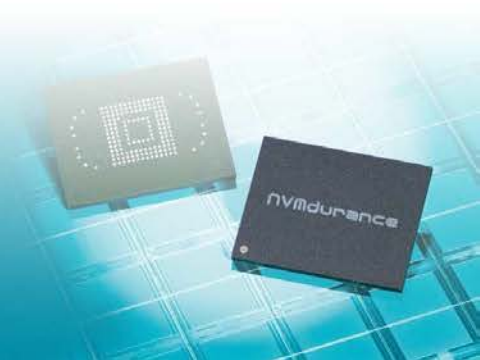




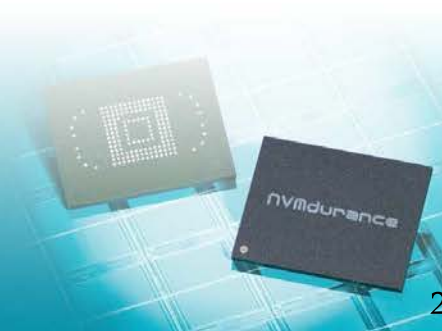
# Extending Flash Memory Through Adaptive Parameter Tuning



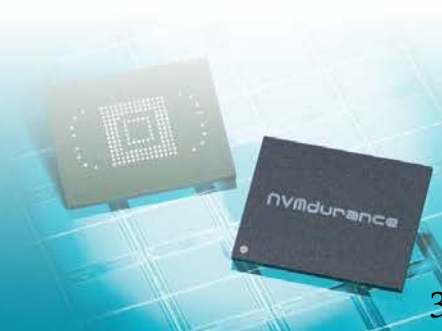
Prof. Conor Ryan  
CTO - Software  
[Conor.Ryan@NVMdurance.com](mailto:Conor.Ryan@NVMdurance.com)



- **20x increase in endurance**
- **Works in addition to ECC**
- **Lightweight, autonomic system**
- **Use the least *force* possible**



- **NVMdurance Pathfinder**
  - Suite of Machine Learning Algorithms
  - Searches hypertopology of register values
  - Plots “safe” temporal paths through hypertopology
- **NVMdurance Navigator**
  - Autonomic system
  - Navigates the paths

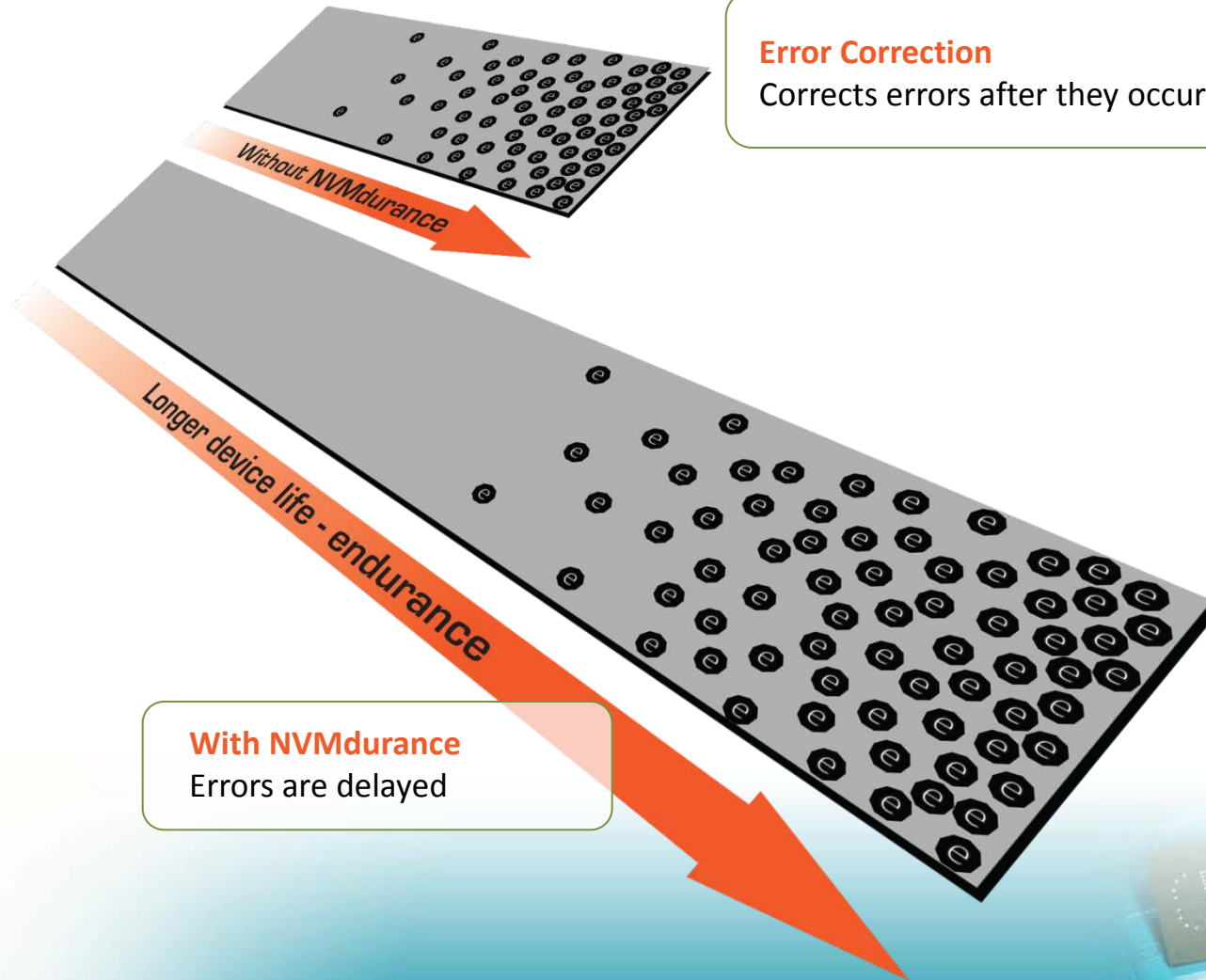


## Error correction



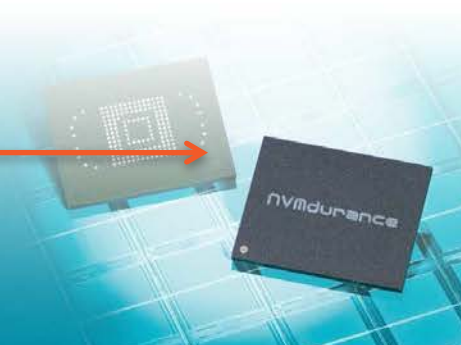
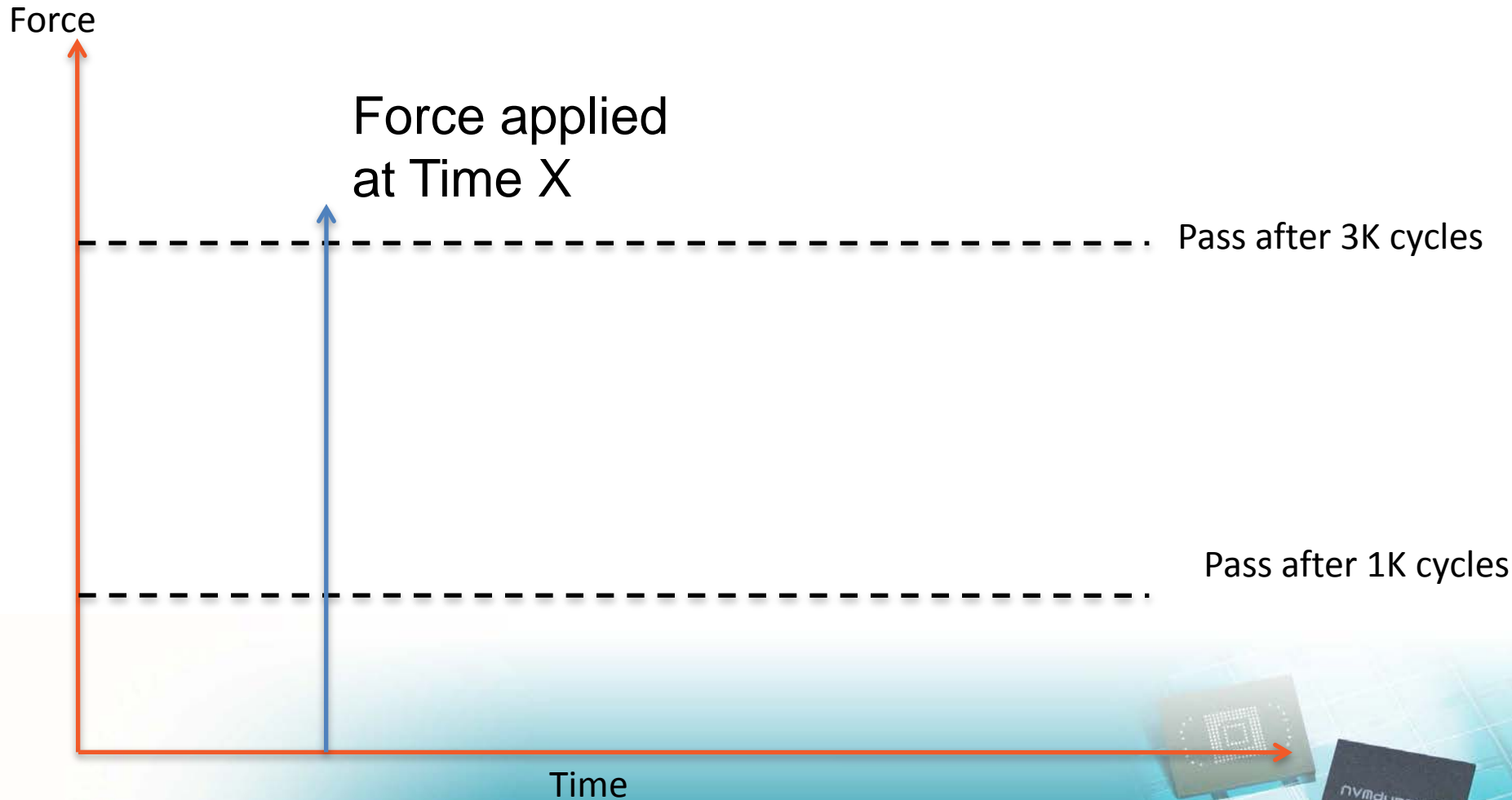
### Error Correction

