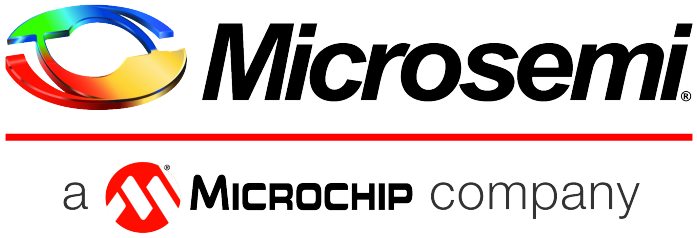

A Machine Learning Framework for NAND Flash Lifetime Extension

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A World of Machines… Learning

In the last few years, machine learning has become ubiquitous

Machine Learning

Deep Learning

- Machine vision
- Object detection
- …

Data Analysis

- Time series analysis
- Regression
- …

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Deep Learning

- **Machine vision**
- **Object detection**
- **…**

Data Analysis

- **Time series analysis**
- **Regression**
- **…**

The common approach today is:
Do you have a problem? Fix it with Machine Learning!

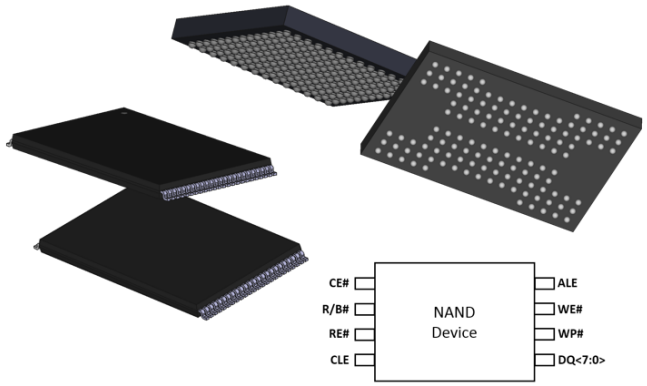
The "Devil" in Machine Learning

Using machine learning is not as simple as it appears…

- One of the biggest problems when using machine learning is neither the algorithm nor the implementation…
- "The problem is not the problem. The problem is how you define the problem…"

NAND Flash Memories Today

- 3D up to 96 layers
- 8 Tbits in a single BGA package
- Quad level cell (QLC)
- Circuits under array
- I/O bus @ 1200 MT/s
- tPROG ≈ 3 ms
- tREAD ≈ 100 µs
- tERASE ≈ 10 ms
- Cost per Gb ≈ HDD



R. Micheloni (ed.), *Solid-State-Drives (SSDs) Modeling*

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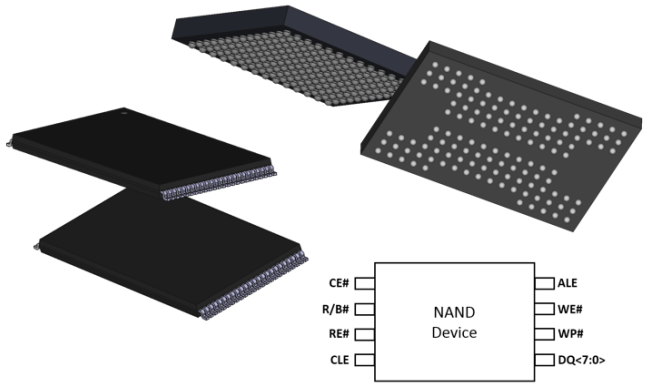


