ARM

ARM Cortex处理器:
新一代高性能、低功耗
嵌入式系统的最佳选择

罗霖

ARM 中国嵌入式业务开发经理

2009年4月9日，深圳

提纲

1. 知识产权发展对集成电路和嵌入式系统的影响

   后PC时代-嵌入式的到来！

2. ARM的技术及发展路线

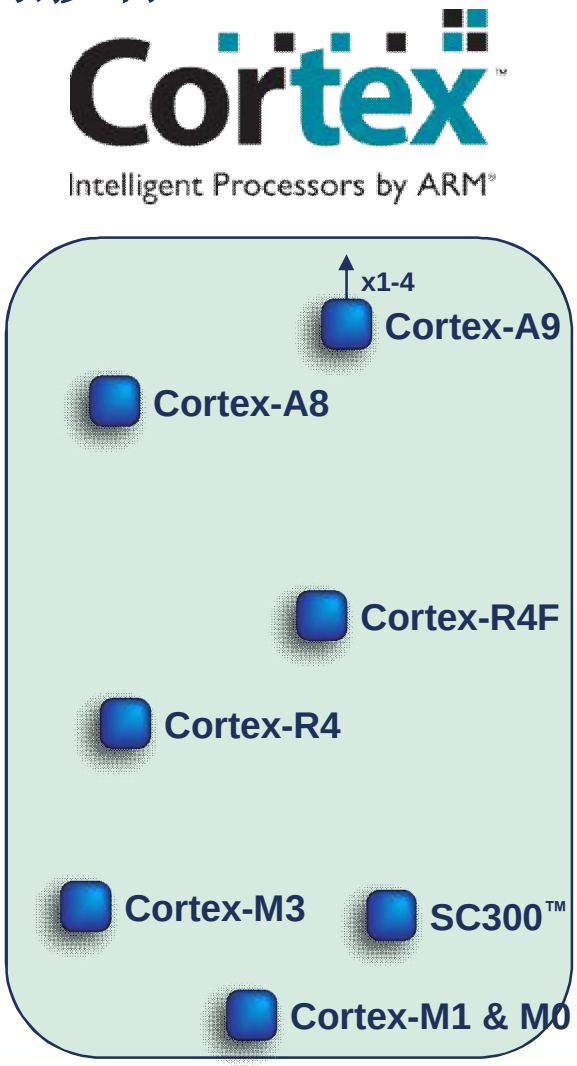
   新一代高性能、低功耗处理器

3. 嵌入式开发的市场机遇

   如何在有限功耗实现高性能

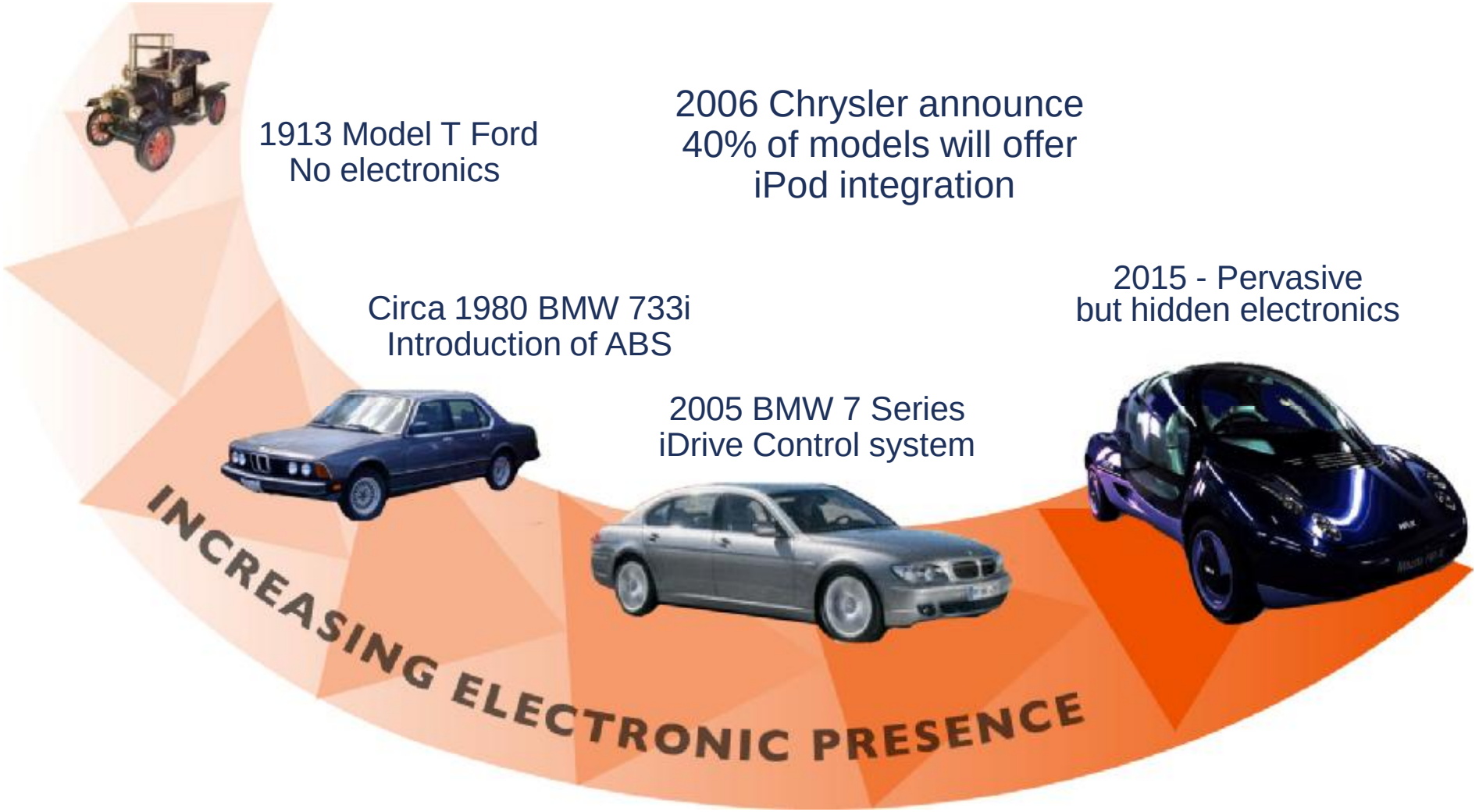
4. 未来嵌入式开发的挑战

   软件的复杂性及平台化开发



消费者身边日益增多的数字产品

逐渐“隐藏” 的嵌入式技术


1913 Model T Ford
No electronics
2006 Chrysler announce
40% of models will offer
iPod integration
Circa 1980 BMW 733i
Introduction of ABS
2005 BMW 7 Series
iDrive Control system
2015 - Pervasive
but hidden electronics
INCREASING ELECTRONIC PRESENCE

不断提高的性能（计算、通信、图形、用户界面）

- Increased performance and functional integration
  - Multiple processors
  - Multiple software layers
  - Very high gate counts
  - Mixed signal
  - Platform cost put at $1B*

*Gartner, February 2006

ARM CPU Estimator (ACE)

	Device	Name	CPU Family	Speed
	O2	Xda Exec	ARM9	520 MHz
	Dell	Axim X51v	ARM9	416 MHz
	T-Mobile	MDA III	ARM9	377 MHz
	Orange	SPV M2000	ARM9	377 MHz
	T-Mobile	MDA II	ARM9	299 MHz
	Motorola	E680	ARM9	286 MHz

