# The Future of SSD Architectures

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**SanDisk**

Flash Memory SUMMIT

# IS 5% ENOUGH?

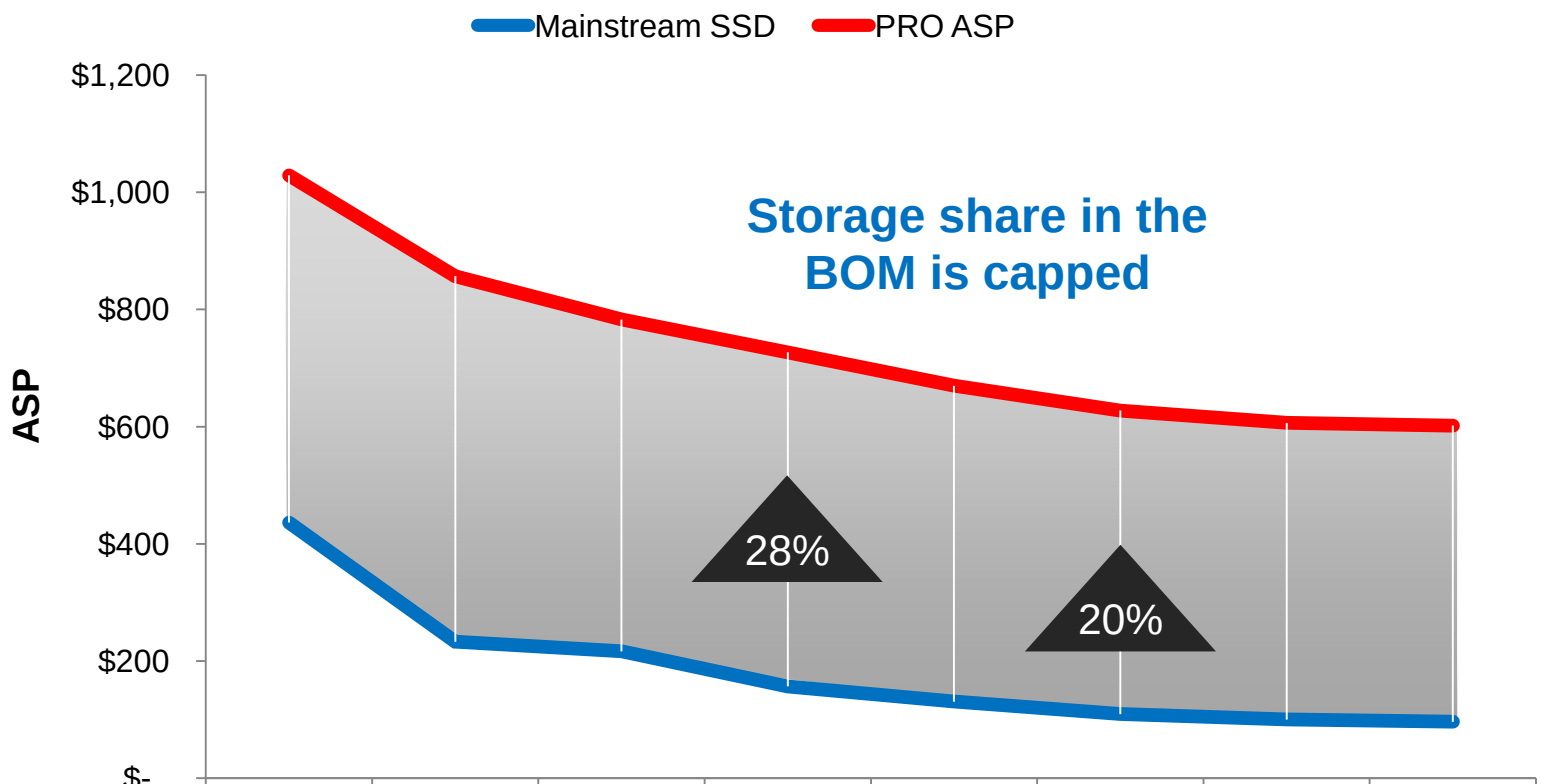
| HDD | SSD |
|---|---|
| 1 TB | 128GB |
| | • Instant On<br>• Lightweight<br>• Slim<br>• Longer battery life<br>• Rugged |

