Life ___(3 words)___ Flash
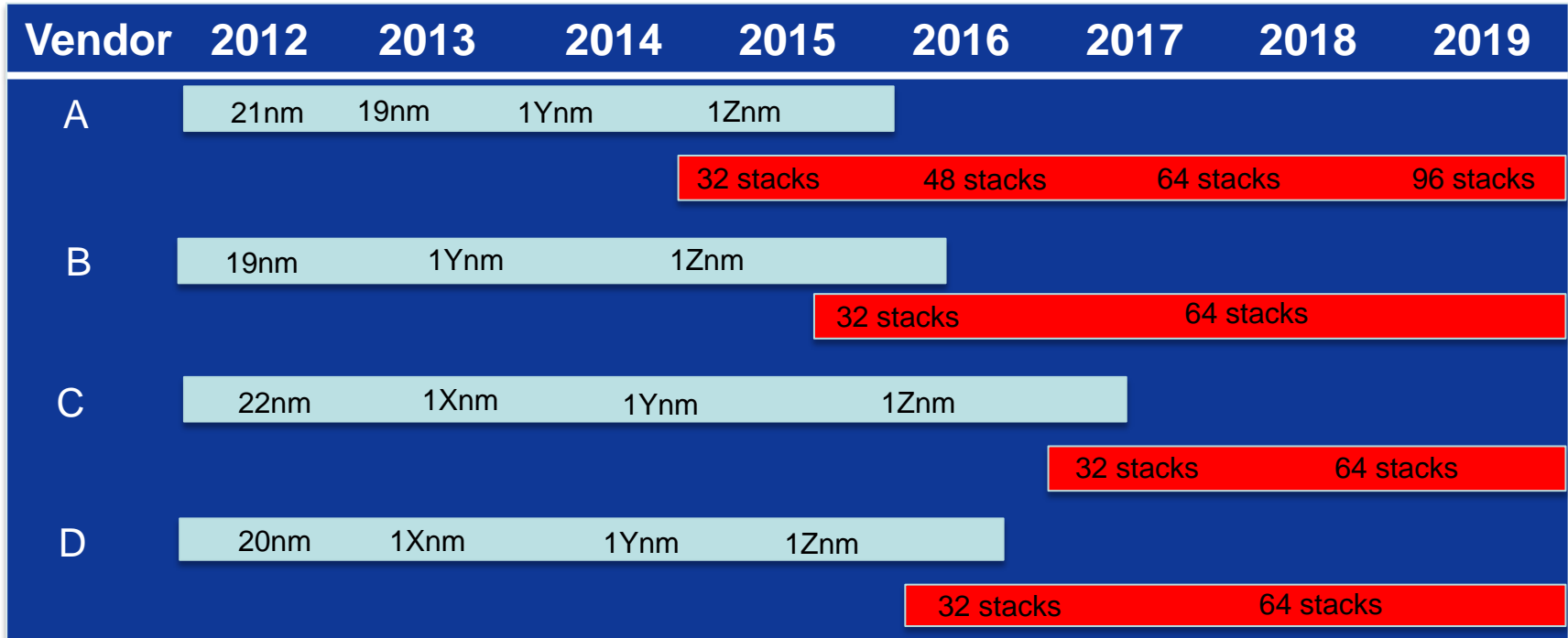## *(or, what to expect the next 7 years)*

David Eggleston

Principal, Intuitive Cognition Consulting

Memory Truthiness…

A. The future of NAND is ___(1 word)___ .
   The future of DRAM is ___(1 word)___ .

B. The ___(3 words)___ always wins.

C. The opportunity gap is in reduced ___(1 word)___ .

D. "I want to say one word to you. Just one word."

   ___(1 word)___ .

Forecast: NAND Technology

| Vendor	2012	2013	2014	2015	2016	2017	2018	2019
A	21nm	19nm	1Ynm	1Znm				
A				32 stacks	48 stacks	64 stacks		96 stacks
B	19nm	1Ynm	1Znm					
B					32 stacks		64 stacks	
C	22nm	1Xnm	1Ynm	1Znm				
C							32 stacks	64 stacks
D	20nm	1Xnm	1Ynm	1Znm				
D						32 stacks	64 stacks	

