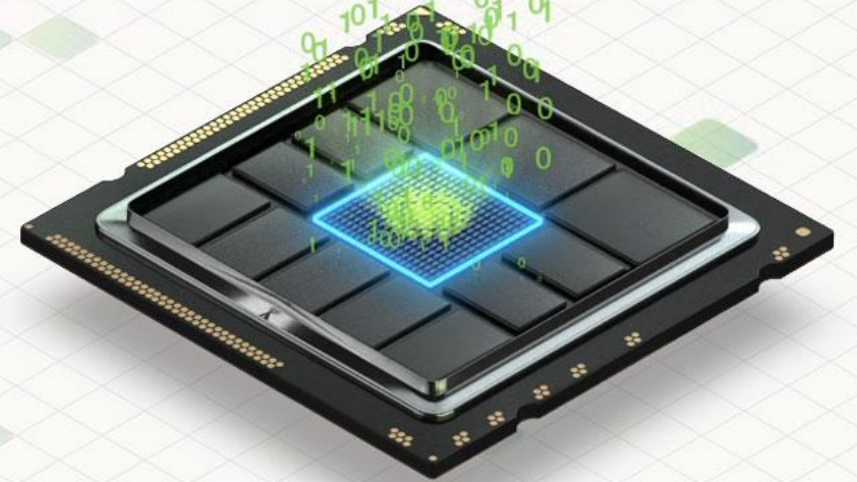**Weebitnano**

THE NEXT NVM IS HERE

Plotting the Course for ReRAM in Automotive

Select Slides from EDTM 2024

Automotive Market Reliability

- ❖ In recent years, new vehicles types, including electric cars, have rapidly gained popularity

- ❖ Modern automotive consumers no longer settle for basic vehicle functionality
  - ◆ Expect advanced technologies such as connectivity, autonomous driving, shared services, and electric powertrains