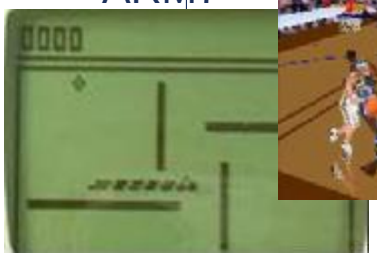
www.arm.com/ace/jbench/login

ARM7

ARM9

ARM11

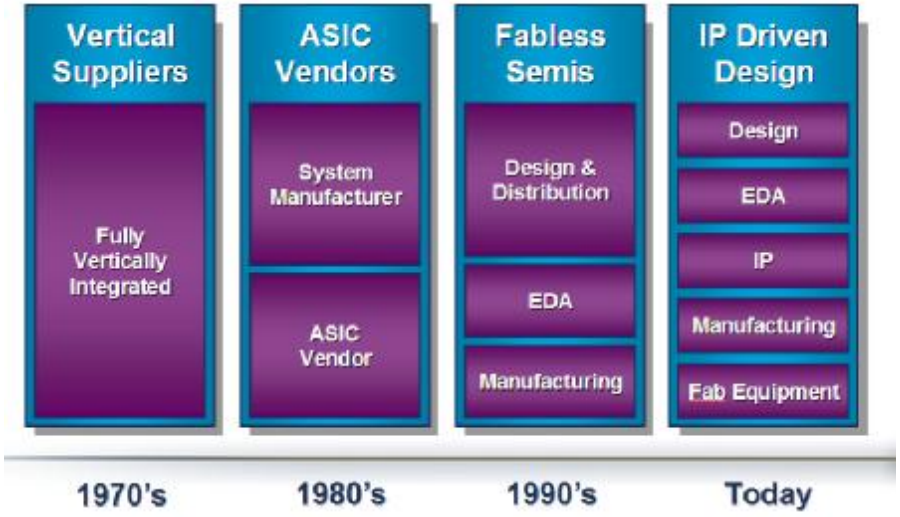
ARM7

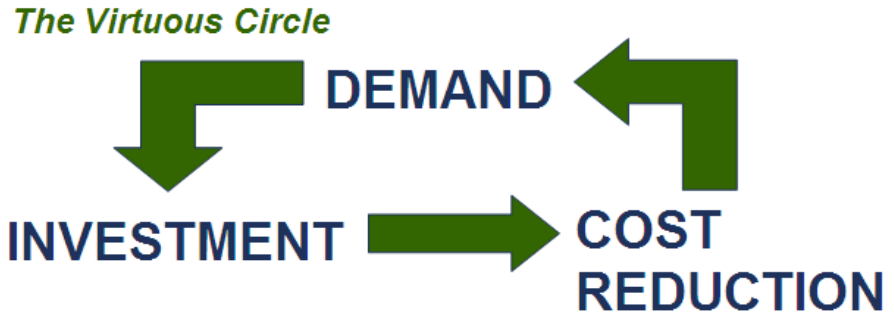


ARM9

ARM11

今天：一个“崭新”的半导体产业

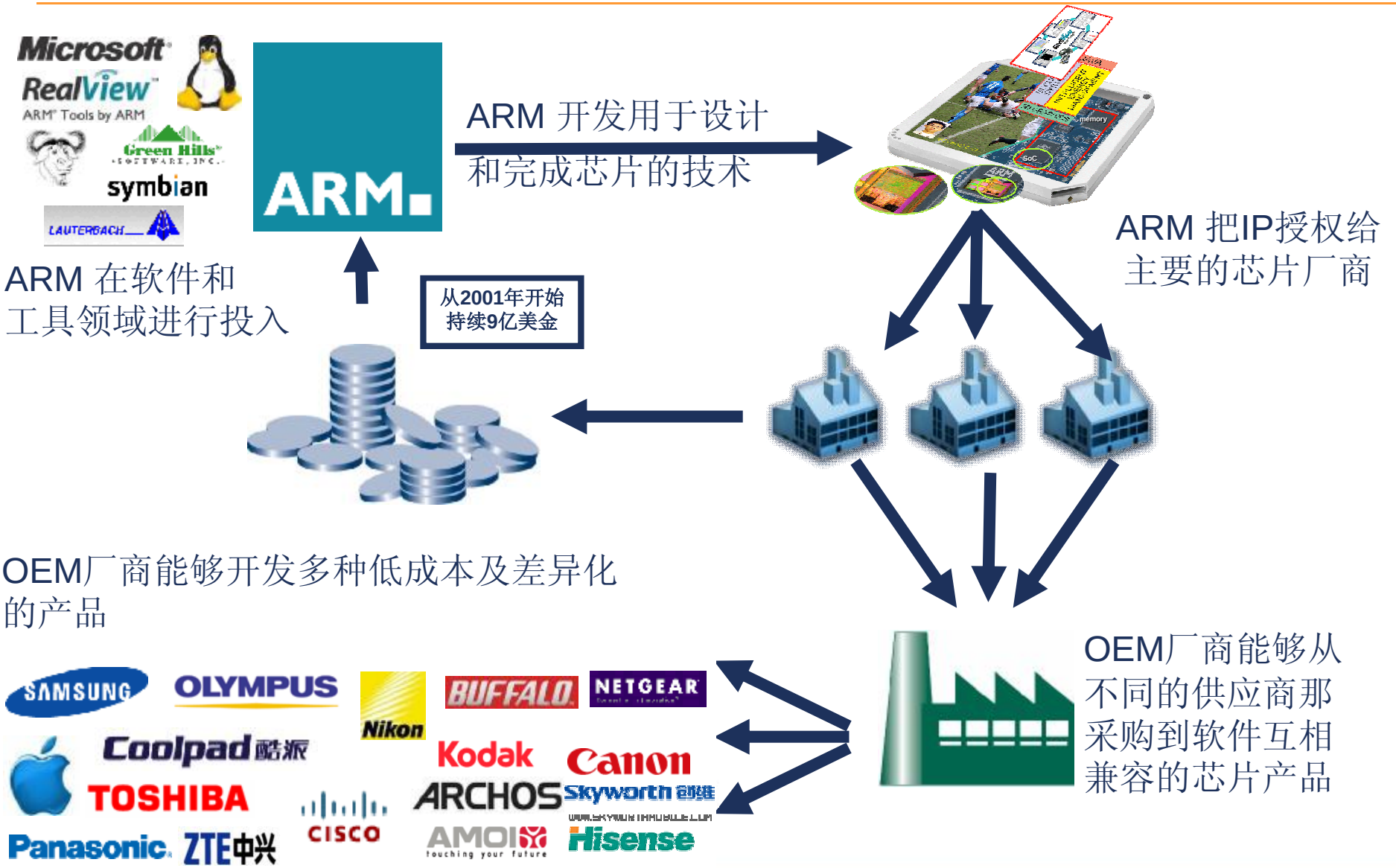




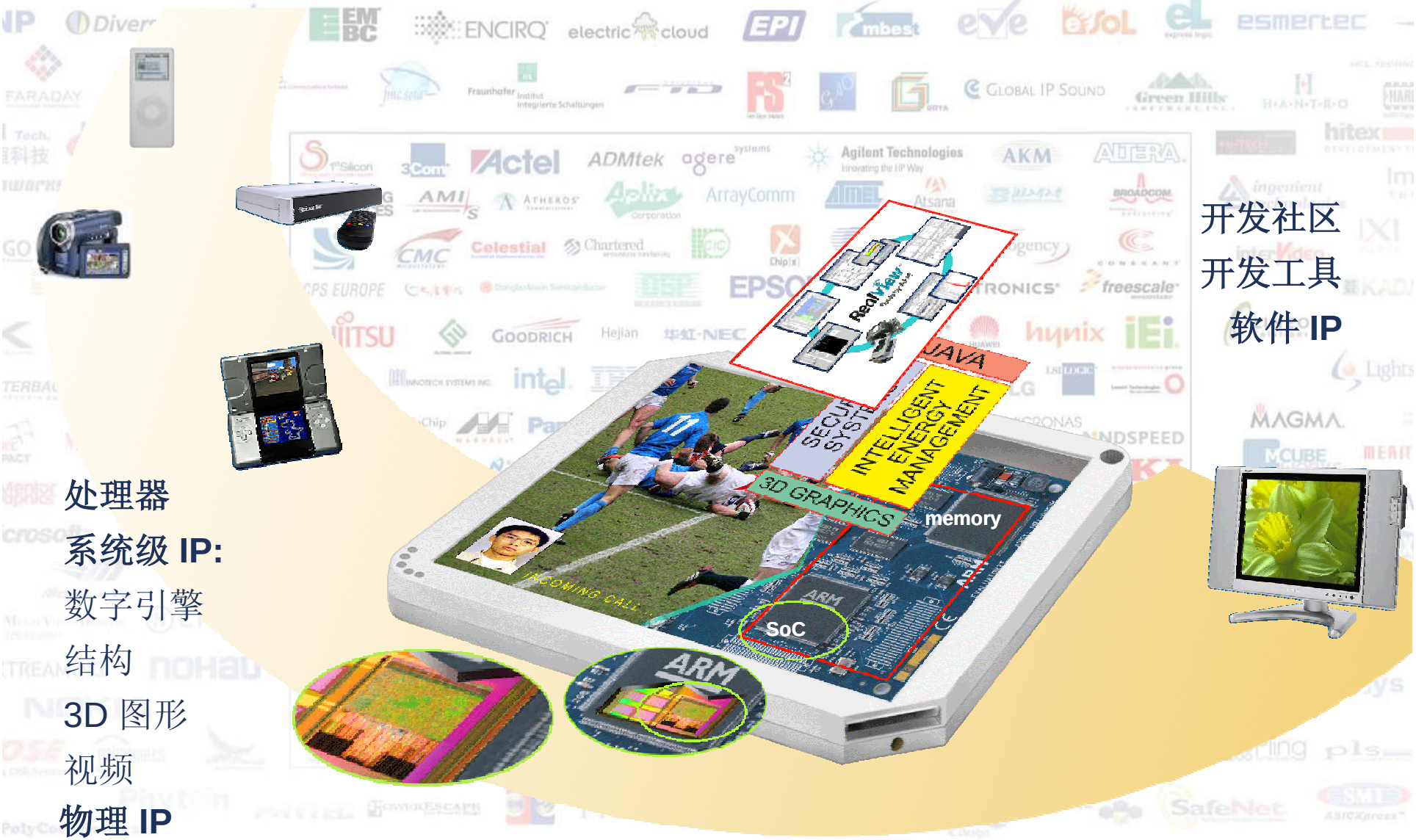
	1970	1980	1990	2002
Cost of 1MHz	$7,600.82	$103.40	$25.47	$0.17
Cost of 1 Megabit storage	$5,256.90	$614.40	$7.85	$0.33
Cost of sending 1 trillion bits	$150,000.00	$129,166.67	$90.42	$0.12

Source: “The New Paradigm” Federal Reserve Bank of Dallas 1999 Report and 2002 Actuals

ARM商业模式: 知识产权（IP）授权



ARM的创新技术



处理器

系统级 IP:

数字引擎

结构

3D 图形

视频

物理 IP

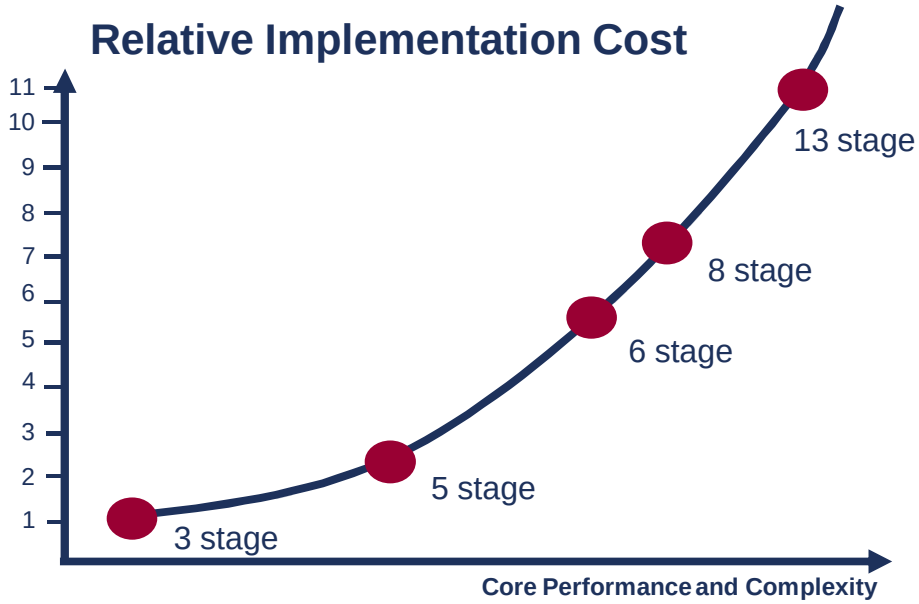
开发社区

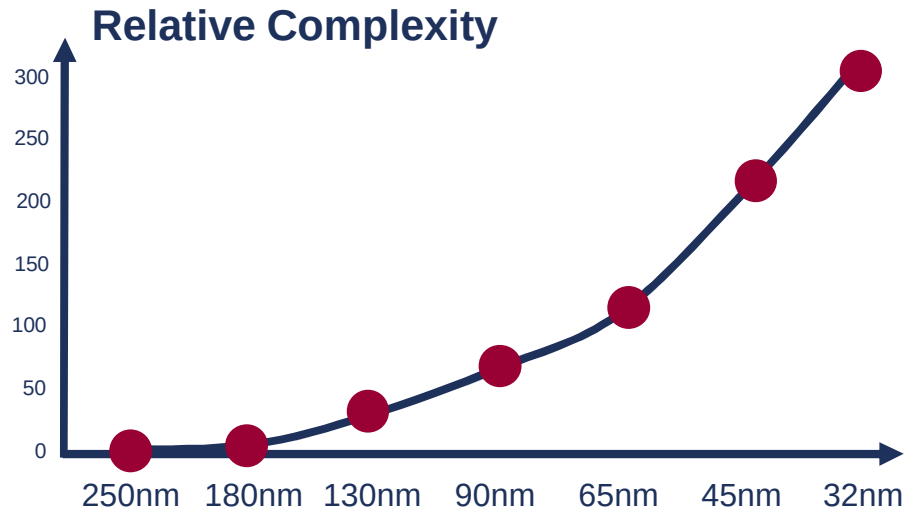
开发工具

软件 IP

知识产权业务模式的经济效益

- Outsource R&D
  - Reduces up-front design costs
  - ARM has invested **$900M** in R&D since 2001 and created ARM11 and Cortex families
    - **72** ARM11 licenses
    - **56** Cortex licenses
  - Would have cost industry more than **$16Bn** to create equivalent product portfolios
  - Adding delay and risk without differentiation
- IP **cost-sharing** business model is required for a mature industry to remain profitable





知识产权业务模式促进差异化创新及市场增长

1997 ARM and Partners Enabling

Ecosystem Delivering Low Power Today

Diverse Range of Products

Rapidly Growing Markets

4 Bn Users (2009)

Intel Platforms have only driven size and speed

How much has your laptop changed over the years ?

1 Bn Users[2]

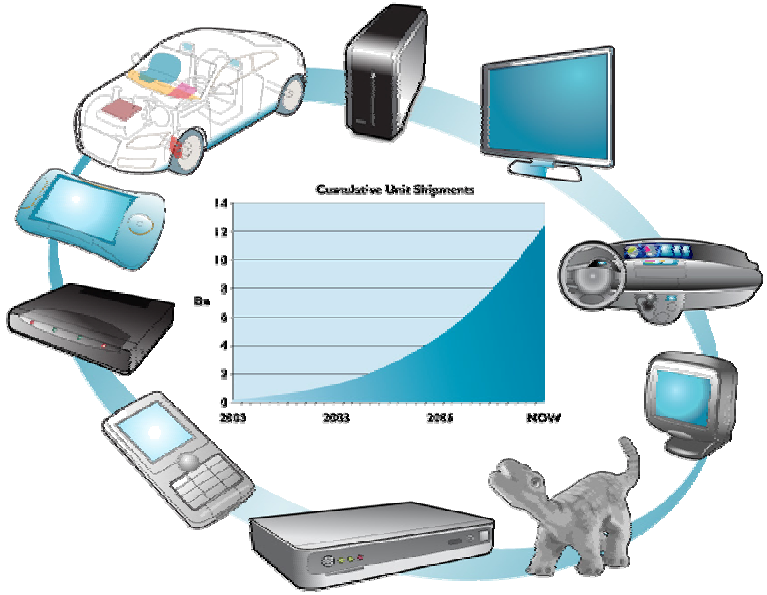
[1] Strategy Analytics 2007

[2] www.c-i-a.com

Innovations: Costs + Risks + Time to Market

2009年：今天的ARM

- 业界领先的硅知识产权公司
  - 领先的32 bit RISC 体系架构
    - 累计出货140亿ARM处理器
      - 全球每人两个ARM
  - 领先的物理知识产权
    - 每年1500新项目基于ARM的标准单元