□ = Planar NAND ■ = 3D NAND
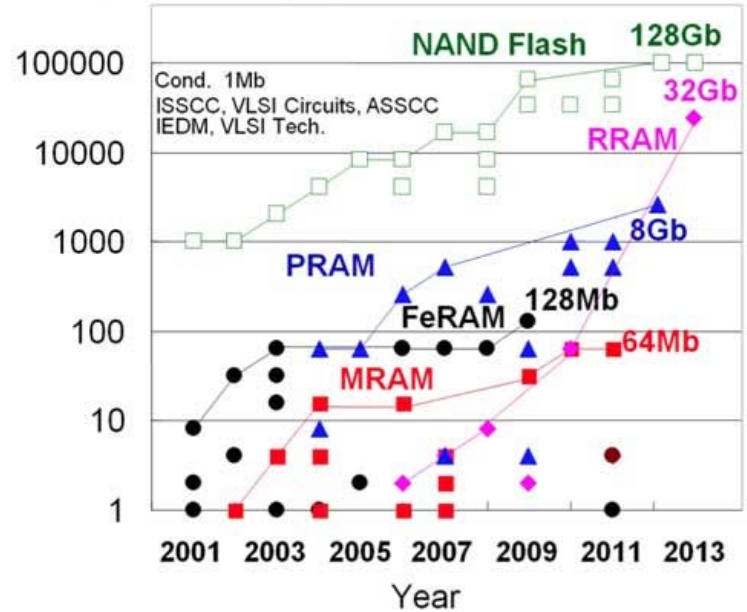
Source: Intuitive Cognition Consulting

- Planar NAND scaling continues thru 1Znm using hi-K metal gate
- 3D NAND production ramps in 2015 for 5+ years of production
- RRAM production follows after 3D NAND (year 2020?)

Why is it so hard to displace NAND?
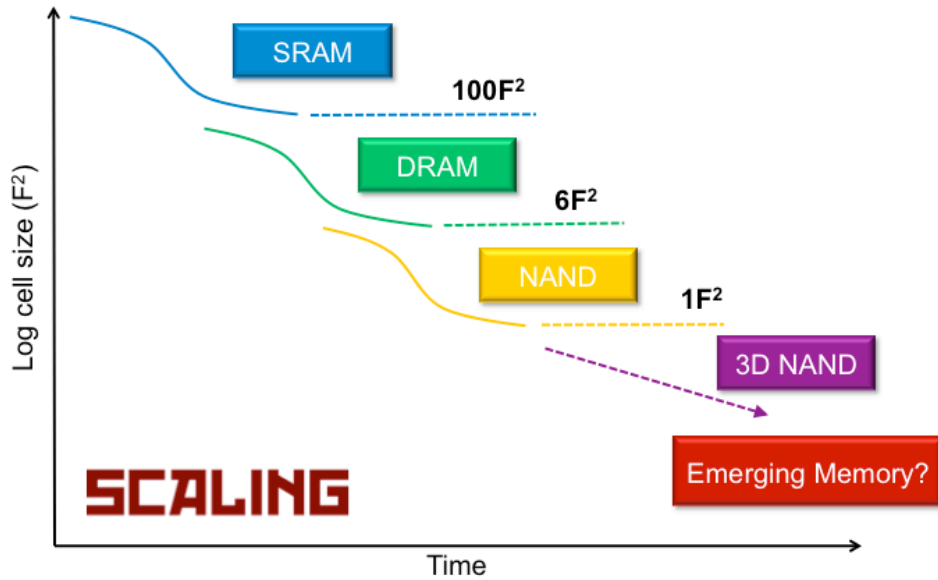
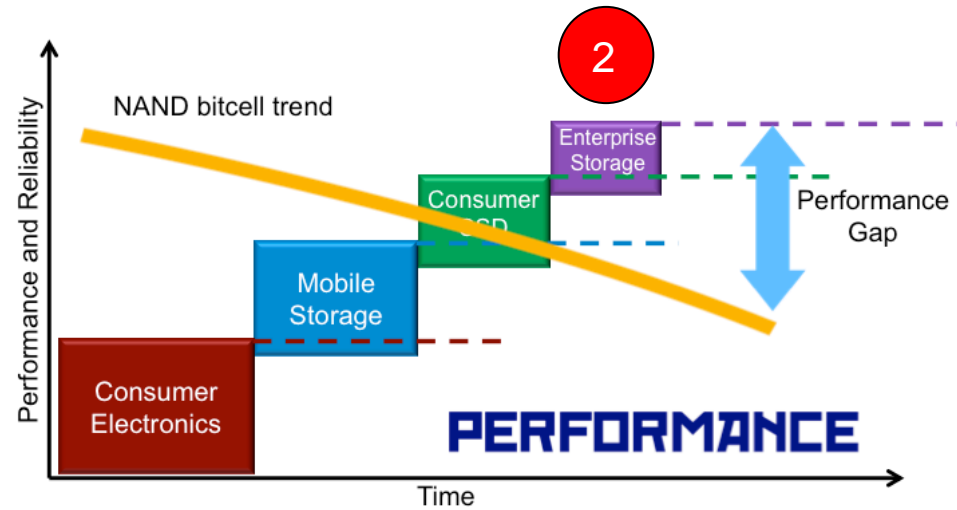Source: Intuitive Cognition Consulting