- ❖ With EVs advancing, reliability of automotive semiconductor components is more crucial than ever
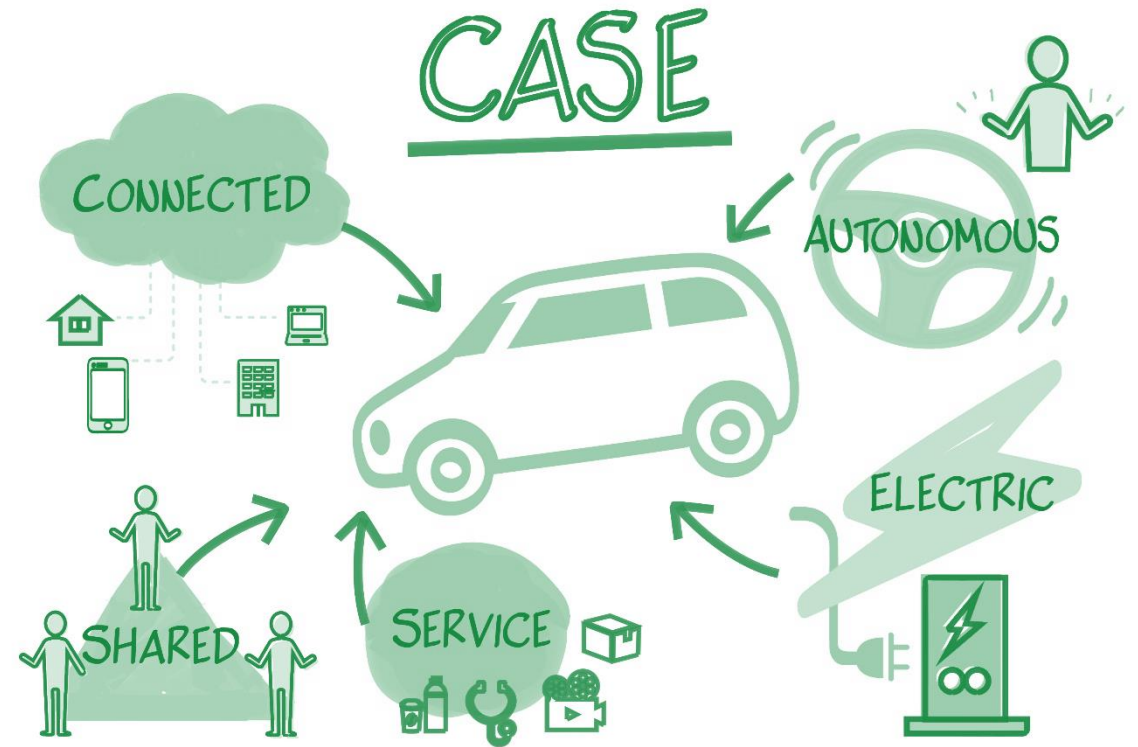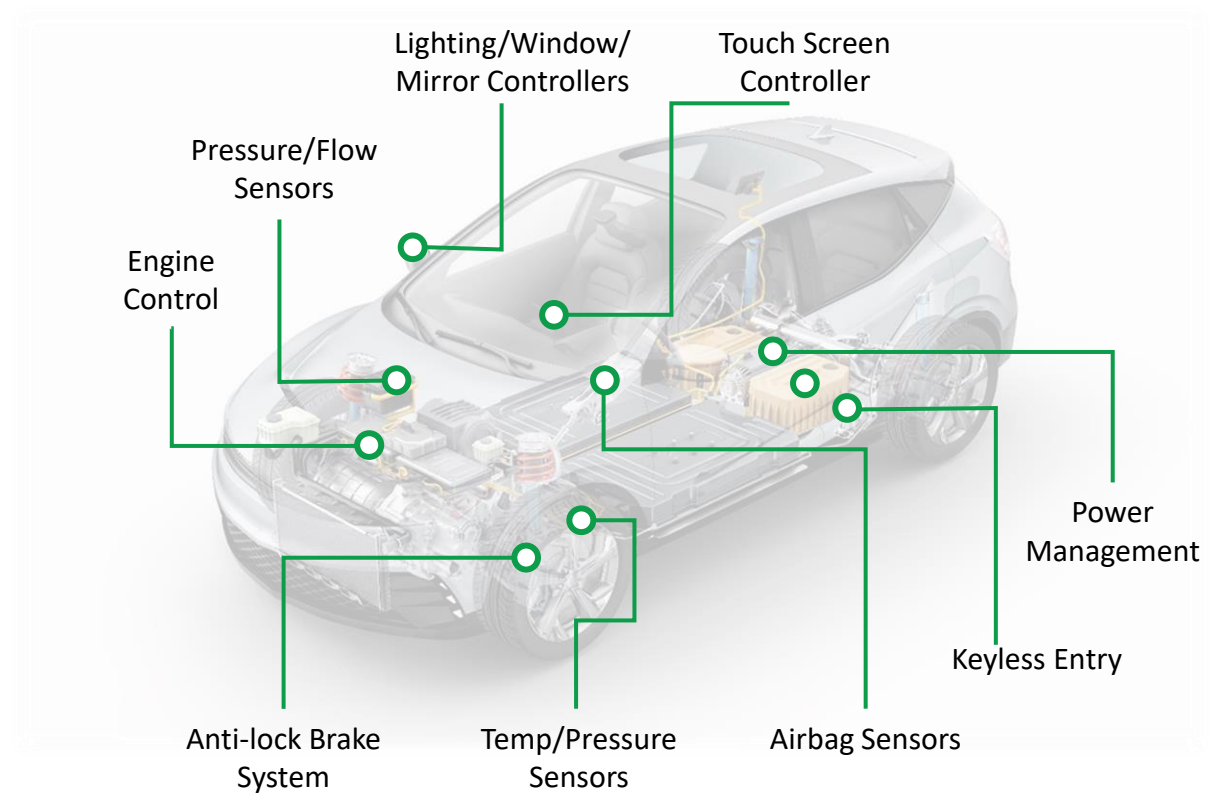

Automotive **CASE**:
Connected, **A**utonomous, **S**hared & Service, **E**lectric

Automotive in Need of New NVM Technologies

- ❖ Growing needs for emerging NVM
  - ◆ Needed for code storage, trimming, data logging

- ❖ Weebit ReRAM
  - ◆ High-temp reliability, immunity to EMI, endurance, fast switching speed, longevity, secure
  - ◆ Can effectively scale to the most advanced process nodes

- ❖ Automotive ICs have unique requirements
  - ◆ Design for safety, security and longevity
  - ◆ Reliable against extreme temperatures, EMI, vibration, humidity, etc.
  - ◆ Support fast boot, instant response, frequent OTA updates
  - ◆ Advanced process nodes are adopted quickly