- 2008年： 40亿个 ARM处理器出货
  - Now 1 Billion ARM Processors shipments each Quarter

- 全球1700位员工, 32 个地区办公室

- 2008年：全球四分之一的电子产品是由我们的合作伙伴提供的并基于ARM的技术。

2. ARM的技术及发展路线

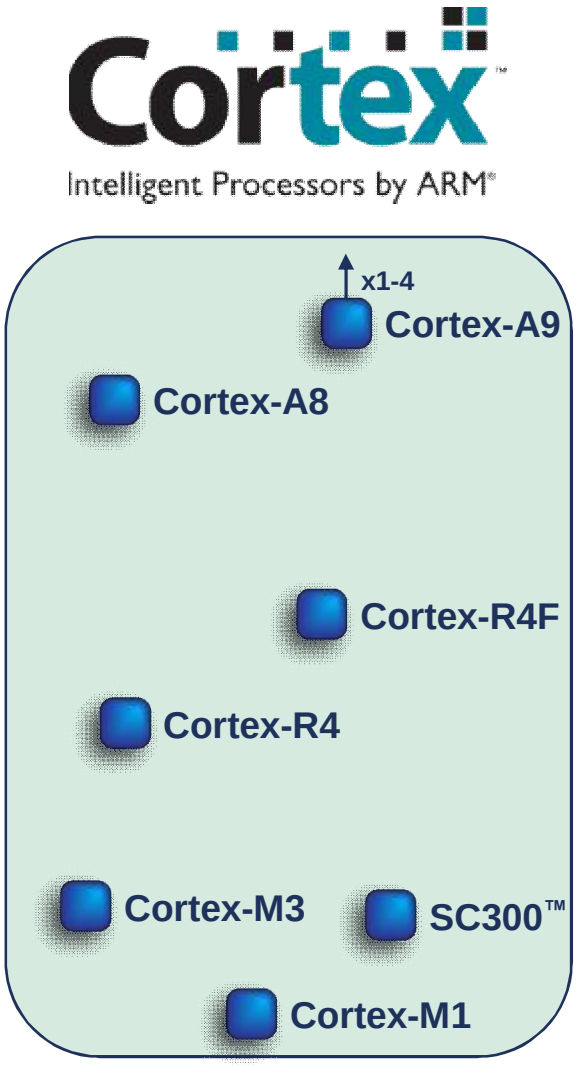
ARM公司的远景

ARM designs technology that lies at the heart of advanced digital products

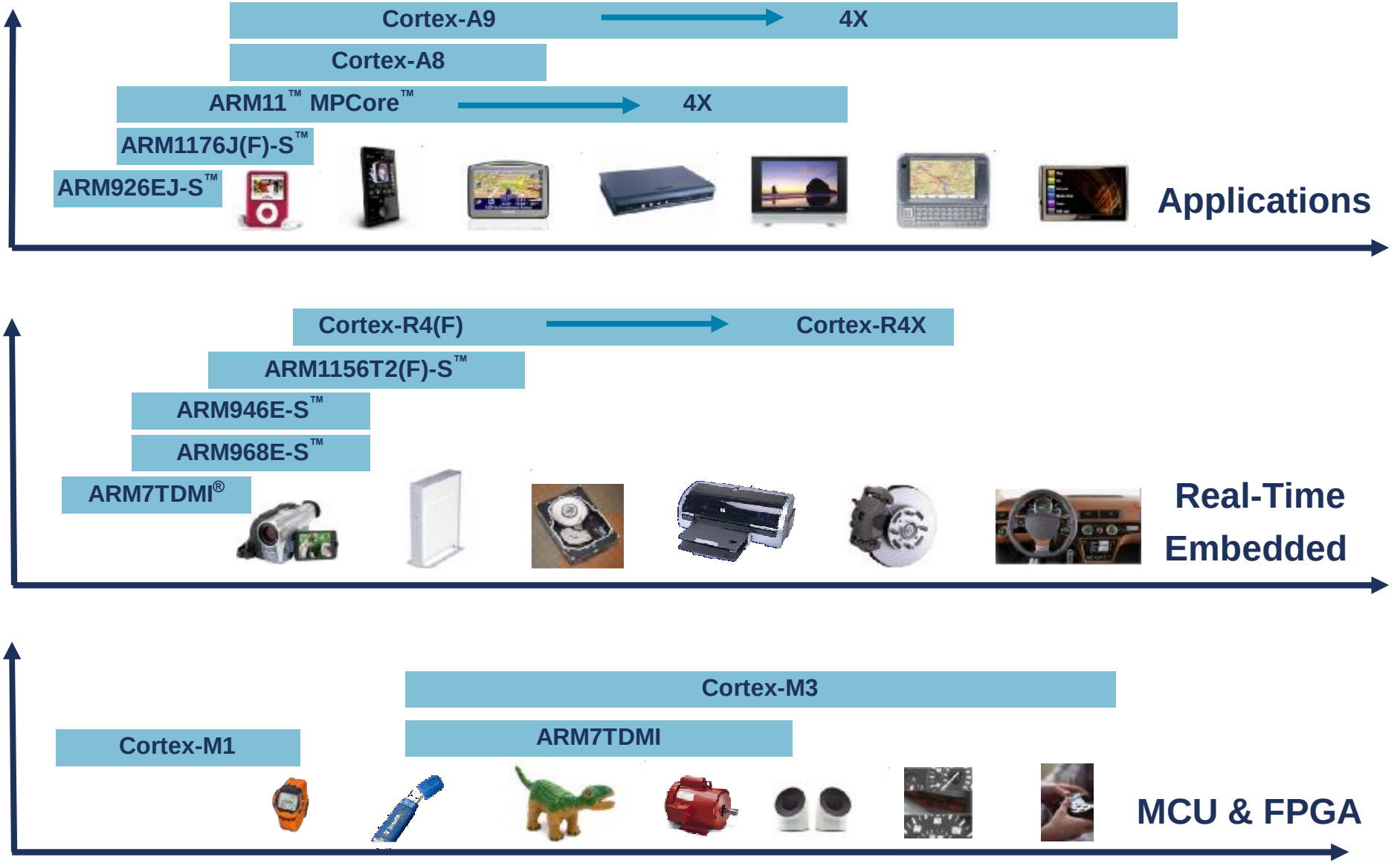
ARM Cortex 系列处理器

Bringing the benefits of architectural innovation across the computing spectrum

- ARM Cortex™-**A** Series:
  - Applications processors for complex OS and user applications
- ARM Cortex-**R** Series:
  - Embedded processors for real-time signal processing and control applications
- ARM Cortex-**M** Series:
  - Deeply embedded processors optimized for microcontroller and low-power applications

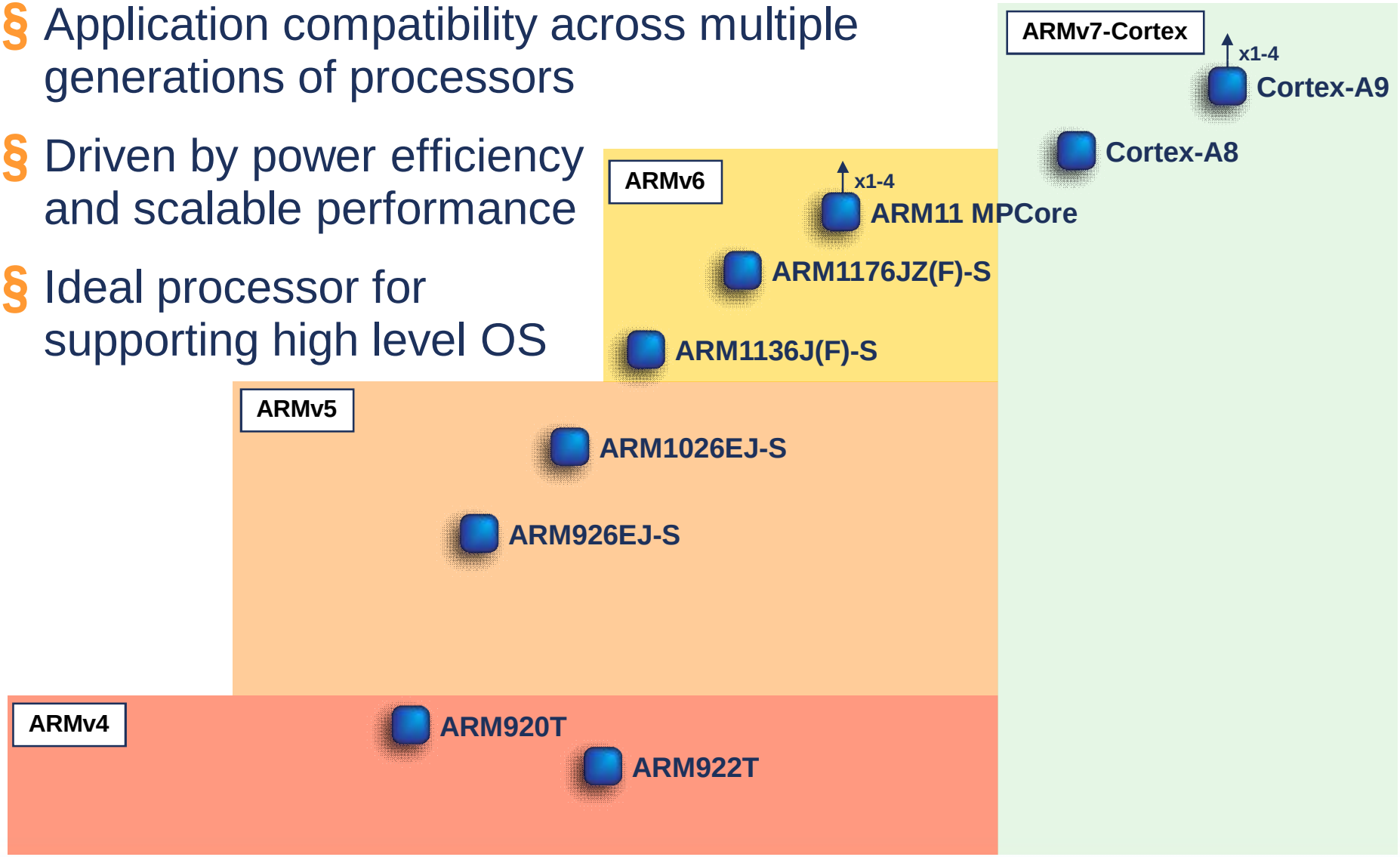


满足不同需求的ARM处理器



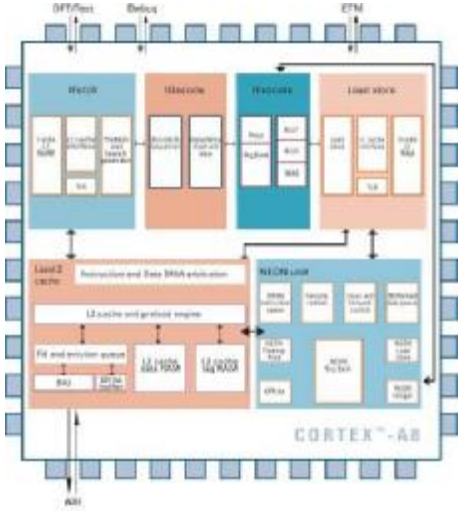
应用处理器的技术路线

- Application compatibility across multiple generations of processors
- Driven by power efficiency and scalable performance
- Ideal processor for supporting high level OS



Cortex-A8 处理器介绍

- Highest performance Cortex-A processor proven in silicon mass production today
  - Superscalar pipeline delivers 2 DMIPS/MHz
  - Thumb-2 ISA for performance **and** code density
  - TrustZone extensions for secure transactions and DRM
  - NEON multimedia and signal processing unit delivers over 2x performance of ARMv6 SIMD
  - Integrated L2 Cache with configurable size and ECC



- Maximum implementation flexibility
  - Synthesizable RTL –or– Optimized with customs
  - Same verilog code base

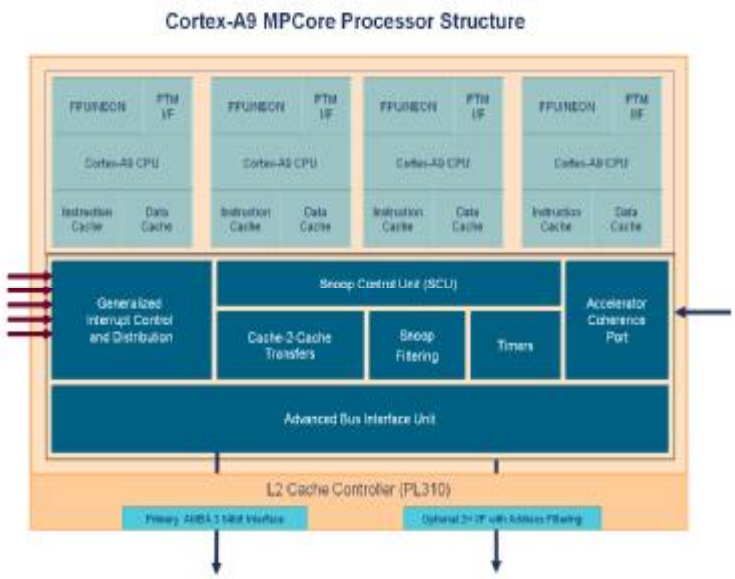
PPA	65nm LP process		65nm G+ process	
	Optimized	Synthesized	Optimized	Synthesized
Standard Cells	Advantage-CE	Advantage-HS	Advantage-CE	Advantage-HS
Memories	Custom	Advantage**	Custom	Advantage**
Frequency (MHz)	660-700	500-550	1.1 GHz+	800+
Area with cache (mm²)	3.86	4.2	3.86	4.2
Area without cache (mm²)	2.79	3.1	2.79	3.1
Cache size	32K/32K	32K/32K	32K/32K	32K/32K
Power with cache (mW/MHz)	0.58	0.75	0.43	0.55
Power w/o cache (mW/MHz)	-	-	-	-

** Optimized instances of Advantage RAMS
Area includes L1 RAMS, L2 control. Excludes NEON, ETM, L2 RAMS

- Ecosystem in place
  - Tools
  - Middleware
  - OS support

Cortex-A9处理器介绍

- Optimized Cortex-A processor enabling breakthrough performance and power scalability
  - 2nd generation 1-4X SMP technology
  - Delivered as Uniprocessor and 1-4X MP
  - Advanced pipeline delivering ~25% more DMIPS/MHz over Cortex-A8 (2.5)
  - Comparable F_{MAX} to fully synthesized Cortex-A8 in same configuration
  - Optimized floating-point unit; NEON engine



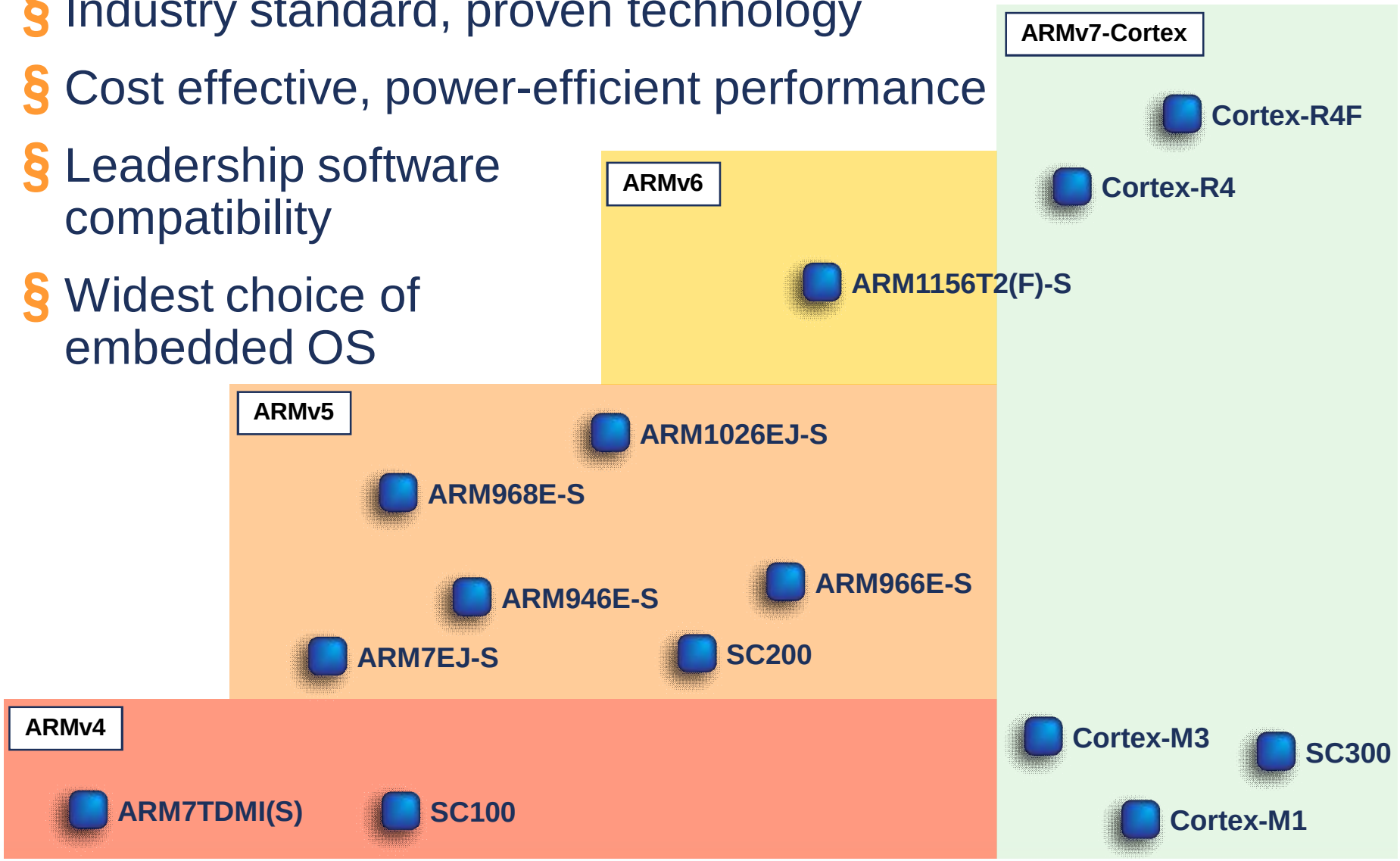
- New system-level integration features for design optimization
  - Accelerator coherence port
  - Advanced bus interface unit for maximum throughput
  - Generalized interrupt control and distribution system

