CONVERGENT semiconductors

The Fallacy of "Universal Memory"

August 2009

Bob Merritt

Current Memory Technologies are Driven by Two Forces

Incompatibility of Memory and Logic processes

- Memory + Logic (i.e. embedded memory) is a specialty area
- Memory follows Moore's law by choice, not by technology dictate

Currently shifting the target application for new memory technologies away from the Mainframe and PC Commodity Memory Array

Changing the Target Application Changes the Value Proposition

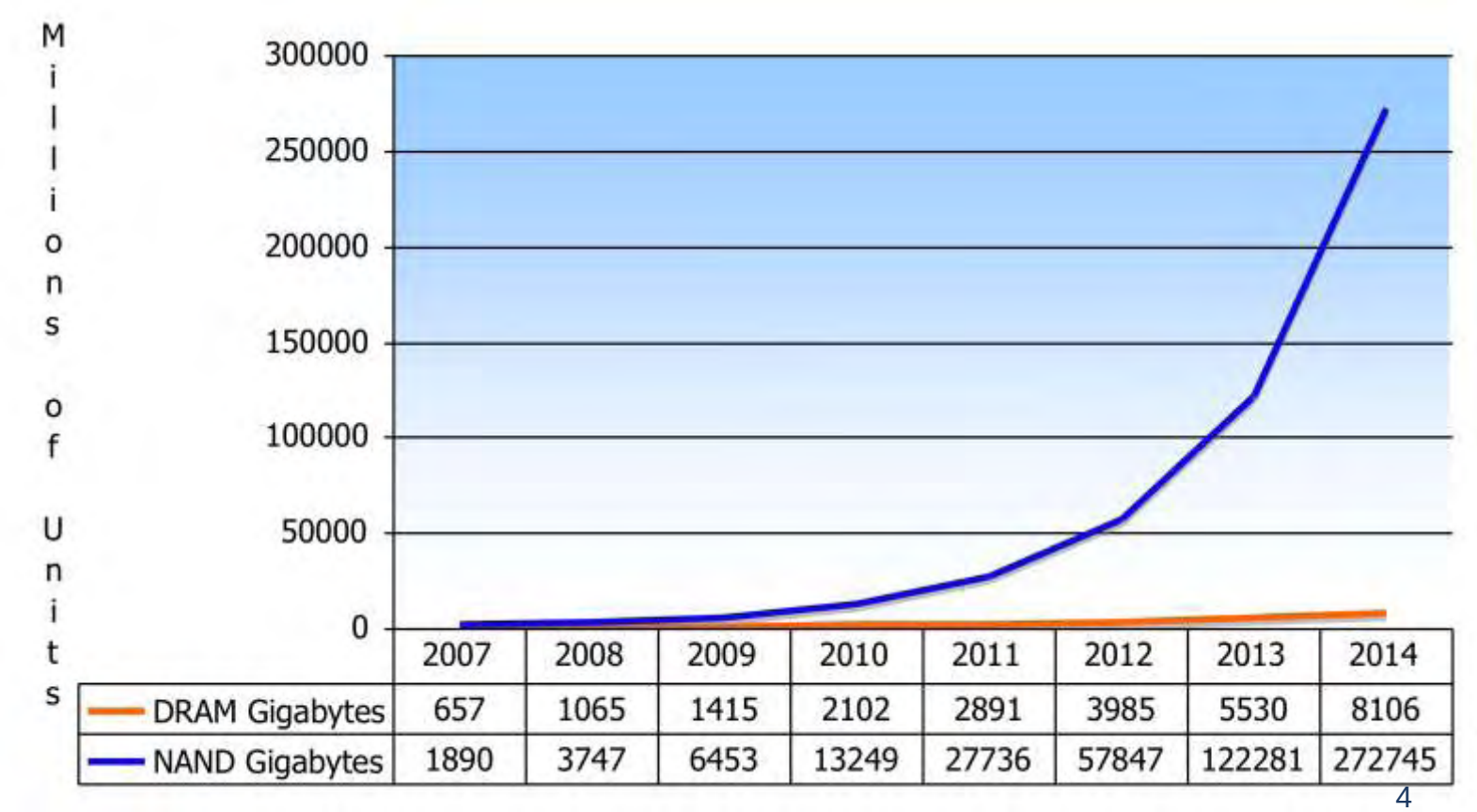
Heat generation and power consumption issues compete with DRAM cost/bit in large systems

- Spansion Eco-RAM
- Schooner NAND Cache

NVM speed and power consumption in SSD competes with HDD cost/bit in Mobile applications