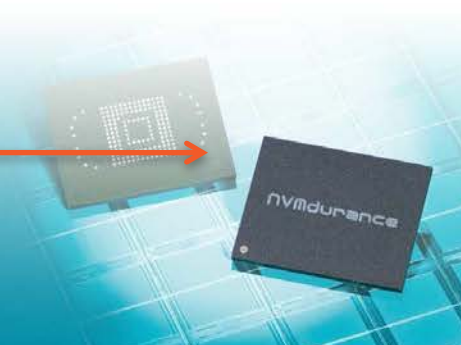
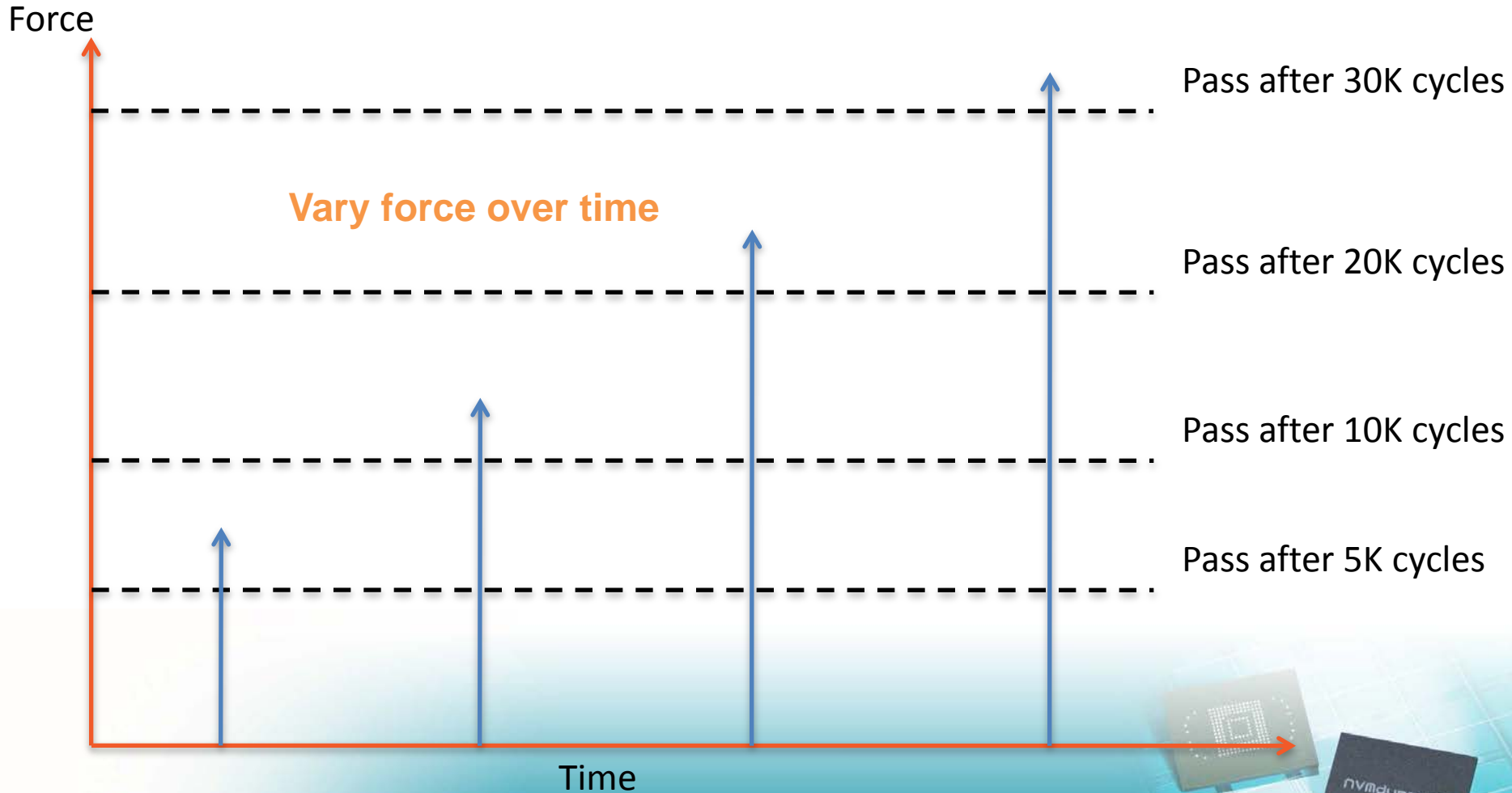
Corrects errors after they occur