Some Places Where NVM is Found in a Car

Lighting/Window/Mirror Controllers

Touch Screen Controller

Pressure/Flow Sensors

Engine Control

Power Management

Keyless Entry

Airbag Sensors

Temp/Pressure Sensors

Anti-lock Brake System

Automotive Standards AECQ-100 vs. JEDEC

❖ General ICs qualified according to **JEDEC standards** – baseline for consumer application markets

❖ Automotive industry follows **AEC-Q100 standards** (Stress Test Qualification for Integrated Circuits)

◆ For automotive qualified ICs, tests are much stricter than those of an industrial or commercial IC

◆ These stringent qualification tests assure reliable operation and long lifetimes in harsh automotive environments

A typical automotive Grade 0 mission profile

| Time Index	Duration (%)	Temp. Spectrum 4
T1	6%	-40°C
T2	20%	23°C
T3	65%	85°C
T4	8%	125°C
T5	1%	150°C
Sum	100%	

Automotive Lifetime

❖ Overall car lifetime: 15~20yrs (1year = 8760hrs)

❖ Engine on time: ~3.5hrs/day = 12~15%

❖ Engine in idle time: ~0.5hr/day (~2.0%)

❖ Engine in off time: ~20hrs/day (~83%)

❖ Average car speed: 30mph/50km/h

❖ Overall mileage in car lifetime: 30m*3*365*15 ~ 500,000miles

❖ For **consumer** qualification: >10 years EFR (Early Failure Rate): 0.1%

❖ For **automotive** qualification: use >10 years EFR: 0.01%

❖ This is why DPM level of nearly zero is needed

ReRAM Qualification Plan

| Stress	Test Item	Reference	Stress Conditions	Test Conditions / Acceptance Criteria		Sample Size	
NVCE	Endurance	JESD22-A117 JEDEC 47	$T_{Cycling} = 25°C$	10K Cycles*		**Consumer**	**Automotive**
			$T_{Cycling} = 85°C$			3 Lots x 77 units ½ Hot ½ Room	3 Lots x 77 Only hot
			Hot Temp: $T_{Cycling} = 125°C$				
UCHTDR	Data Retention	JESD22- A117 JESD47	$T_{Bake} = 130°C$	1000 hrs Bake		3 Lots, 77 units from each lot	
			Hot Temp: $T_{Bake} = 175°C$				
PCHTDR	Post Cycle Data Retention	JESD22- A117	$T_{Cycling} = 85°C + T_{Bake} = 130°C$	**Consumer**	**Automotive**	**Consumer**	**Automotive**
			Hot Temp: $T_{Cycling} = 125°C + T_{Bake} = 175°C$	10 hrs Bake	1000-2000h @150C Or mission profile if higher	3 Lots, 39 units from each lot	3 Lots, 77 units from each lot
LTDDR	Low Temperature Data Retention and Read Disturb	JESD22 - A113	$T_{cycling}, T_{read} = 25°C$	500h		3 Lots, 38 units from each lot	

150°C Operation

❖ For automotive qualification, need to demonstrate operation at Tmax

❖ Automative grading for temp according to the specific application

❖ Grade 0 (-40°C to +150°C) is the most stringent and usually needed for under-the-hood applications

Cycling: 150°C & 150°C bake
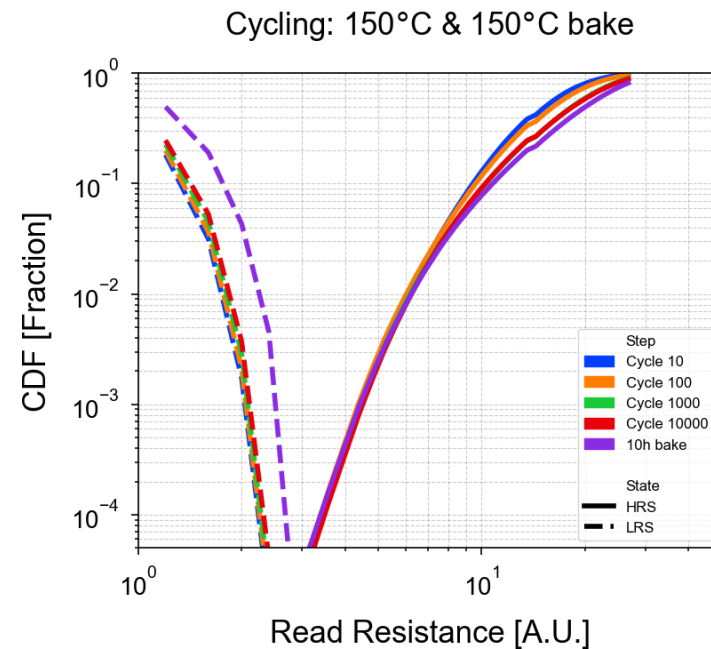
Grade	Ambient operating temperature range
0	- 40°C to +150°C
1	- 40°C to +125°C
2	- 40°C to +105°C
3	- 40°C to +85°C