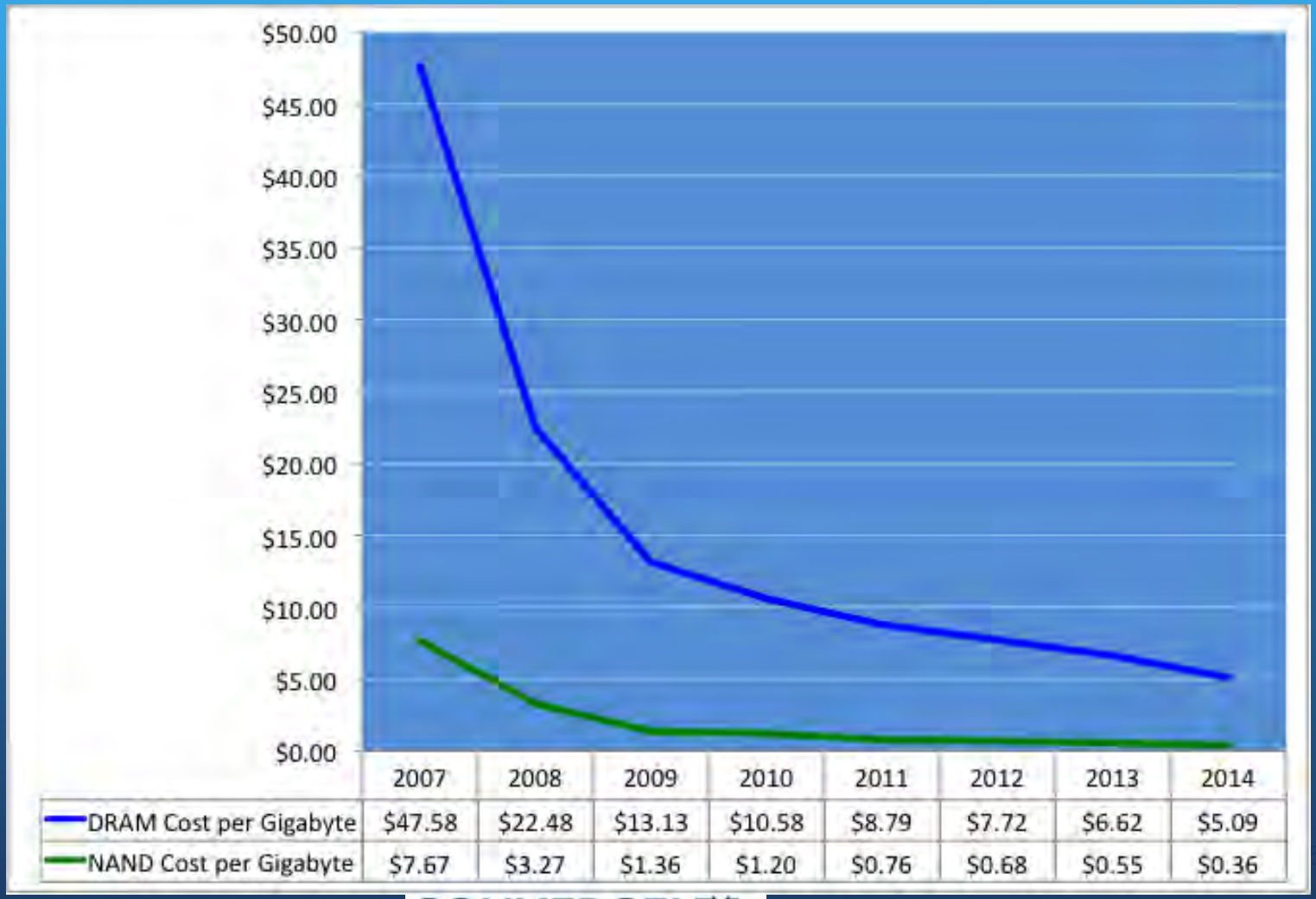
Semiconductor memory technologies are expected to compete with high-capacity HDD technologies in Enterprise-level applications

DRAM and NAND Gigabyte Shipments



	2007	2008	2009	2010	2011	2012	2013	2014
DRAM Gigabytes	657	1065	1415	2102	2891	3985	5530	8106
NAND Gigabytes	1890	3747	6453	13249	27736	57847	122281	272745

Cost per Gigabyte



	2007	2008	2009	2010	2011	2012	2013	2014
DRAM Cost per Gigabyte	$47.58	$22.48	$13.13	$10.58	$8.79	$7.72	$6.62	$5.09
NAND Cost per Gigabyte	$7.67	$3.27	$1.36	$1.20	$0.76	$0.68	$0.55	$0.36

CONVERGENT semiconductors

“Universal Memory”- Leads to The Ultimate Trick Question

- “When does the “Universal Memory” compete with DRAM/NAND on cost/bit?”
- How can it replace a high volume product like DRAM/NAND if it doesn’t compete on cost-per-bit?
- Manufacturing costs are related to previous volume of production. What identified new apps can quickly ramp to DRAM/NAND levels of production?
- Problem is with the label, not the technologies

Competition for new memory technologies is *not* NAND or DRAM

- New technologies don't replace older technologies in high volume applications.
- New technologies enable new applications

NAND Continues as the Primary Vehicle for High-Volume Memory Production

- NAND enables consumer demand for high-performance mobile data storage
- NAND confirms that duty cycle requirements vary by application
- NAND continues to drive ever-lower cost/bit and ever-higher volumes

Target Specs for New Memory Technologies?