- Suitable for high-end enterprise networking through to wireless handsets

"Symbian and ARM Cooperate in Bringing Symmetric Multi Processing (SMP) to Future Phones Enabling High-End PC Capabilities to Consumers' Pockets"
– http://www.symbian.com 10/07

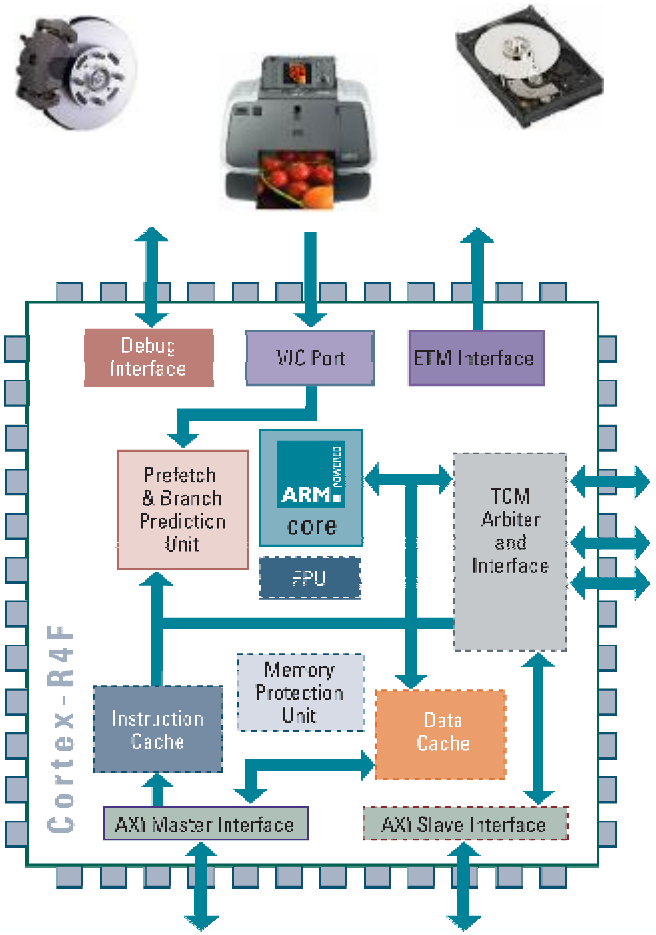
嵌入处理器的技术路线

- Industry standard, proven technology
- Cost effective, power-efficient performance
- Leadership software compatibility
- Widest choice of embedded OS



Cortex-R4(F) 处理器介绍

- High-performance processor optimized for deeply embedded signal-processing and control applications
  - 8-stage superscalar pipeline delivers up to 400MHz+ @ 1.6DMIPS/MHz on 90nm
  - Thumb®-2 technology, hardware divide
  - State-of-the-art ECC support in all memories
  - AMBA 3 AXI slave port for DMA to TCMs



- Fit-for-purpose configurability
  - Separately configured L1 caches: 0kB, 4-64kB
  - 0 to 3 TCMs of up to 8MB each
  - 8 or 12 regions in MPU, or no MPU
  - 2 – 8 Breakpoints, 1 – 8 Watchpoints
  - Parity or ECC can be optionally included
  - Optional SP-optimised FPU (full IEEE754)
  - Optional slave port

Cortex-M3处理器介绍

An ARM7TDMI-S for the 21st century

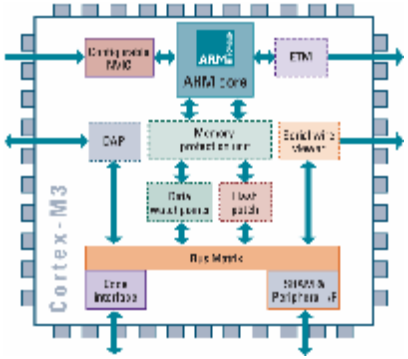
- For extreme cost and power-sensitive complex applications
- Comparable or better F_{MAX} and gate count with r2p0 min config
- 30% more DMIPS, 28% more geomean EEMBC
- 85% more DMIPS per mW

"…. the Cortex-M3 processor will propel us again towards a breakthrough in performance, ease of use and quality, while also providing a competitive cost structure for our products. We feel that the Cortex M3 processor will play an important role in accelerating the convergence of the MCU market…"

– Jim Nicholas, GM Microcontroller Division, ST

State-of-the-art functionality

- Code ***everything*** in C
- Thumb-2 ISA → 6X code density, 10X perf. v 8051
- Integrated Nested Vectored Interrupt Controller (NVIC) with lowest interrupt latency of any ARM
- Configurable/optional memory protection, debug, trace
- uA device stand-by enabled with integrated sleep modes, ULL libraries, state retention

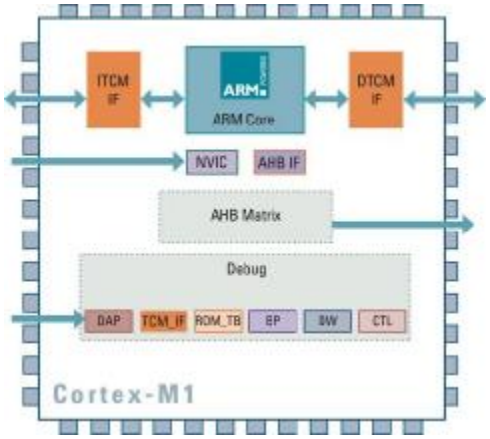


Broad adoption within Microcontroller industry

Cortex-M1处理器介绍

- First ARM processor specifically optimized for FPGA
  - High frequency, low-area soft processor for low-cost volume FPGA
  - Upwards compatible with Cortex-M3 onwards on ASIC/ASSP/MCU
  - Capable of up to 200MHz on fast FPGA device
  - Delivers up to 0.8 DMIPS/MHz efficiency from TCM

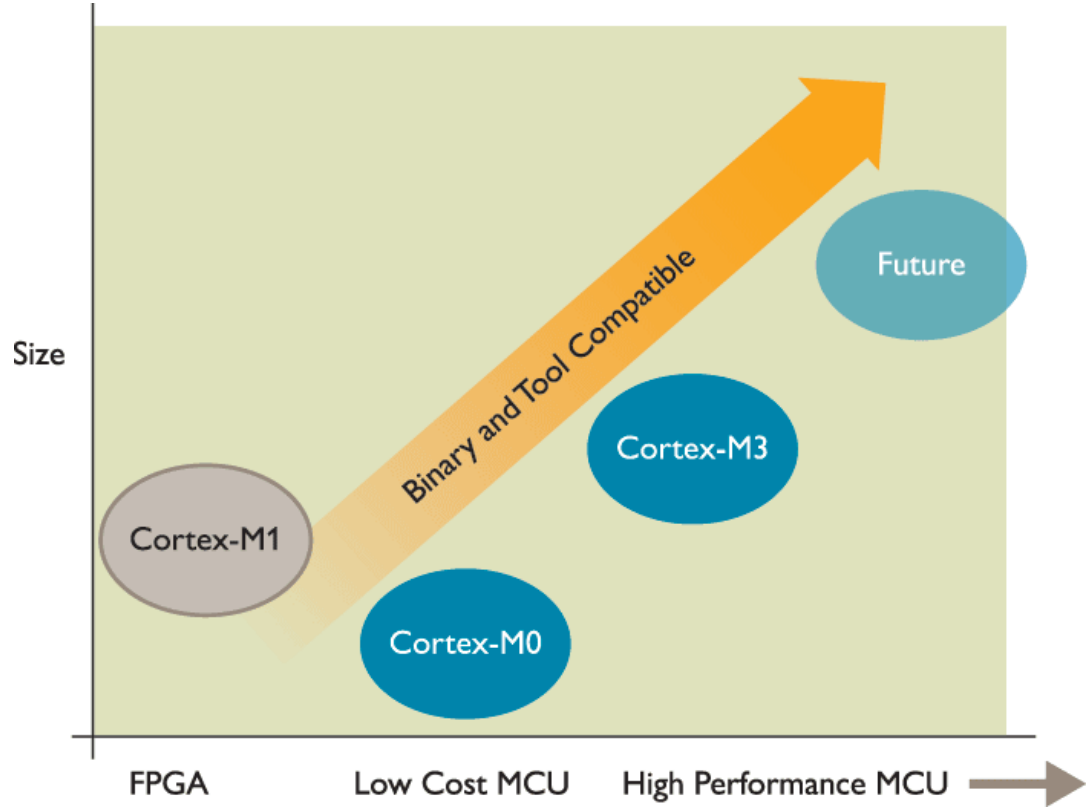
- Designed for synthesis on multiple FPGA types
  - Actel ProASIC3, Actel Igloo and Actel Fusion
  - Altera Cyclone-III, Altera Stratix-III
  - Xilinx Spartan-3, Xilinx Virtex-5



- 3 Channels to market
  - Traditional ARM licensing
  - NEW: Altera/Arrow 1X design start
  - NEW: Freely available to Actel users

ARM推出体积最小、能耗最低、最节能的处理器

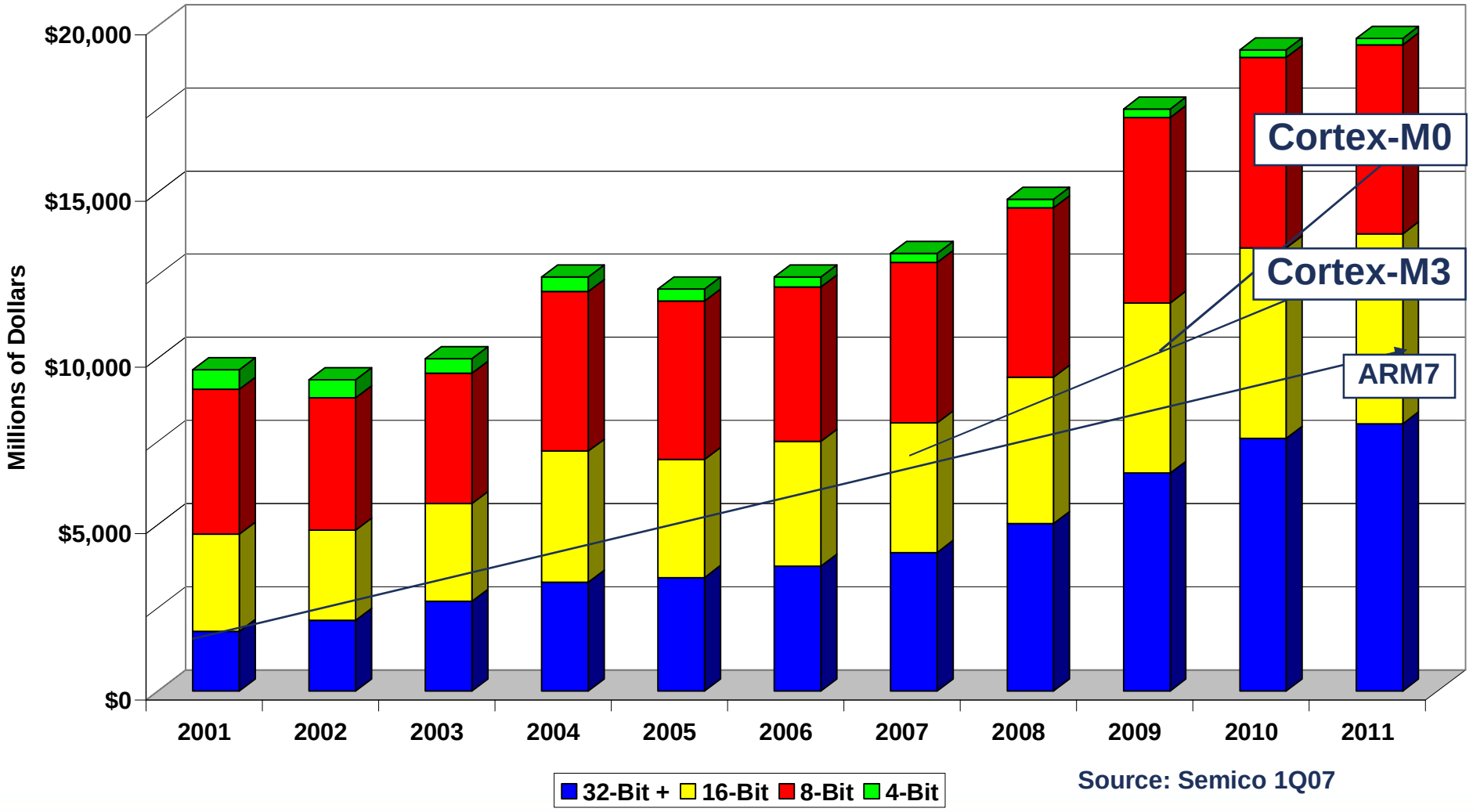
Cortex-M0处理器以8位处理器的价位提供32位处理器的性能，并兼容诸如Cortex-M3产品的多功能处理器



