Market Directions for Persistent Memory

Flash Memory Summit

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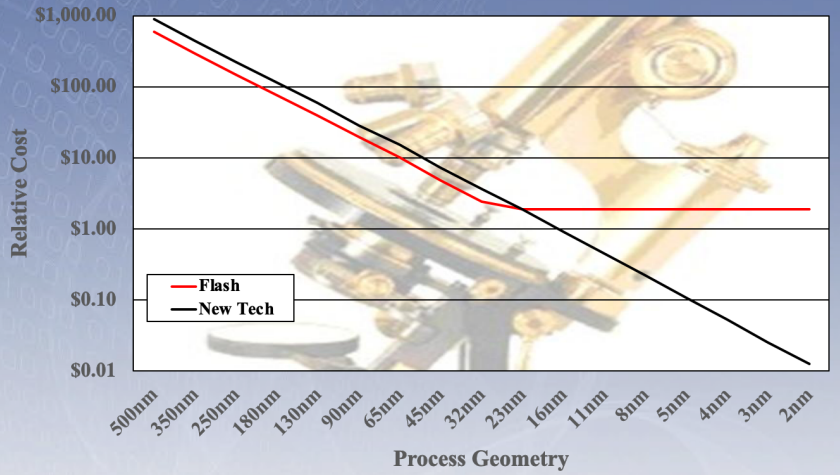
Why Emerging Persistent Memories are Necessary

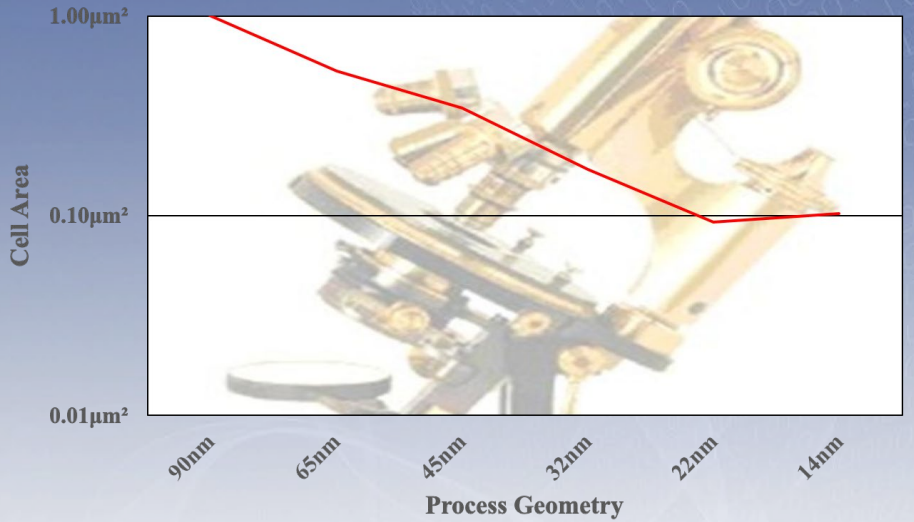
- Flash can't scale with process advances
  - NAND flash went 3D at 15nm
    - 3D is not cost-effective in a CMOS logic process
  - NOR scaling stops with FinFET
    - 28nm & smaller processes need something new
  - SRAM scaling may stop at 14nm
- DRAM consumes lots of power with refreshes
- Standalone PM applications are growing
- Low power high density memory needed for embedded applications

End of Lithographic Scaling



NOR Flash scaling ends at 28nm

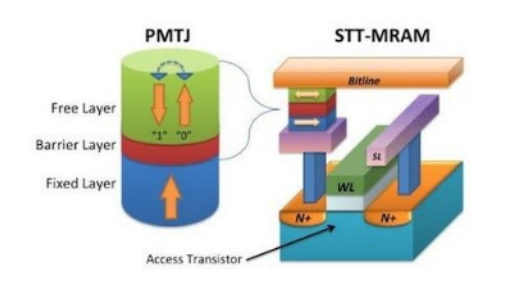
Charts from Jim Handy of Objective Analysis



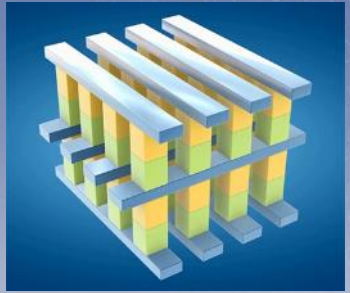
Does **SRAM** scaling end at 14nm?