R. Micheloni (ed.), *Solid-State-Drives (SSDs) Modeling*

Reliability!!
NAND FER fighting against the Shannon limit

NAND Flash

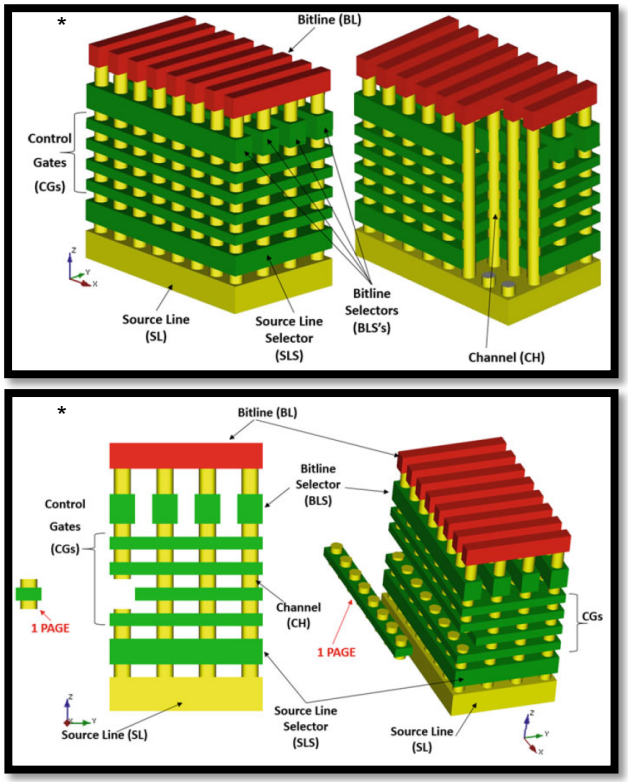
- The higher the data reliability, the longer the device's lifetime (and the cheaper the solution…)
- Problem statement: increase data reliability to extend NAND flash's lifetime

…Now what?...

3D NAND Flash Memories

Having a deep understanding of the device's physics is the only way to get good data reliability

- 3D NAND flash is a stack of multiple memories
- Array architecture
- Cell-to-cell variability



R. Micheloni (ed.), *3D Flash Memories*, DOI 10.1007/978-94-017-7512-0_3

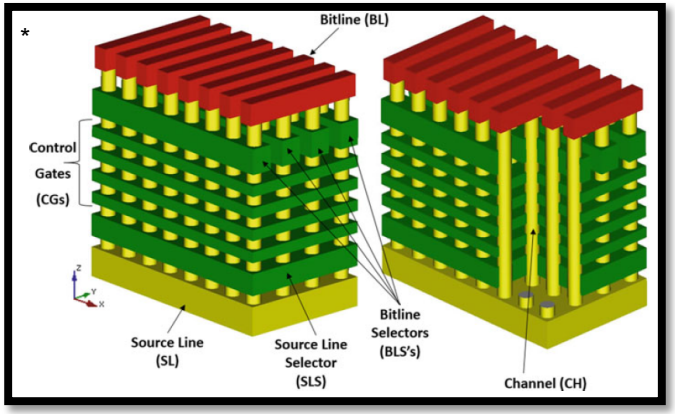
"…Welcome to the jungle…"

Many parameters impact NAND flash reliability including soft info, code-rate, cycling speed, and temperature.

- Too many parameters to look at
- Too many possible correlations
- Too many features

There is no guarantee that we'll find the best setting for each working conditions…

Problem? Use Machine Learning



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NAND flash know-how

Machine learning know-how

…Now what?...

* Rino Micheloni, 3D Nand Flash Memories, Springer 2016

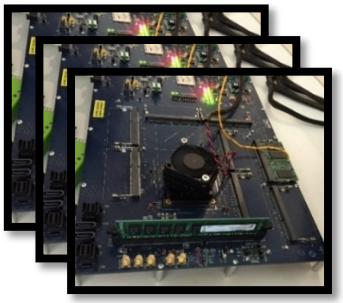
Goals

What do we want to achieve?

- A framework able to test which parameters impact the reliability of a NAND flash (and which parameters do not)
- An framework able to tune these parameters depending on the reliability target
- Output: An algorithm (model) able to learn how to enhance the reliability in a completely agnostic and autonomous way → Machine Learning!
- Remember, we are looking for a framework and not an algorithm! The algorithm is just the output of the framework.