Source: analysts average PC SSD attach rate: 2010

SanDisk®

# Cutting SSD Cost Is Needed to Drive Growth

## SSD ASP vs. PC ASP

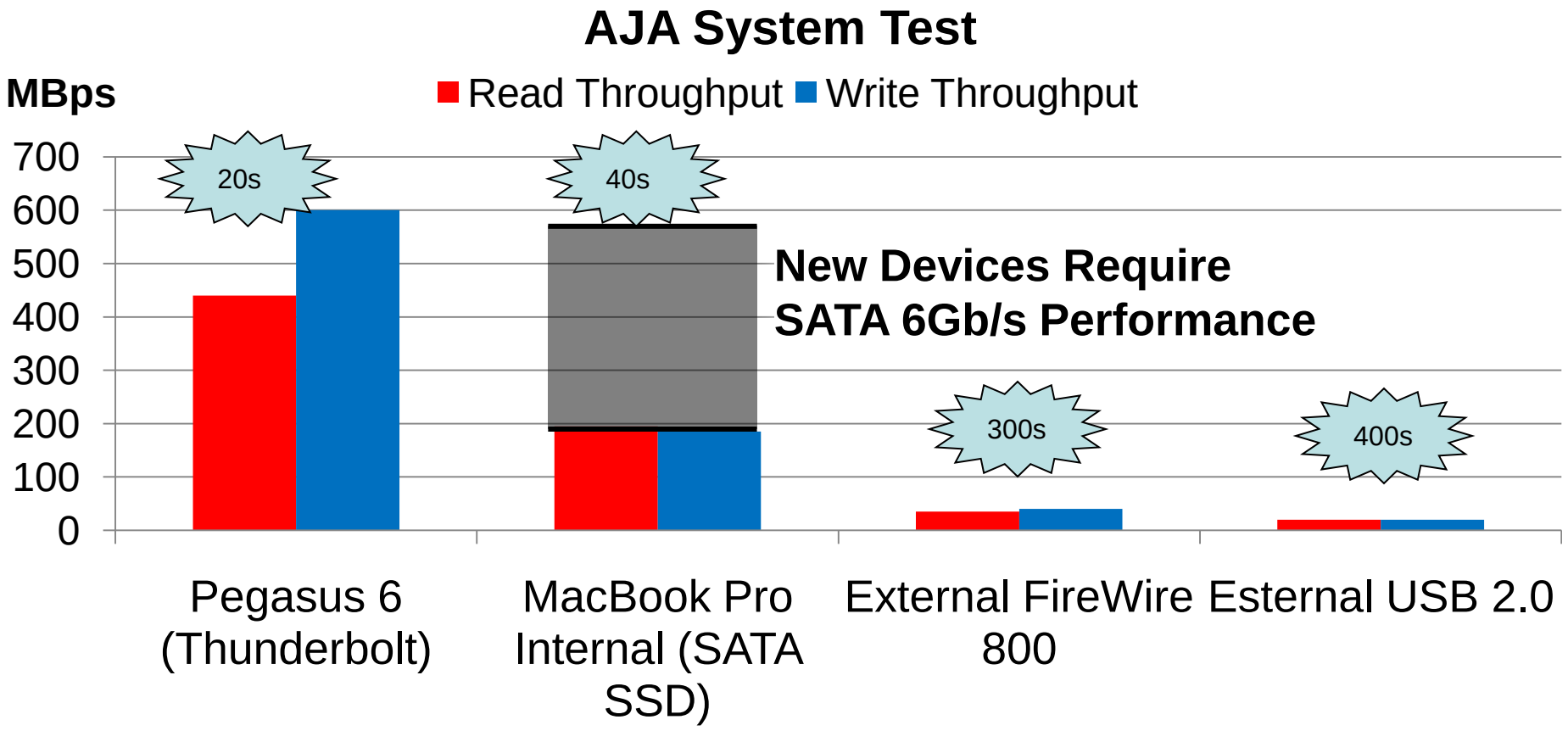



| | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|
| Mainstream SSD | $436 | $233 | $216 | $157 | $131 | $110 | $100 | $96 |
| PRO ASP | $1,029 | $857 | $783 | $727 | $670 | $627 | $606 | $602 |