Candidates for NOR/SRAM Replacement

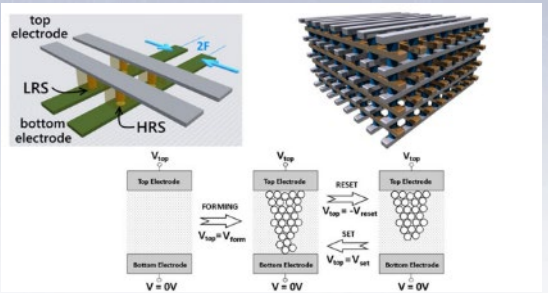
MRAM



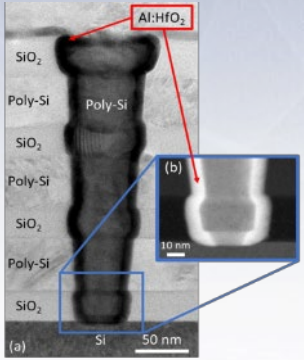
PCM



ReRAM

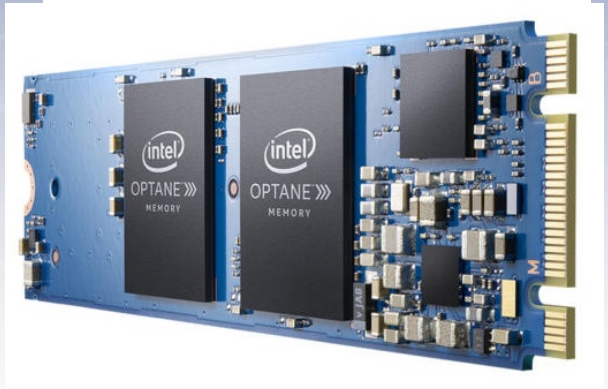


FRAM



MRAM and PCM

- MRAM
  - Everspin shipped over 120 M standalone MRAM Chips. Company has partnership with Global Foundries, who is building 300 mm wafers and targeting embedded memory applications
  - TSMC, Samsung and other foundries—are starting to ship STT MRAM products
  - IBM was showing an Everspin MRAM write cache for an SSD at the 2018 MRAM Developers Conference
- PCM
  - Intel Optane NVMe products shipped in 2017.
  - Intel introduced their Optane DIMM products in June 2018
  - Both products current used in storage systems



Key Issue: Pricing!