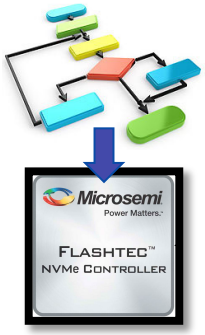
Machine Learning Framework at FSPL

- Characterization of NAND flash memories



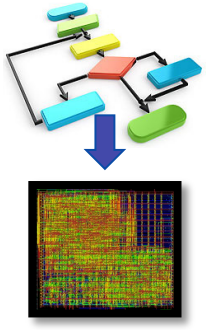
- Brute force testing of thousands of different machine learning algorithms
- Create a software model of the target algorithms

- Implement best candidate algorithm at firmware level

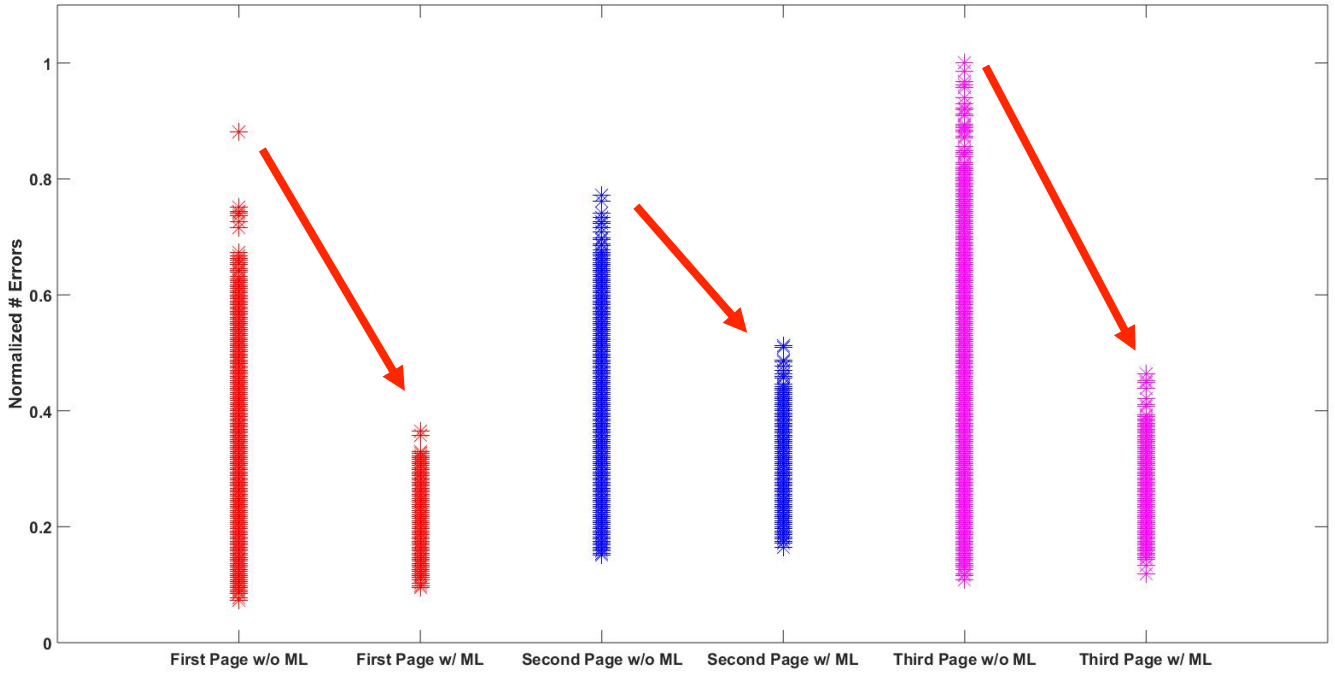


- Test with NVMe Flashtec™ controller

- Hardware acceleration



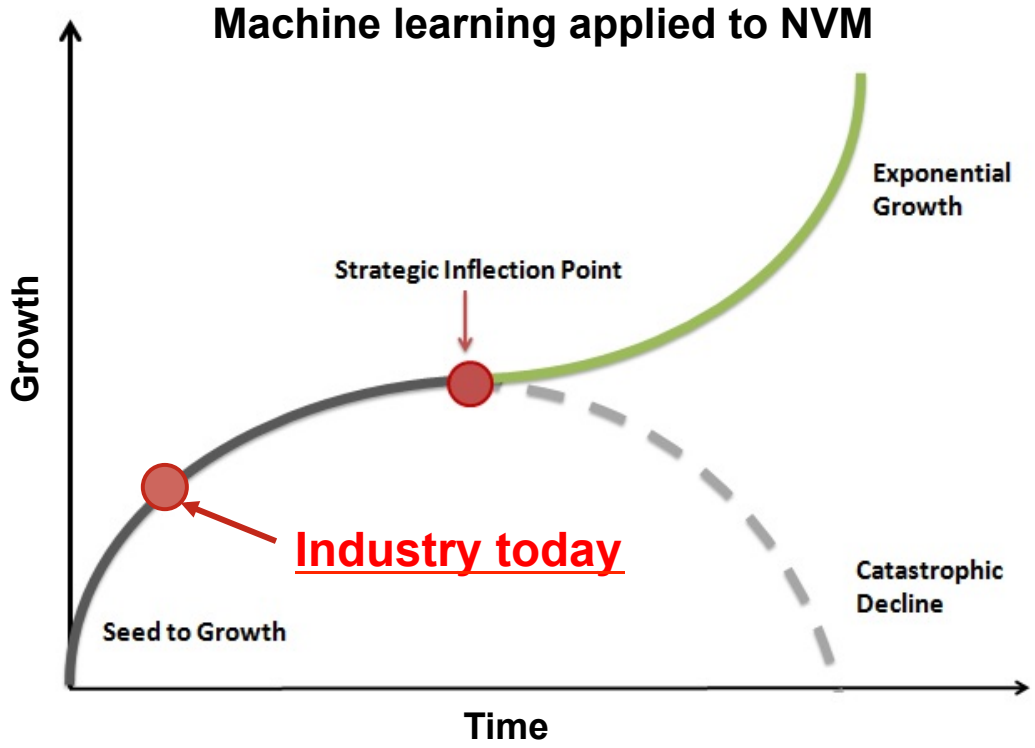
Example



Firmware to hardware latency gain ≈ 100x

Where Are We Today?

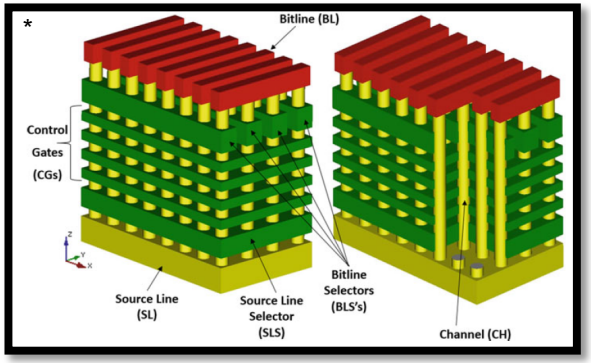
"…a strategic inflection point is a time in the life of business when its fundamentals are about to change. That change can mean an opportunity to rise to new heights. – Andy Grove"



Conclusions: M²ZC Conjecture

"In hyperscaled NAND flash memories each layer will be optimized by machine learning"

- **Takeaway #1:** Does machine learning work with NAND flash memories?→ Yes!
- **Takeaway #2:** Are humans obsolete? → Don't think so! We still need to guide the machine (a student can learn at a much faster rate with a good teacher…)



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Thanks

Q&A

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