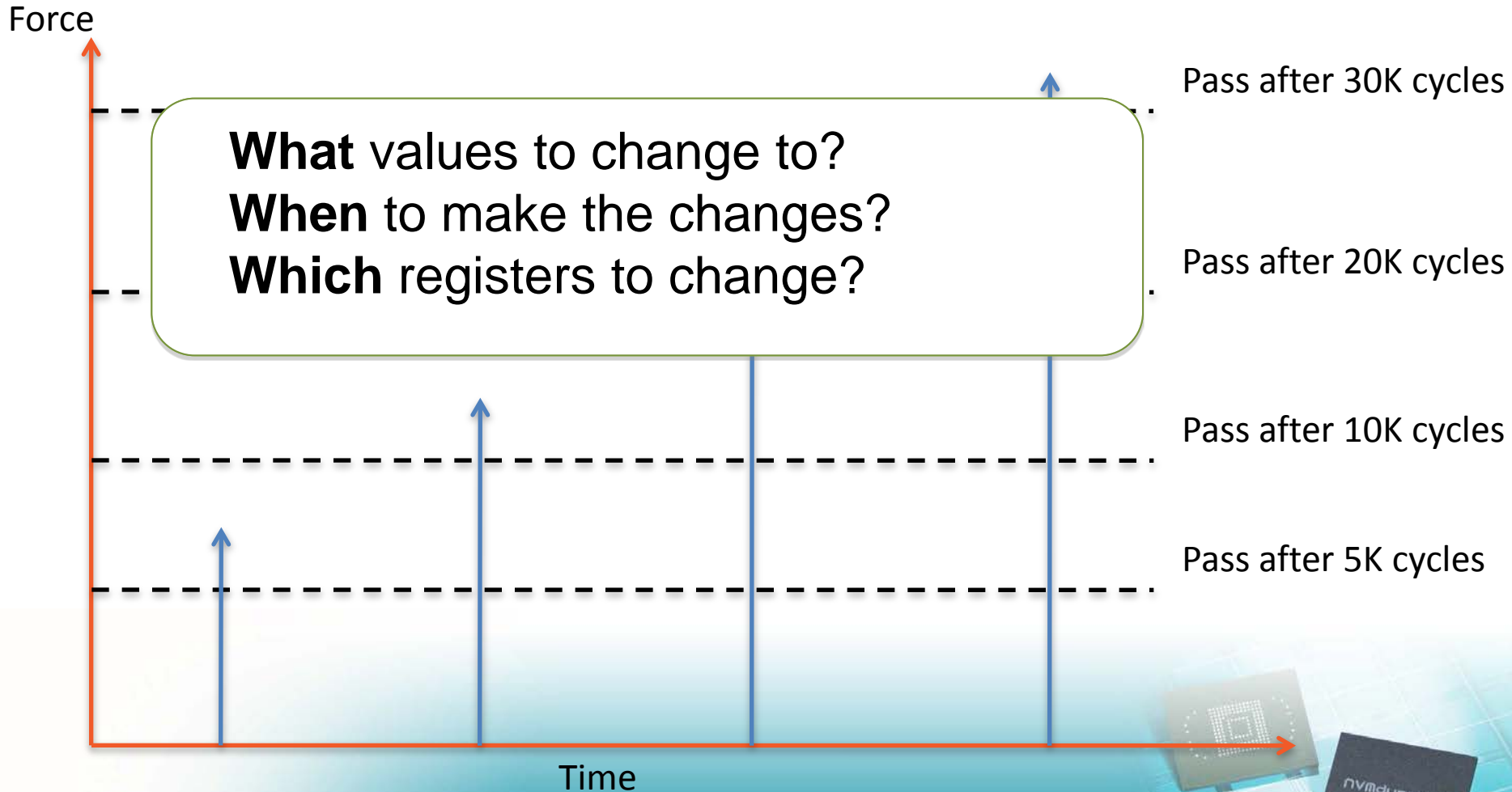


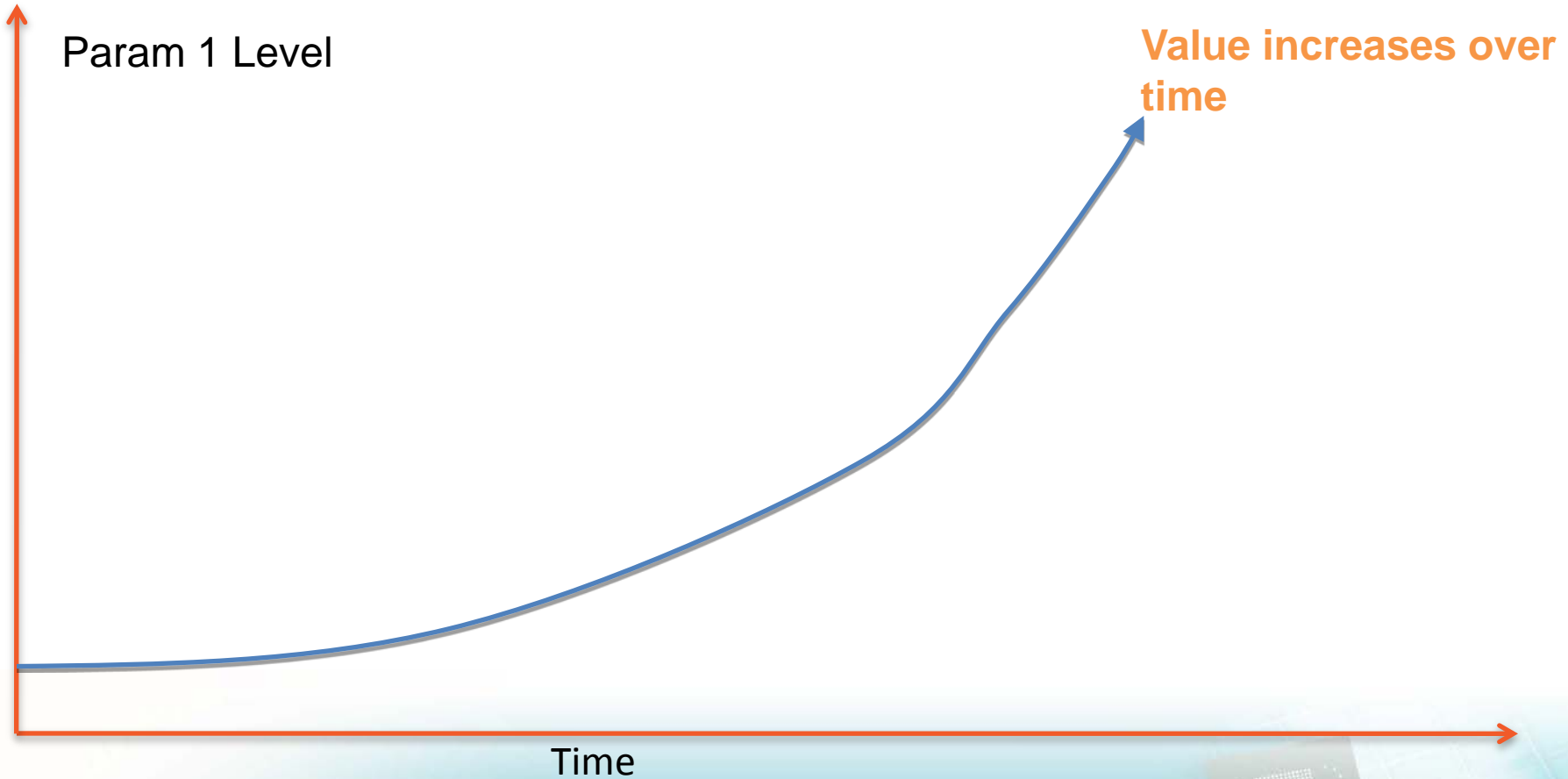
### With NVMdurance

Errors are delayed

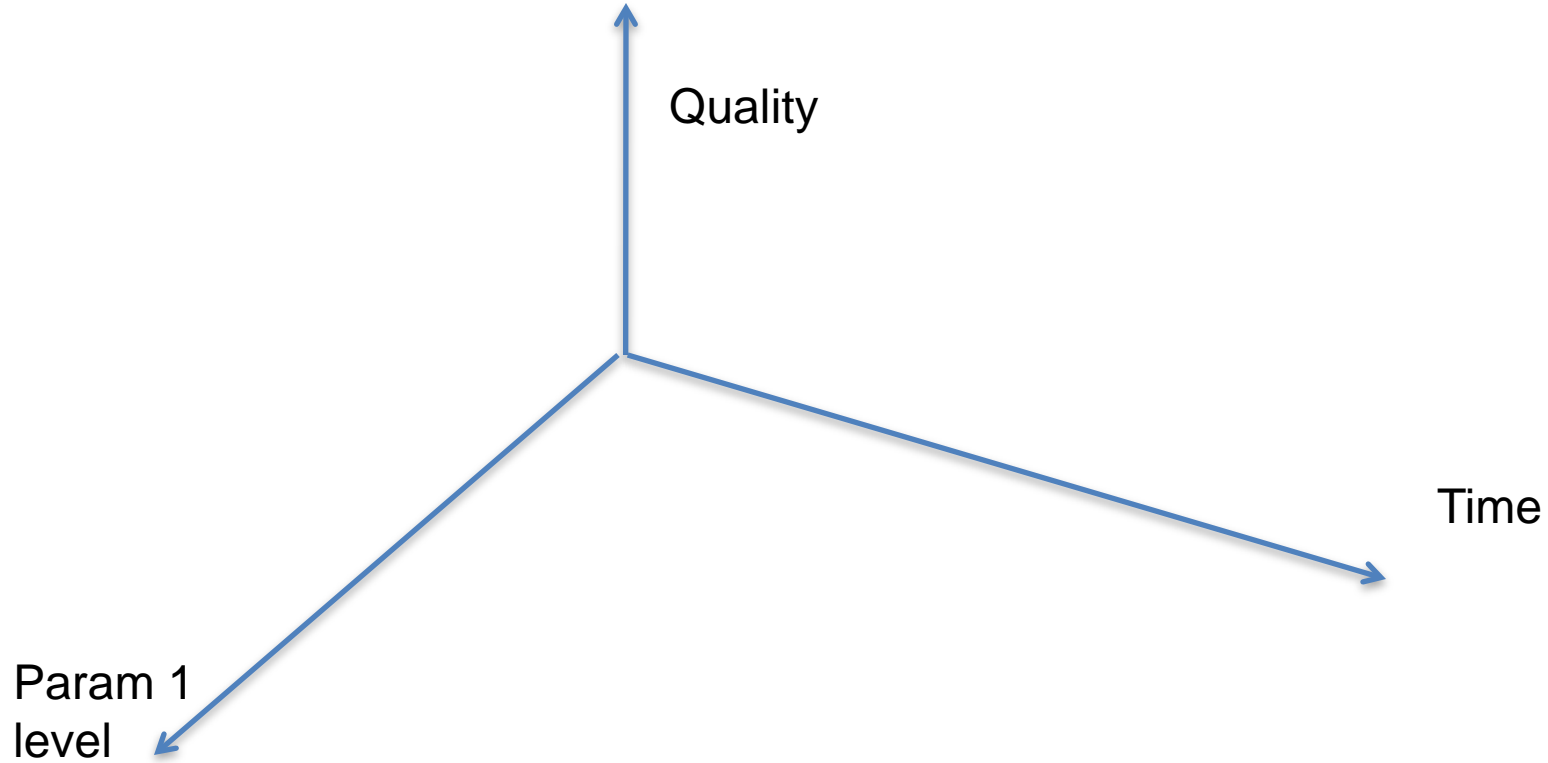


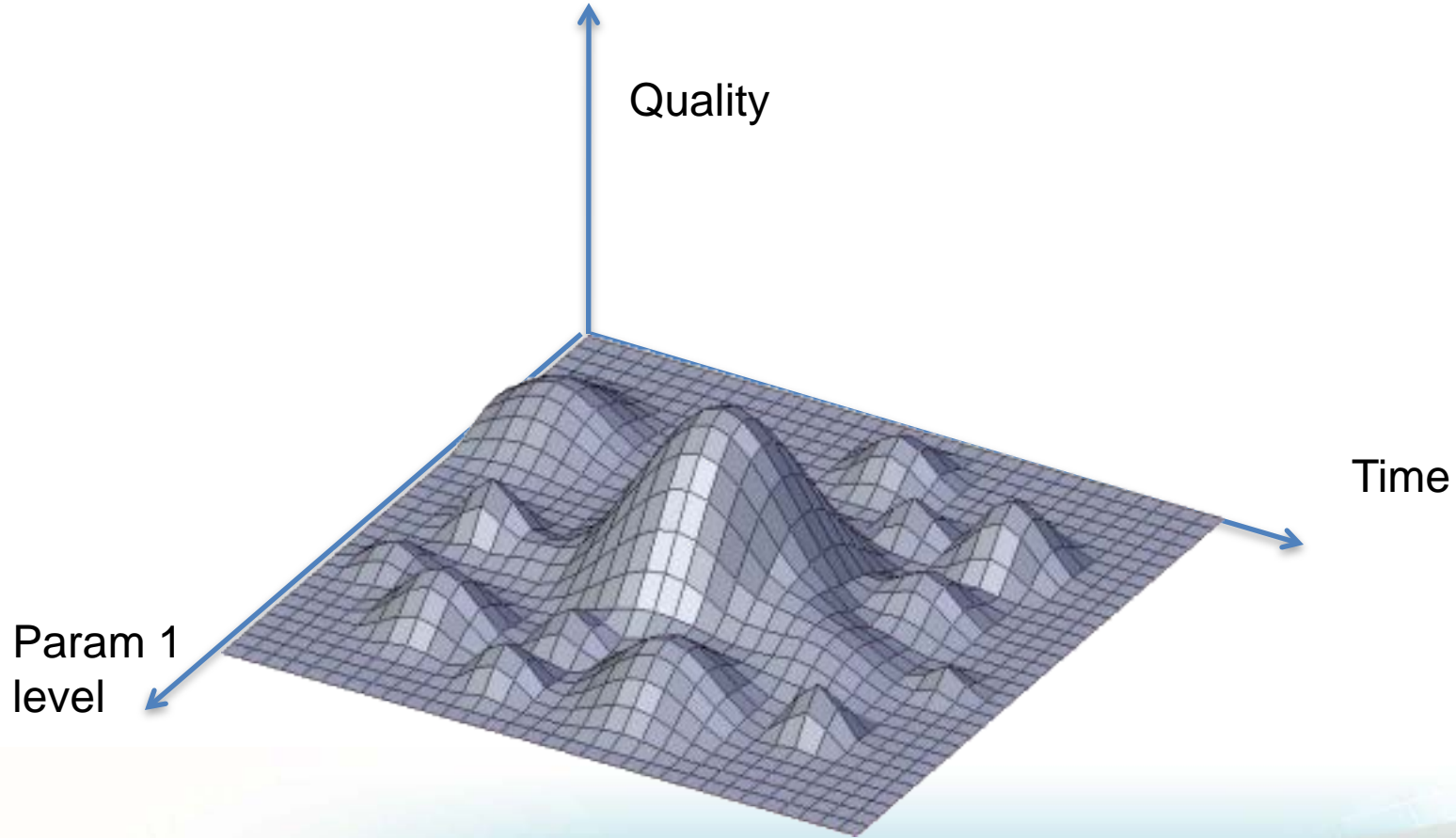


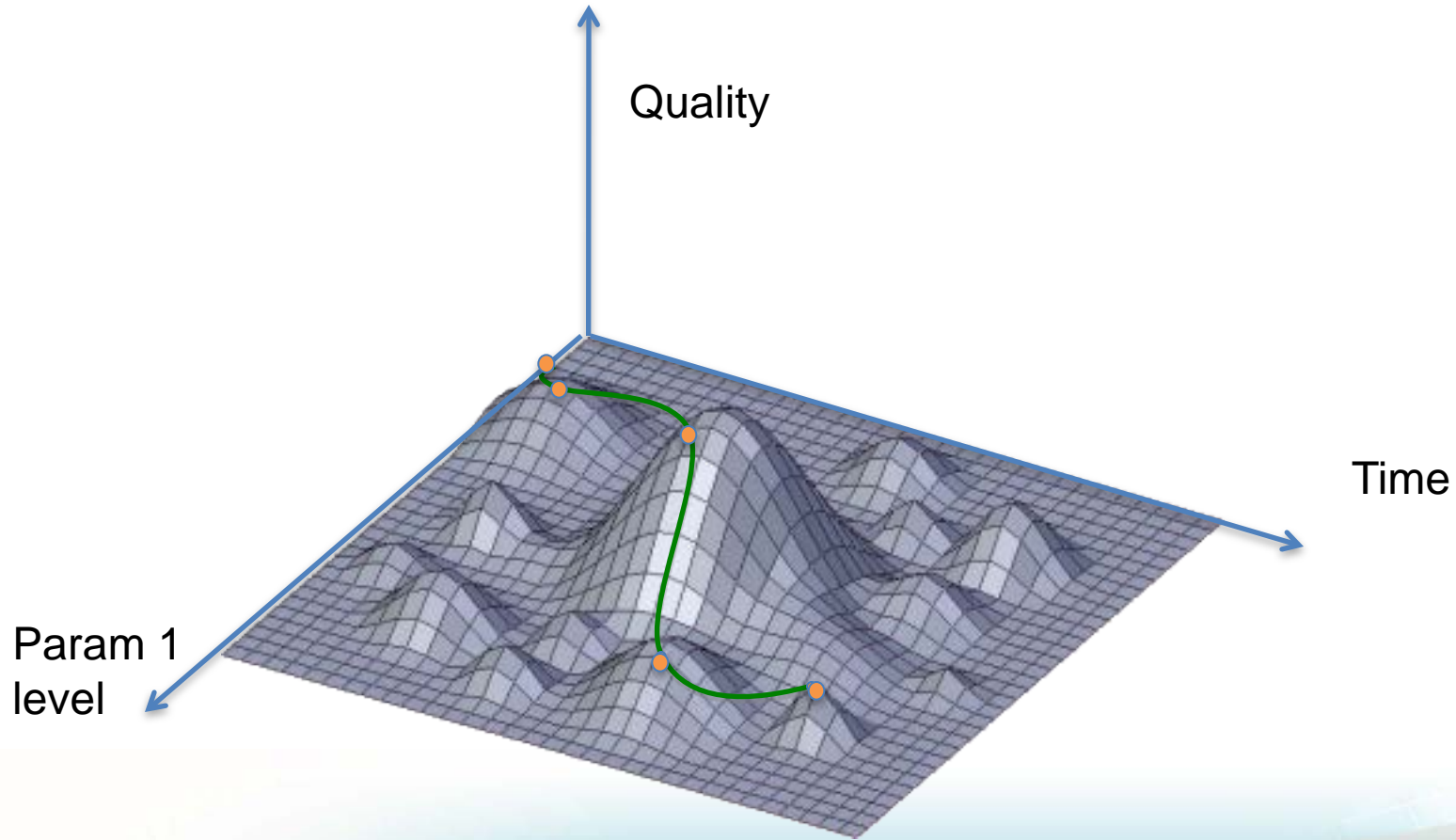












- Each free parameter adds three dimensions
- $8^{28}$  possible VALUE combinations
  - $1.93428131138341 \times 10^{25}$  at each possible time step
  - JEDEC style tests (3 weeks per set)
    - $1.1128741791521 \times 10^{24}$  YEARS
  - Vary over time?

- **Reduce Dimensionality**
  - Understand the silicon
- **Guide the search**
  - Be sensible, if not insightful
- **Test only what has to be tested**
  - Or at least know what NOT to test
- **....This is still an astronomically difficult problem!**

- **90 dimensional space**
  - Plot hypertopology
- **Calculate set of “safe” paths**
  - The space is huge
- **Tune paths on the fly**
  - All Flash is different; “The Tolstoy Principle”
    - Factory testing abuses all SSDs in the same way;
    - Field use abuses SSDs in many different ways