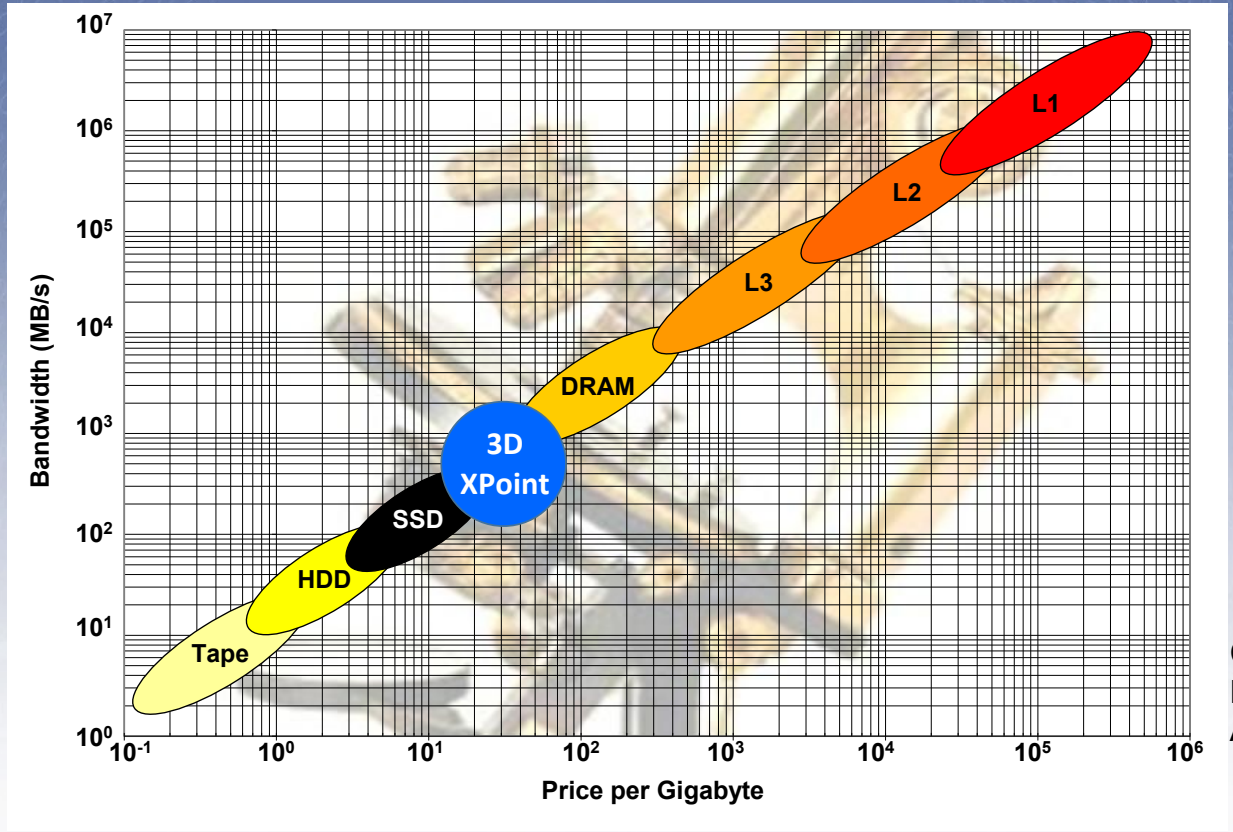
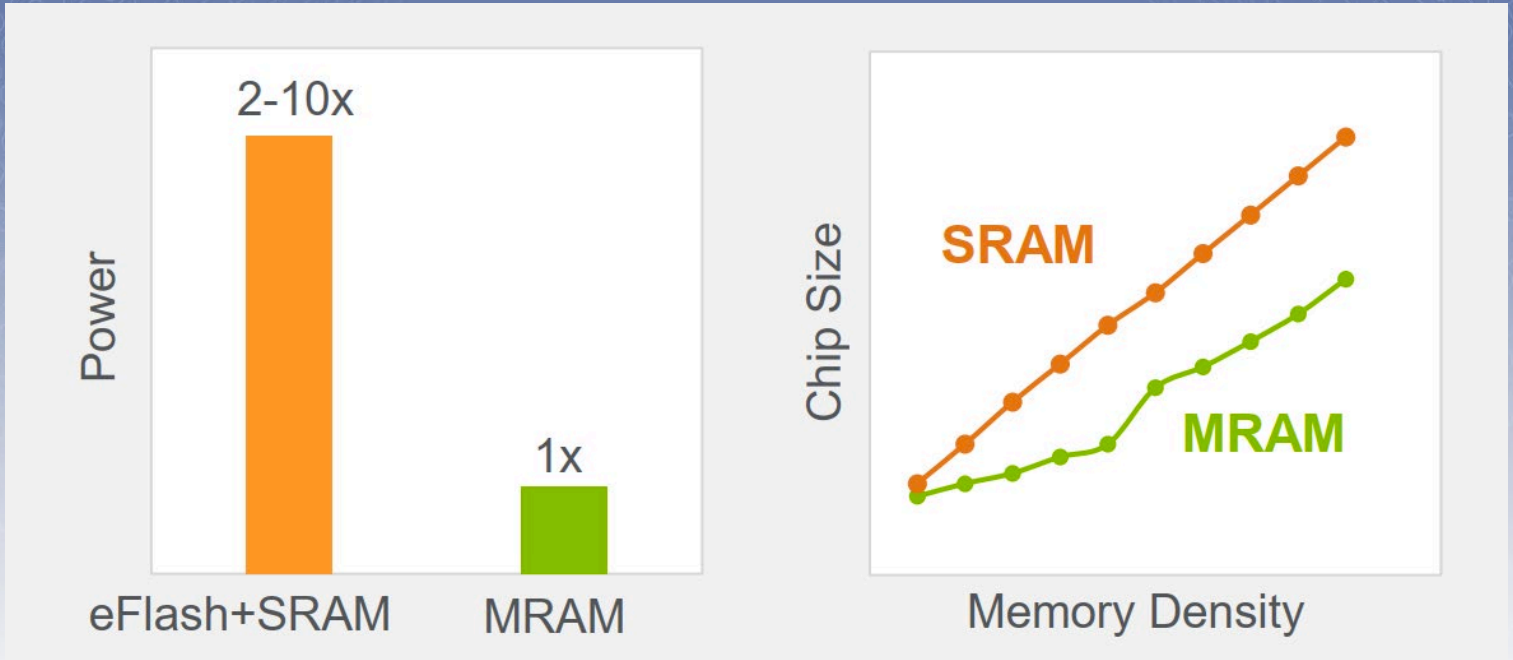


