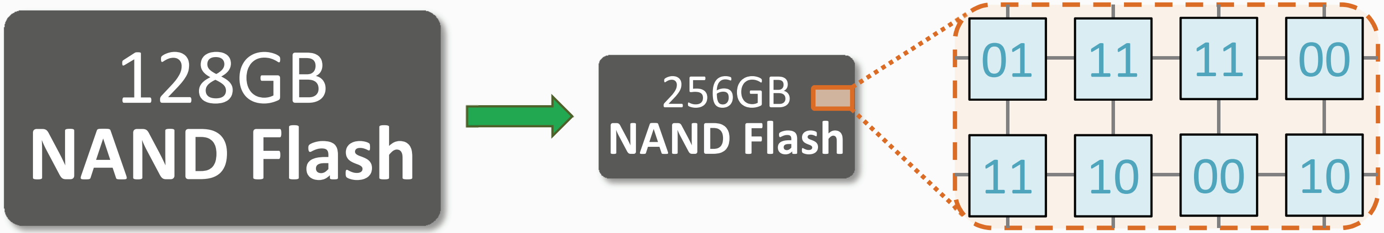
# Vulnerabilities in MLC NAND Flash Memory Programming: Experimental Analysis, Exploits, and Mitigation Techniques

Carnegie Mellon University SEAGATE ETHzürich SAFARI

## HPCA Session 3A – Monday, 3:15 PM, Salon F



NAND flash scaling: **shrink size** of each flash cell, **store *two bits*** per cell

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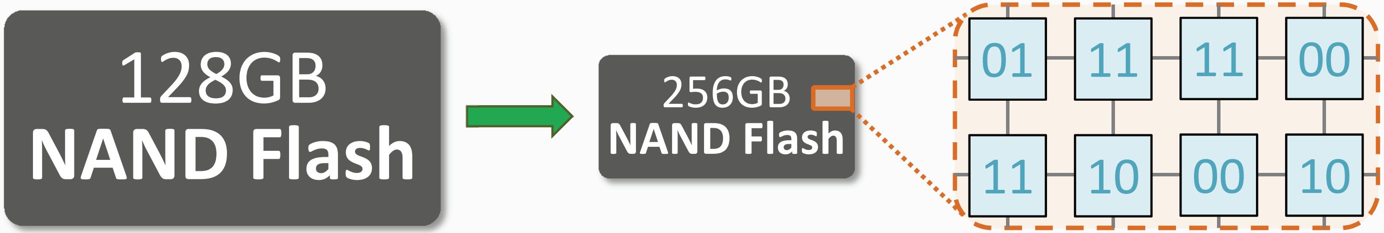

128GB **NAND Flash**

256GB **NAND Flash**

| | | | |
|---|---|---|---|
| 01 | 11 | 11 | 00 |
| 11 | 10 | 00 | 10 |

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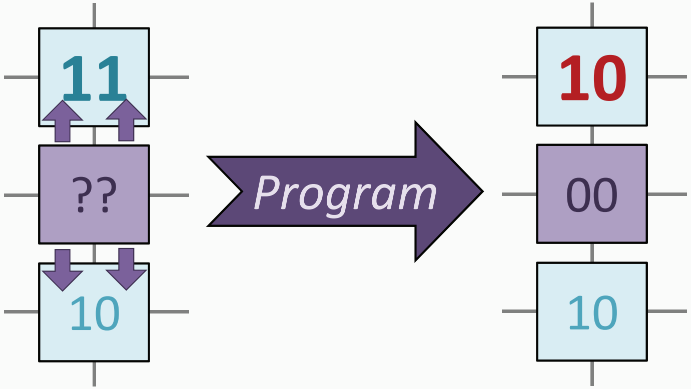

11

??

