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# Push the Possibilities of Embedded Memory Applications with MRAM

Arm Technology Symposia

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October, 2019

# What is (STT-) MRAM?

BEOL-based fast, dense and low mask adder non-volatile memory

MRAM stands for Magneto-resistive RAM

- Magnetic polarization sets the memory state

STT stands for Spin Transfer Torque

- Electron spin is used to switch magnetic polarization

1T 1MTJ bitcell

- Allows dense configuration and scalability
- MTJ in metal stack enables low mask count add

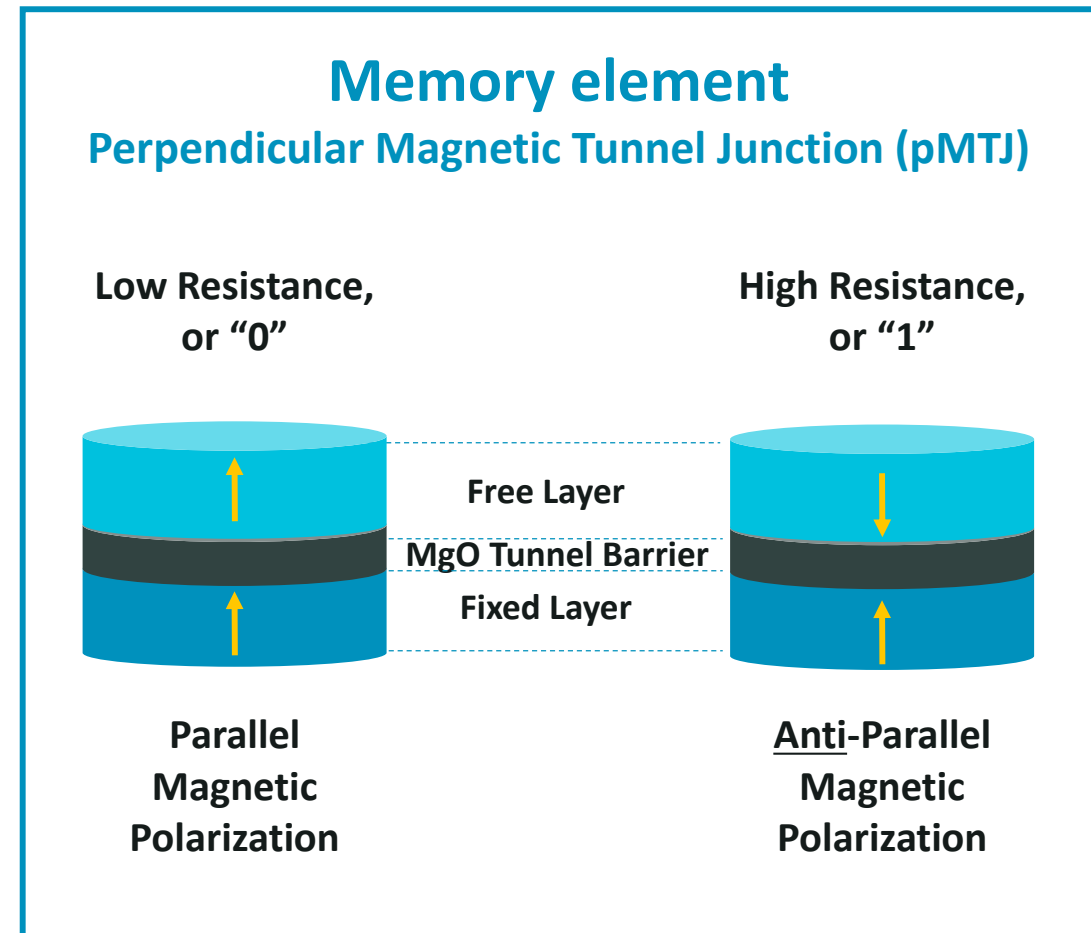
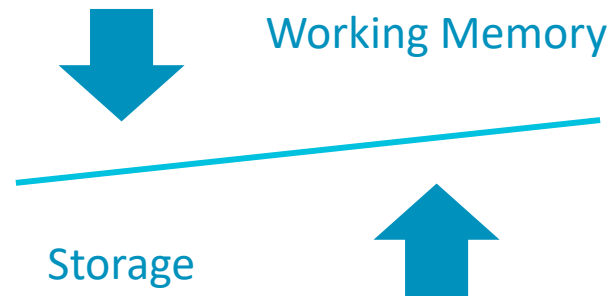


Image source: Spin Memory Inc.

