Delivering Nanosecond-Class Persistent Storage

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Storage Scaling Challenge

- Dramatic changes in Compute & Storage ahead
  - Cloud, Virtualization, Social Media, …

- Capacity & Performance Storage requirements exploding

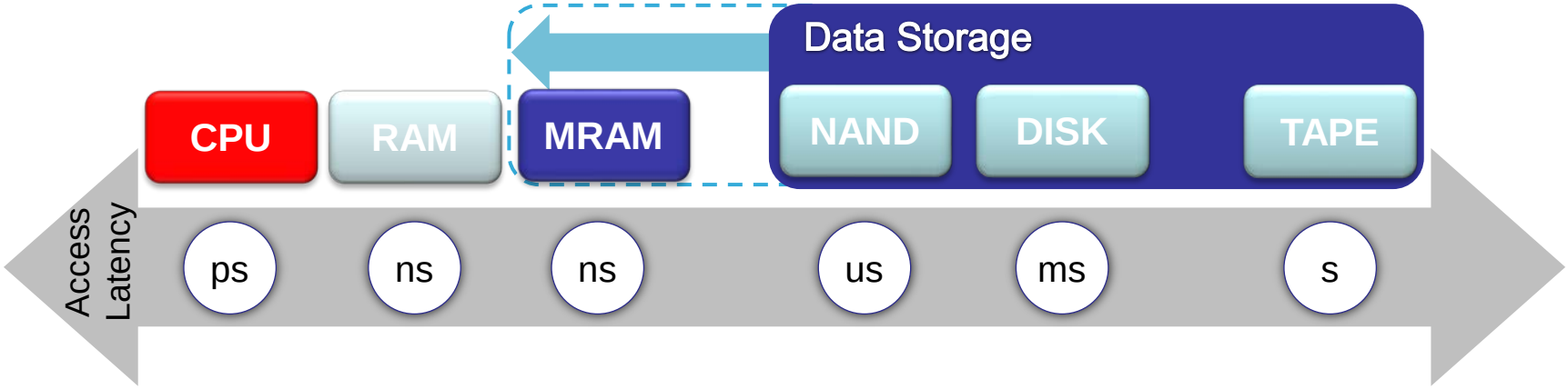
Need to bridge gap between CPU & Storage

The Latency Storage Revolution

MRAM, *Fastest non-volatile memory with unlimited endurance*

combines memory & storage attributes:

Nanosecond-Class Persistent Storage



Enables new architectures for CISC, RISC & ZISC

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ST-MRAM delivers 10x+ IOPS/$

Cloud Storage Needs:

- More content & users, instant access
- Better response times from storage
- Predictable balanced performance

Nanosecond-class MRAM Storage

NAND SSD

500x Performance…

	NAND	MRAM
Density	64Gb	1Gb
Latency	50us	45ns
4kB Write IOPS	800	400k
Cost/GB	1	50

…at only 50x Cost/GB

MRAM SSD

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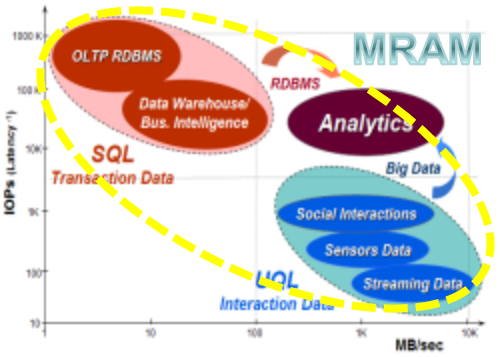
ST-MRAM delivers 100x+ IOPS/W

Data Center needs:

- Number of servers & CPU cores exploding
- Better bandwidth & IOPS to handle Big Data
- More performance @ less power to scale up



