



Flash Memory Summit

# A New Scenario for Emerging Memories and Markets

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- Emerging/New Memories: What we have been looking for?
- Current status and scorecard
- What we have achieved
  - MRAM History and Status
  - ReRAM History and Status
  - PCM/3D XPoint/Optane: History and Status
- CXL Impact
- The Scenario: Memories are only EVER successful in three categories

# Emerging Memories: What Have We Been Looking For?



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- Two Models that we are looking for when we have new memory technologies
- UNIVERSAL MEMORY!
  - I thought we voted to give up on this 4-5 years ago at FMS... but I see an article every few months highlighting a new “Universal Memory”
  - Fast, Random, Non-Volatile, cheap, long retention.
  - Physics seems to prohibit this, but some people are still looking.
- Memory that addresses a major weakness of existing memory
  - DRAM -> NV DRAM
  - NAND -> Faster and Byte accessible
  - This actually makes sense!

# Memory Technologies Reviewed

## whats new?

	Latency	Density	Cost	HVM ready
DRAM	*****	***	***	*****
NAND	*	*****	*****	*****
MRAM 1T1R	*****	*	*	***
RRAM 1T1R	*****	*	*	***
3DXP/Optane	***	*****	*****	*****
NRAM	***	**	***	*
FE RAM	***	**	***	*
Other	***	**	**	*



# What Have We Achieved with MRAM?

- MRAM: moved from 30 years of MRAM development, 10 years of STT development to production (This is a typical timeline)
- Standalone: Real Products, Real Applications where MRAM make the most sense. Fast NOR, NV DRAM
- Embedded: MRAM is the correct answer for embedded memory. eFLASH is functional but is extremely costly.
  - MRAM is better where eFLASH cannot scale and better everywhere else also
  - Its better, faster, cheaper for embedded
- SRAM Cache replacement. Even though SRAM didn't stop scaling. It is best for some apps
- We need to realize the cell size is not 6F, but 50F due to drive transistor.
- MRAM is “mature” and is the right solution for all of these markets.
- We are optimizing based on retention, speed, scaling needs
- This is what we wanted in 2013!
- Market is <\$100M for standalone. Cache and embedded is not quantifiable



# What Have We Achieved with ReRAM?

- RRAM: After 20 years of development, we have 1T1R ReRAM in some markets
- Standalone: Very low density products (<1M typical). Options for 64M.
- Embedded: ReRAM has similar application and cell size to MRAM.
  - MRAM vs ReRAM comes down to application needs and ReRAM cell maturity vs MRAM. ReRAM still has reliability and endurance development work.
  - Its better faster cheaper than NOR in embedded
- In current applications, 1T1R Cell size is 50F due to drive transistor.
- 1TnR (crosspoint) is still in development. All of the challenges of 1T1R plus selector issues and declining performance as we scale up. Not easy!
- You can buy small density chips today and select ReRAM options from foundry today.
- Market is <\$100M for standalone. Embedded solutions available

# 3D XPoint/Optane



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- Developed over the last 20 years, new Mbit test chips every couple years
- Published at FMS in 2011 as PCMS, Announced in July 2015
- Hype aside, it is faster than NAND, Cheaper than DRAM, Byte access
- Fastest SSD and DIMMs up to 512Gbyte
- Billions spent on development and Intel added tremendous marketing/ecosystem support
- \$500M in revenue per year, more bits than all other emerging memories combined.
- <5% of the server market, it's a niche.... A big niche
- It is a VERY VERY Successful emerging memory....
- And it was announced, after months of rumors and discussions, it is being ramped down and will end
  - Note: Micron, the co owner of the IP, cancelled all work and sold the fab last year.