# MRAM Value Proposition: Cost and Application-Specific PPA

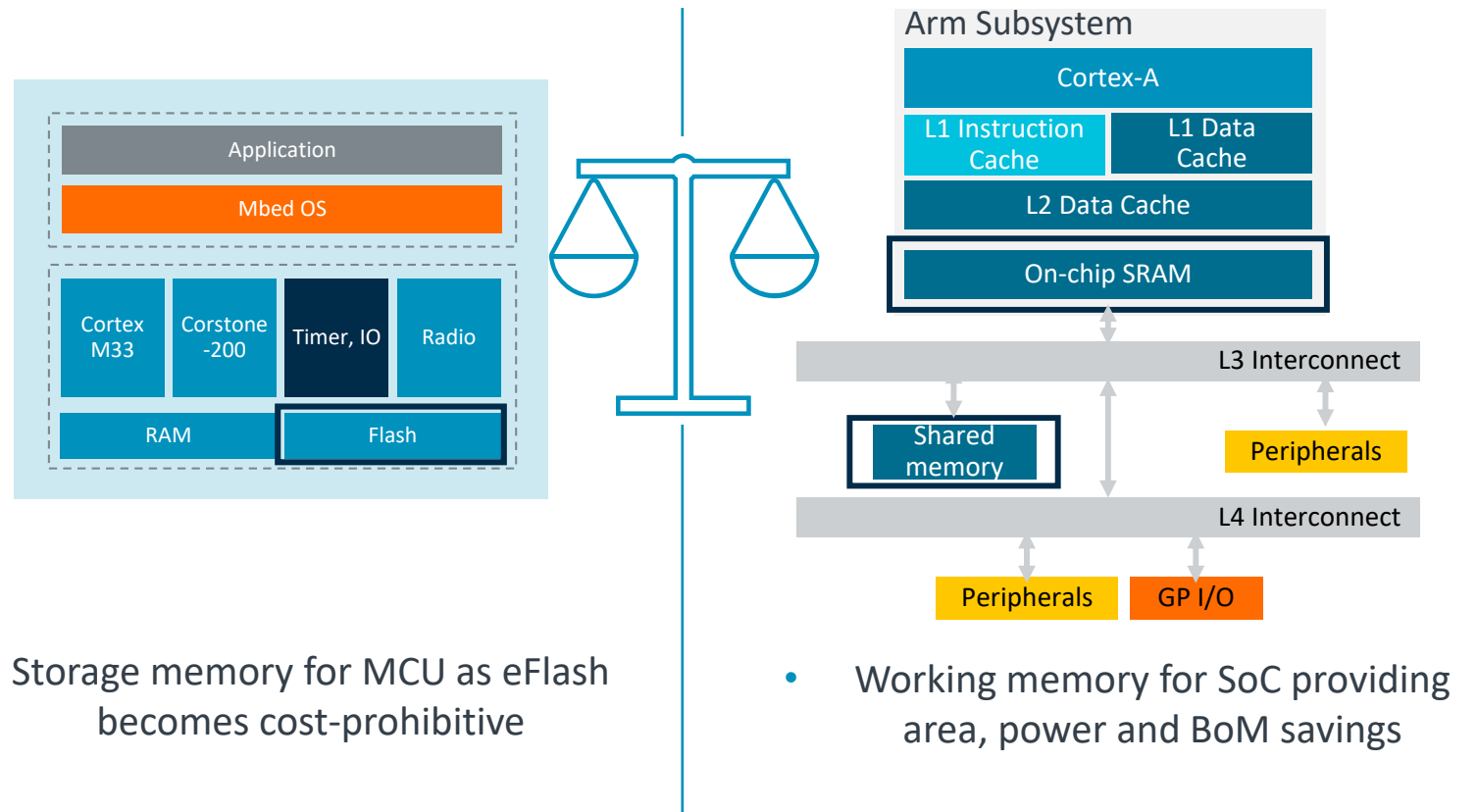
Broad industry interest for embedded storage and working memory applications

## Application-specific tuning



- Physics results in Retention vs. Endurance/Speed trade-off

## Novel working-storage memory



- Storage memory for MCU as eFlash becomes cost-prohibitive

- Working memory for SoC providing area, power and BoM savings

# Candidate Devices Span a Broad Spectrum

Expect proliferation of MRAM availability across process nodes



Edge IoT and AI



CMOS Image Sensor



Display Driver IC



AI training



MCU



SSD Controller



CPU and Networking

22-28nm

5/7nm

Image source: Spin Memory Inc.