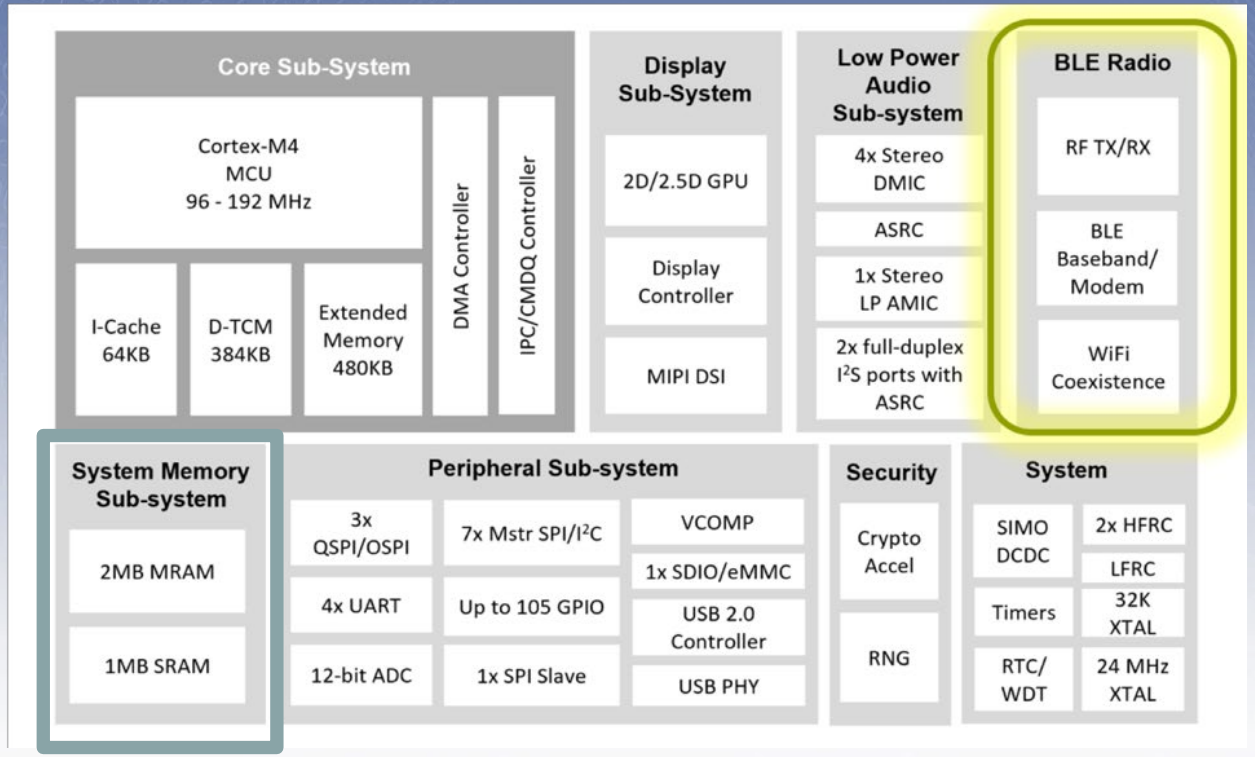
Chart from Jim Handy of Objective Analysis