Just the usual specs…more speed, higher performance, less cost

BUT OVER A MUCH RICHER PARAMETER SPECTRUM

- High-performance embedded NVM
- Higher performance processes
- Denser packing of memory cells in CMOS
- Blurring the distinction between Memory and Logic
- Changing the value ratio between Memory and Logic

New Memory Technologies - New Performance Attributes

	FeRAM	MRAM	PCRAM	RRAM
Basic Mechanism	Polarizing ferroelectric crystals	Tunneling magneto-resistance effect	Material's phase change causes resistive effects	Mechanism depends on material used
Current Status	Product	Product	Development	Early Development
Prospects	Embedded low-power applications	Embedded/ standalone high-speed applications	Candidate for high duty-cycle Enterprise Storage	Potential Candidate for Enterprise Storage

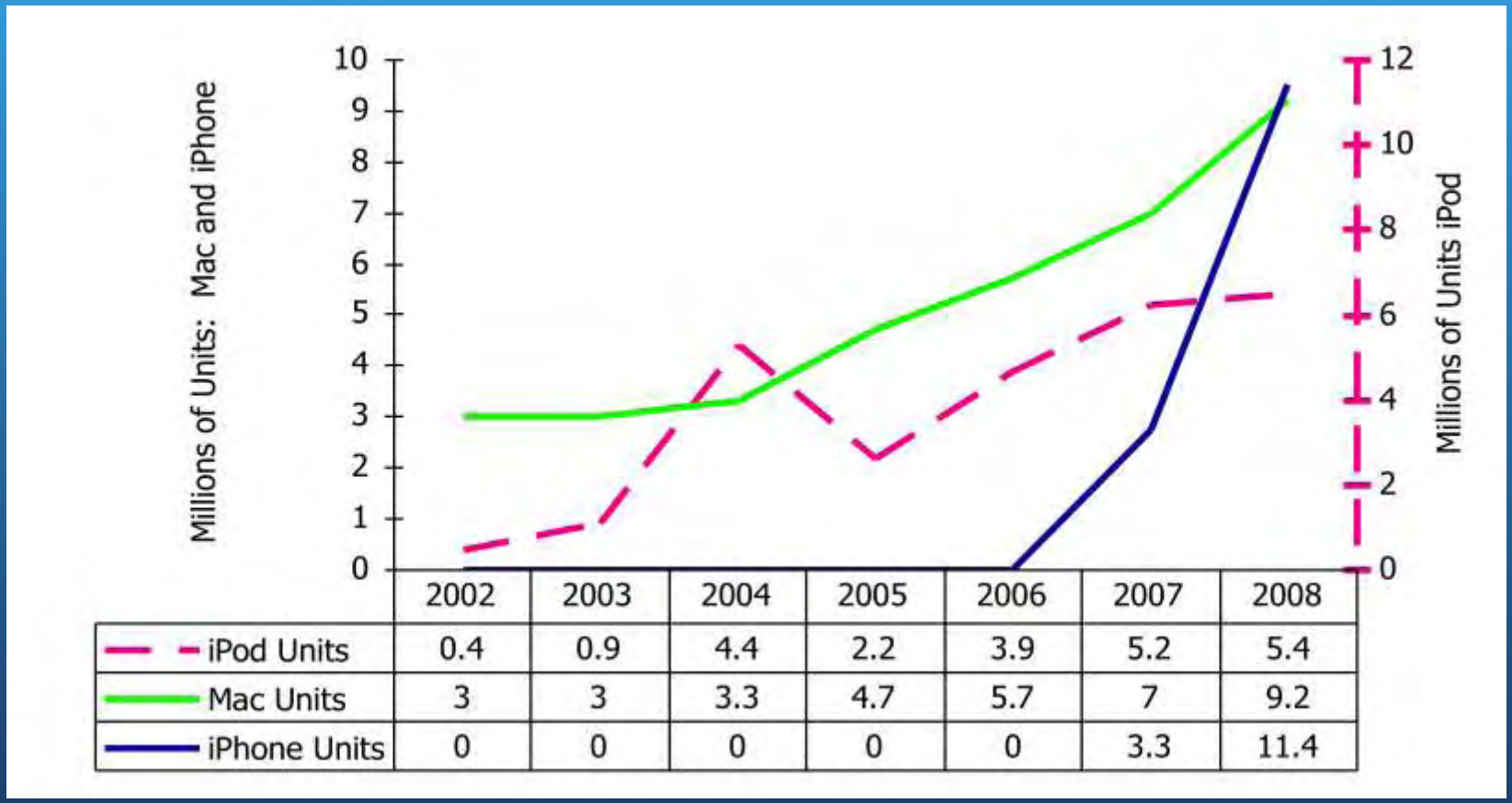
New Architectures Shift Memory's Value Proposition

- Memory and logic combined in novel architectures
- Reconfigurable and reprogrammable processing elements
- Fundamental changes in manufacturing strategies blur the boundaries between memory and logic processes

Insider's View on Market Change

- Speaking on its 4Q08 conference call, CEO Steve Jobs said Apple changed value proposition for mobile devices. He said App Store offered more than 5,550 software applications available in 62 countries around world, and would see 200 millionth download the next day. Rate of new submissions increases every week. "We've never seen anything like this in our careers," Jobs said.
- Hardware is not the value driver it once was.