High Performance, Power-Efficient MRAM Storage

NAND SSD

500x Performance…

	NAND	MRAM
Density	64Gb	1Gb
Power	80mW	400mW
4kB Write IOPS	800	400k
Cost/GB	1	50

…at only 5x Power

MRAM SSD

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Ultra Low Latency Memories

- Three new low latency memories on horizon
  - Spin-Torque Magnetic RAM
    - Optimized for performance – targeting nvDRAM
  - Phase Change RAM
    - Optimized for read performance – targeting NOR
  - Resistive RAM
    - Optimized for capacity/cost – targeting NAND

New system architectures required to fully take advantage of these new non-volatile memories

MRAM – Simplifying system design

- **Addressing a fundamental Problem of Storage:**
  - *Truly Non-Volatile RAM – Power Fail Data Protection*
  - *Eliminates complicated power fail management HW & FW*
  - *Reduces development time and effort for products*

- ***Complementing DRAM and NAND***
  - *Making NAND perform better and last longer*
  - *MRAM for write caching, DRAM for read caching*
  - *More IOPS/$ and better IOPS/Watt than NAND*

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1st Gen MRAM Progress

- Async SRAM & (Q)SPI I/F
- 256kb to 16Mb density
- 20/10Mpcs+ (e)MRAM shipped
- Today: Enterprise & Industrial
- Future: Growth in Auto & High Rel.
- Usage: Metadata storage & log

Broad deployment with exemplary quality

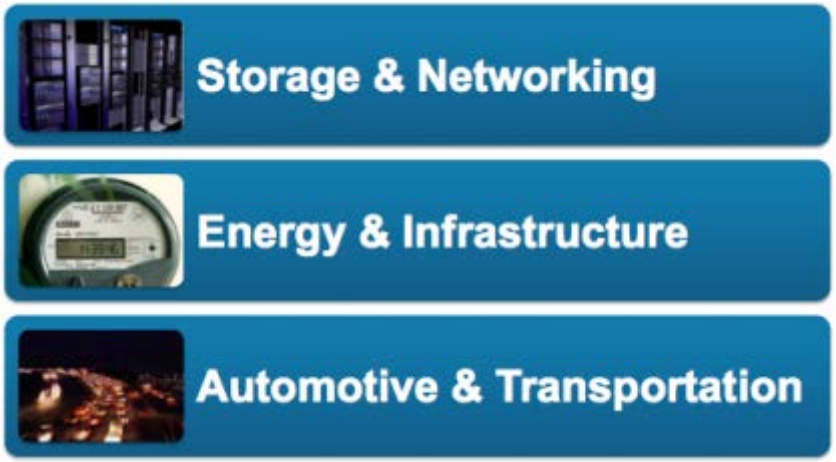
MRAM used as write journal for RAID Storage
Power fail recovery increasing system reliability & uptime

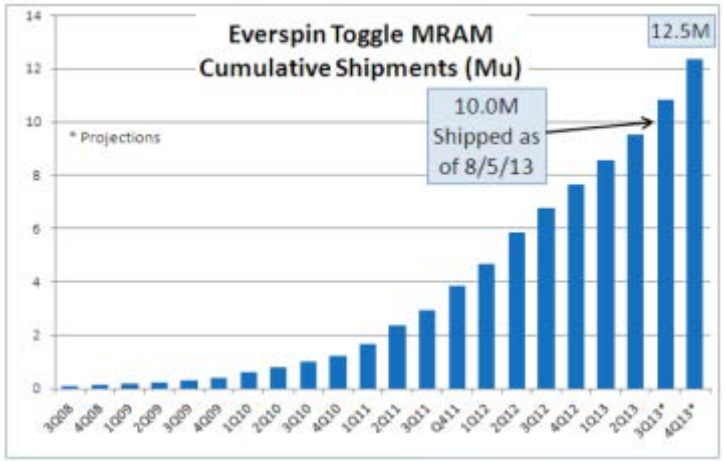
Recognized Everspin for Perfect MRAM Quality
250k+ systems with no reported failures to-date