Gartner Q2/'11

# Use Case 1 – Super Fast Side Loading




(*) copy time in seconds for HD movie

**Source:** http://www.pcmag.com/article2/0,2817,2388114,00.asp

# Use Case 2 – Read or Write Intensive

**Consumption Class**

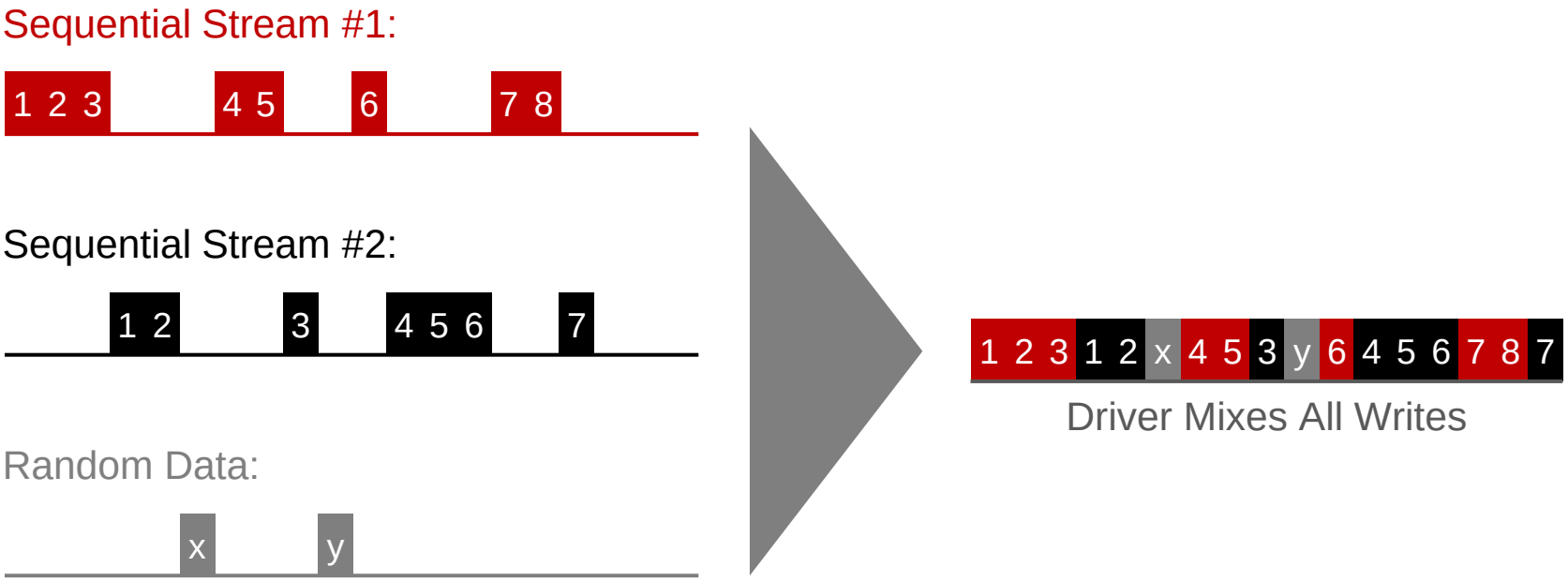

**Creation Class**




Source: Sandisk internal testing

# Use Case 3 – Multi Tasking

1. Outlook
2. Windows Media Player,
3. Internet Browser (Download)