New Product Intros and an Existing Product Boost

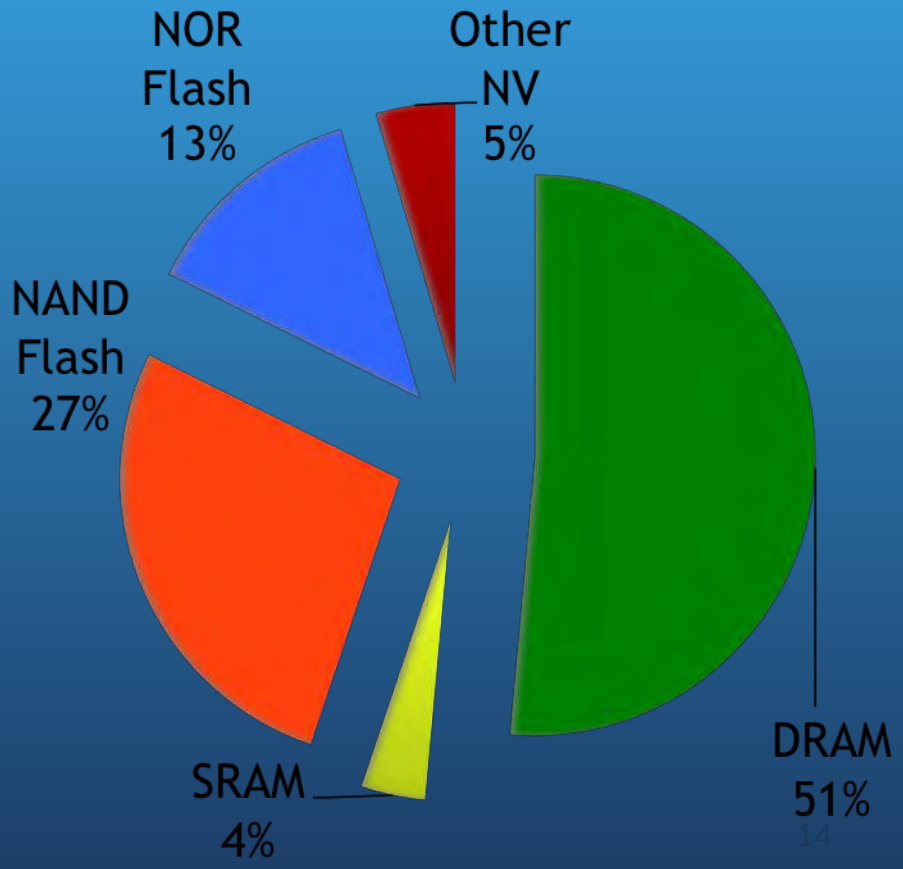


	2002	2003	2004	2005	2006	2007	2008
iPod Units	0.4	0.9	4.4	2.2	3.9	5.2	5.4
Mac Units	3	3	3.3	4.7	5.7	7	9.2
iPhone Units	0	0	0	0	0	3.3	11.4

Source Data: Apple Reports

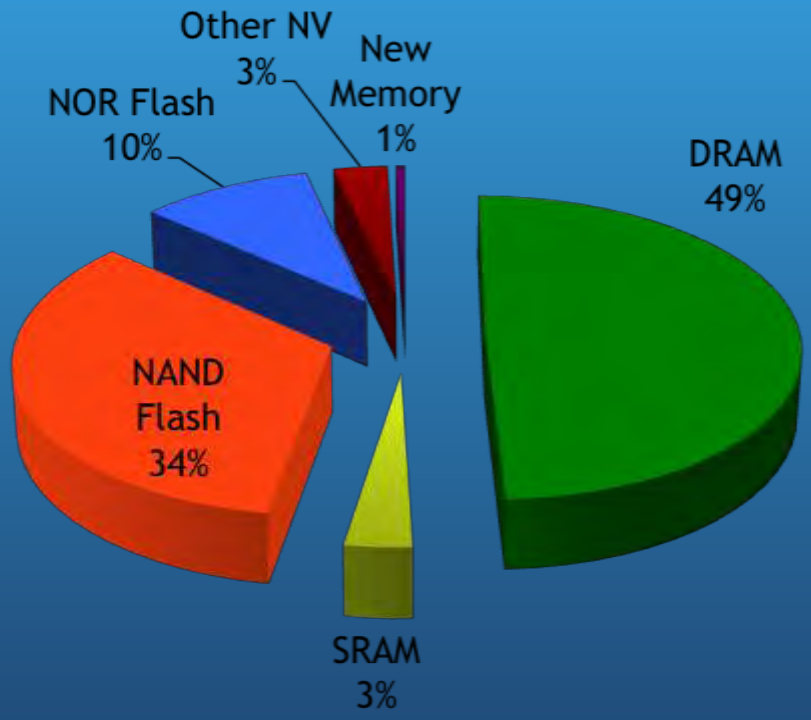
Memory Markets 2008

- Memory Market Revenue Today
  - DRAM
  - SRAM
  - NAND Flash
  - NOR Flash
  - EPROM
  - EEPROM
  - MROM
  - OTP ROM