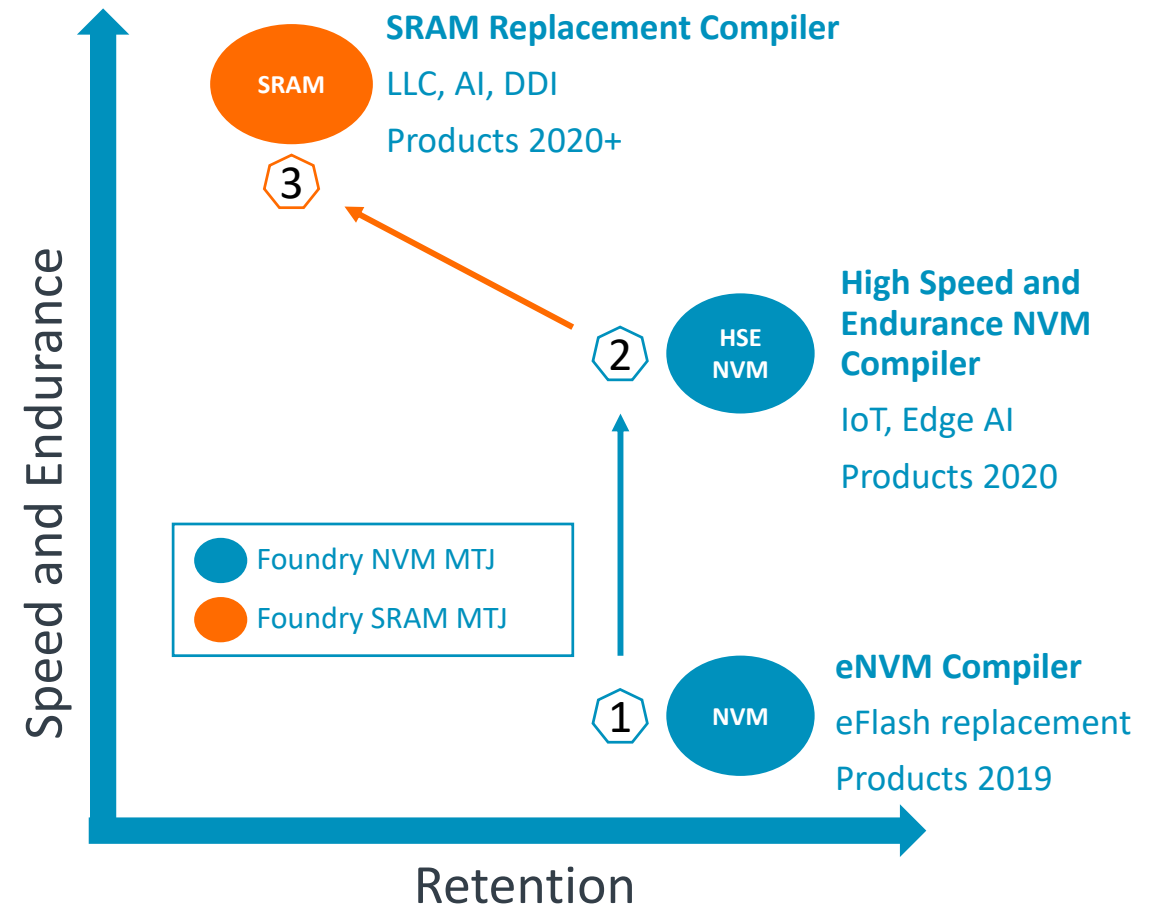


# Arm Embedded MRAM (eMRAM) Compiler Roadmap

# Arm Compiler Roadmap Covers MRAM's Broad Application Set

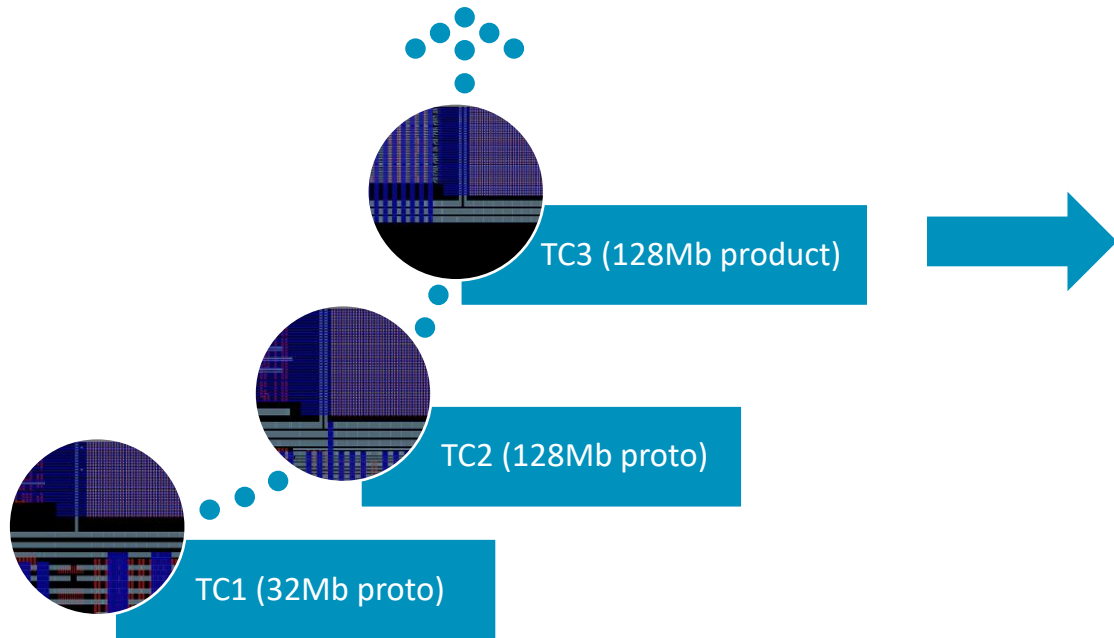
Arm plans to develop the industry's broadest portfolio of MRAM compilers to support partners across segments