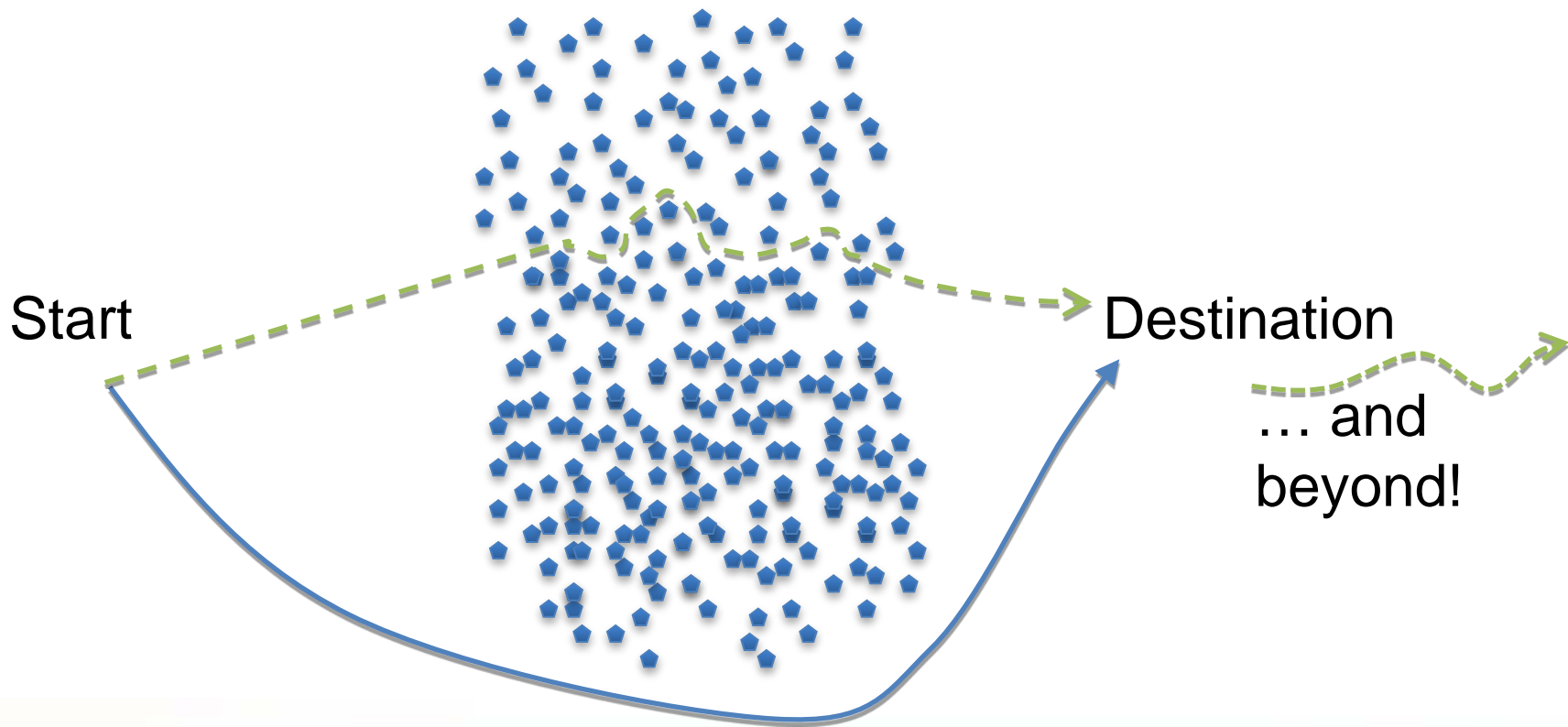


## NVMdurance Pathfinder

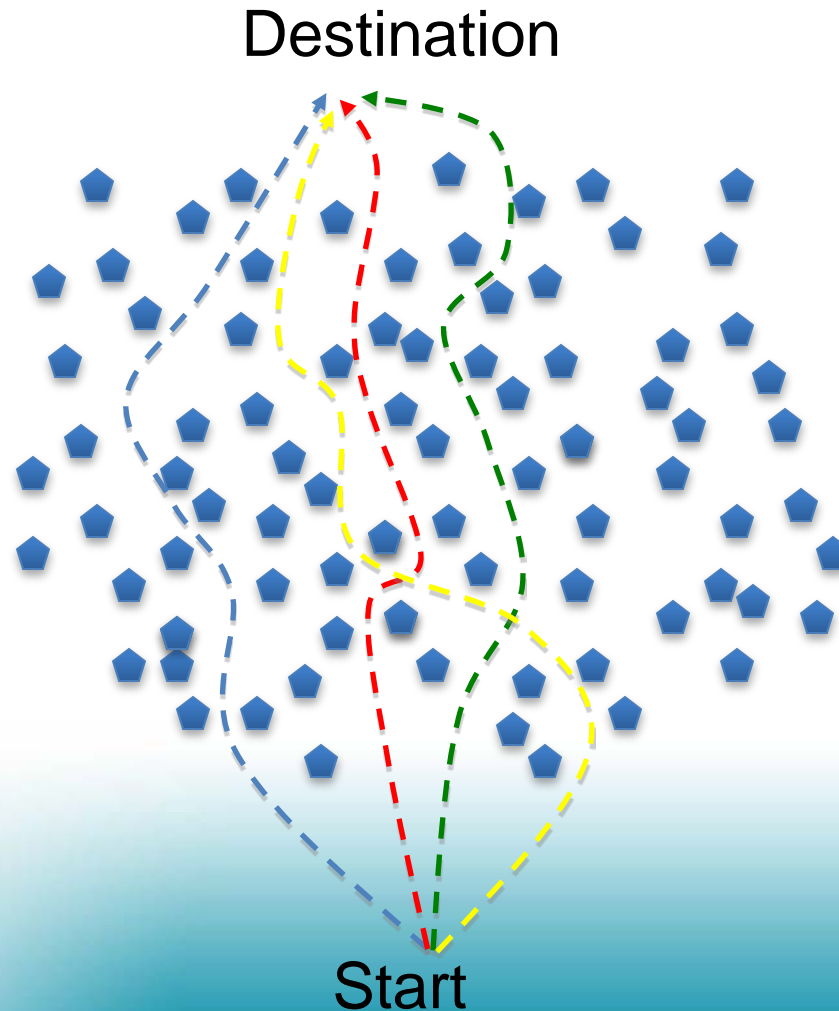


Start

Destination

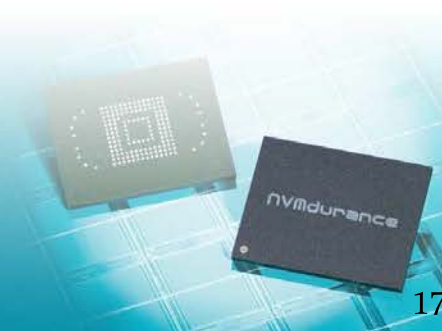


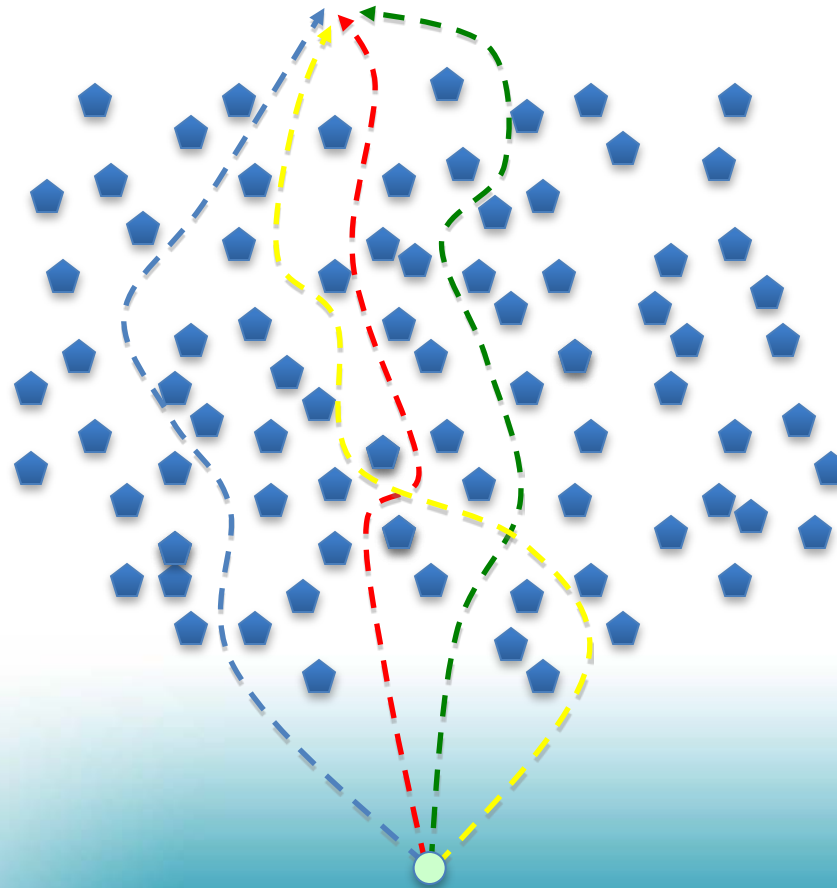




Asteroid Belt

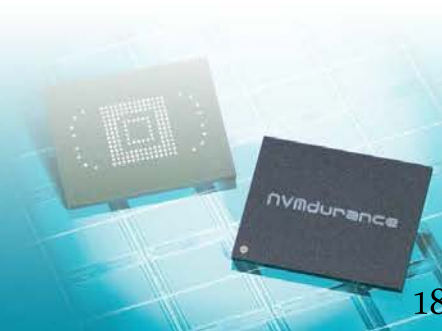
NVMdurance Pathfinder identifies a number of viable routes through the asteroids

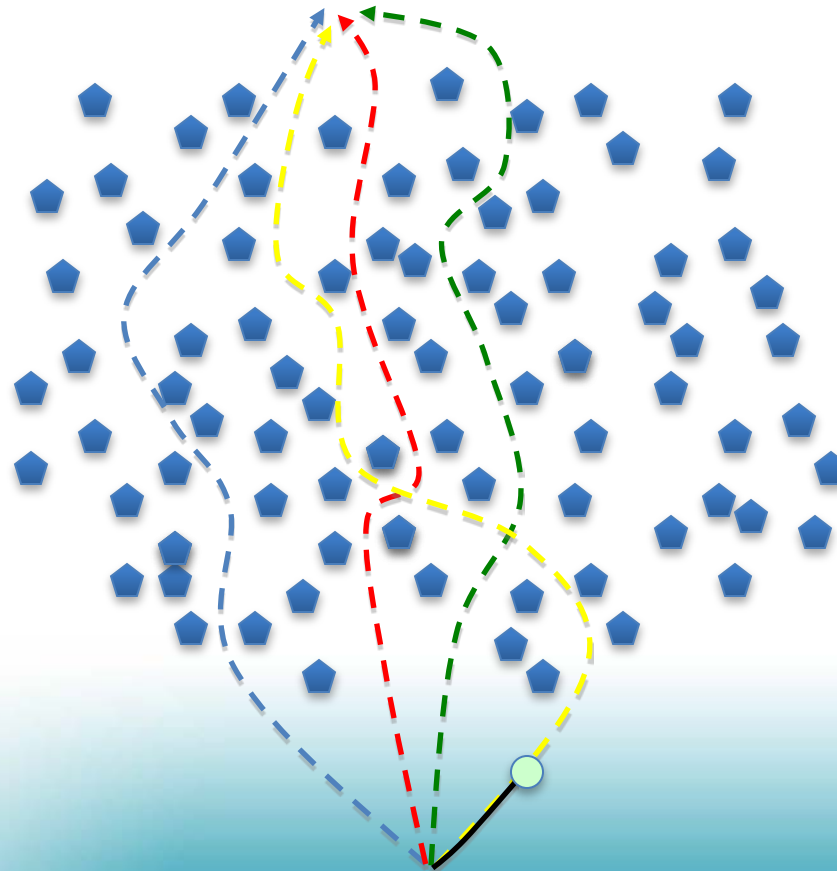




## Asteroid Belt

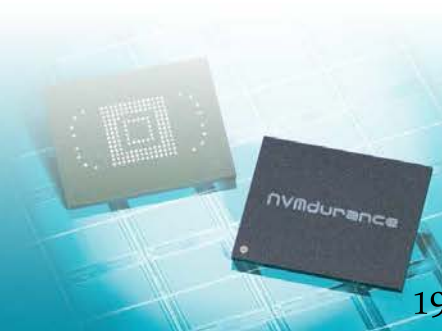
Live on device  
NVMdurance  
Navigator  
chooses which  
path to use,  
based on the  
“health” of the  
device.

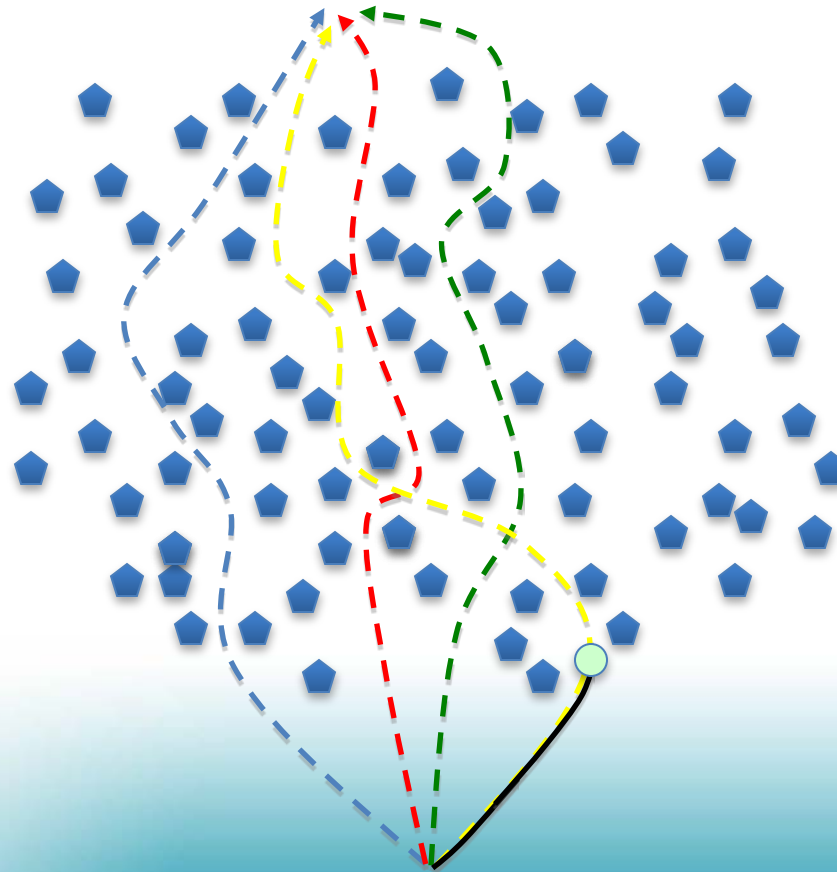




## Asteroid Belt

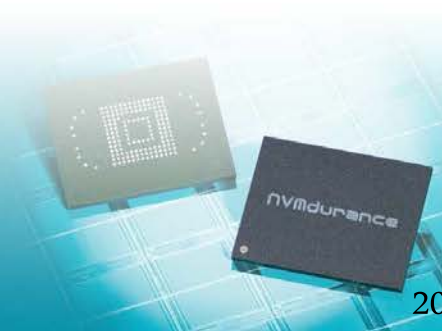
Live on device  
NVMdurance  
Navigator  
chooses which  
path to use,  
based on the  
“health” of the  
device.