100K Endurance

❖ Automotive requires up to 100K endurance cycles

❖ Our performance demonstrates good BER throughout the entire 100K cycles
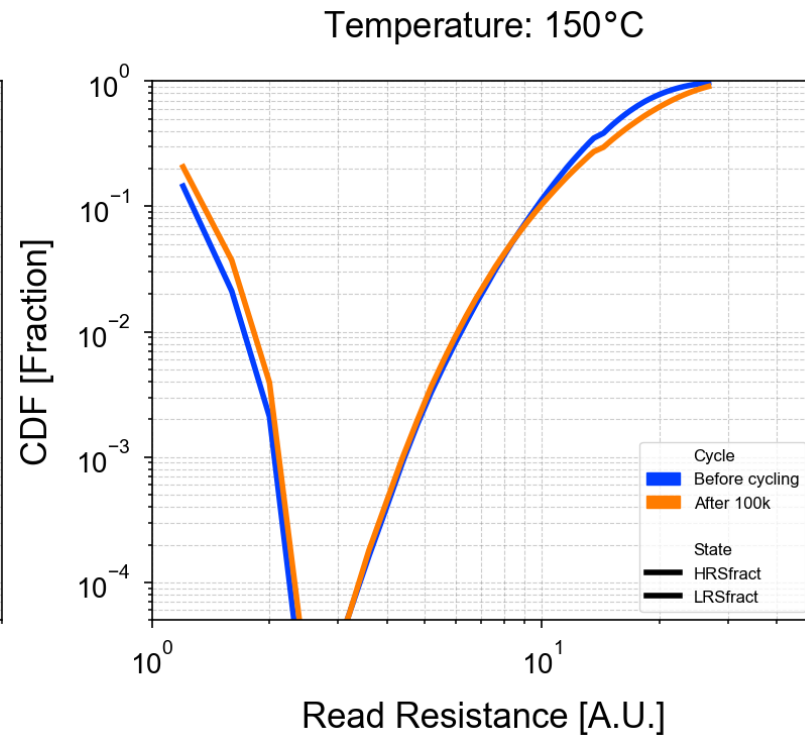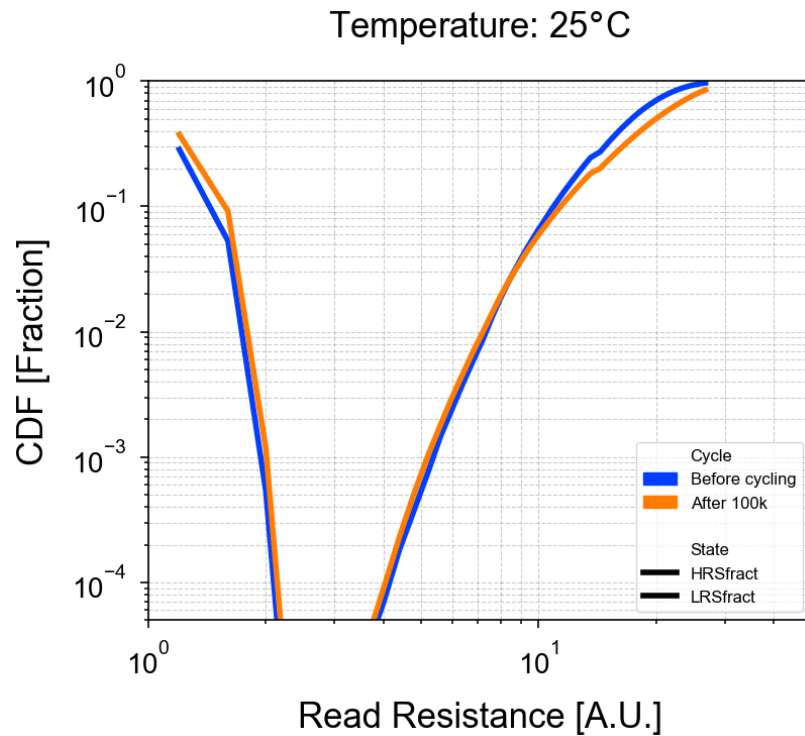
32 Data Bits Average Fail Rate @BER = 5E-5

