3D Xpoint Status and Forecast

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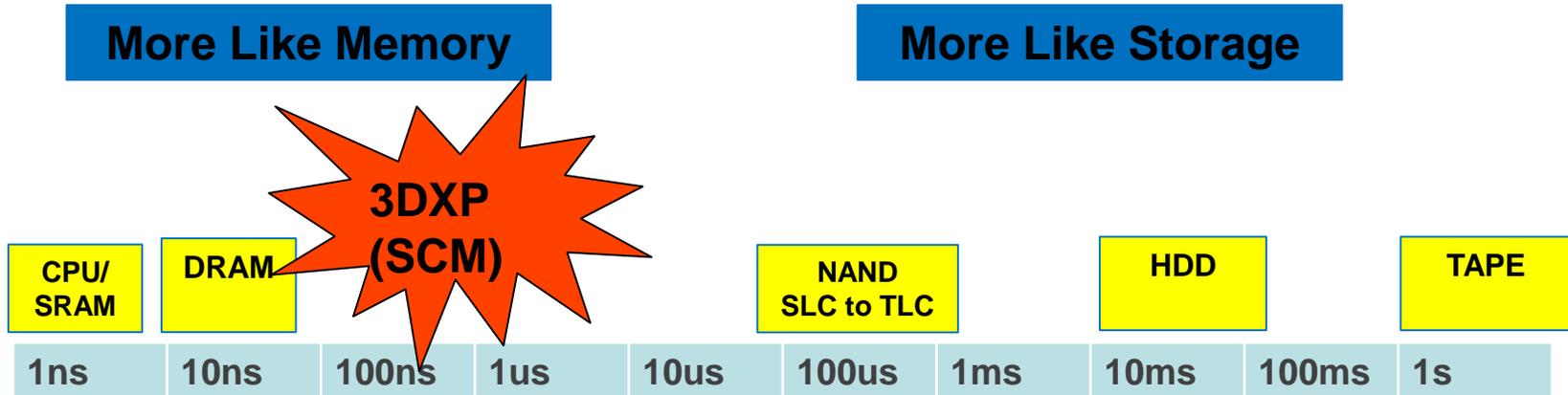# Memory Technologies

	Latency	Density	Cost	HVM ready
DRAM	*****	***	***	*****
NAND	*	*****	*****	*****
MRAM	*****	*	*	**
PCM (Micron)	***	****	**	*
3DXP	***	****	****	*
ReRAM	***	****	****	*

3D Xpoint is perfect SCM once it reaches Volume Manufacturing

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What we know about 3DXP

- ■ Announced in July 2015
  - • 128Gb device… ~200mm^2
  - • "1000x faster than NAND, 10x denser than DRAM, 1000x better endurance than NAND"
  - • SSDs and other products available in 2016
- ■ Various implementations shown at Intel presentations
  - • NVMe SSDs and DIMMS coming
  - • Speeds for actual demonstrations 5-7x faster than NAND based.

The Latency Spectrum and Gaps

More Like Memory

More Like Storage

3DXP (SCM)

CPU/ SRAM	DRAM				NAND SLC to TLC		HDD		TAPE
1ns	10ns	100ns	1us	10us	100us	1ms	10ms	100ms	1s

Increasing Density →

← Increasing Cost

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Why is 3DXP so great?

- Lots of NVMs out there. Everyone claims breakthough hype
- Intel (and Micron) putting so much support adds confidence of <u>real product</u> from <u>high volume</u> companies
- 128Gb is <u>big</u> deal. High density is needed
- Crosspoint means it is competitive in cost and scalable ($4F^2$)
- SCM requires backing of architecture. Intel is all in.
- SCM Applications are huge: Fastest SSD, IMDB at lower cost
- <u>No confidence in any of these before 3D Xpoint</u>

Challenges

- Its been one year. Some dreams were dashed
  - Demonstrations are not 1000x better, 5-7x shown
  - Proprietary interfaces discussed and debated
  - No complete products announced, no 3rd party analysis, no Apple products, no commit dates….
  - Statements other than Intel far more reserved
- New markets are ALWAYS slow to grow
  - SCM will grow … more slowly than hoped

500x faster is actually 2x Faster
Hypothetical NAND SSD vs HDD Example

	SATA HDD	NAND SATA SSD	SSD Improvement	Notes
Bit Latency	50ms	100us	500x	Raw speed
Random IOPS	500	50000	100x	Accessing individual bytes
Seq Reads	70 MB/S	500MB/s	7x	Copy/backup
Boot time	30s	15s	2x	load time
Excel Macro	10s	10s	1x	Running in memory. No effect

Lots of details on why… and, yes, DIMMS change this in servers

Revenue Forecast/Guesstimate

- ## Sales of 3DXP were expected to be meaningful in 2016 (even by me).

  ..... And I was wrong

Revenue Guesstimate

	2016	2017	2018	2019
3DXP	<10M	300M	1B	1.5B
SCM Other	<10M	50M	200M	500M

Notes: I am predicting 3DXP revenue for unannounced products in a market that is undefined.
For SCM other, I am predicting revenue for technologies that have not been sampled for a undefined market.
See Intel for actual revenue forecasts

Additional Predictions

- 2017 Cost of 3DXP is between NAND and DRAM
  - **3.5x cost of MLC NAND, <50% of cost of DRAM***
  - No data to show these will improve over time
- Adding layers or MLC is not a given
  - Adding either will be significant development, slow down the latency, and erode the value proposition.
- Intel created the value proposition for SCM
  - Other SCMs now have an application, demand, and solid example of ROI.
  - RRAM vendors, even Micron have competing options that fit this role well.
  - Those have been published and will come out in volume over next 2 years

Summary

- 3DXP is a great achievement in NVM
- Classic SCM and applications
  - Faster than NAND, Slower than DRAM
  - Cost will always be between NAND and DRAM
    - Currently 3.5x the bit cost of MLC NAND
- Applications and Support abound
- It will ramp slower than every hopes
- It enables SCM competition in next two years