Critical Storage for Industrial Computing Boards
Robust & reliable non-volatile memory solution

MRAM products for A350 Flight Control Computer
Critical program and data storage in extreme environment

Non-volatile memory for Superbike Engine Control
Reliable power fail safe memory for automotive temperature





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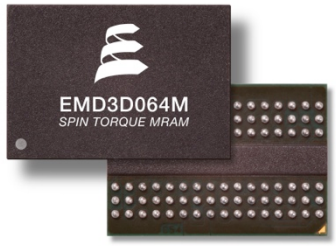
2nd Gen MRAM – ST-MRAM

- Targeted at persistent DRAM memory applications
- DDRx roadmap scaling from 64Mb to Gb densities
- Non-volatile Buffers & Caches for Storage Systems
- Initial use: Protecting data in flight & coalesce buffers
- Introduced initial product: 64Mb DDR3 ST-MRAM
- Delivered working samples to top OEMs
  - Evaluate & explore new system architectures
- Sampling DIMM modules for evaluation platform
  - 64MB and 128MB SO-uDIMMs and uDIMMs
- Developing PCIe FPGA eval platform
  - Close partnership with Altera and Gidel
  - PCIe Memory and Storage sub-system



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Storage Solutions craving ST-MRAM

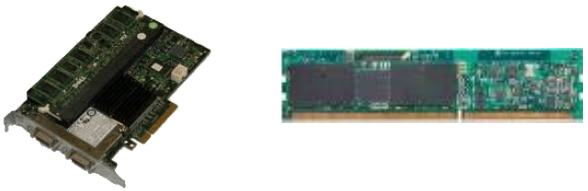
MRAM complements solid state & magnetic storage

Improved response time due to low latency & high bandwidth

MRAM as Buffer Memory

MRAM instead of low density DRAM

Better performance & reliability



MRAM as I/O & Network Cache

MRAM instead of NV-DRAM

Better reliability & overall TCO

MRAM as Fast Storage-Tier

MRAM in addition to SSD/HDD

Better IOPS/$/W & reliability

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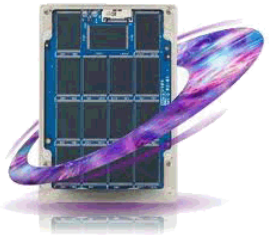
MRAM in SSD, HDD and Hybrid