10

*Program*

**10**

00

10

As the cells become smaller, they ***interfere*** with each other during **programming**…

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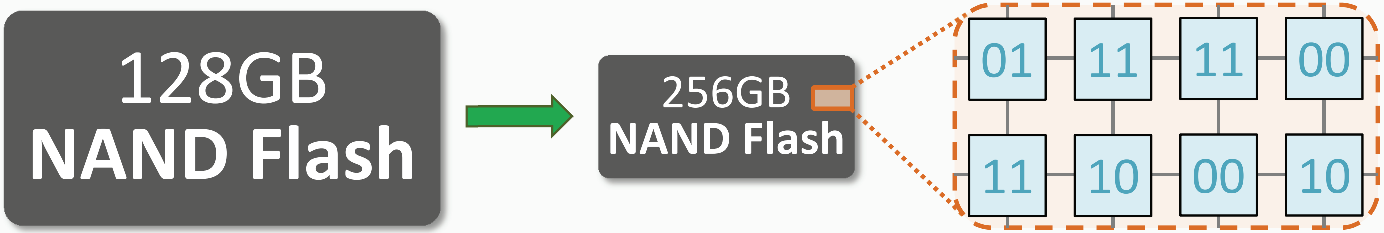

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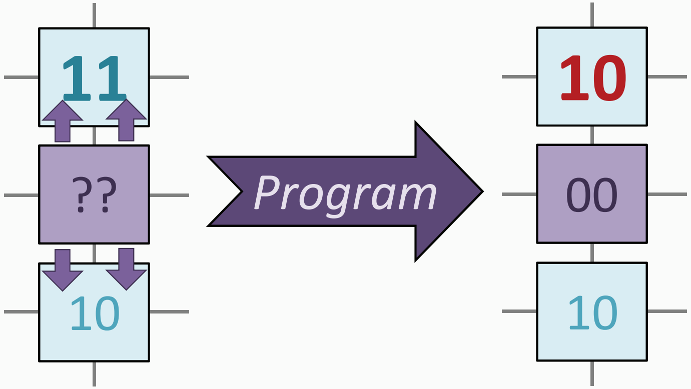

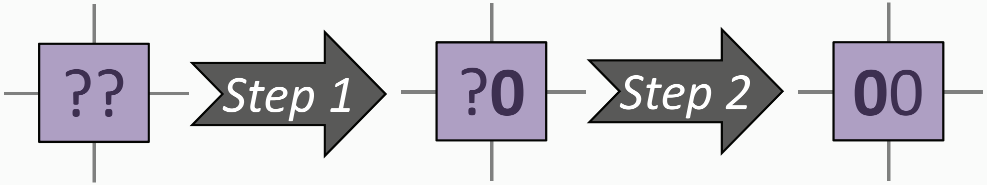

As the cells become smaller, they ***interfere*** with each other during **programming**…

…to reduce interference, today's MLC NAND flash chips use ***two-step programming***

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Using **real MLC NAND flash chips**,
we show that two-step programming introduces
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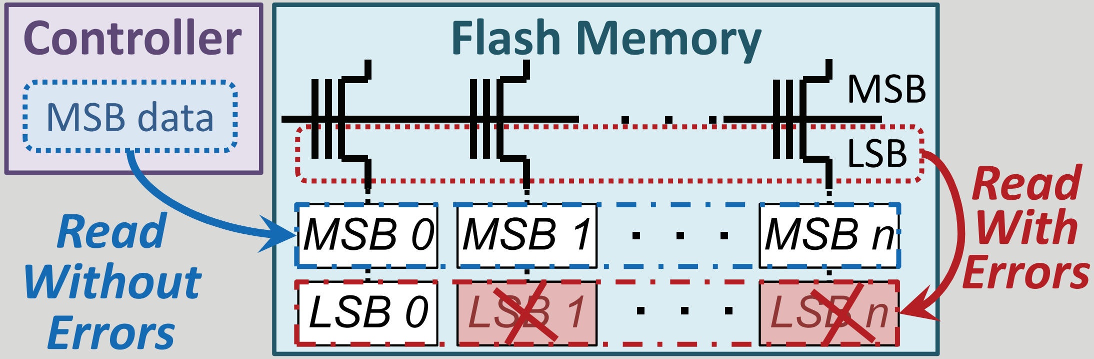
We find that **cells with only one bit programmed** are **more vulnerable** to **interference during reads and writes** than fully-programmed cells