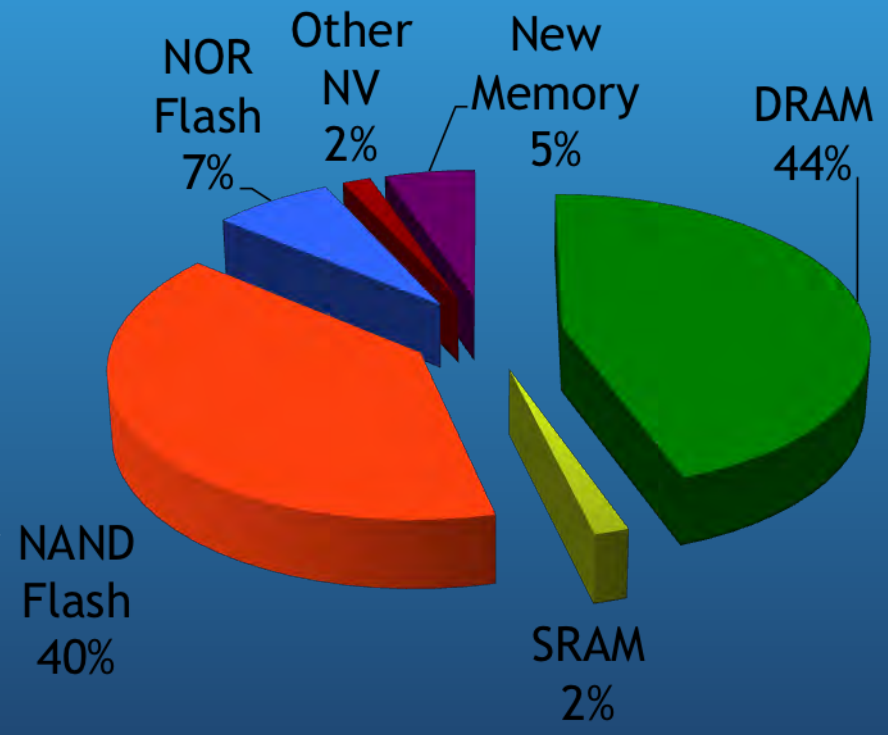
Memory Market 2010

- DRAM
- SRAM
- NAND Flash
- NOR Flash
- EPROM
- EEPROM
- MROM
- OTP ROM
- Future



Memory Market Revenue 2012

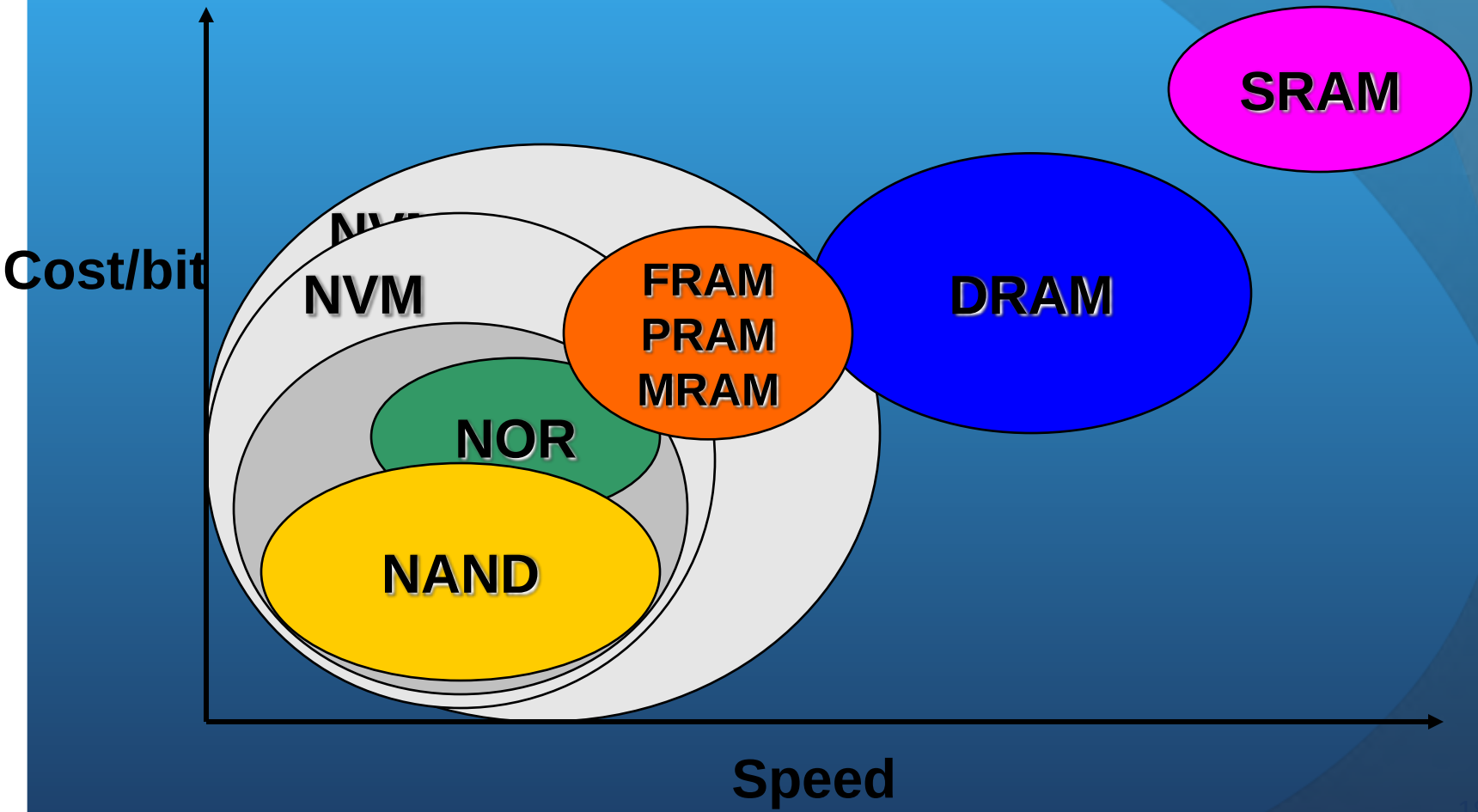
- DRAM
- SRAM
- NAND Flash
- Other Non-Volatile
- Future Composite/ Convergent