- AI and IoT
- Datacenter
- Mobile
- Industrial and automotive



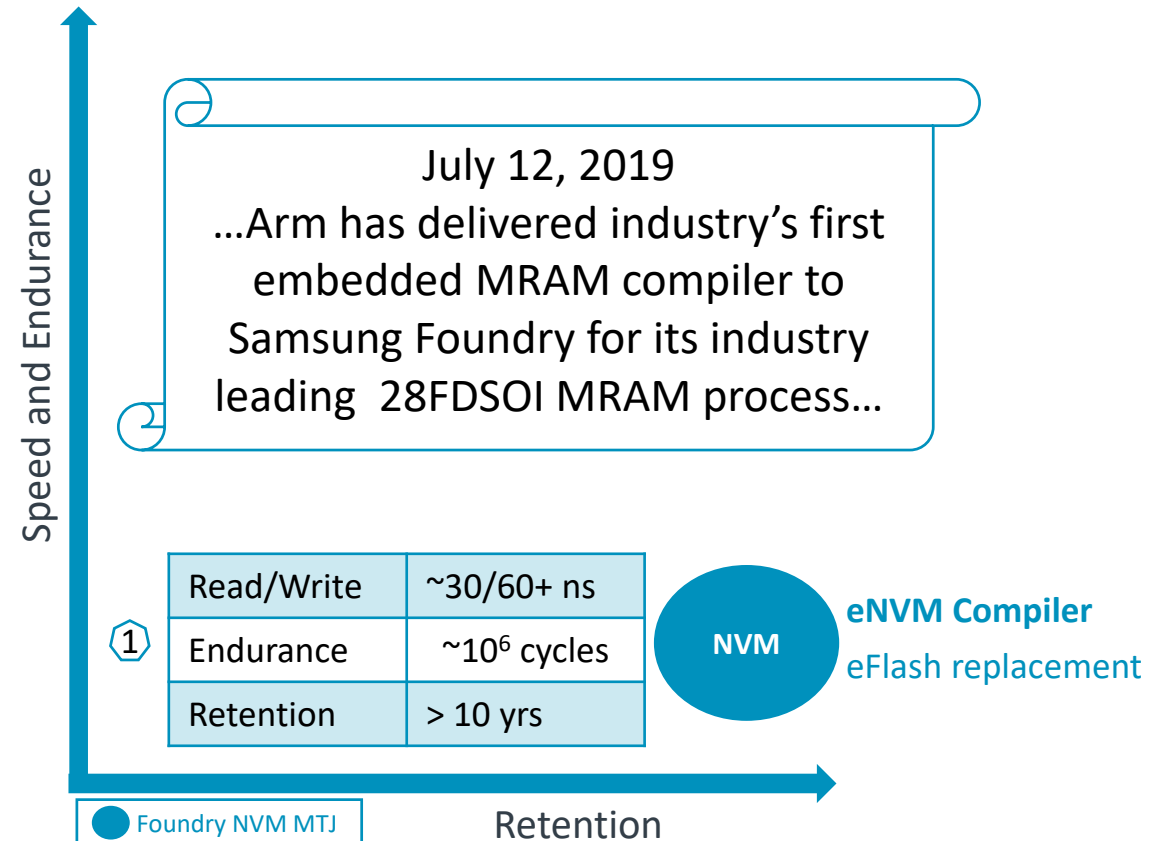
# ① Arm Delivers Industry's First MRAM Compiler for Storage

Product development based on a rigorous design methodology and rapid prototyping



## 1-128Mb Wide Capacity embedded MRAM compiler

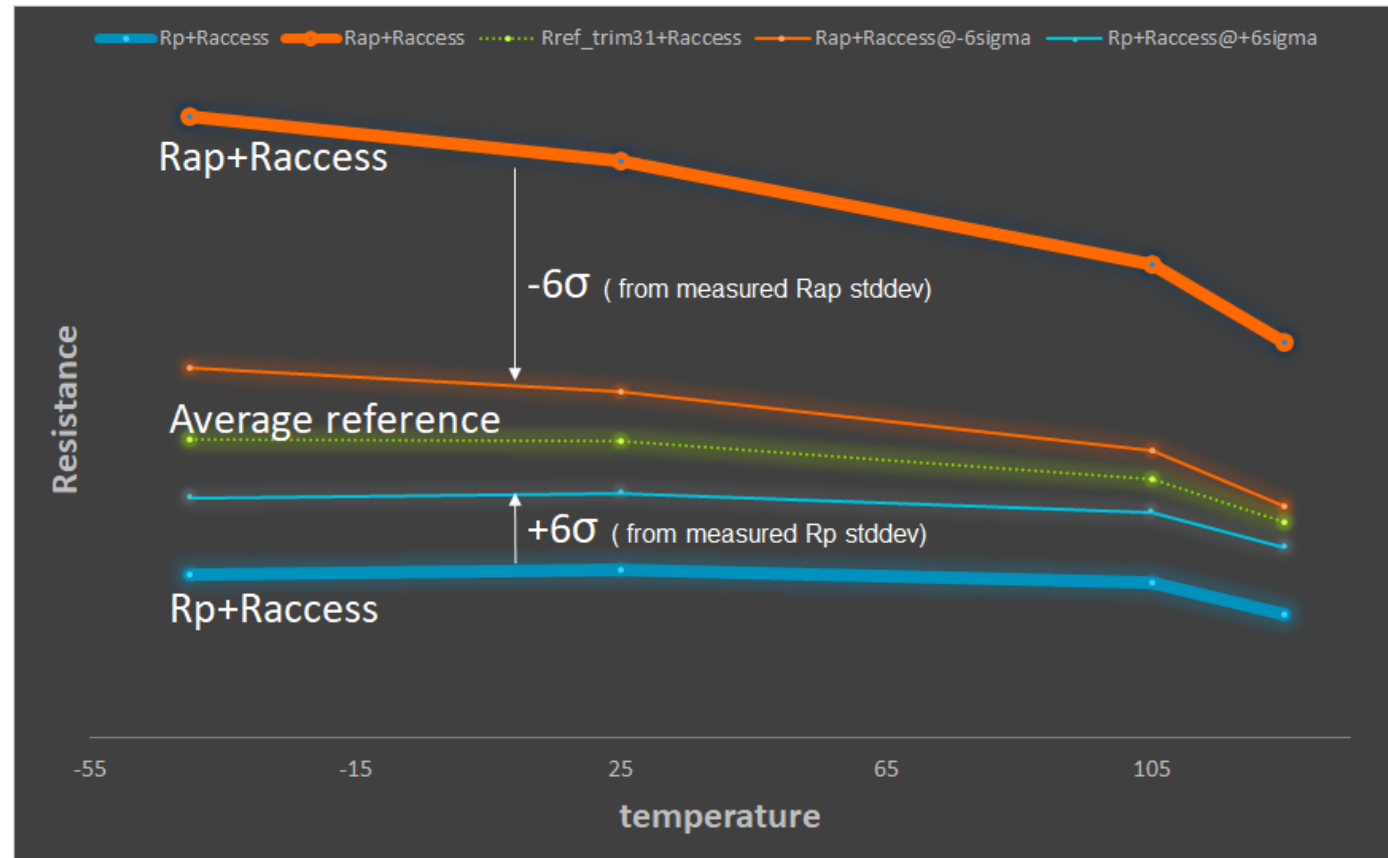
- Delivers capacity range and configuration flexibility for a broad range of code and data storage applications