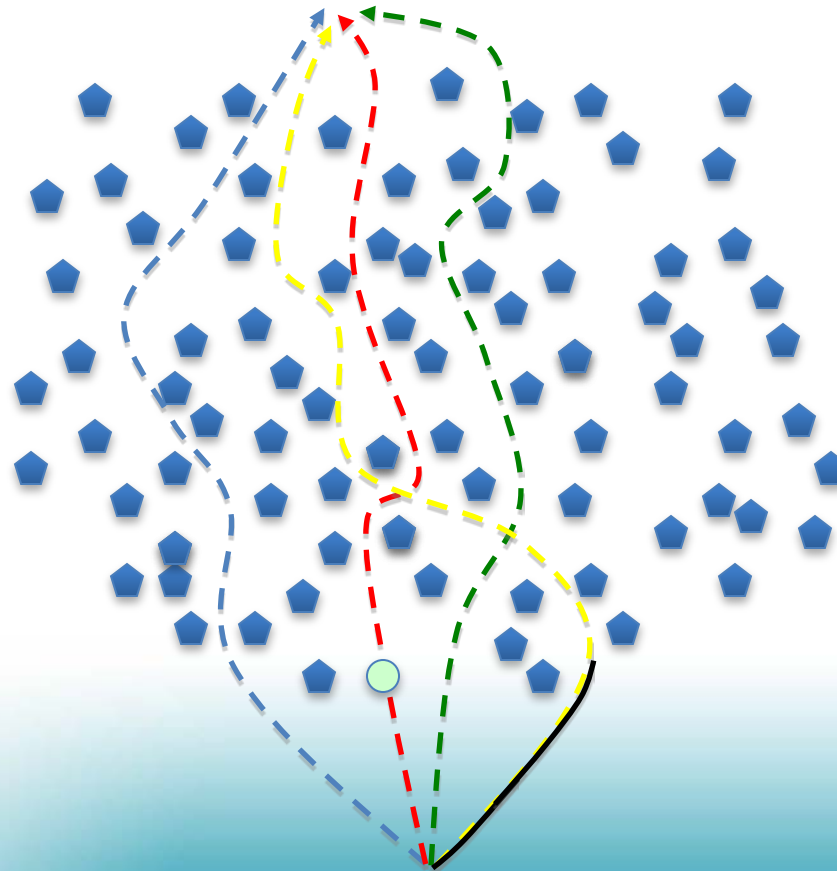




## Asteroid Belt

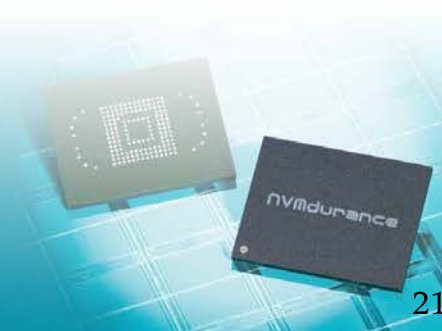
Live on device  
NVMdurance  
Navigator  
chooses which  
path to use,  
based on the  
“health” of the  
device.

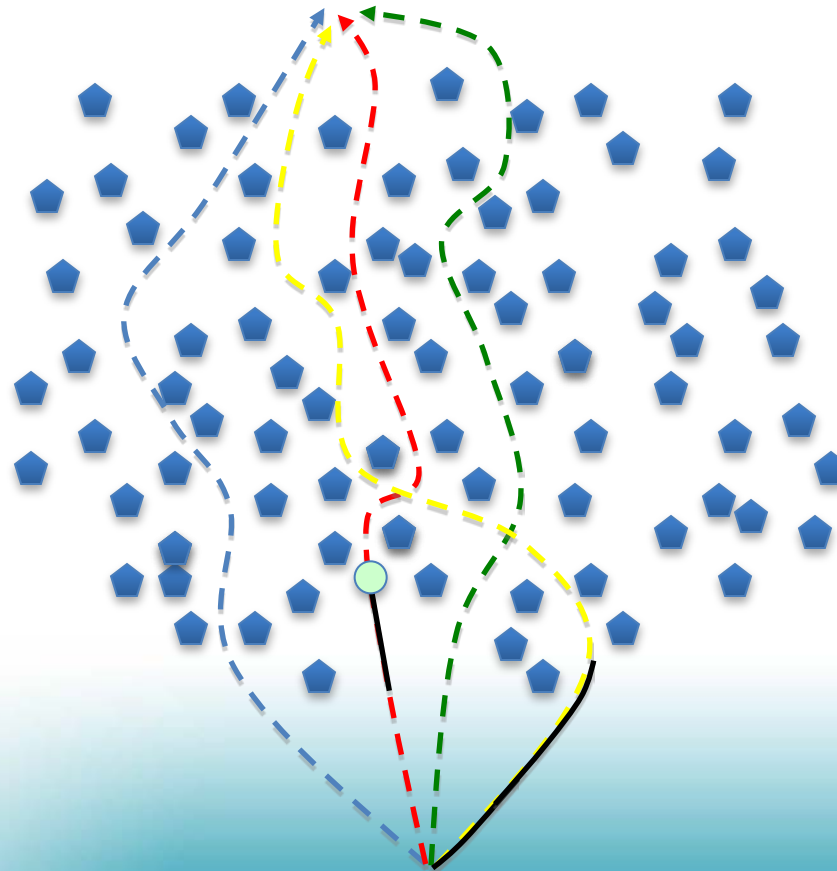




## Asteroid Belt

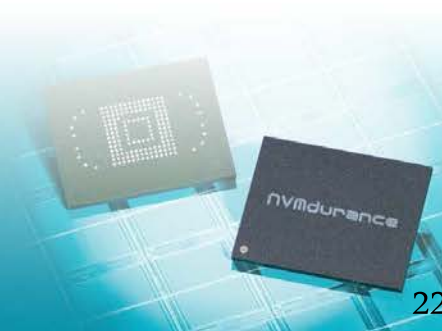
At any time NVMdurance Navigator may change to another one of the previously identified viable paths.

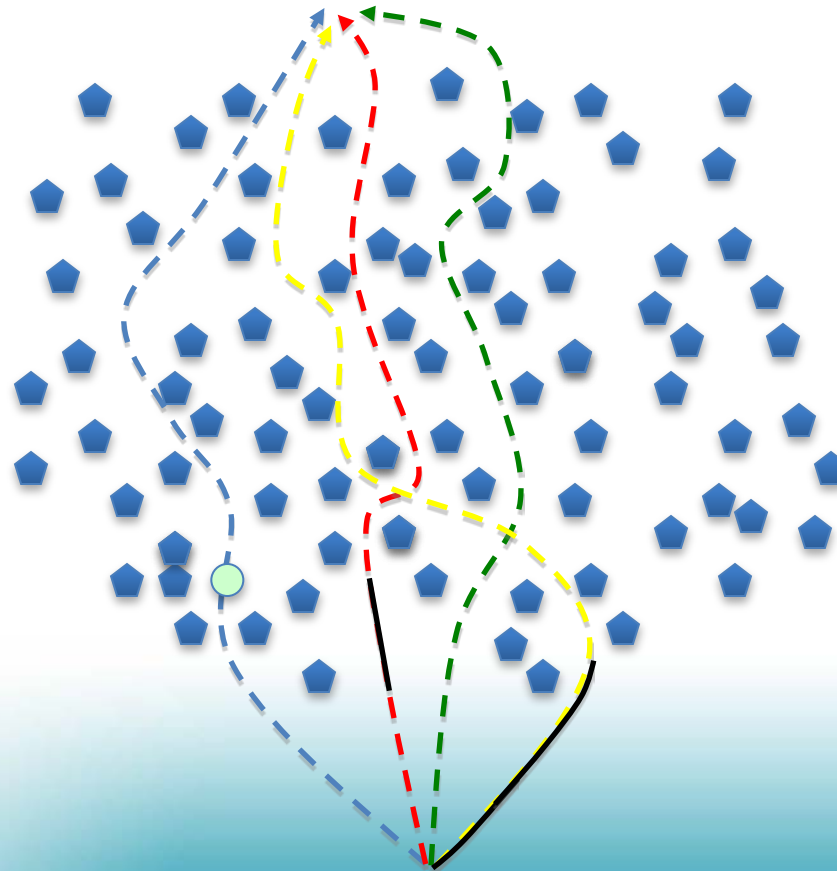




## Asteroid Belt

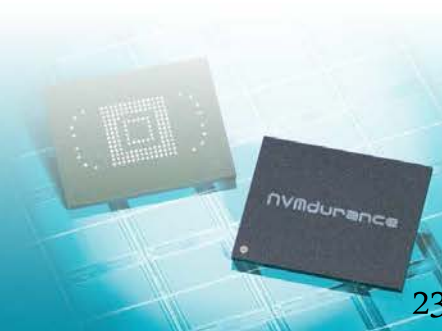
At any time NVMdurance Navigator may change to another one of the previously identified viable paths.

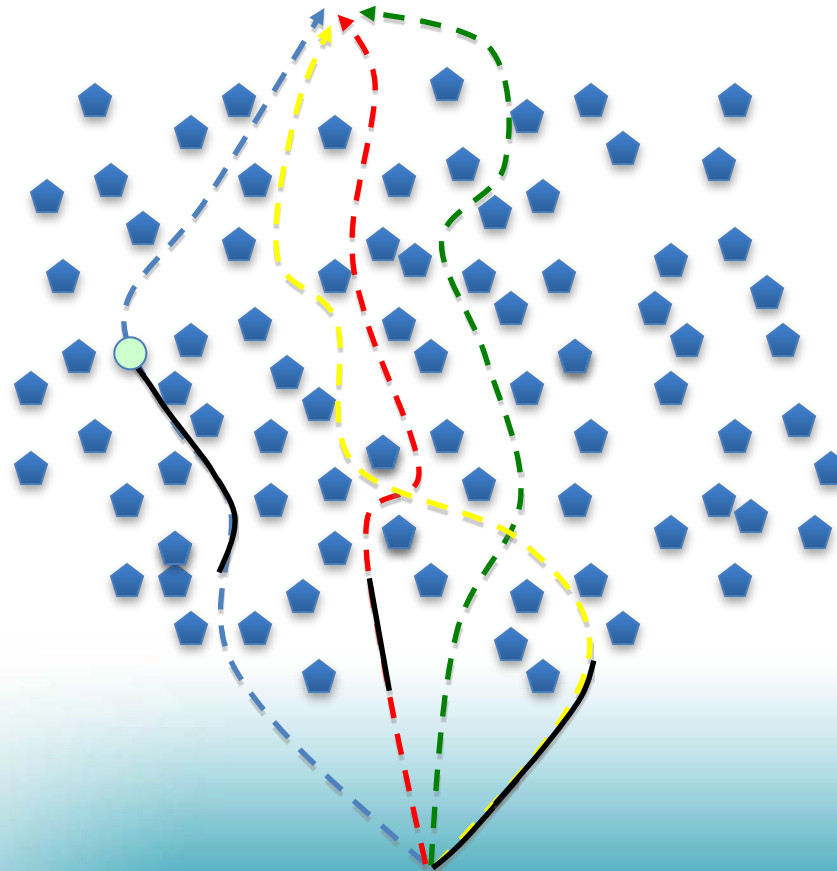




## Asteroid Belt

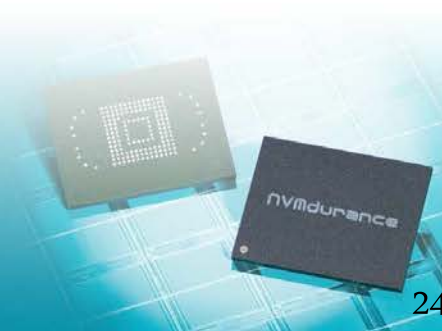
At any time NVMdurance Navigator may change to another one of the previously identified viable paths.