Enabling the next 10+ billion units from under $1 to over 1GHz

Cortex-M系列处理器加速ARM MCU市场的发展

- 32-bit taking 8/16-bit sockets

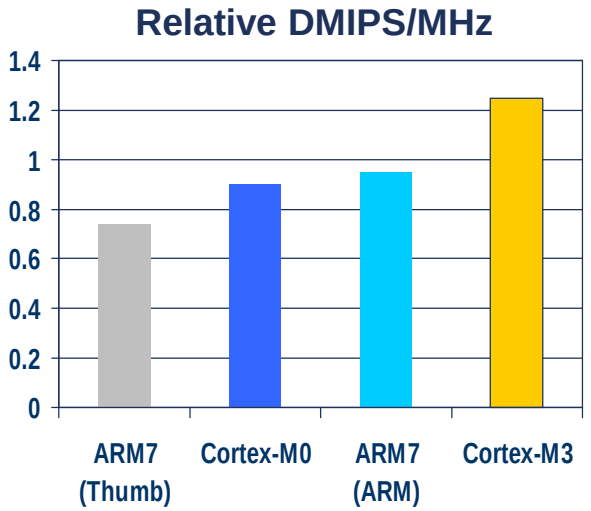


Source: Semico 1Q07

Cortex-M0 和 Cortex-M3 处理器

- **Cortex-M3 processor is ARM's flagship Cortex-M class processor**
  - Offering superior efficiency and flexibility
- **Cortex-M0 processor is an ultra low-power, streamlined subset of Cortex-M3 processor**
  - With easy migration to the Cortex-M3 processor
- **Coherent architecture spanning cost/performance points**

Comparison	Cortex-M0	Cortex-M3
DMIPS/MHz	0.9	1.25
Energy efficiency DMIPS/mW	60	31
Gate count	12k	48k
Area	0.25 mm^2	0.68 mm^2
Number interrupts	1-32 + NMI	1-240 + NMI
Interrupt priorities	4	256
Breakpoints, Watchpoints	4/2, 2/1	8/4, 2/1
MPU, integrated trace option	No	Yes
Hardware Divide	No	Yes



超低的功耗 Ultra Low Power

§ Designed for low per MHz power

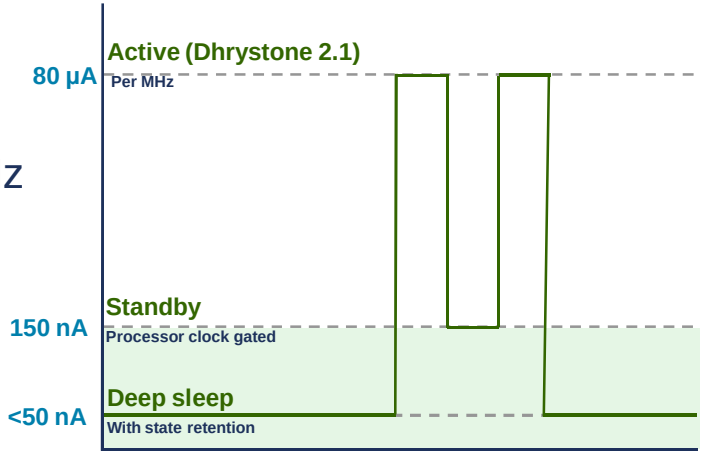
- § Just 15 µW/MHz (90G Advantage implementation)
- § Delivering exceptional 60 DMIPS/mW efficiency

§ Architected for ultra low power deep sleep

- § Excellent static power results using Metro™ 180ULL libraries
- § Processor supports latest State Retention flow using ARM PMK
- § Easy integration to power management unit via Wake-up Interrupt Controller

§ Never change the battery!

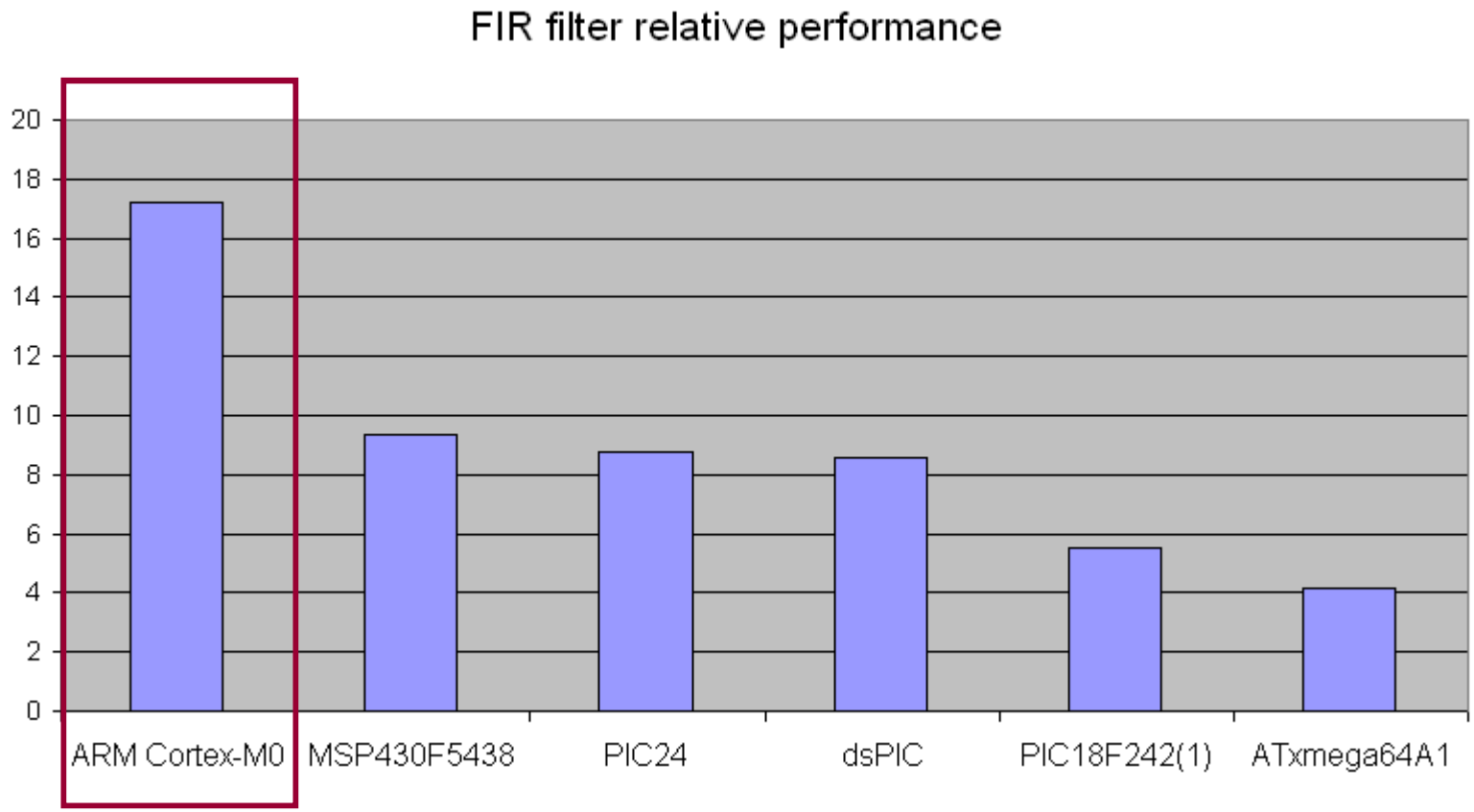
- § Using a standard 230mAh lithium cell
- § For example a ZigBee node - 0.1% activity at 10MHz
- § This gives 30 years of battery life



Artisan Metro 180ULL "Cortex-M0" prototype implementation

优秀的效率 Excellent Performance Efficiency

- Superior per cycle performance to 16-bit devices
  - Lower MHz, shorter active duty cycles, longer battery life



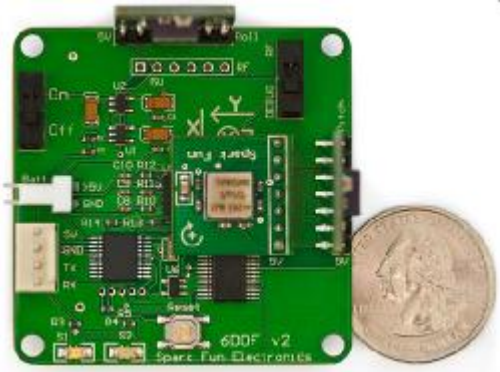
智能传感器

- **Sensor elements that capture analog data**
  - Temperature, Voltage, Pressure, Acceleration

An absolute pressure sensor that uses MEMS technology

- **The sensor is combined with digital logic**
  - Pre-process the results for example to filter or resample
  - Transmit the results to another device
  - Cortex-M0 is designed to perform these digital tasks

- **Sensors can have multiple uses**
  - E.g automotive accelerometers used in airbags and stability control



Inertial Measurement Unit (IMU), single chip triple axis accelerometer and three iMEMs gyroscopes to provide Roll, Pitch, and Yaw

3. 嵌入式开发的市场机遇

“酷”的产品 Cool Products

Blackberry Bold
Marvell "Tavor" PXA930
ARM Architecture Based – Xscale processor

Innovations for learning - Teachermate
ARM9 Processor

D-Link DNS323 Network Storage Enclosure
Marvell 88F5181 Soc – ARM9 processor

iRiver Unit 2 Multimedia Home Networking device
Telechips and Samsung – ARM9E + ARM11 Processors

Samsung SMT-H30560 Cable STB
Conexant CX2417X – ARM920T Processor

Sonosite MTurbo (Portable Ultrasound Device)
Texas Instruments TMS320DM644x - ARM926 Processor

Sunlink International - SunView PMP + Projector
Samsung S3C244A – ARM9 Processor

Embedded Automation – mPanel (Digital Home Device)
ARM architecture-based – Marvel XScale

Garmin Nuvi 205
ST Cartesio Processor - ARM926

Everex Cloudbook UMPC
GCT Semiconductor – ARM9 Processor

Importek Apollo VoIP Video Phone
ARM9 + Marvell Xscale processor

Thomson WiFi Tablet
TI DaVinci TMS320DM6441 – ARM926EJ-S

Artega - Artega GT (Dual-Dashboard Display)
Fujitsu MB86R01 "Jade" graphics controller
ARM926EJ-s + Jazelle Java Acceleration Technology

VivoPay – Vivo Kiosk
ARM Powered

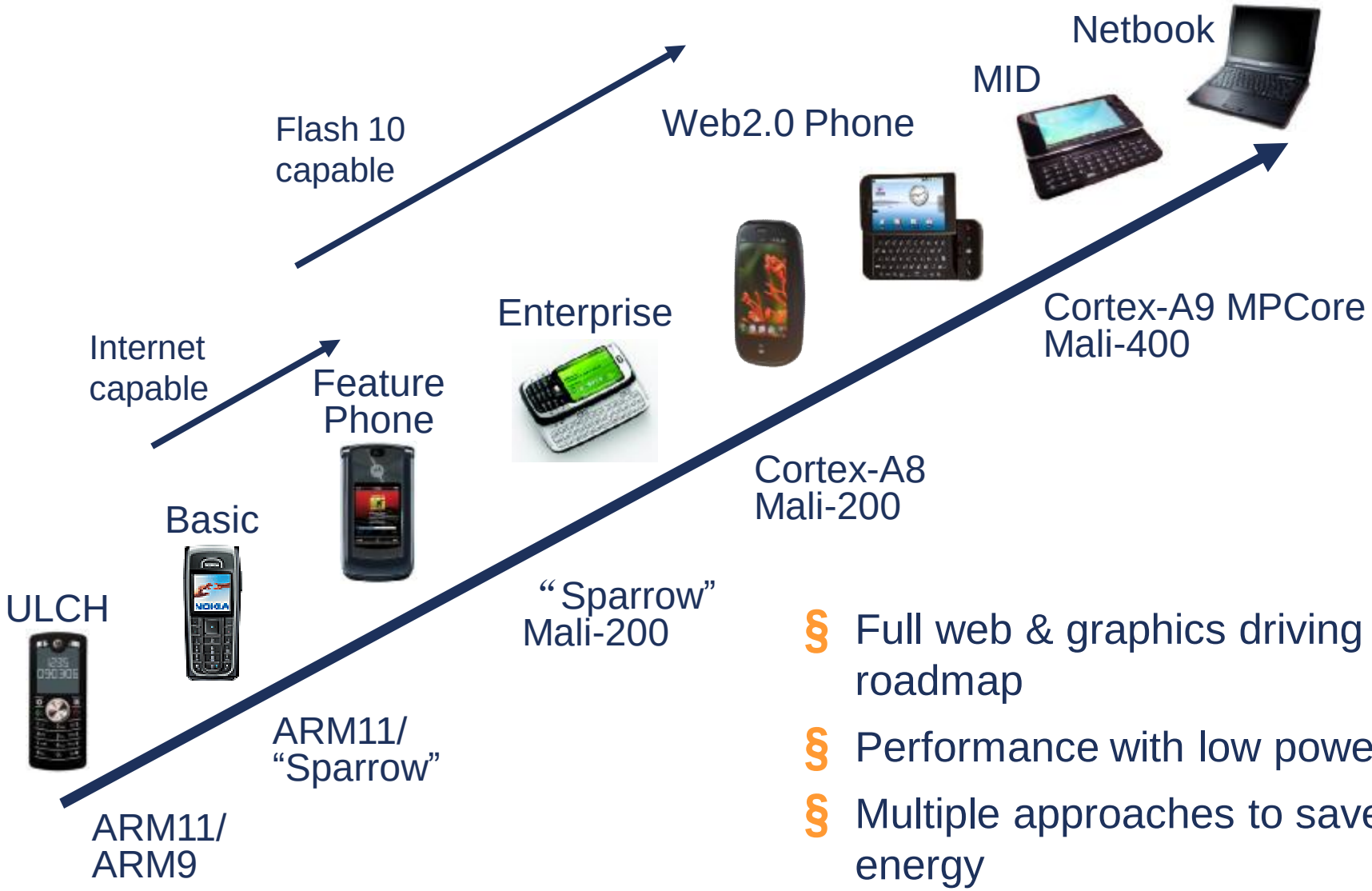
iRiver NV Life PMP
Magic Eyes - ARM926EJ + ARM946E