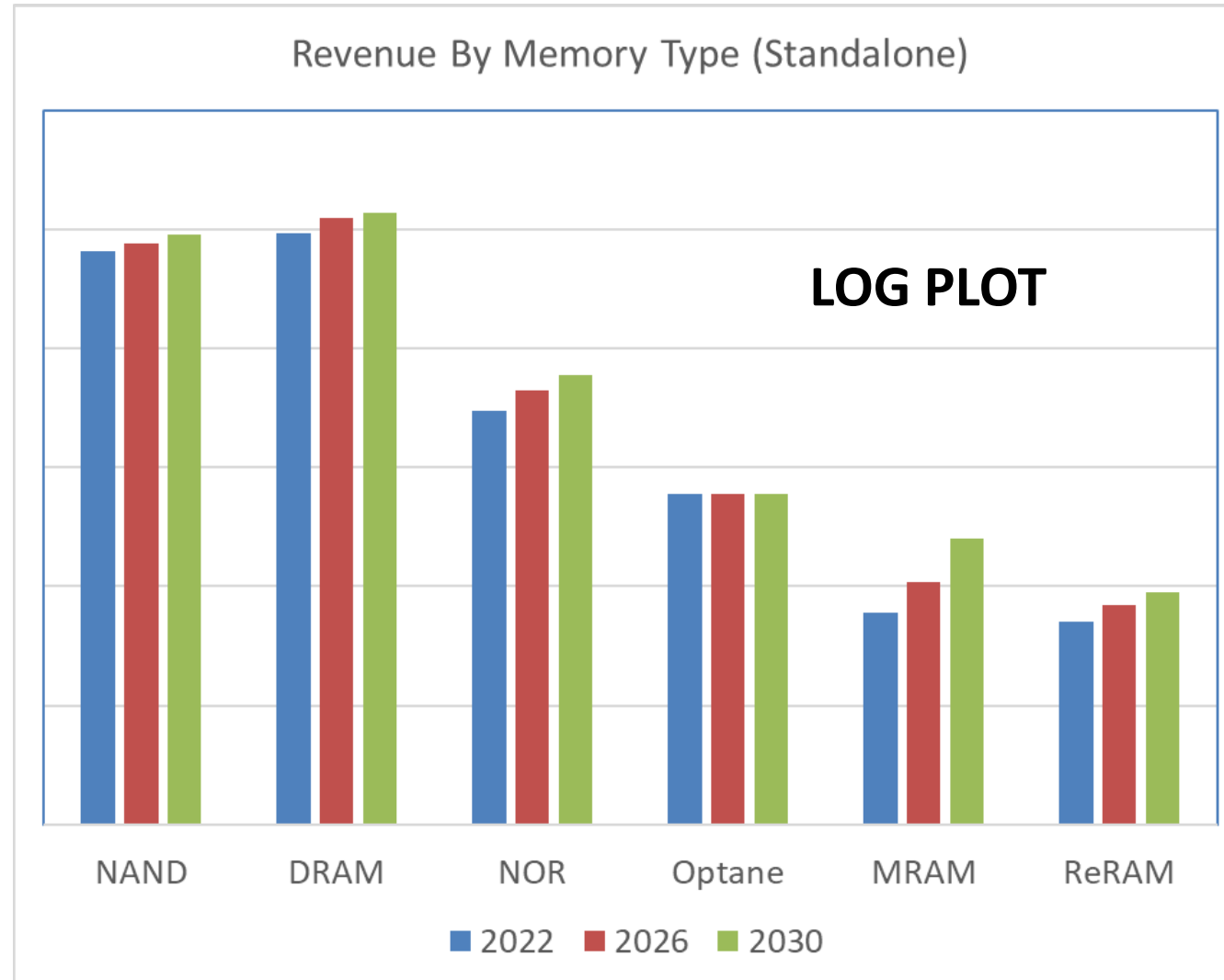
- Optane cancellation
  - Not due to LACK of ecosystem, Fabs, capacity, Marketing, money, or patience
  - It was not DRAM or NAND replacement. Nothing is.
  - It was ALWAYS aimed at memory applications and worked well there. Fast SSDs were side tech
  - The market size was <5% of servers rather than 50% of servers
  - Development can't continue, CXL requires different solutions. No plan to ever make money
  - IP control limits many future options
- Is there a large (\$10B+) market for Non-volatile RAM memory?
  - Faster than NAND, Slower than DRAM. Cheaper than DRAM, More expensive than NAND
  - It seems like the market has spoken...
- We can discuss what happened, why, past options and future options in detail
- The focus is “what does this mean for ALL emerging memories



# Summary of Emerging Memories

- We have at least 3 memory technologies that have achieved success
  - One had massive financial and marketing support, and was cancelled last week
- But no replacements for any memory
  - The future of DRAM is DRAM. The Future of NAND is NAND
- Takeaway: Any new memory technology must be better than these three, and must overcome ALL of the challenges that these have
  - What is on track to achieve this in the next 10 years?
- High density NV-RAM is popular as a large niche (Optane) but does not currently show the demand to ever achieve 5% of the memory market.
  - Or financially support ongoing development

# Approximate Revenue by Memory Type (2030)



- Yes, I have a Log plot of this
- Linear is more enlightening
- Emerging memory is operating at a different level

# CXL to the Rescue... Sort of

- 3 years ago I stated that CXL could provide a tipping point on 3D XPoint/ReRam etc.
  - CXL will enable 3D Xpoint to attach to any server and enable massive ramp.
- New Model: What if CXL makes emerging memory for servers .... unnecessary?
- I can share DRAM memory across servers, have wildly large and flexible memory pools
- I can attach fast or slow NAND/Storage or NVDIMM-N type hybrid products (NAND/DRAM).
  - NVDIMM-N type has been around and is well suited for lower volume type applications
- CXL provides a platform to mix and share memory and storage
  - We could achieve similar system and cost results to “Universal Memory”
- This could reduce the existing Optane DIMM created Niche



# The NEW Scenario for ALL Successful Emerging Memories

- Emerging Memories cannot assume cannibalizing either NAND or DRAM market share (future of DRAM is DRAM)
  - See Presentations from me and Techinsights
- Existing and proposed memories must fit into the following categories
  - Niche: A market where the features match perfectly, with minimal competition, and the pricing/margin matches product support.
    - Billions of dollars in ecosystem support for <5% of memory Market didn't work
    - Small more focused niche makes more sense
  - Embedded. Better than MRAM/ReRAM and provide competitive advantage for the foundry companies. Foundry will develop technology
  - Subprocess of existing NAND or DRAM process. <20% different steps, <20% cost adder.
    - FE DRAM or 3D-NAND Replacement, Very similar array architecture and periphery
    - Only Storage node is different

# SUMMARY



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- New Memories have Emerged and are successful!
- MRAM and ReRAM are here today in 1T1R form with many apps.
- Optane did not show market to support continuation
- Any other new emerging memory MUST be BETTER than MRAM, Optane, ReRAM for the intended app. Not equivalent
- All Emerging memories must fall into three categories to thrive
  - Well suited niche
  - Embedded (better than current solutions)
  - Small change to an existing process/product architecture

# Thank You

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