❖ 2 bit ECC suitable for consumer DPM requirement

❖ 3 bit ECC suitable for automotive grade; we get between 0- 1dpm level

$$\frac{\left(1 - (1 - BER)^{ECCbits} + ECCbits * BER\right) * (1 - BER)^{ECCbits-1} + ECCbits * BER * (ECCbits - 1) * BER * \frac{(1 - BER)^{ECCbits-2}}{2} + ECCbits * BER * (ECCbits - 1) * BER * (ECCbits - 2) * BER * \frac{(1 - BER)^{ECCbits-3}}{6}}{}$$
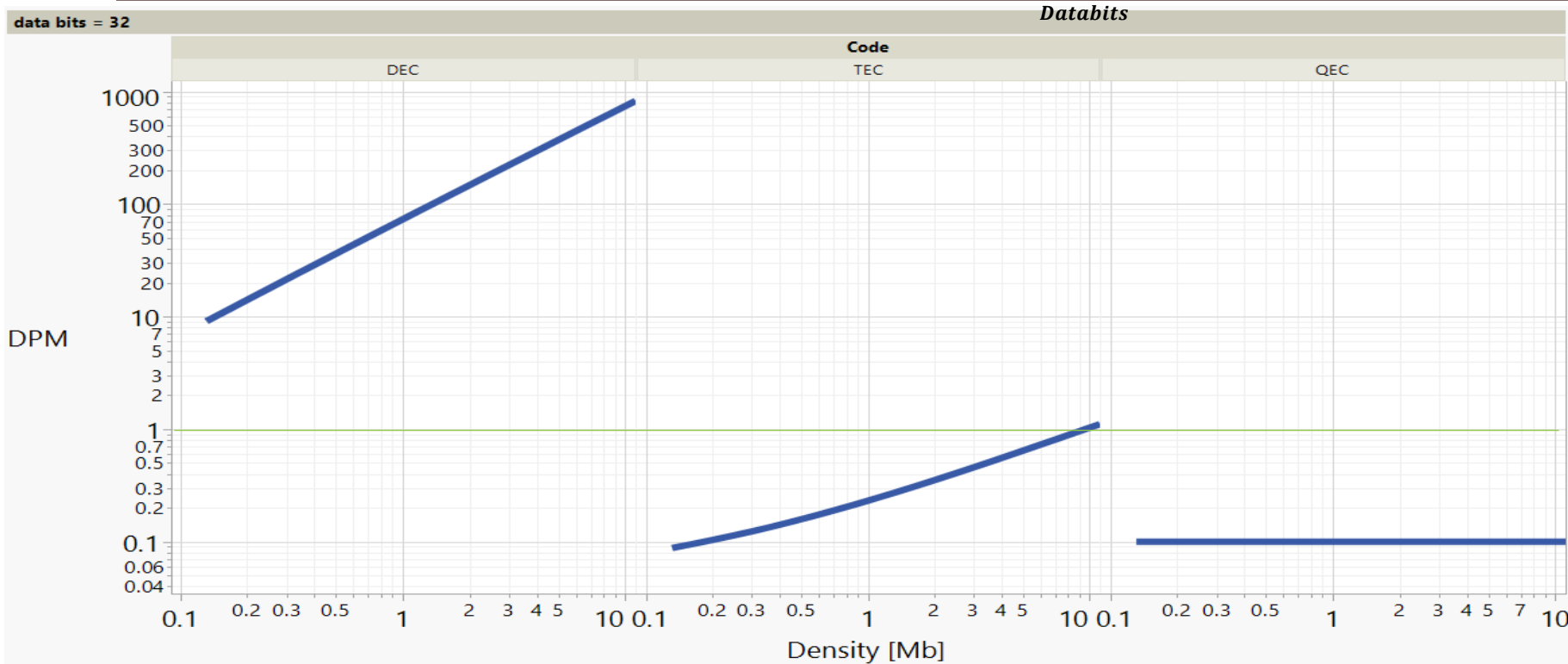

$$UBER = \frac{1}{k}\left[1 - \sum_{i=0}^{corr} \binom{N}{i} RBER^{i}(1 - RBER)^{N-i}\right]$$

where:
- N is the number of bits per error-correcting code (ECC) word,
- k is the number of data-bits per code word (k≤N),
- corr stands for the maximum number of correctable errors per code word [corr is equal to 2 in the case of a double-error correcting (DEC) code],
- i is iterated over the numbers of correctable erroneous bits in a code word.