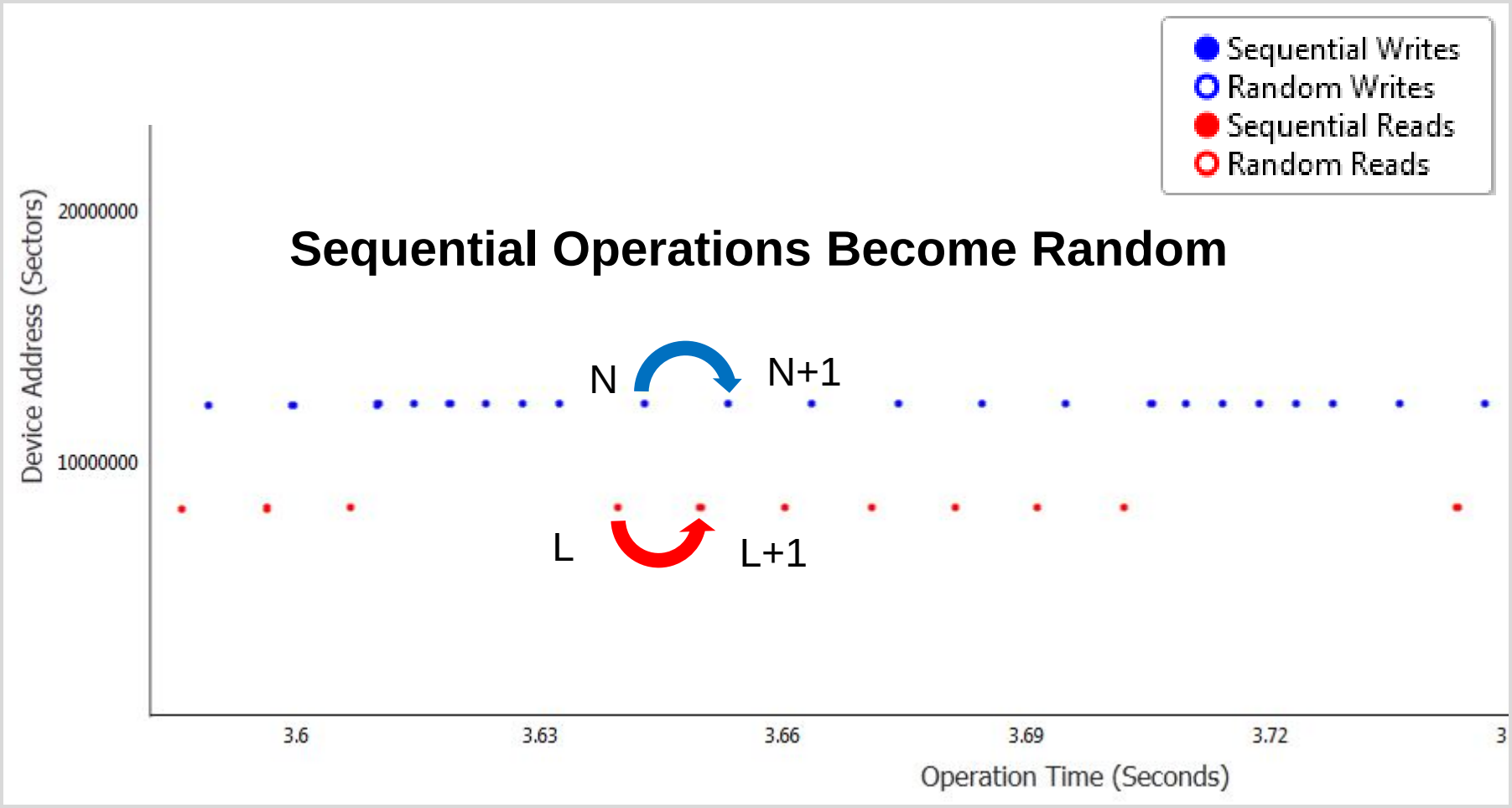
# Use case 4 – Instant On without Losing Battery Life

- **What's Wrong with Existing Sleep?**
  - Empties battery as memory remains powered
  - Not safe – loss of last saved work in case of power outage
- **New Deep Sleep Enabled by SSD's**
  - Data in memory is saved in hiberfil.sys
  - Computer can shutdown completely achieving much longer standby time
  - Safe – data is saved