Survival of the Fittest

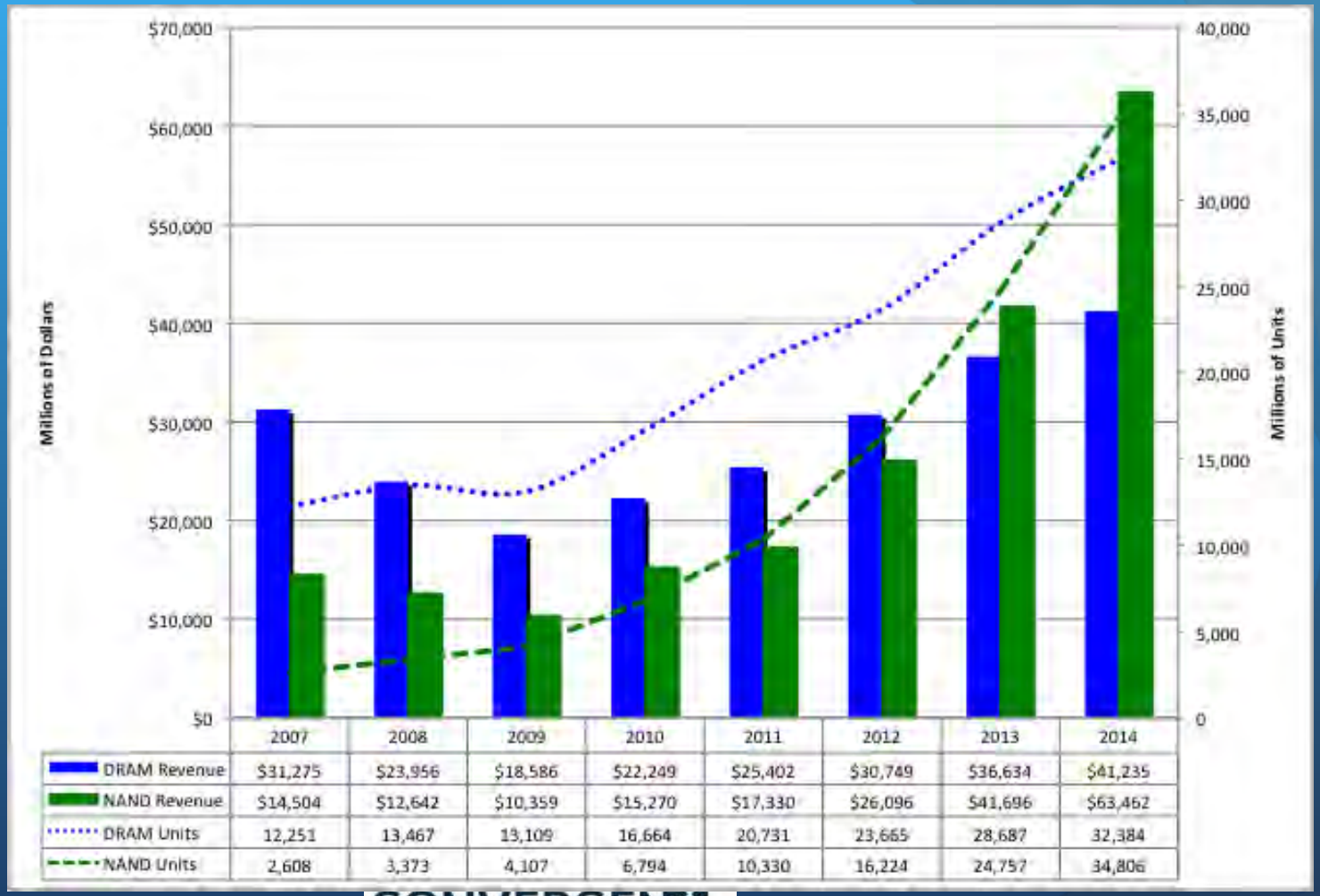
- “It is not the strongest of the species that survive, not the most intelligent, but the one most responsive to change.” Charles Darwin