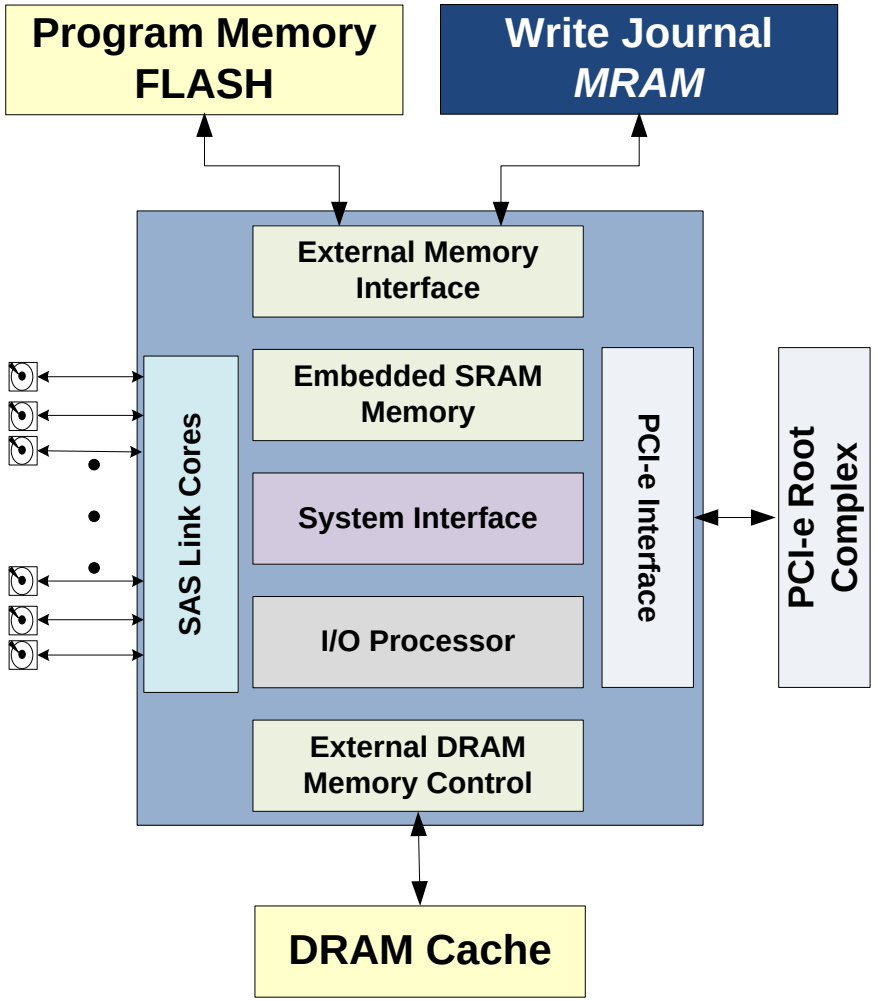
- Enterprise/Industrial SSD
  - NV-Buffer, 2-8MB Program Data Buffer
  - NV-Cache, 8-128MB Write Cache
  - Power Fail Safe, Write Buffer & Caching
- Hybrid HDD
  - NV-Buffer, 2-8MB Program Data Buffer
  - NV-Cache, 4-32MB Media Management
  - Power Fail Safe, High Performance Hybrid
- Enterprise HDD
  - NV-Buffer, 8-16MB, Media Write Caching
  - NV-Cache, 32-64MB Write Cache
  - Power Fail Safe, Write Caching



Source: Aggregate Industry Analyst Projections, October 2011

Case Study: RAID – Dell & LSI

- Write Journal Memory for RAID Storage Systems
  - Storing Metadata Transactions
  - Rapid power loss data recovery
  - Superior data integrity
  - Fast transaction data log
  - No separate board level discrete devices, batteries or capacitors



Case Study: Solid State Drive

- Buffalo Memory announced a new Industrial SSD that uses Everspin MRAM for the cache.
  - Exhibited at the15th Embedded Systems Expo in Japan
  - 4GByte SSD with 8MByte of MRAM cache

- "MRAMs are nonvolatile memories that use magnetic materials as elements and feature *high-speed random access,* high integration and *non-volatility*. There are three advantages in using MRAM as cache, compared with normal high-speed SSDs that use volatile DRAM as cache."

- *MRAM unique value proposition:*
  1. *Excellent resistance to power interruption*
  2. *Improve booting speed*
  3. *Excellent power-saving capability*

Motoyuki Oishi, Nikkei Electronics

Case Study All Flash Appliance

- The world's first all solid state storage appliance
  - MRAM replaces capacitor-backed RAM solution
  - Protecting data in flight through storage in MRAM

- Overwhelming customer interest for this product
  - Initial use of Toggle MRAM in lieu of Capacitor Backed SRAM
  - Transitioning to ST-MRAM in lieu of Capacitor Backed DRAM
  - MRAM density deployed growing from MB to GB

Building the MRAM Ecosystem

- Increasing the awareness of MRAM's advantages
  - Versatile use as memory or storage device
  - Persistent memory architecture element
- Optimizing memory host controller ecosystem
  - Enable mixed use of MRAM combined with DRAM
  - Increase availability for FPGAs and SOC development
- MRAM BEOL manufacturing eco system
  - Establishment of volume manufacturing at 300mm
  - Improving availability and cost of BE processing
- Expanding MRAM market opportunities
  - Scaling to Gb densities yields exponential growth
  - Developing persistent memory optimized interface