Custom Engineering - TK300II Desktop Ticket Printer
ARM Processor (266MHz)

基于ARM的应用


MOBILE SOLUTIONS
HOME SOLUTIONS
ENTERPRISE SOLUTIONS
EMBEDDED SOLUTIONS
MOBILE COMPUTING
EMERGING APPLICATIONS

2011年的移动设备

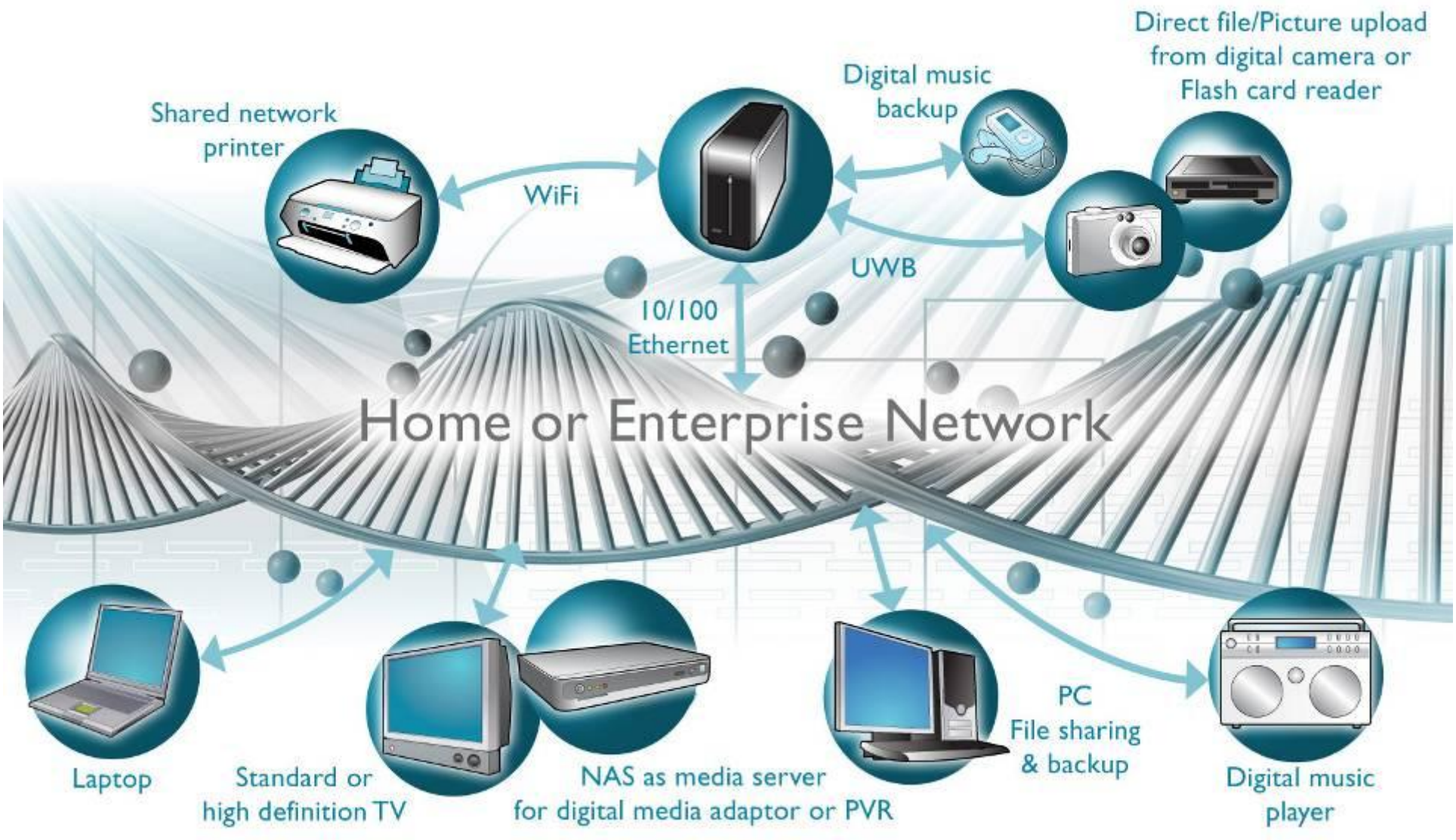


- Full web & graphics driving roadmap
- Performance with low power
- Multiple approaches to save energy

基于ARM的DTV / STB / BD 方案

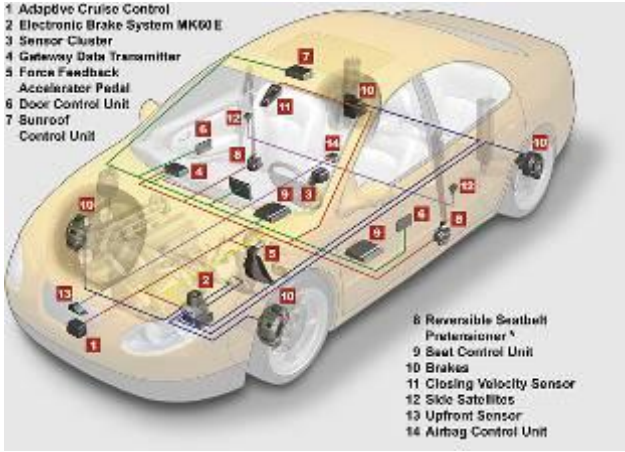
	STB	DTV	BluRay
			
CPU	ARM11 / Cortex-A8; Cortex-A9	ARM11 / Cortex-A8; Cortex-A9	Cortex-A8; Cortex-A9
Memory	128-512MB	128-256MB	1GB+
Graphics GPU	Mali-200 / Mali-400 MP	2/3D Graphics	Mali-200 / Mali-400 MP
Video	Dual SD/HD Multi-std decode	SD/HD Multi-std decode	Dual SD/HD Multi-std decode
Audio	Software	Software	Software
Java	For Tru2Way / MHP boxes	Tru2Way	Required (CDC)
Internet/ Browser	Some	Some	Required (profile 2.0)

未来的家庭及企业网络应用



ARM在汽车市场的应用

- Safety and Driver Assistance
  - ARM in over 65% of EBS and 40% of airbag
  - Fault Robust technology enabled
  - Integration with modeling tools for Driver Assistance and Active/Passive Safety Integration



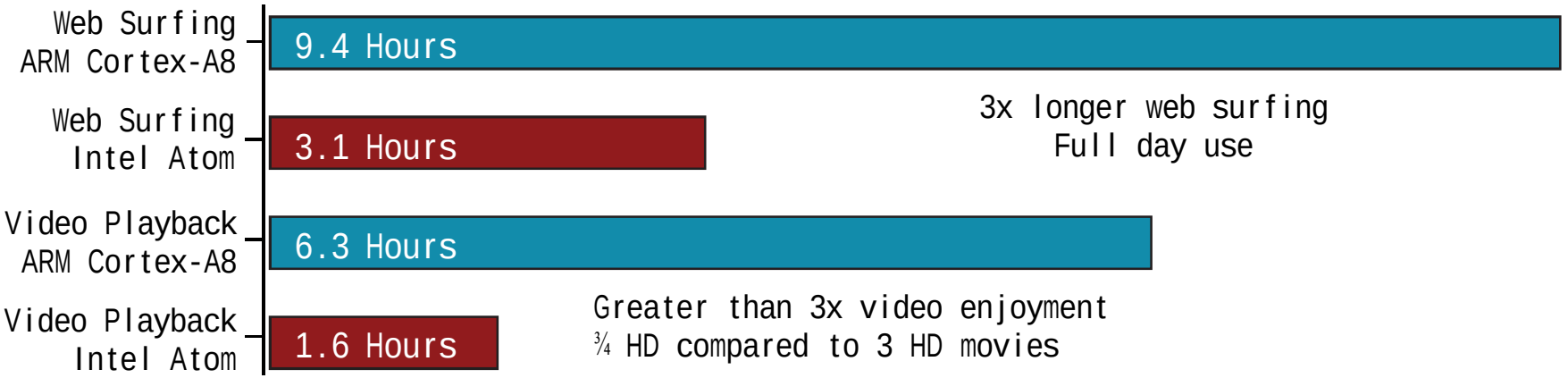
- Navigation and Car Multimedia
  - Convergence with PND market
  - Driver Information: LCD prices driving adoption of virtual dashboard
  - ARM Ecosystem enables strategic platforms opportunities such as Ford + Microsoft Sync

GARMIN MAGELLAN Mio explore more NAVIGON tomtom

未来的机会: 不受“线”制的移动计算

低功耗：全天使用的前提

- All Day Use Model



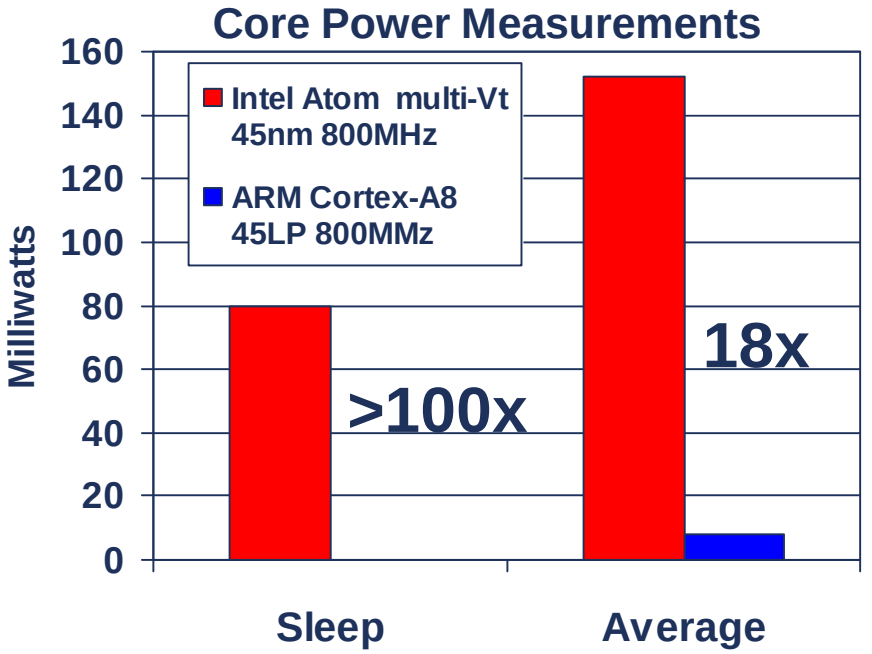
Estimates for ultraportable notebook with 2200 mAh battery

- Differentiation
  - Low thermal requirements enables freedom of industrial design
  - Select the “best in class” SoCs from ARM’s partners
  - Multiple suppliers drives competition and innovation
  - ARM based SoCs enable BOMs < Intel Atom based systems
  - Wireless communication is designed in, not an after thought

移动应用：电池寿命是关键

Low Power =
Great User Experience

- Usability - Average Power
  - Consumers want to be Mobile
  - Cortex-A8 delivers days-of-use, not hours
- Sleep
  - Cortex-A8 saves contents to external DRAM and turns off
  - Weeks of standby not hours



Life from a 1400mAh Battery

Processor Core Only

	Sleep	Average
Intel	0.8 days	0.4 days
ARM	Weeks	6.9 days

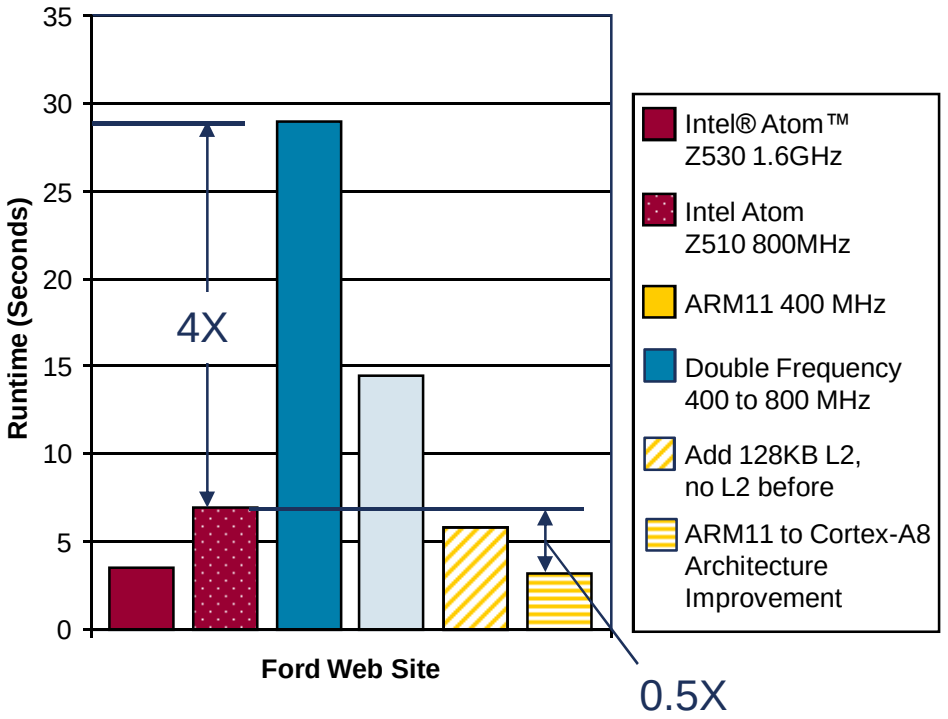
•ARM Cortex-A8 projections use the same statistical distribution of power states as Intel Atom.
• Average use assumes following power state distribution- C0: 5%,C1-C4:15%, C6: 80%
• Projections for core only at 800 MHz. Days calculated on 24hr clock.
• Intel Z500 (C0-C6) state power state estimates from Intel datasheet (319535-001US). Average power estimates based on Microprocessor Report article “Intel’s tiny ATOM”.