PPM for 2T2R RBER: 1Mb – 32Mb Densities

❖ **2T2R architecture assures real zero dpm levels**
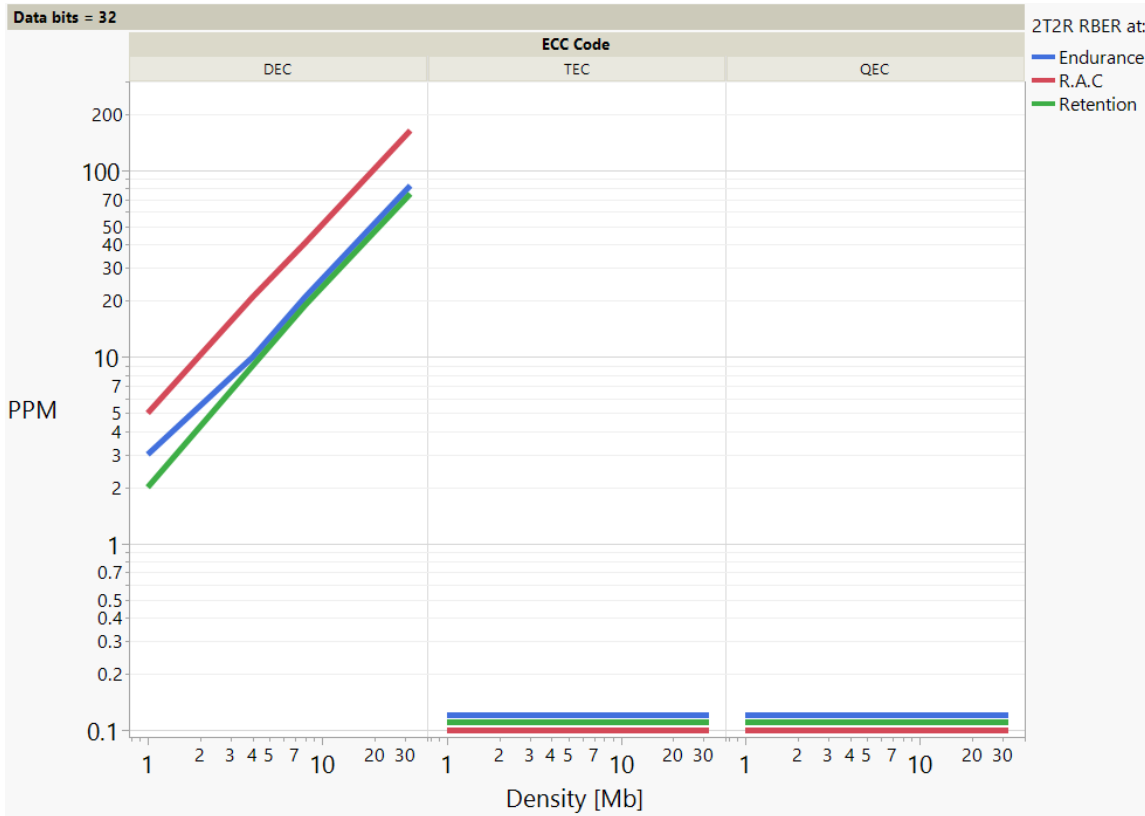
- Statistically, the probability of having both the LRS bit at the tailing percentile (IE 10E-5) and its associated HRS bit at the tailing percentile (IE 10E-5) is a multiplication of probabilities
- No need for reference; avoid reference inaccuracy
- No temperature dependency – both bits shift together over temperature
- ➔ ~3X smaller window can be tolerated