Embedded MRAM



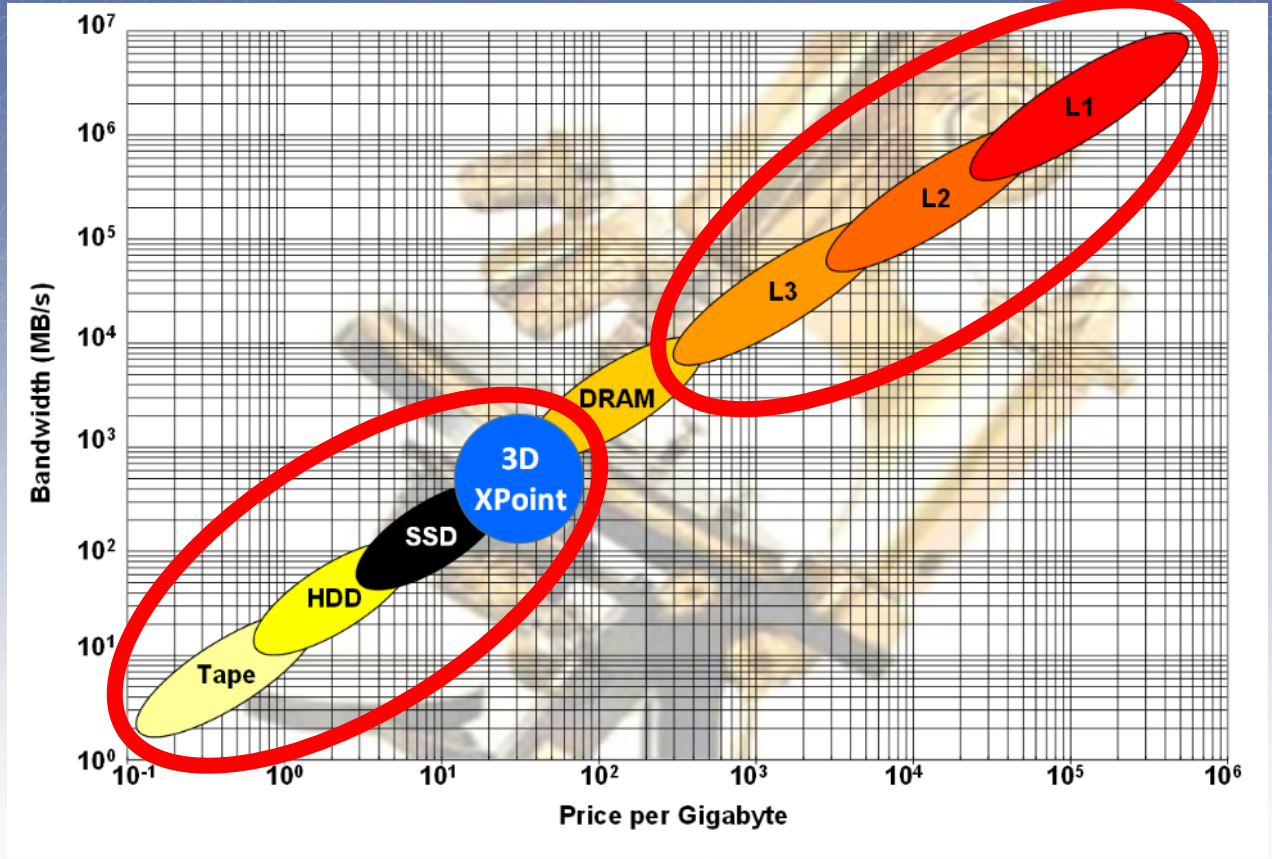
Source: AMAT, 2019

Embedded Devices Will Prime the Pump

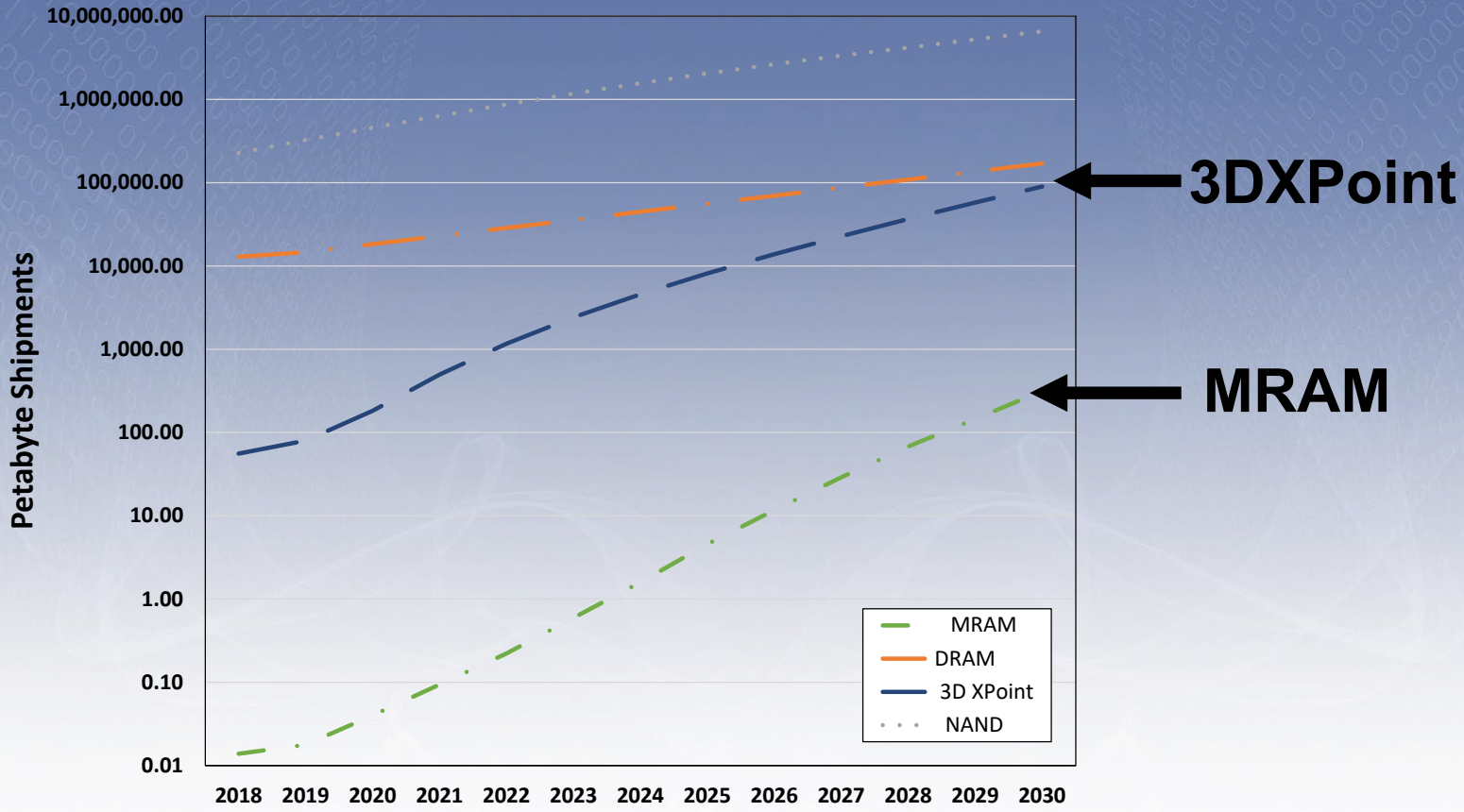


- Ambiq 4th generation Apollo SoC for ultra-low power intelligent endpoint IoT devices
- Note the use of 2 MB MRAM memory
- The Apollo4 serves as both an application processor and a coprocessor for battery-powered endpoint devices