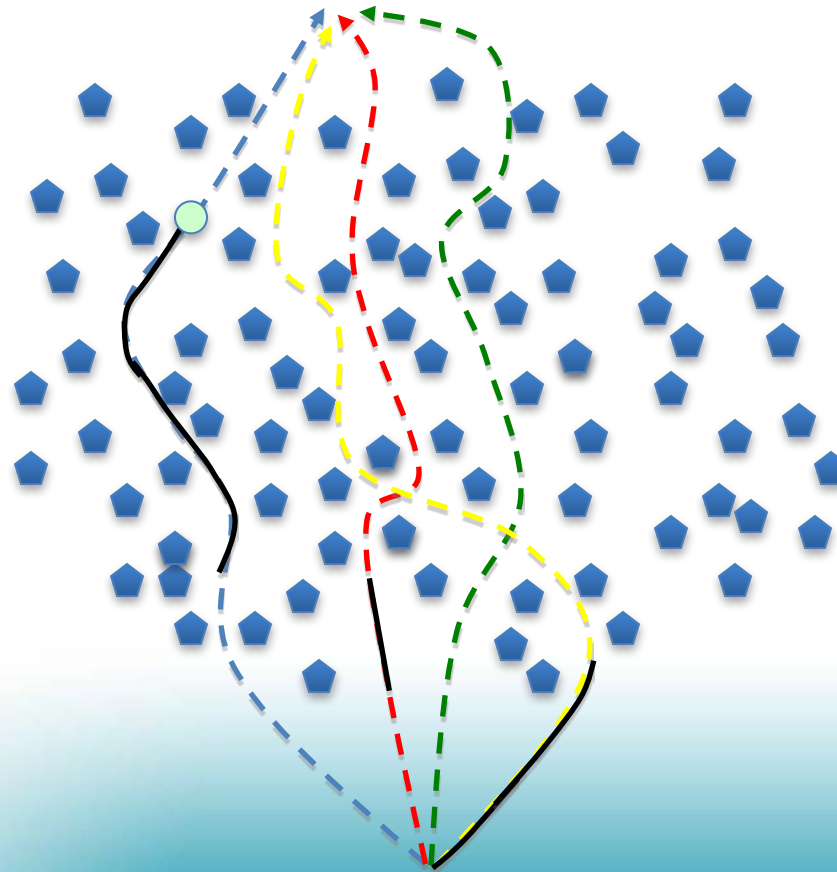


## Asteroid Belt

At any time NVMdurance Navigator may change to another one of the previously identified viable paths.

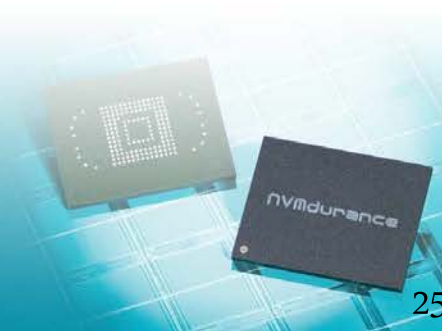


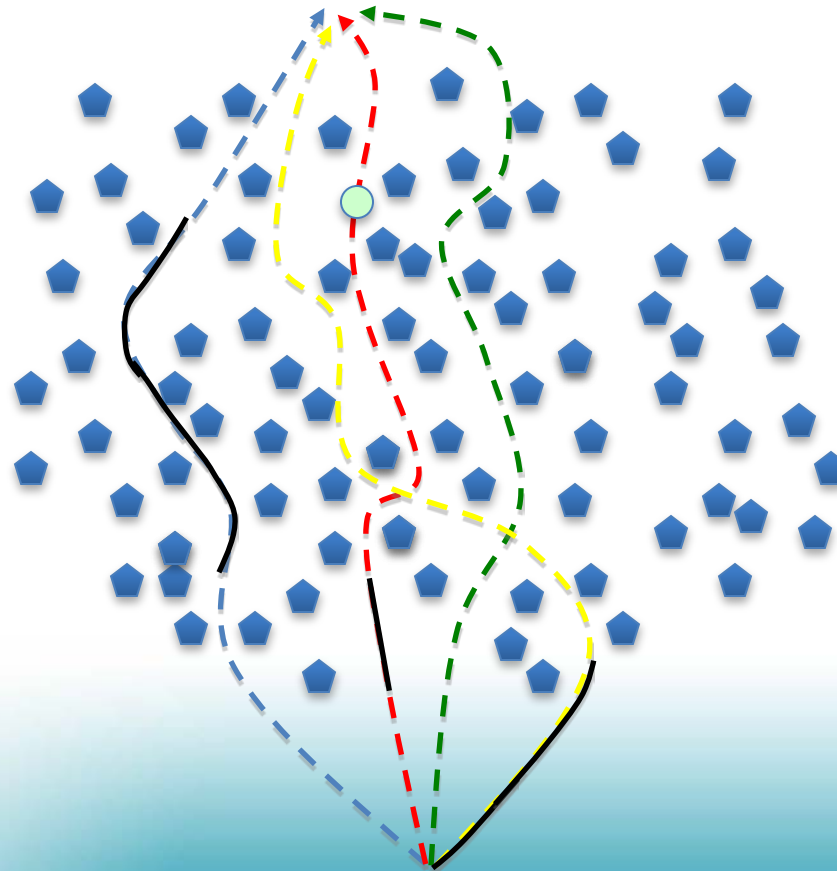




## Asteroid Belt

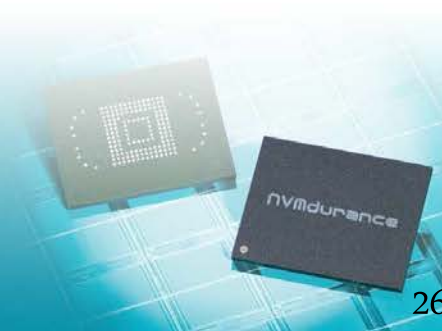
At any time NVMdurance Navigator may change to another one of the previously identified viable paths.

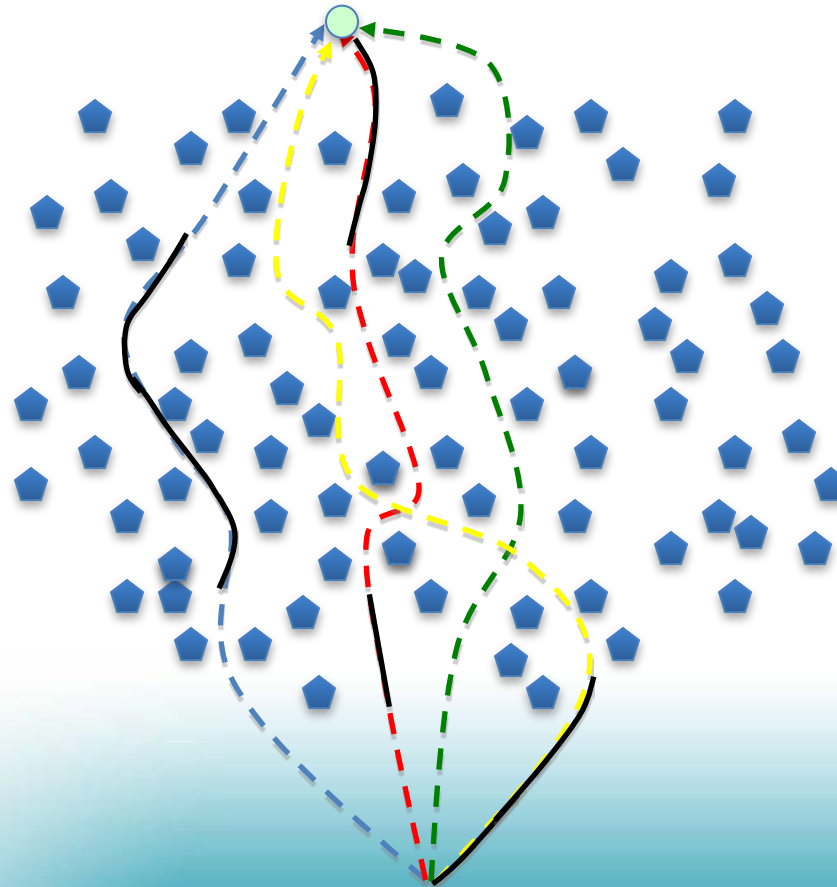




## Asteroid Belt

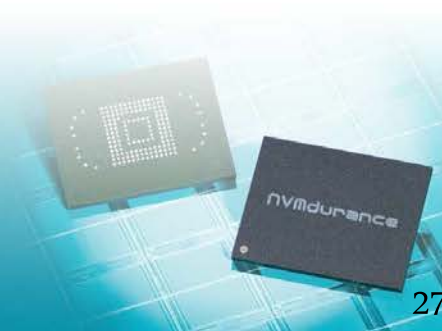
At any time NVMdurance Navigator may change to another one of the previously identified viable paths.





## Asteroid Belt

At any time NVMdurance Navigator may change to another one of the previously identified viable paths.





**Offline Preproduction Parameter Discovery**

*NVMdurance Pathfinder*: Discover routes through multidimensional space such that every parameter set passes retention for that point of life

**Autonomic (runs live on the SSD controller)**

*NVMdurance Navigator*: Observes deterioration of the SSD; chooses when to change parameters

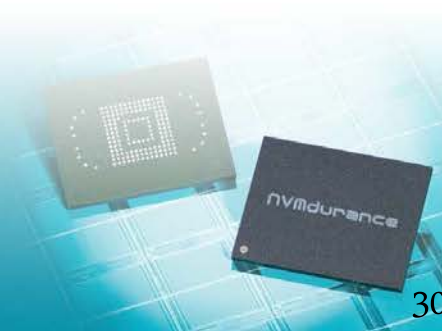


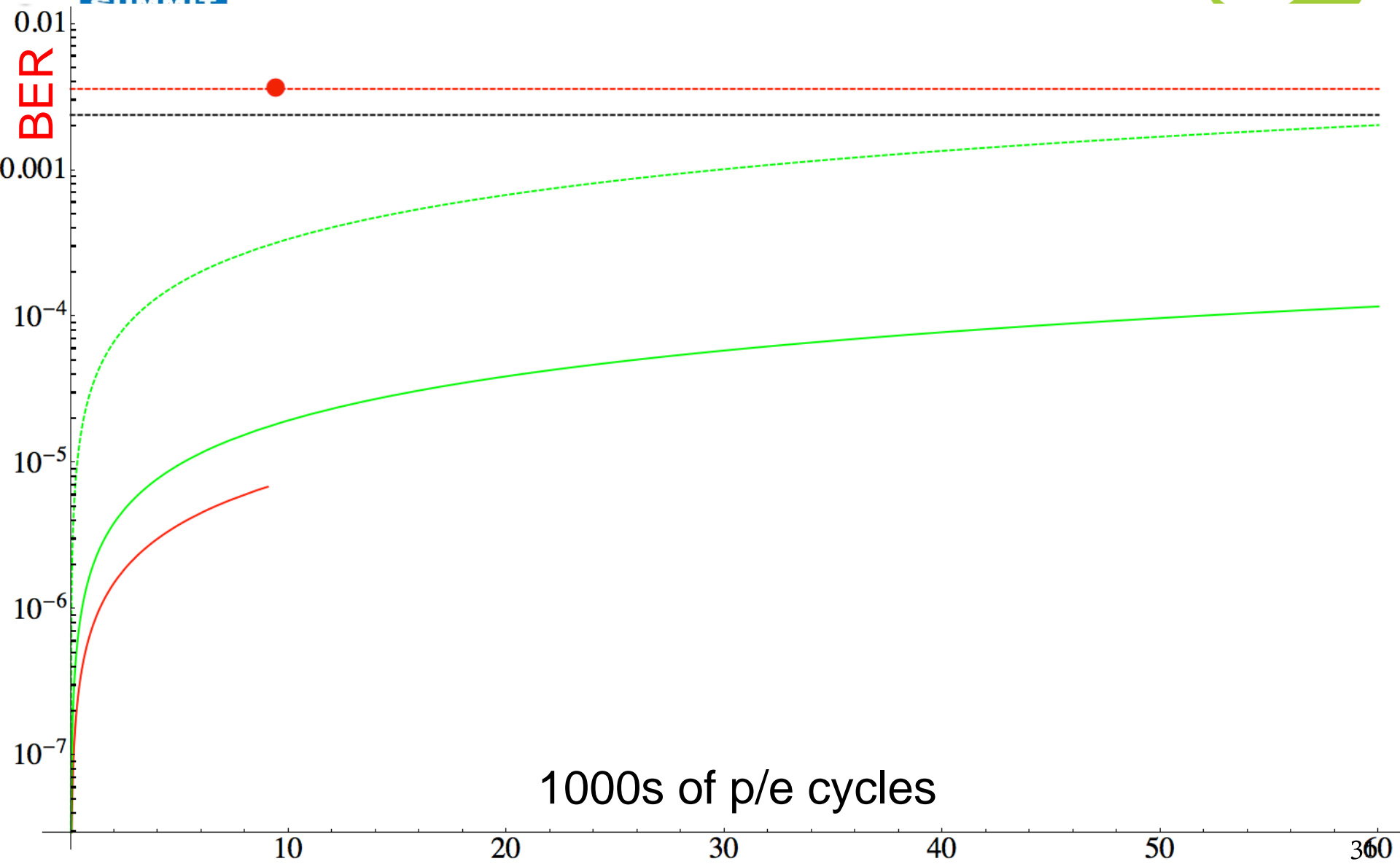
<b>Device</b>	3X
<b>Endurance</b>	3,000
<b>Retention</b>	12 months
<b>Intrinsic Endurance (3 months retention)</b>	8,000