illustration
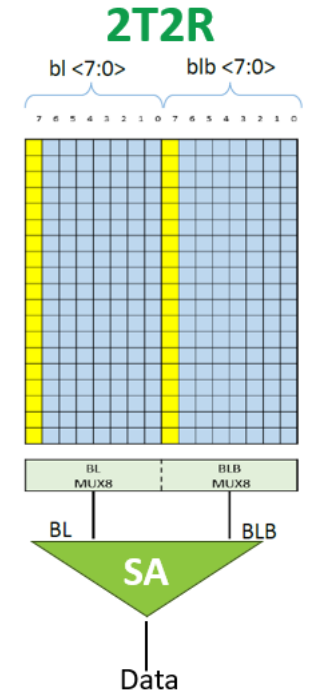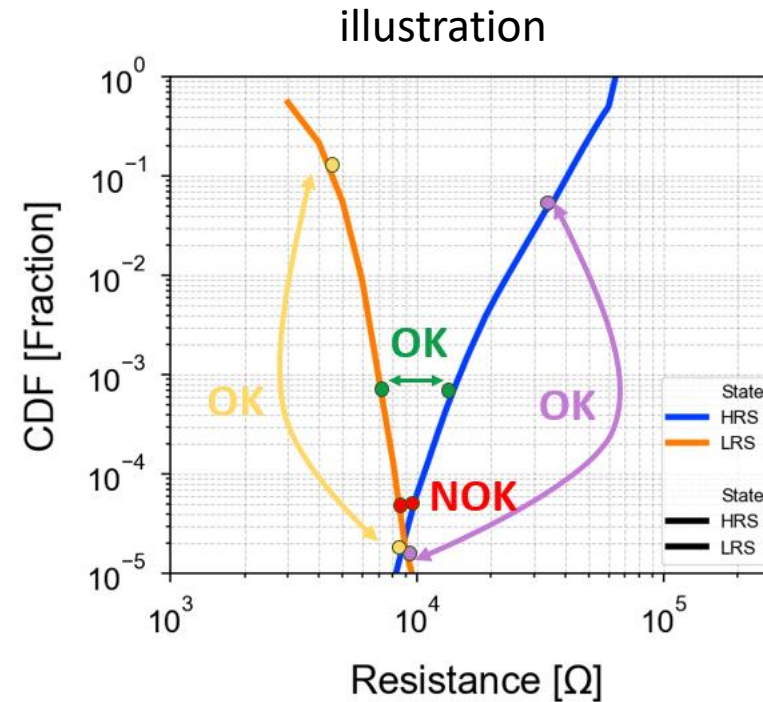
ReRAM is Inherently Radiation Tolerant

❖ ReRAM cell stores data within dielectric stack in back-end-of-line (BEOL) process, so various types of radiation do not affect it

   ◆ Does not use charge trap like flash

❖ Weebit is partnering with University of Florida's Nino Research Group to test ReRAM structures under radiation

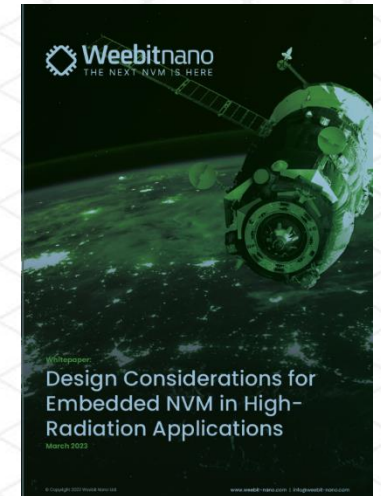   ◆ Initial study irradiated pre-cycled 130nm 16Kb 1T1R arrays in 0.5Mrad-10Mrad in UF training reactor

Results confirm that Weebit ReRAM preserves data and can be fully reprogrammed after high doses of irradiation

Whitepaper available

https://tinyurl.com/dbk2nmwv
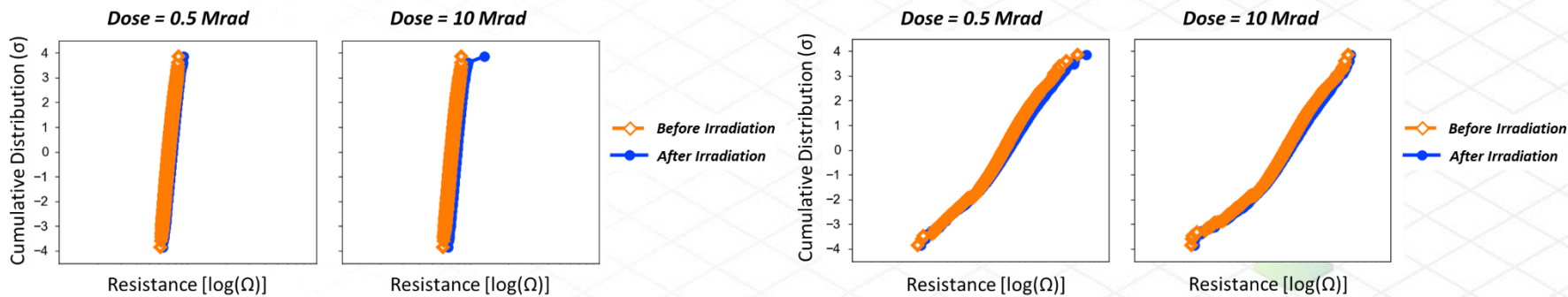
Low Resistance State (LRS) distribution before and after different radiation doses