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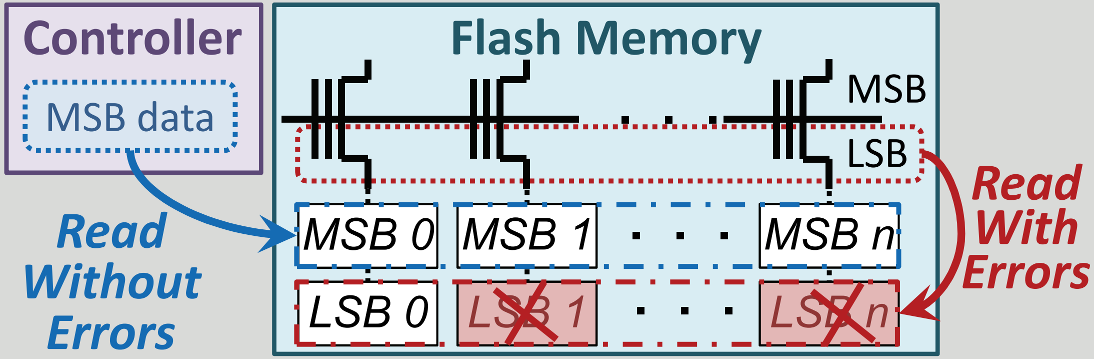

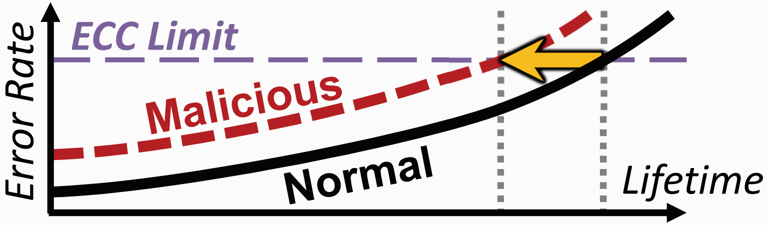

Vulnerabilities can be **exploited** to corrupt data and **reduce flash lifetime**

We propose **three solutions**
to minimize vulnerabilities at **negligible latency overhead**

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One solution completely eliminates vulnerabilities

*4.9% increase in flash programming latency*

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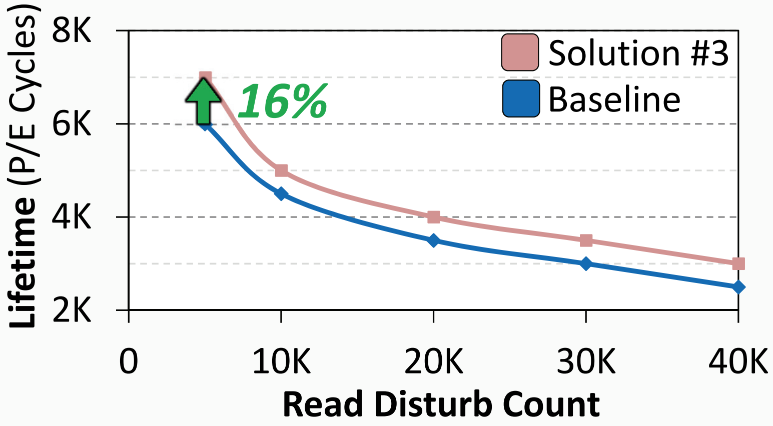
Two other solutions **mitigate vulnerabilities**

*No increase in flash latency, errors not completely eliminated*

***Increases flash lifetime by 16%***



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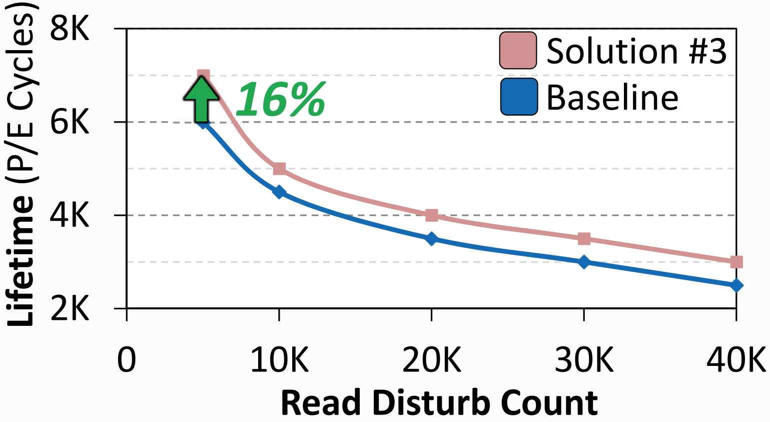

**Want more? Come to our talk! Read our paper!**

*Authors:* Yu Cai, **Saugata Ghose**, Yixin Luo, Ken Mai, Onur Mutlu, Erich F. Haratsch