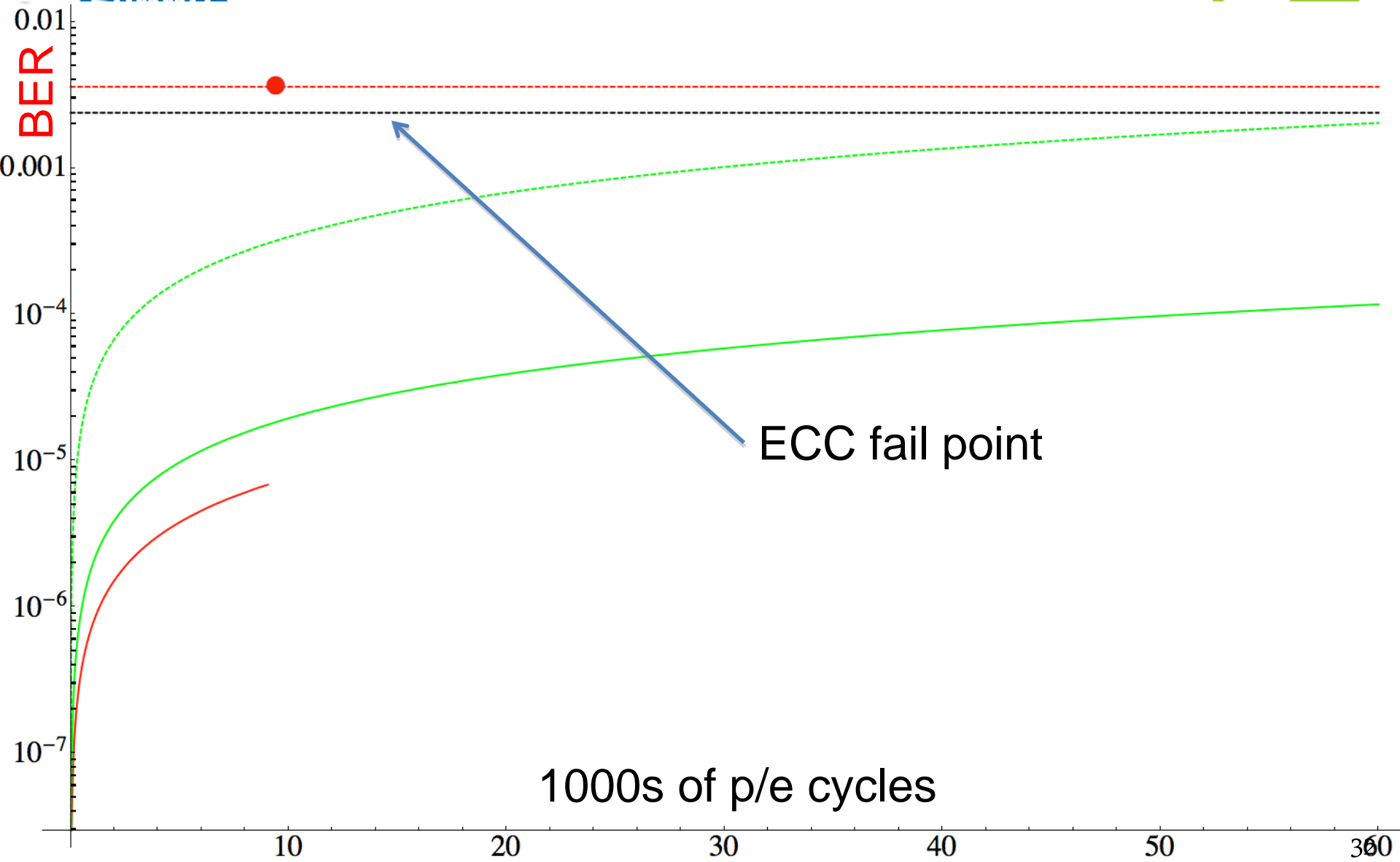


Type	p/e Cycles	Retention
3X Default	3,000	12 months
3X Default Intrinsic (lower retention)	8,000	3 months
NVMdurance	60,000	3 months