# Si Validation: Data Bit and Reference Resistance Measurement

128Mb TC2 measurement validates trimmable reference cell temperature tracking

- VDDCE=1.8V
- DC measurement
- Typical silicon
- 1280 bits





# How to Access?

Please visit [designstart.arm.com](https://designstart.arm.com) to download

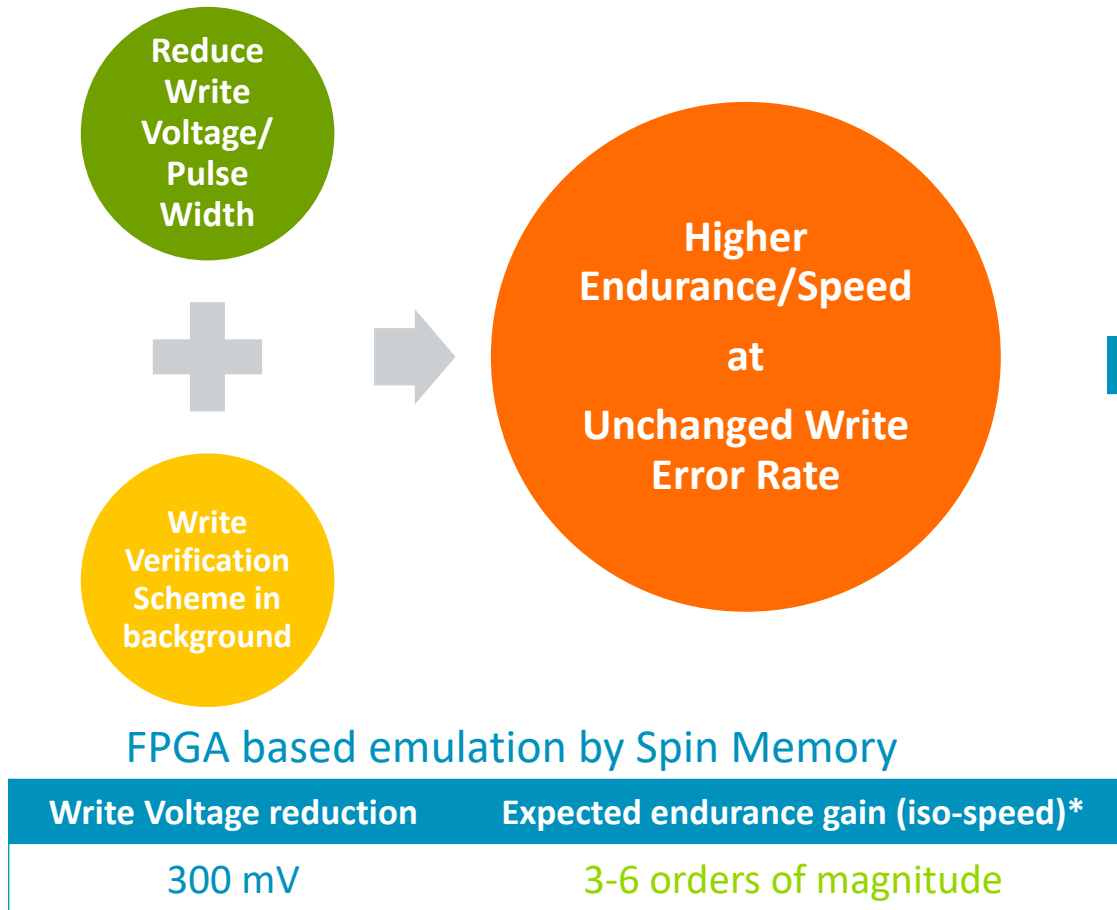


\*Samsung Foundry pre-approval required before access

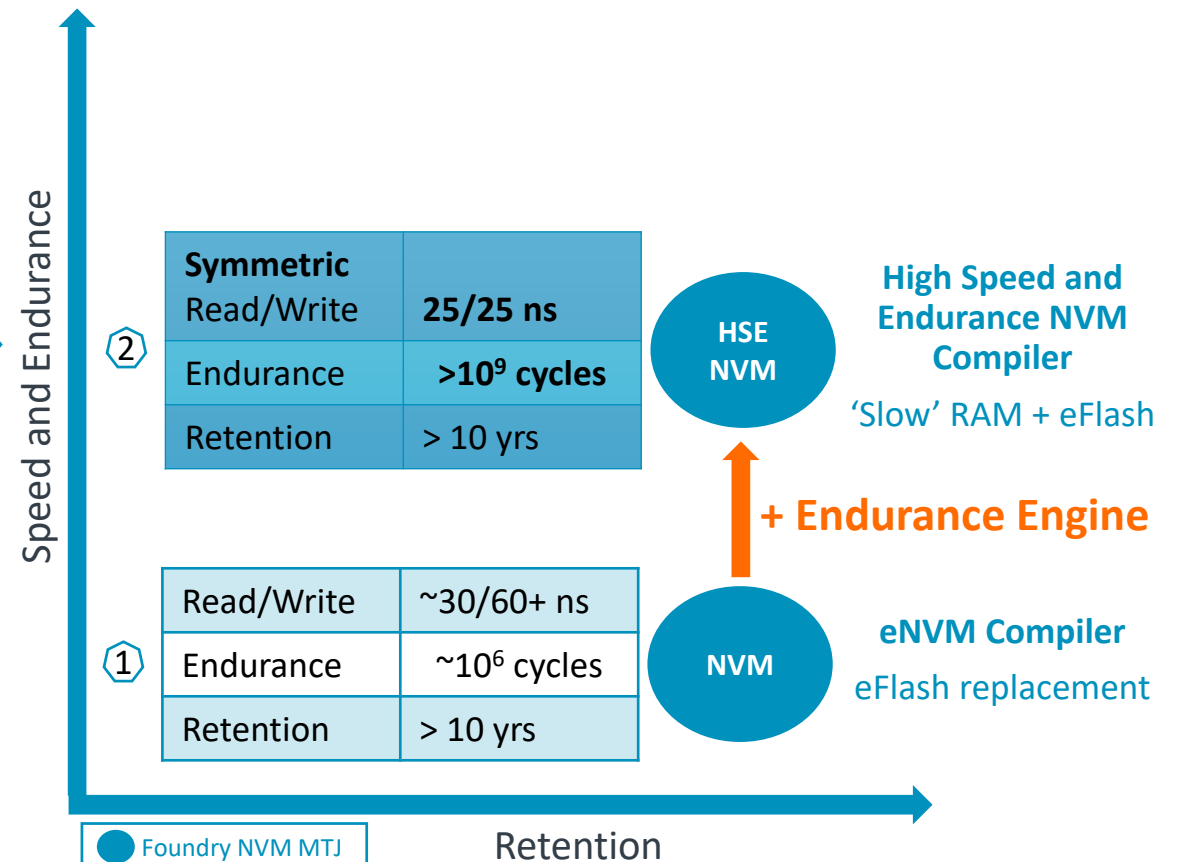
# ② Arm-Spin Collaboration for MRAM Design Innovation

Novel design enabling MRAM macro endurance/speed gains for RAM-like performance