Source: Zhang; Intel; ISSCC technology review 2013

- 3D NAND extends bitcell scaling below $1F^2$ by going vertical
- None of the contending technologies have demonstrated $< 1F^2$
- RRAM has shown the most promise, but has a long way to go to beat NAND in smallest cell size (i.e. storage capacity)

Where can Emerging Memories launch?

	FRAM	MRAM/STT MRAM	PCM	RRAM
Industrial & Transportation	RAMTRON, Cypress, Panasonic, FUJITSU, LAPIS	EVERSPIN		Panasonic, adesto
Smart Card MCU		Infineon, RENESAS	STi	
Cache Memory for Enterprise storage		SAMSUNG, Avalanche technology, SK hynix, EVERSPIN, Spin Transfer Technologies	SAMSUNG, Micron, SK hynix	
Mobile phones		TOSHIBA, QUALCOMM	SAMSUNG, SK hynix, Micron	
Mass Storage				SAMSUNG, Micron, SK hynix, TOSHIBA, SanDisk

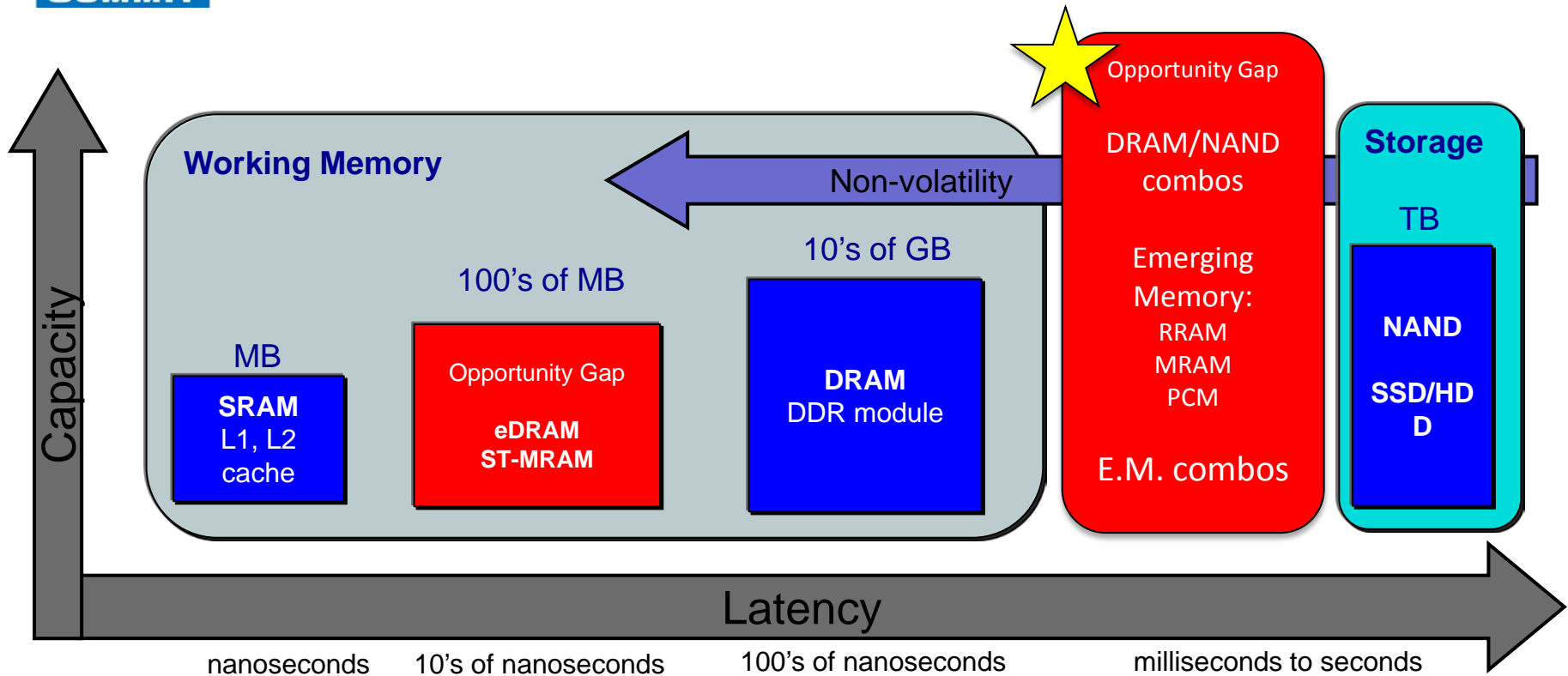Source: Yole Developpment, Feb 2013

Source: Intuitive Cognition Consulting

1 Embedded memory applications
  ➢ Take advantage of ease of integration with logic processes
  ➢ Lower cost eNVM and additional features (security)

2 Performance applications
  ➢ Exceed NAND speed and reliability…

Panasonic

CROCUS Technology
Blossoming future