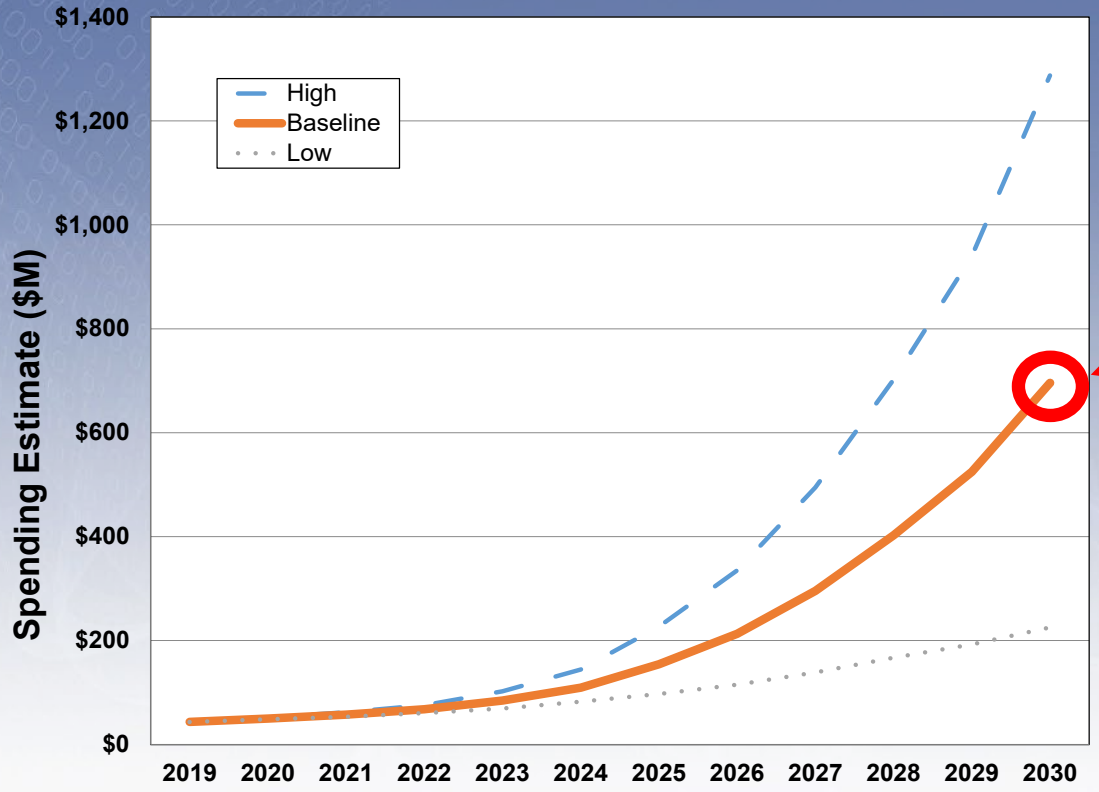
What Becomes Persistent?



Growth in New Memory Shipments



New Memory Capital Spending

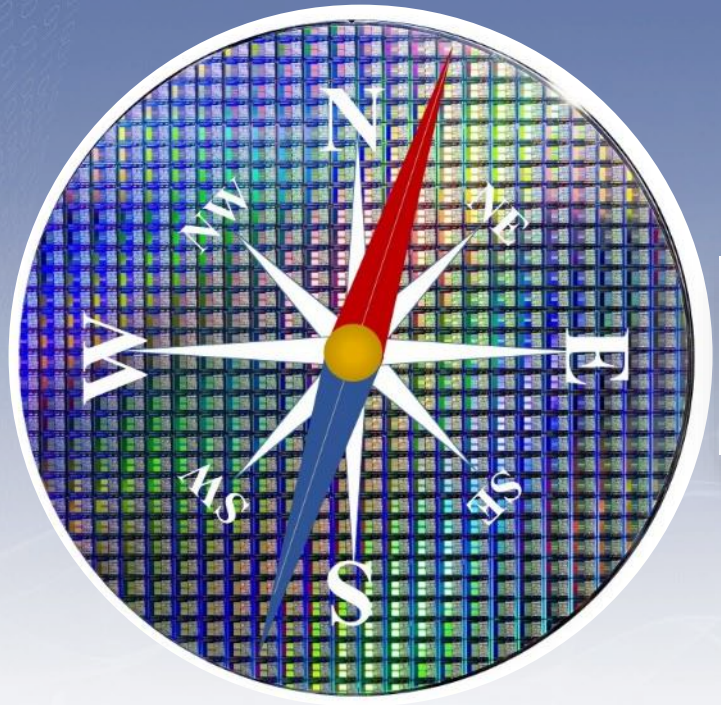


$700 Million!

Summary

- Lithographic scaling is limiting the use of NOR flash and possibly SRAM for high density embedded devices
- Persistent memories that scale beyond NOR flash and SRAM are now available and these will change the storage/memory hierarchy
- MRAM will grow for embedded low power applications running AI/ML
- Persistent memories will eventually replace SRAM cache memory
- MRAM and PCM use will generate over $36B in annual revenue by 2030
- MRAM capital spending will exceed $700M annually by 2030

New Report: Emerging Memories Find Their Direction



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