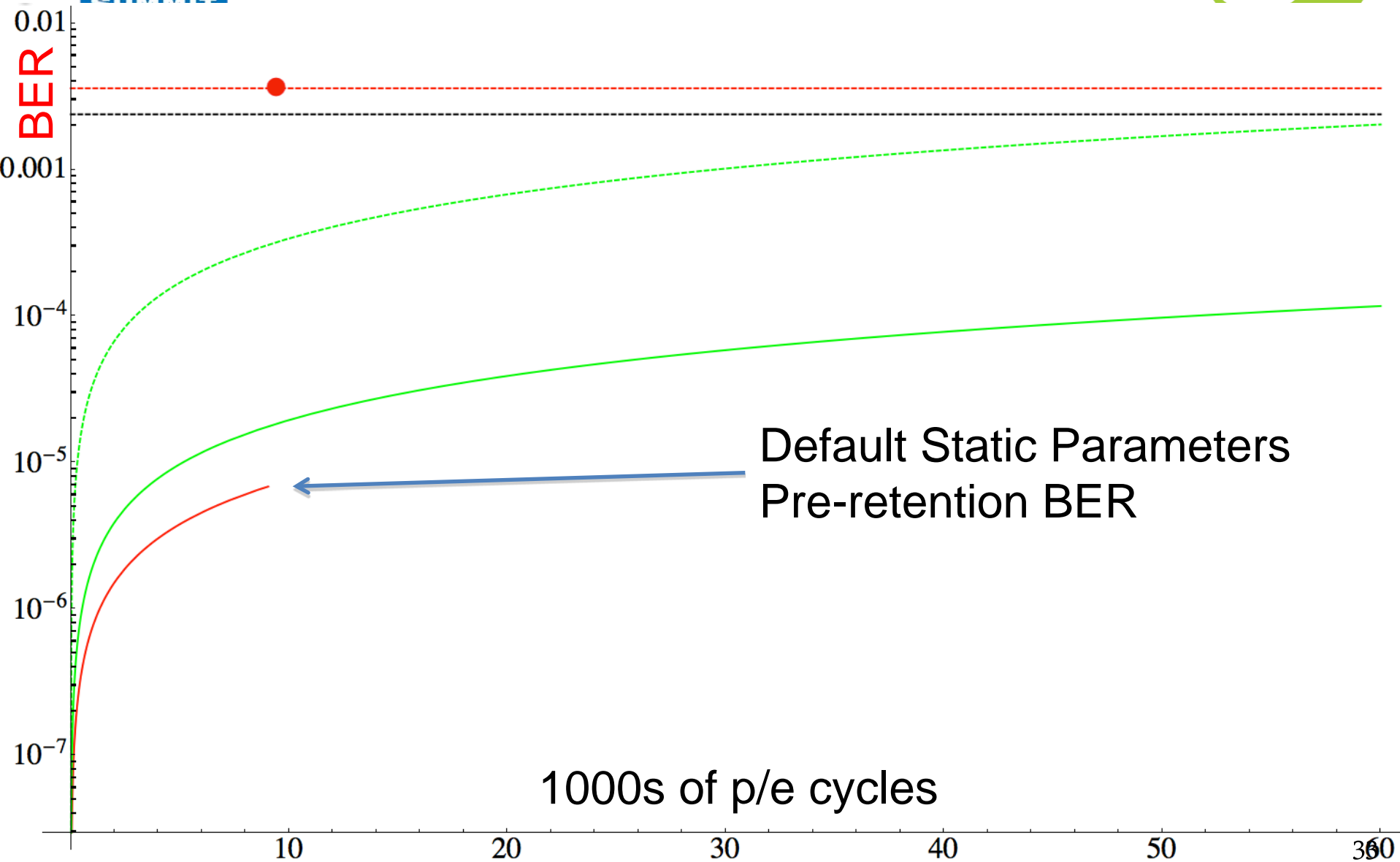
20x Improvement

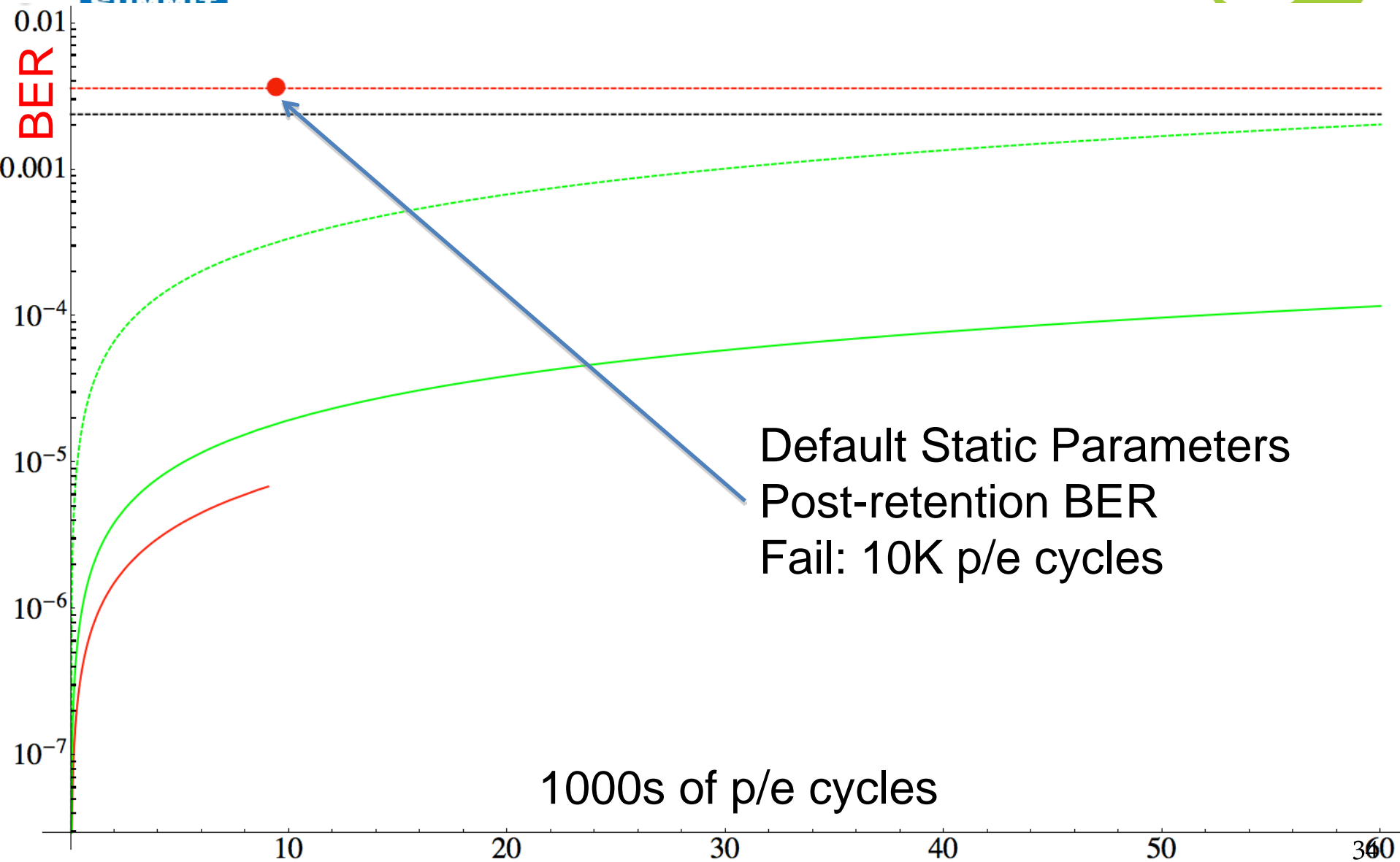


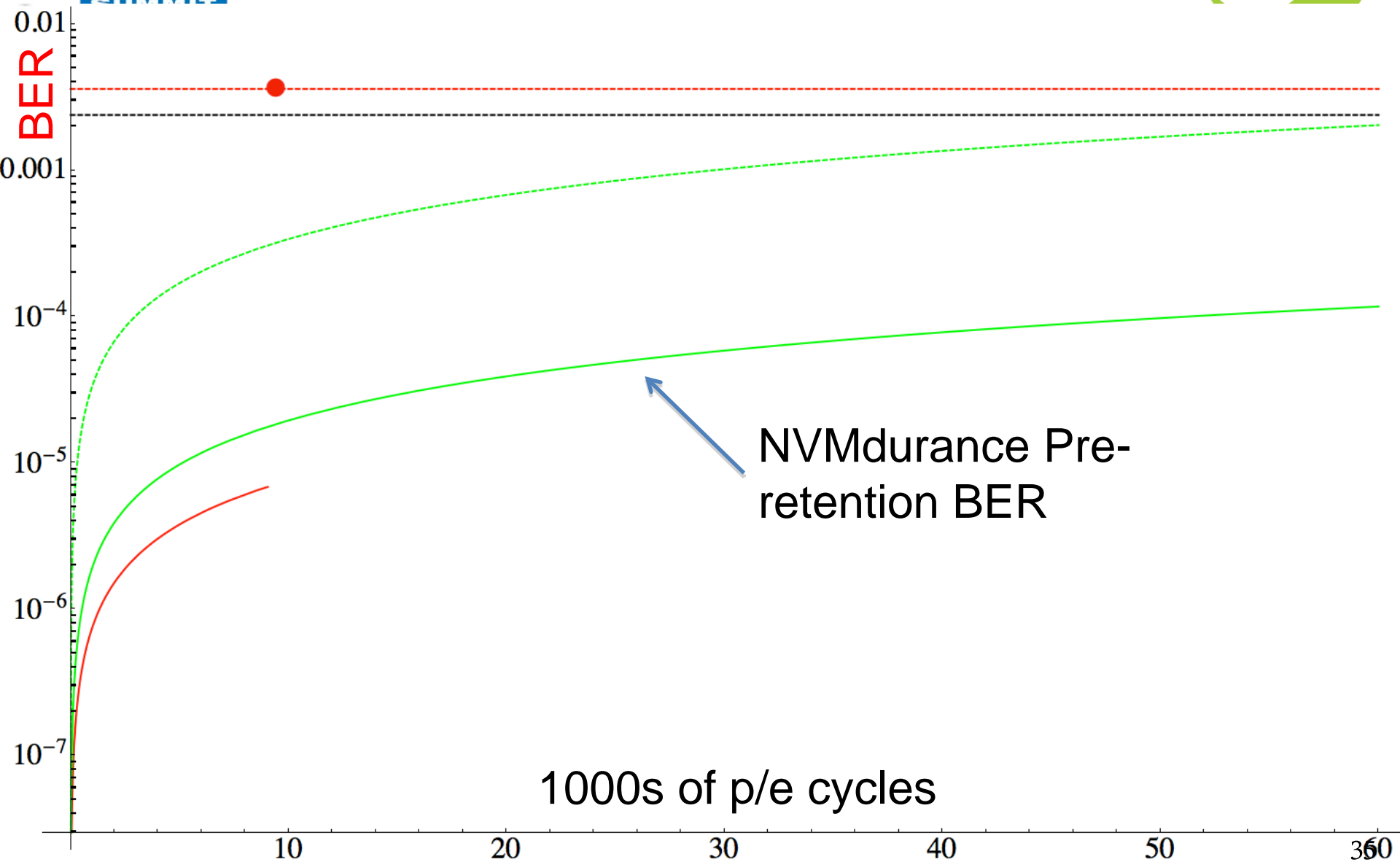


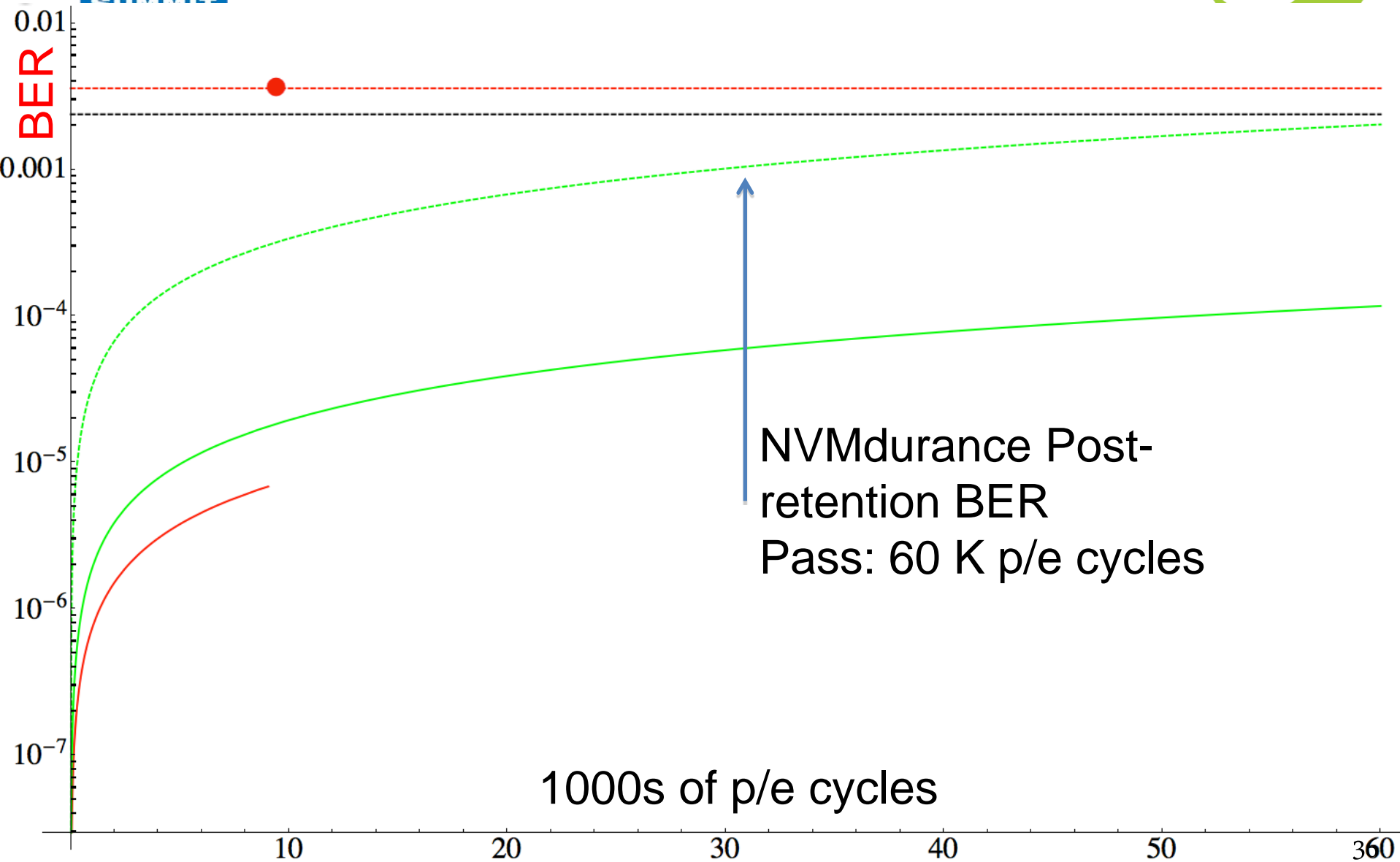


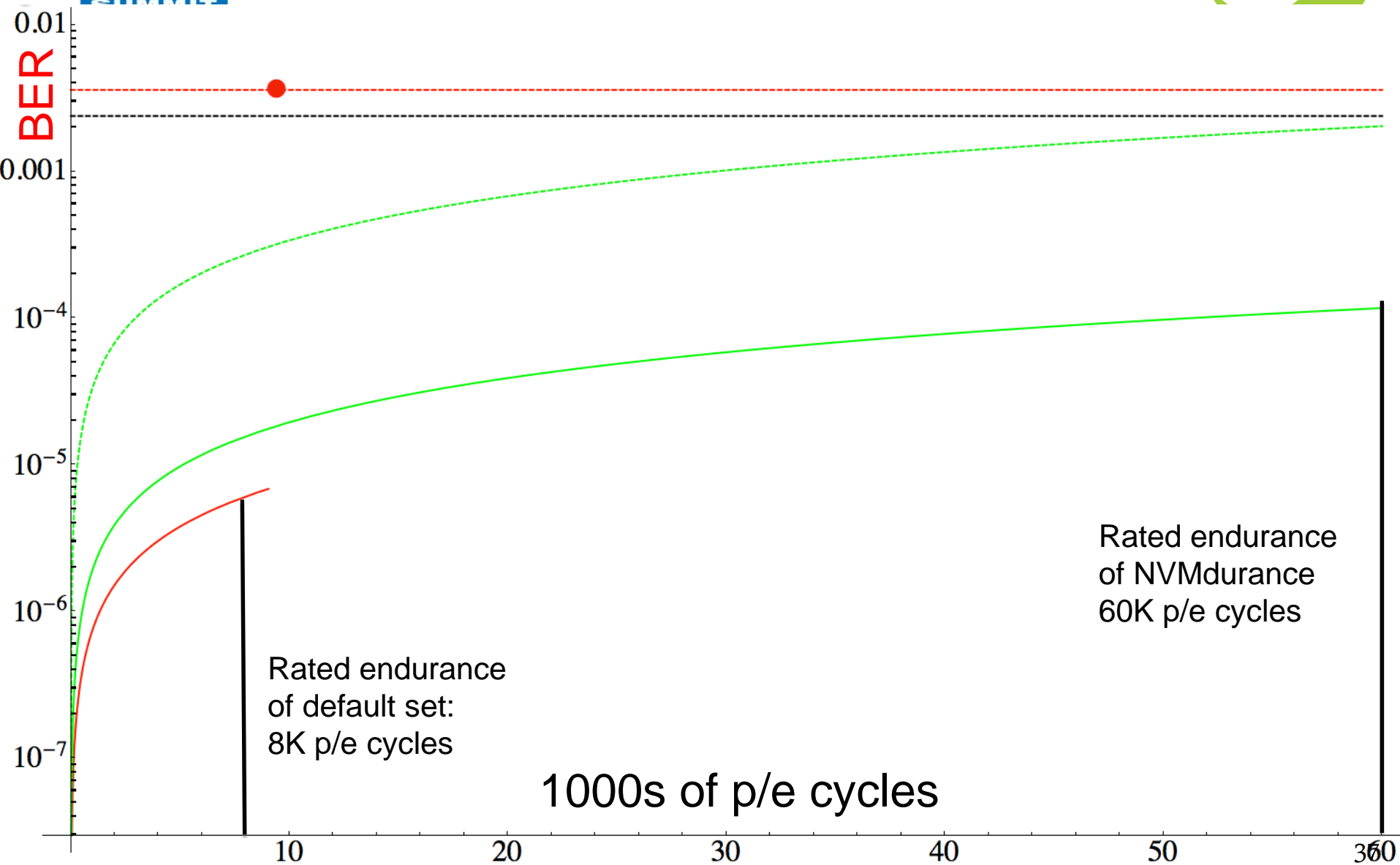












Type	p/e Cycles	Retention
1X	3,000	3 months
NVMdurance	30,000	3 months
NVMdurance Navigator 2.0	60,000	3 months

10x Improvement

In developing NVMdurance 1.0 we have identified several additional techniques that we will implement to deliver further endurance gains in later versions of the product.

- **Avoid the problem of live optimization of parameters**
  - Most work done pre-production
- **20x increase in endurance on 3X**
  - 10x increase on 1X
- **NVMdurance productized; will be deployed on live enterprise SSDs in 2014**
- **Stop by and see us at booth #917**