## Key design element: Endurance Engine




## Enable speed/endurance gain at iso-process




# HSE-NVM MRAM Compiler Expands MRAM Value Prop

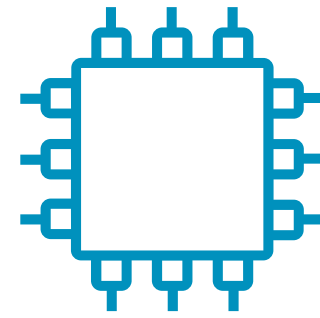
Targeted to drive application and architectural innovations



Endurance-intensive storage  
'Unlimited' OTA updates and data acquisition for Edge IoT devices



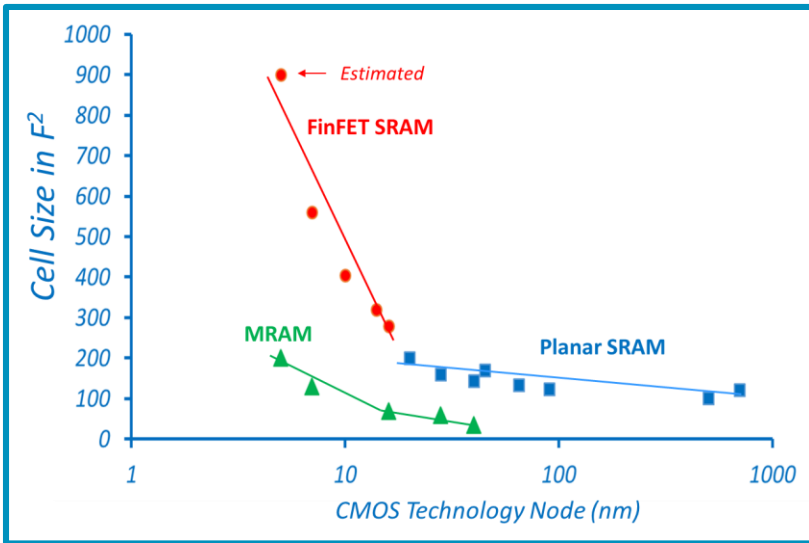
System energy and BoM reduction  
Increased on-chip RAM enabling reduced external DRAM access