Latency, Latency, Latency

Working Memory

Non-volatility

Opportunity Gap

DRAM/NAND combos

Emerging Memory:
RRAM
MRAM
PCM

E.M. combos

Storage

TB

NAND

SSD/HDD

Capacity

10's of GB

100's of MB

MB

SRAM
L1, L2
cache

Opportunity Gap

eDRAM
ST-MRAM

DRAM
DDR module

Latency

nanoseconds   10's of nanoseconds   100's of nanoseconds   milliseconds to seconds

2 **Best performance opportunity:**

➢ Filling the latency gaps between major memories

➢ Combos of DRAM/NAND, MRAM/NAND, RRAM/NAND which are virtualized behind controllers entering the market

➢ Challenge: reduce latency, increase endurance

diablo technologies

skyera

Final Word: The Future

- There are <u>no</u> 1:1 memory replacements. Stop. looking. for. them.

- Moving from SRAM-DRAM-NAND world into one with blended memory combinations.

Just one word. Combinations.

Memory Truthiness…

Life __in parallel with__ Flash:

A. The future of NAND is ___NAND___ .
    The future of DRAM is ___DRAM___ .

B. The___smallest cell size___ always wins.

C. The opportunity gap is in reduced ___latency___ .

D. "I want to say one word to you. Just one word."
    ___Combinations___ .