High Resistance State (HRS) distribution before and after various radiation doses

Note: The scale of these two diagrams is not the same.

State of Weebit ReRAM Today

Technology available for licensing

❖ Demonstrates repeatability, uniformity and maturity of Weebit's embedded ReRAM

Qualified modules at 85°C and 125°C

❖ Temperatures specified for industrial and automotive grade 1 ICs

❖ Qualified for endurance and 10yr retention per JEDEC industry standards

150°C and 100K cycles qualification in progress

• Good results achieved, collecting statistical data for full qualification ongoing

Technology demonstrated on multiple process nodes

❖ 130nm – 90nm – 65nm – 28nm – 22nm

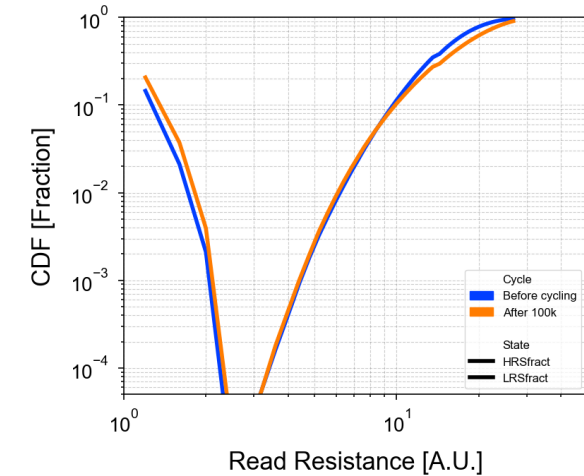**SkyWater:** ReRAM module now available for production

DB HiTek: Technology transfer underway

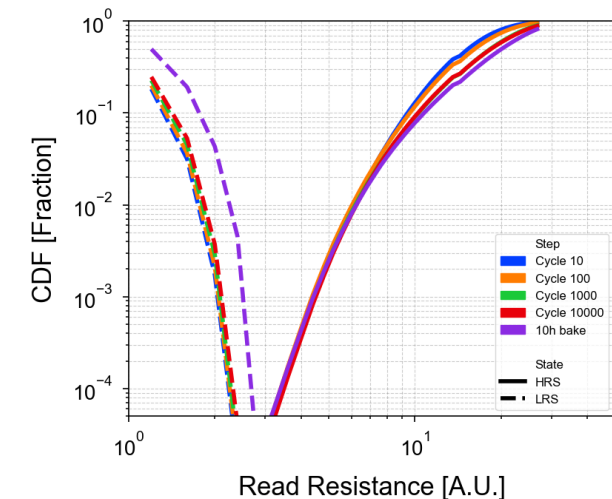**GF22 FDSOI:** 1st silicon is under characterization

Extended Endurance

Temperature: 150°C

Retention after Cycling

Cycling: 150°C & 150°C bake

Conclusions

Weebit ReRAM offers many critical features that enhance SoC and system performance

- Most cost-effective NVM in the market
- Performance is better than flash: power consumption, endurance, speed, radiation tolerance
- Easily scales to advanced process nodes

Huge market potential in the automotive business

- Fast-growing autonomous and electric vehicle segments increases the need for reliable electronics and embedded NVM
- 150°C and 100K endurance shows that Weebit ReRAM can fit into automotive applications

Weebit progress

- Technology transfer underway to DB HiTek; To be followed by qualification in BCD 130 process
- Functional ReRAM modules fully qualified in SkyWater at 85°C and 125°C and demonstrating increasing temperature and endurance capabilities
- Weebit continues developing and scaling ReRAM technology to smaller nodes

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Thank You!

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