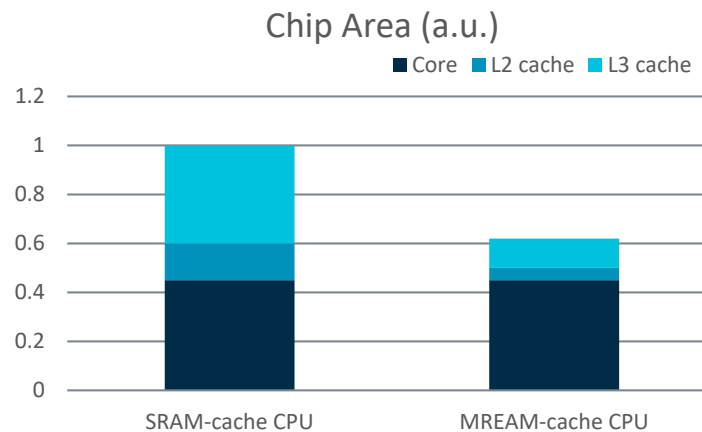
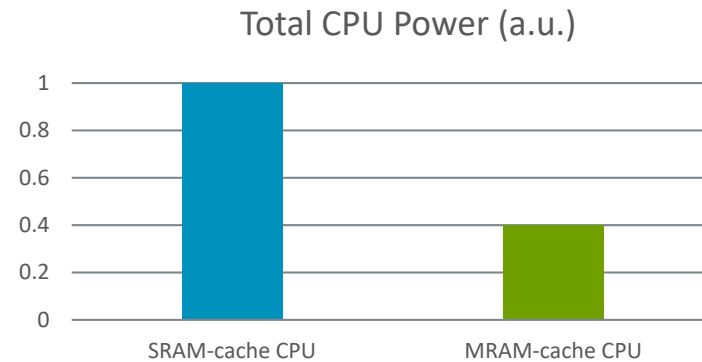
Unified memory  
Merged SRAM and Flash as NVSRAM for low speed SoCs

# ③ Compiler Design for RAM-Class Foundry Process

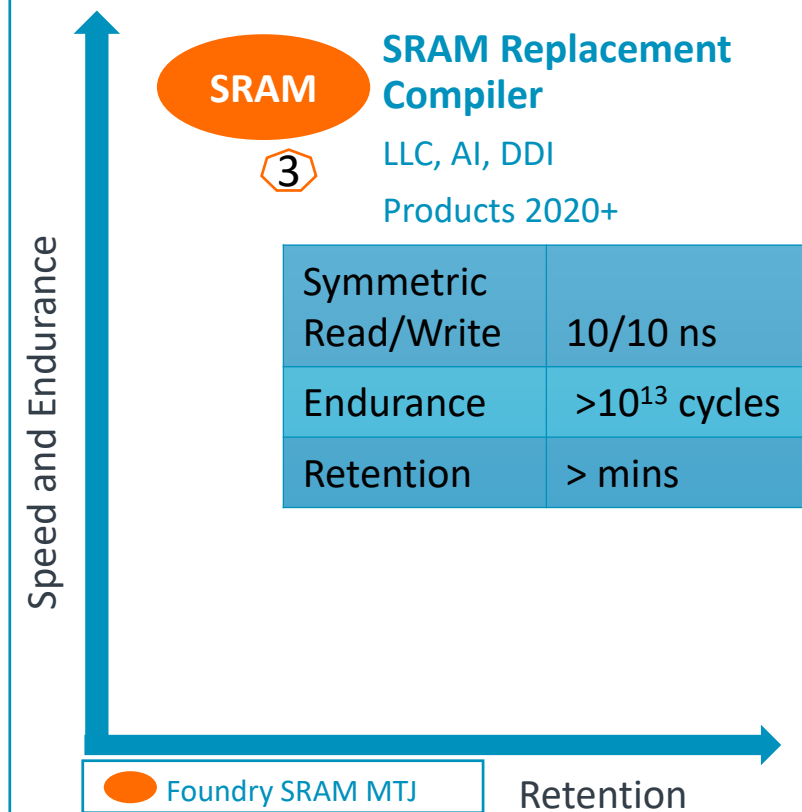
Unlock full PPA benefits of MRAM for SRAM replacement applications



Source: Spin Memory Inc. (compiled from S.H. Kang et al, 2017 IEDM; R.D.J. Verhaar et al., 1990 IEDM; R. de Werdt et al., 1987 IEDM)