The Memory Technologies



CONVERGENT semiconductors

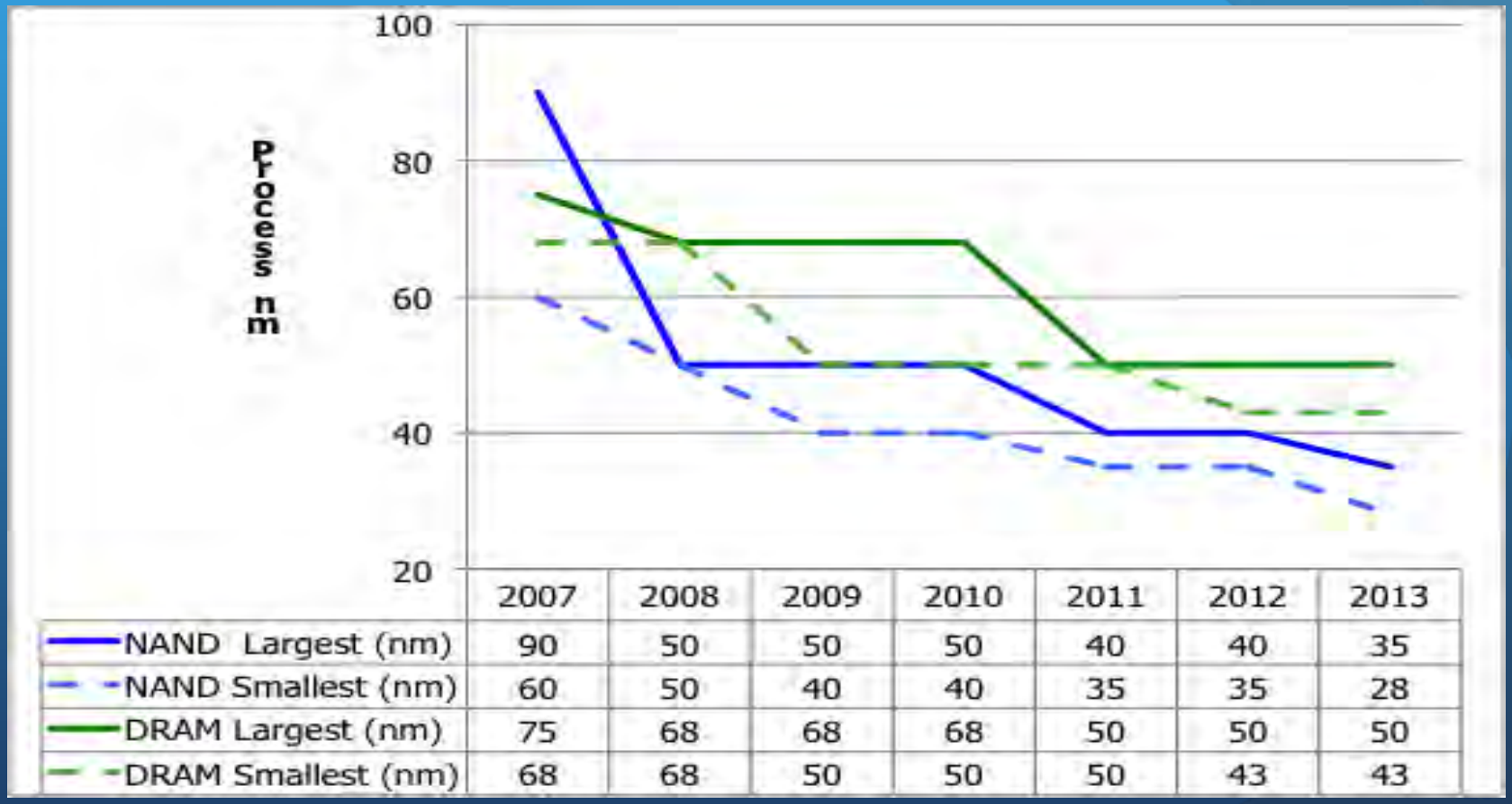
DRAM and NAND Revenue and Units



	2007	2008	2009	2010	2011	2012	2013	2014
DRAM Revenue	$31,275	$23,956	$18,586	$22,249	$25,402	$30,749	$36,634	$41,235
NAND Revenue	$14,504	$12,642	$10,359	$15,270	$17,330	$26,096	$41,696	$63,462
DRAM Units	12,251	13,467	13,109	16,664	20,731	23,665	28,687	32,384
NAND Units	2,608	3,373	4,107	6,794	10,330	16,224	24,757	34,806