性能比较: Cortex-A8 & Atom

- Quick “on a napkin” analysis of Intel performance claims
  - ARM11 @ 400MHz with no L2
  - 800 MHz Intel® Atom™ with 512KB L2
  - 1.6 GHz Atom with 512KB L2
- “Apples to Apples”
  - 2X -- Double the Frequency from 400 MHz to 800 MHz
  - ~2.5X – No L2 to 128KB L2
  - ~1.8X – Architecture improvement from ARM11 to Cortex-A8

Performance Estimates On Webpage Reader
(Network Dependencies Removed)

Smaller is better



Intel benchmark numbers from Intel Fall IDF ’08 Taiwan presentation given by Anand Chandrasekhar

基于ARM的方案

Company	Product	Core	Speed	3D Graphics	HD Video	Radios	Linux	Window Mobile	Android	Window Embedded
NVIDIA	Tegra™ 610	ARM11 MPCore™	800 MHz	X	X			X		X
Samsung	6410	ARM11	667 MHz	X	SD	X	X	X		X
Samsung	S5PC100	Cortex-A8	800MHz	X	X		X	X		X
Qualcomm	SnapDragon™	V7 Architecture License	1 GHz	X	X	X	X	X		X
Freescale	iMX515	Cortex-A8	1 GHz	X	X		X	X		X
TI	OMAP™ 3	Cortex-A8	1 GHz	X	X	X	X	X		X
TI	OMAP™4	Cortex-A9	2 cores, 1GHz ea	X	X	X	X	X		X
Marvell	PXA3## (contact for all the products)	V5 Architecture License	803 MHz	X	SD	X	X	X		X

	MID/Hybrid	Netbook
2009	V7 – Cortex-A8, minimum 256MB, start of integrated radios and GPS	V7 – Cortex-A8 and first Cortex-A9, minimum 512MB
2010	V7 – Cortex-A8 and Cortex-A9, minimum 512MB, highly integrated and cost reduced solutions … radios, GPS, accelerometers	V7 – Mix of single and multi-core, multi GB memory, start of integration for cost reduction

移动计算 OS 的选择

Product	Operating Systems
“Smartphone” 	Symbian Windows Mobile Linux - Various
“MID” PMP, PND, Internet Tablet 	Windows Embedded Linux – Linux.OnARM.com Android
Ultraportable Notebook 	Linux (various flavors) Ubuntu – Canonical Big Windows - TBD
Hybrid ARM for browsing, email, multimedia X86 when needed  > 15 hr use	Windows Embedded Linux – LinuxOnARM.com

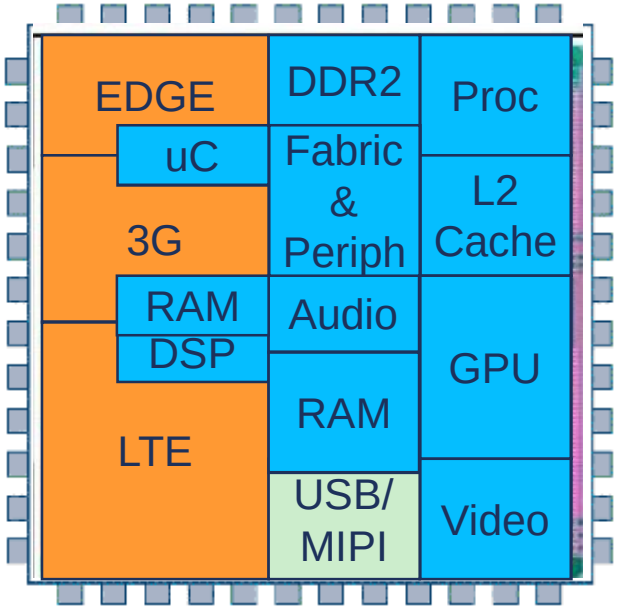
Web 2.0 ARM的生态系统

New Programs	
Mozilla Fennec 	Official release of Mozilla browser for mobile Fennec (FF3 engine) is expected end Q1'09
Adobe Flash Player10 and AIR 	Optimizations for ARMv6 and ARMv7, 2H 2009 Support for GPUs & HW through open standards (OpenGL-ES 2.0)
Silverlight Support for ARM 	Targeting Nokia S60 & WM6.x, 1H 2009 ARMv6 is minimum required, we expect support for OpenGL-ES 2.0 also. .NET is app framework
Java Standard Edition for ARM 	Targeting Java Standard Edition v6.10 to ARM Early access release expected in Q1 2009
Live Mesh on ARM 	Device data synchronization, mixes with Silverlight for rich cloud applications Beta released on Windows Mobile at PDC 2008.

4. 未来嵌入式开发的挑战

未来的移动芯片：复杂的硬件集成

- ARM typically supplies:
  - The processor subsystem
    - How fast facebook opens
    - Whether Flash10 content is possible
    - What type of games can be played
    - Responsiveness of UI
    - Battery life
  - The graphics processor & software
    - Desktop quality graphics
    - “Coverflow” type interfaces
    - Gaming experience
    - Fast panning, zooming, flipping
    - Battery life



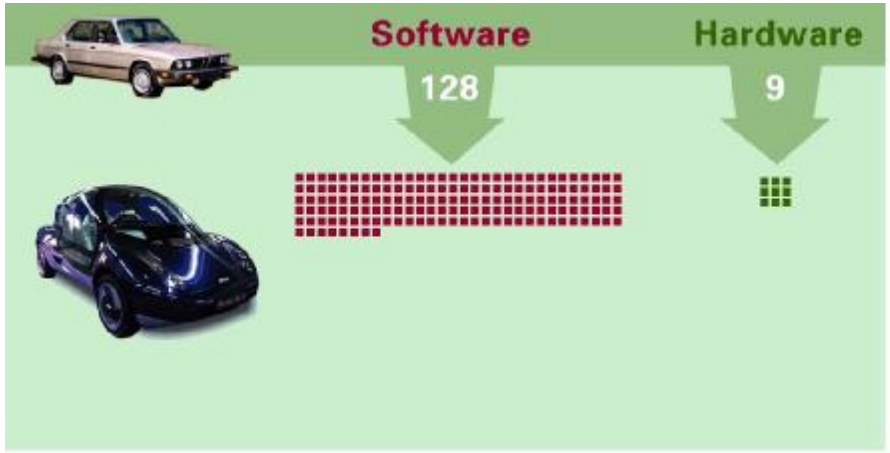
Processor & graphics affect:

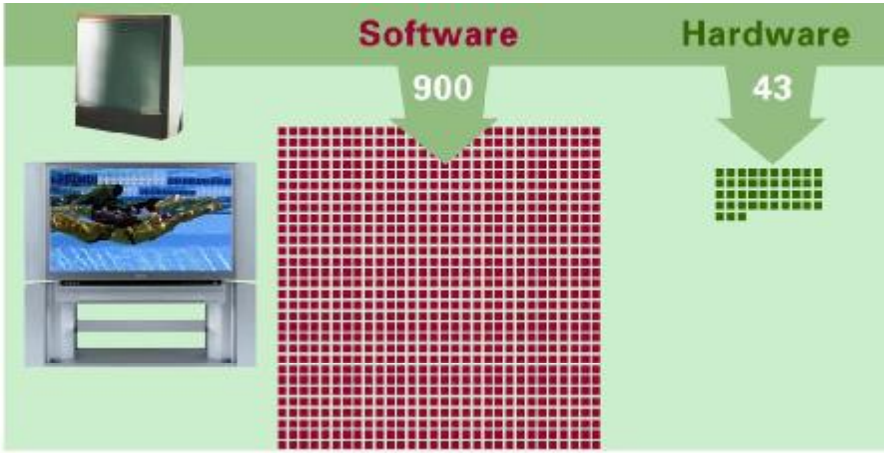
Services

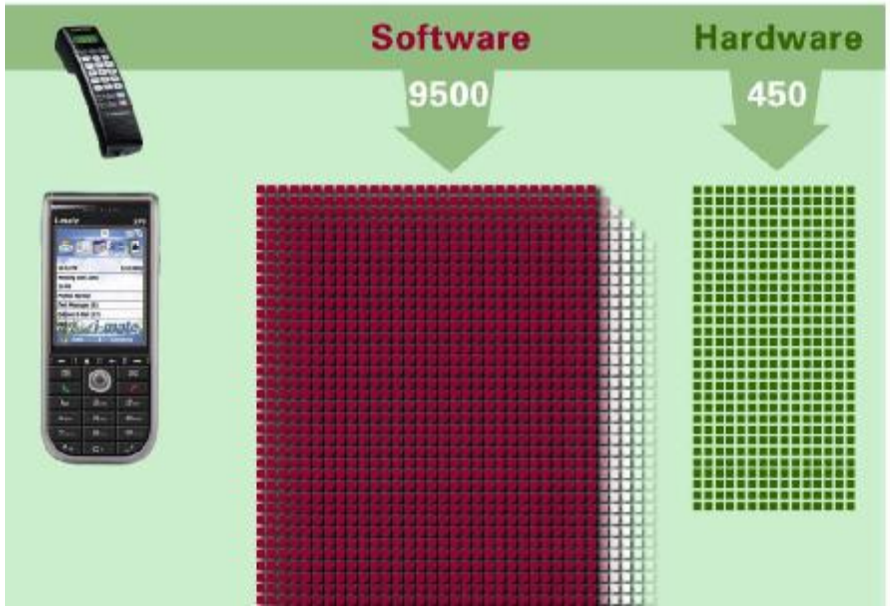
User experience

OEM/Operator ARPU

不断上升的软件集成费用







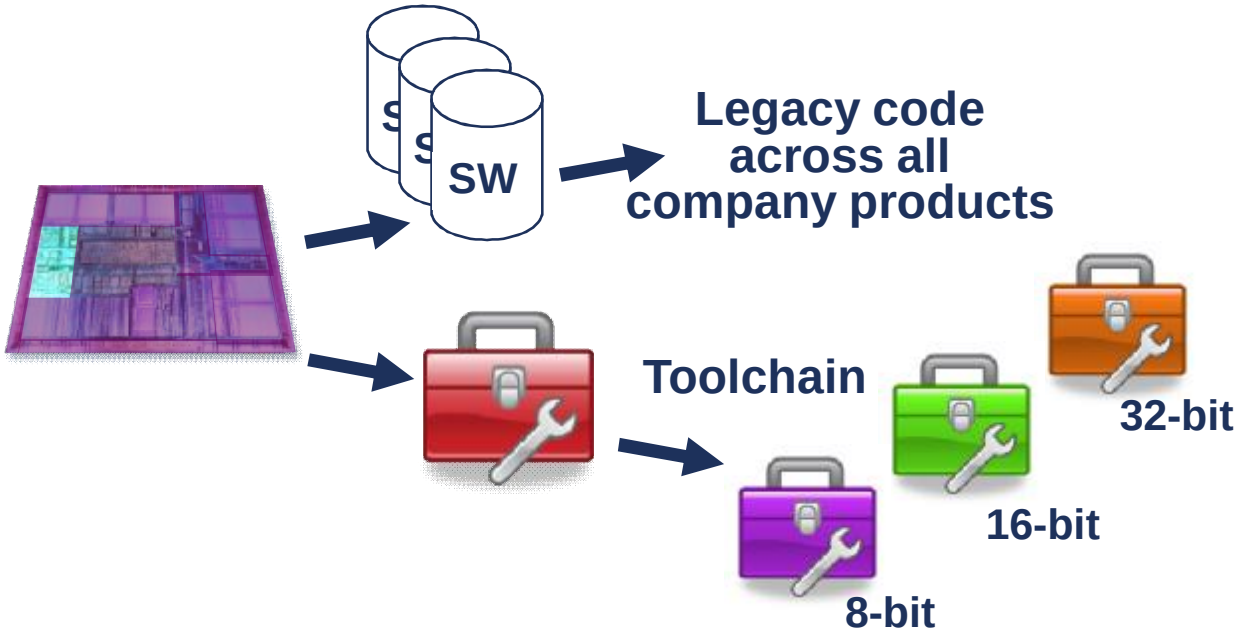
- High-performance devices run large amounts of complex software
- All needs to be developed and integrated into final device

今天的现实：来自复杂的软件挑战

54%	**Device software designs are completed behind schedule** "2003 Embedded Development Tools & RTOSes," EMF, June 2003
66%	**Device software designs are completed over budget** "2003 Embedded Software Study," DDC, September 2003
33%	**Produced devices do not meet performance or functionality requirements** "2003 Embedded Development Tools & RTOSes," EMF, June 2003
14 Billion	**Devices will be connected in 5 years** "X Internet" Reports, 2001-2003