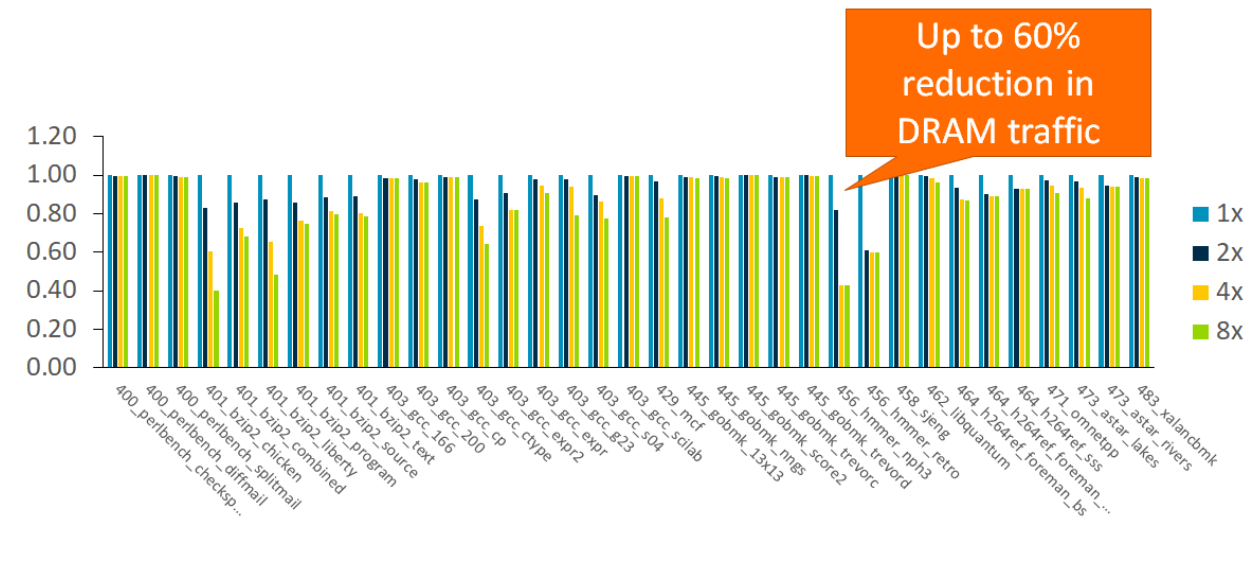
Source: K. Ikegami (Toshiba) et al, 2015 IEDM



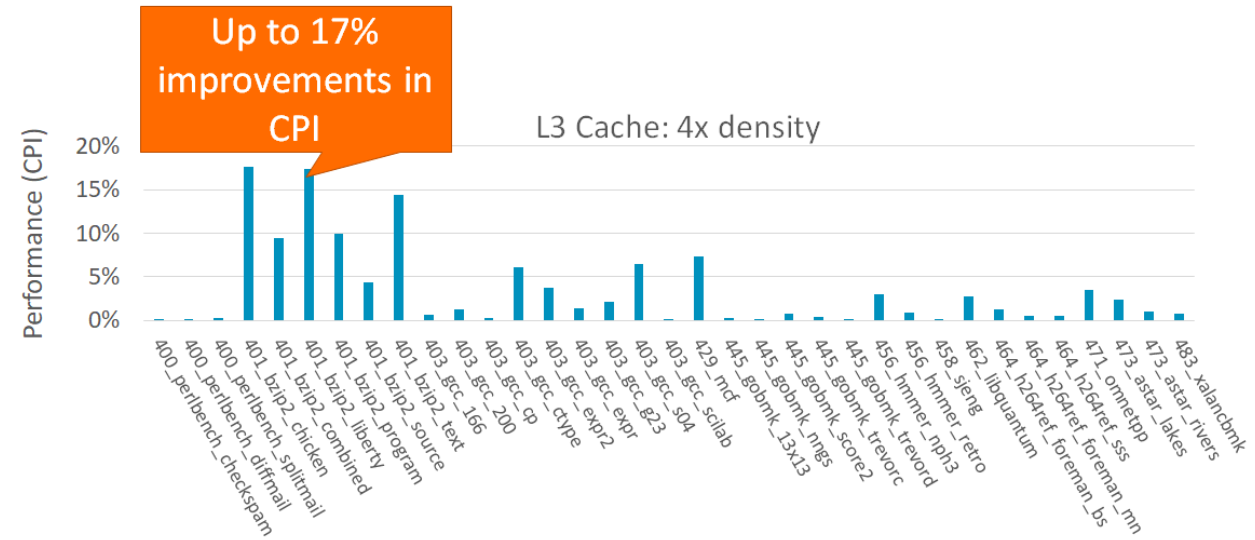
# MRAM as L3 cache in A-Class Systems

Illustrative simulations by Arm Research

## L3 density increase reduces DRAM traffic



## Performance gains from higher L3 density and hit rates



Source: Nikos Nikoleris, Arm Research

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Summary

# Summary

Arm is partnering in enablement of MRAM for full range of embedded memory applications

The MRAM era is here! Broad industry interest for embedded storage and working memory applications

Arm has delivered industry's first production eMRAM compiler on Samsung 28FDSOI MRAM process

Now driving MRAM design innovations in collaboration with Spin Memory to develop RAM-class MRAM compilers and broaden MRAM compiler portfolio to enable full range of embedded memory applications

**Memory technology transition is rare – let's take this exciting journey of MRAM adoption together!**

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Thank You

Danke

Merci

谢谢

ありがとう

Gracias

Kiitos

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