CONVERGENT semiconductors

DRAM and NAND Flash Production Process



	2007	2008	2009	2010	2011	2012	2013
NAND Largest (nm)	90	50	50	50	40	40	35
NAND Smallest (nm)	60	50	40	40	35	35	28
DRAM Largest (nm)	75	68	68	68	50	50	50
DRAM Smallest (nm)	68	68	50	50	50	43	43

CONVERGENT semiconductors

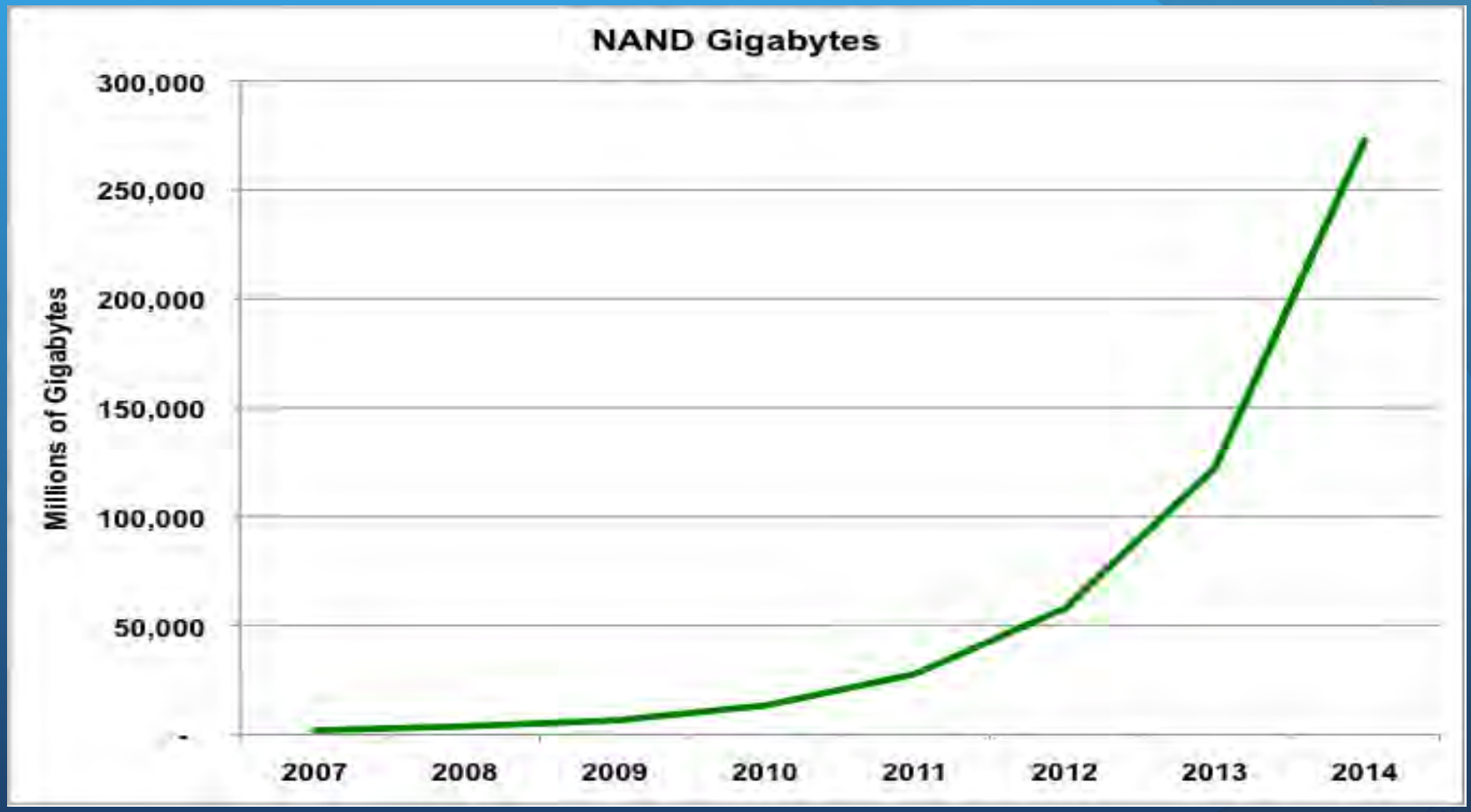
Trends to Watch

- Capacity-shift between DRAM and NAND flash is a manufacturing decision based on market demand and prices
- NAND flash trends
  - NAND is causing system OEMs to re-examine long-held performance assumptions
  - NAND demand continues to evolve with introduction of new mobile products
  - NAND flash vendors extend the number of bits per cell
- NAND is a market with a long-term upside

Thank You

CONVERGENT semiconductors

NAND Growth as New Applications are Supported



The Result Established DRAM as Dominant Memory Technology