Source: WindRiver

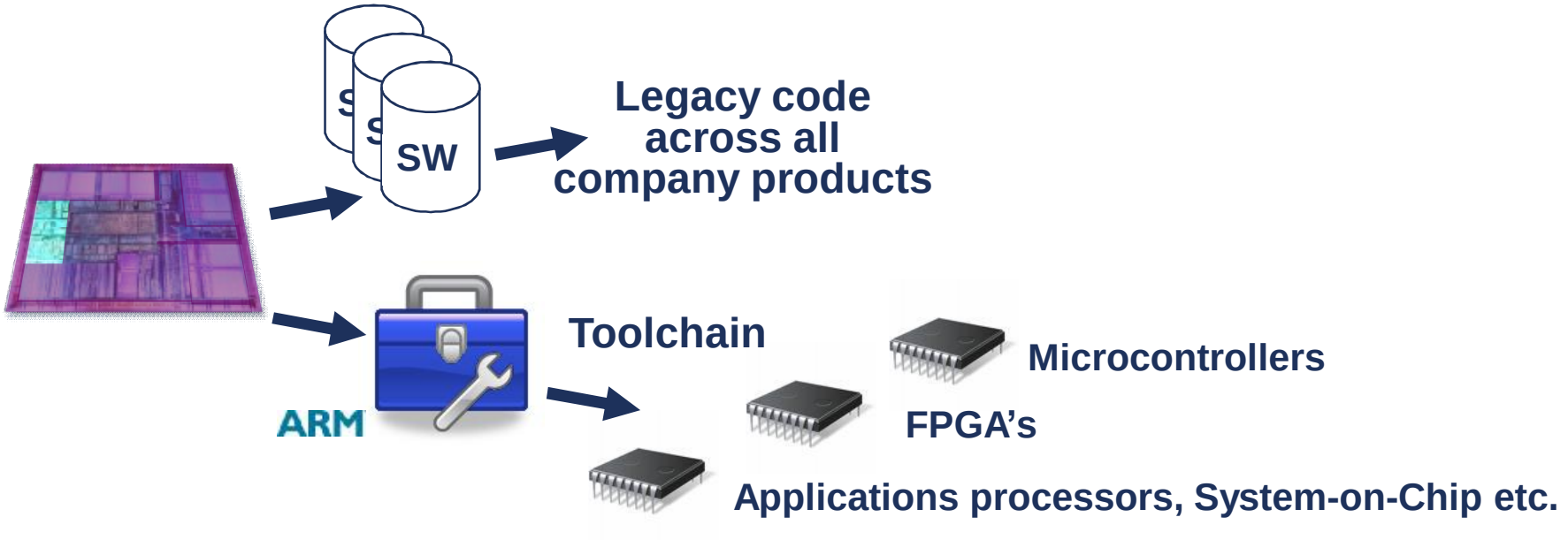
为什么要关心CPU?



- For each additional toolchain:
  - IT Costs $$ ⬆
  - Reliability ⬇
- A consistent CPU architecture enables software and toolchain reuse

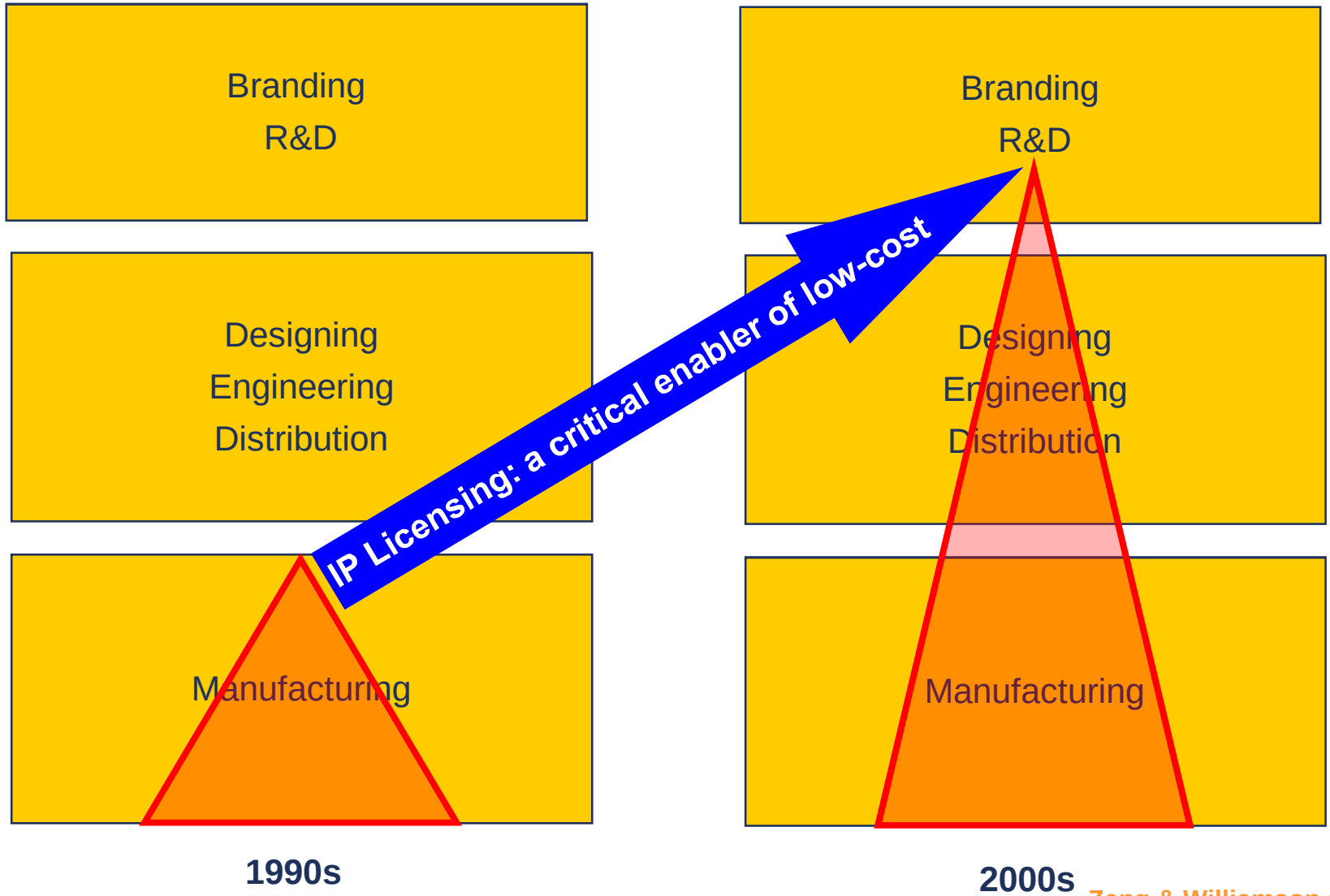
- **What would happen in the computer software industry if..**
  - Every new PC used a different CPU architecture
  - You had to maintain different compilers for every new PC
- **Common architecture can make Embedded Software reuse a reality**

ARM技术授权的软件优势



- **Enabling a standard platform for embedded development**
  - Protecting investment in software design
  - Forget traditional 8/16/32-bit perceptions, think of it as a 'Software Engine'
  - Enable reuse, not just from MCU to MCU but onto other digital solutions

中国低成本创新的新阶段



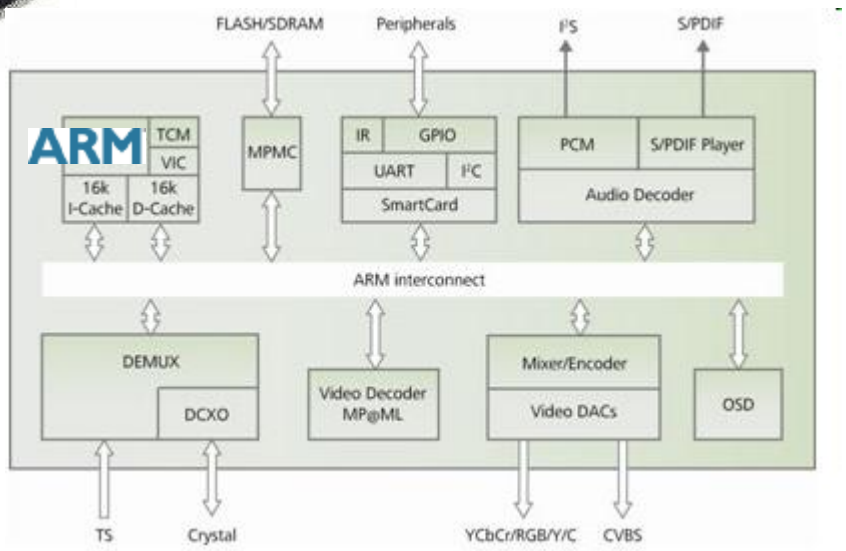
Zeng & Williamson (2008)

ARM客户的成功： 更好的生活，更美的未来！

HiSilicon 海思—双向多功能 DVB-C机顶盒芯片解决方案

SMIC 中芯国际集成电路制造有限公司 Semiconductor Manufacturing International Corporation

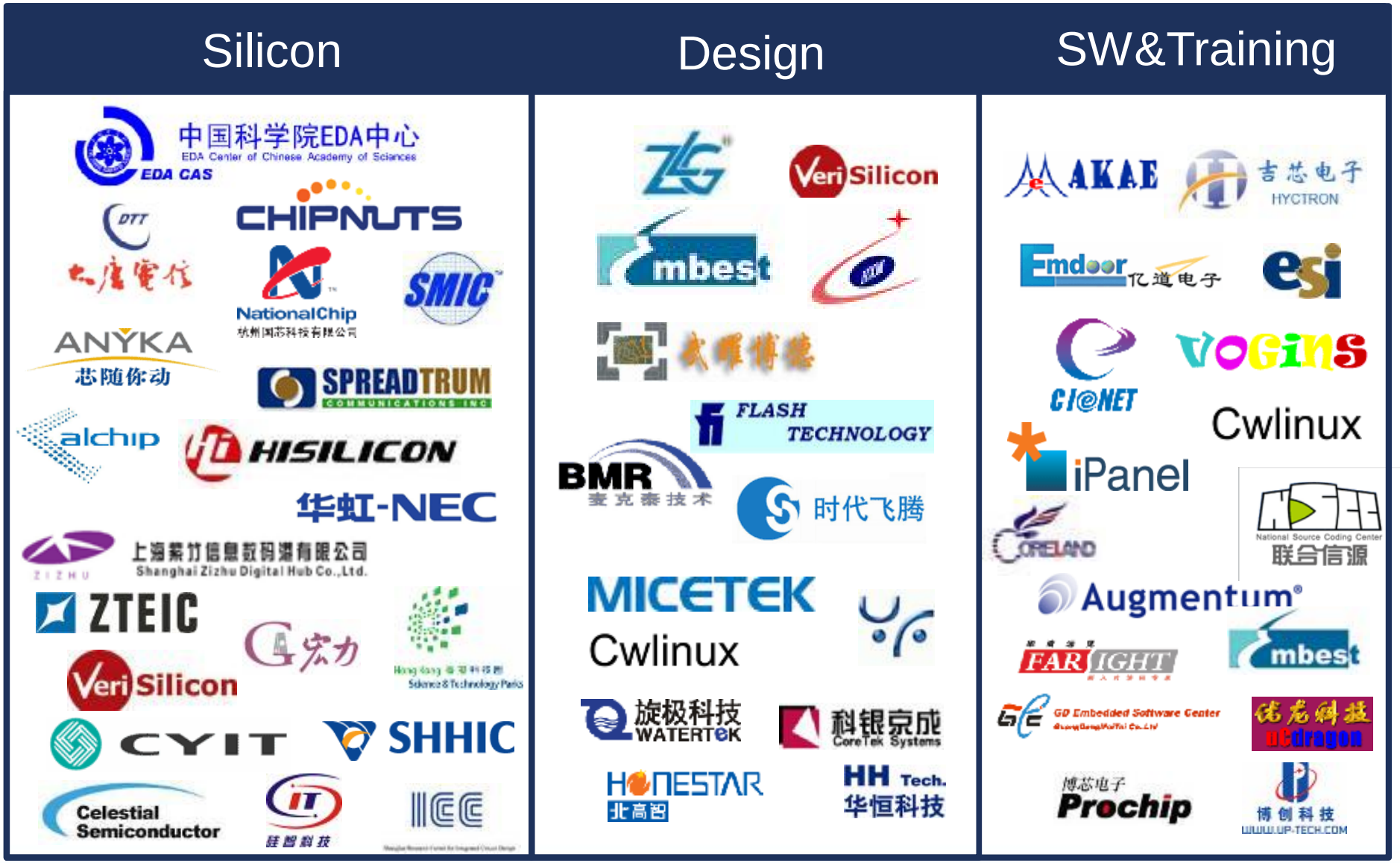
Artisan ARM® Physical IP



Hi3110E集成电源管理模块，支持机顶盒真待机、低功耗、自动唤醒（stand-by power＜1W，working power＜7W）。

海思初步测算如果全国运营商采用基于海思芯片的“绿色机顶盒”，每年节能降耗 **17.34** 亿度

ARM合作伙伴技术联盟: 50多个中国伙伴



未来是属于你们的！

- 半导体行业的不断细分化分工导致了知识产权业务模式的成长
  - 廉价的计算、通信、存储成本使梦想成真
- 消费电子产品的需求正在推动半导体及嵌入式产业的发展
  - 数字化革命才刚刚开始、绿色节能推动模拟控制技术数字化
- 差异化的“产品快速上量、价格的迅速下滑”矛盾挑战陈旧嵌入式的软硬件系统集成
  - 软件复杂度及成本影响竞争优势，平台化开发是必然
- 未来：中国低成本制造+嵌入式创新的成功
  - PC时代已过，未来属于嵌入式！

ARM POWERED®

No Fans, Just Cool Devices !