# In-depth Analysis of Real Computing Usage Workload: Copy File Example

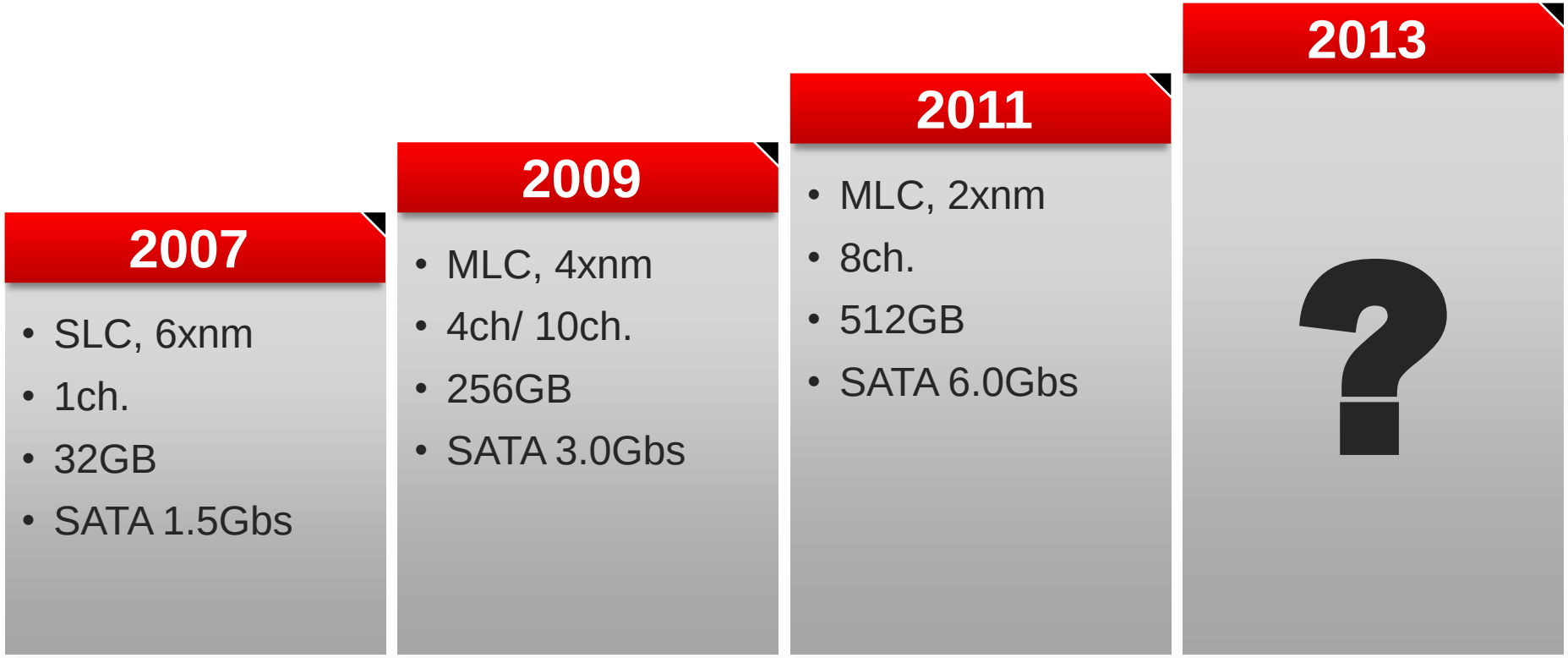

Source: SanDisk internal testing

# Zoom-In




Source: SanDisk internal testing

# SSD Architecture Evolution




**How Do We Keep Scaling and Provide Performance and Reliability of SSD?**

# Features Tailored for Usage Scenario

| USE Case | Challenge | Architecture Features (examples) |
|---|---|---|
| **Multi Tasking** | | |
| **Fast Side Loading** | | |
| **Instant On** | | |

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| **Instant On** | | |

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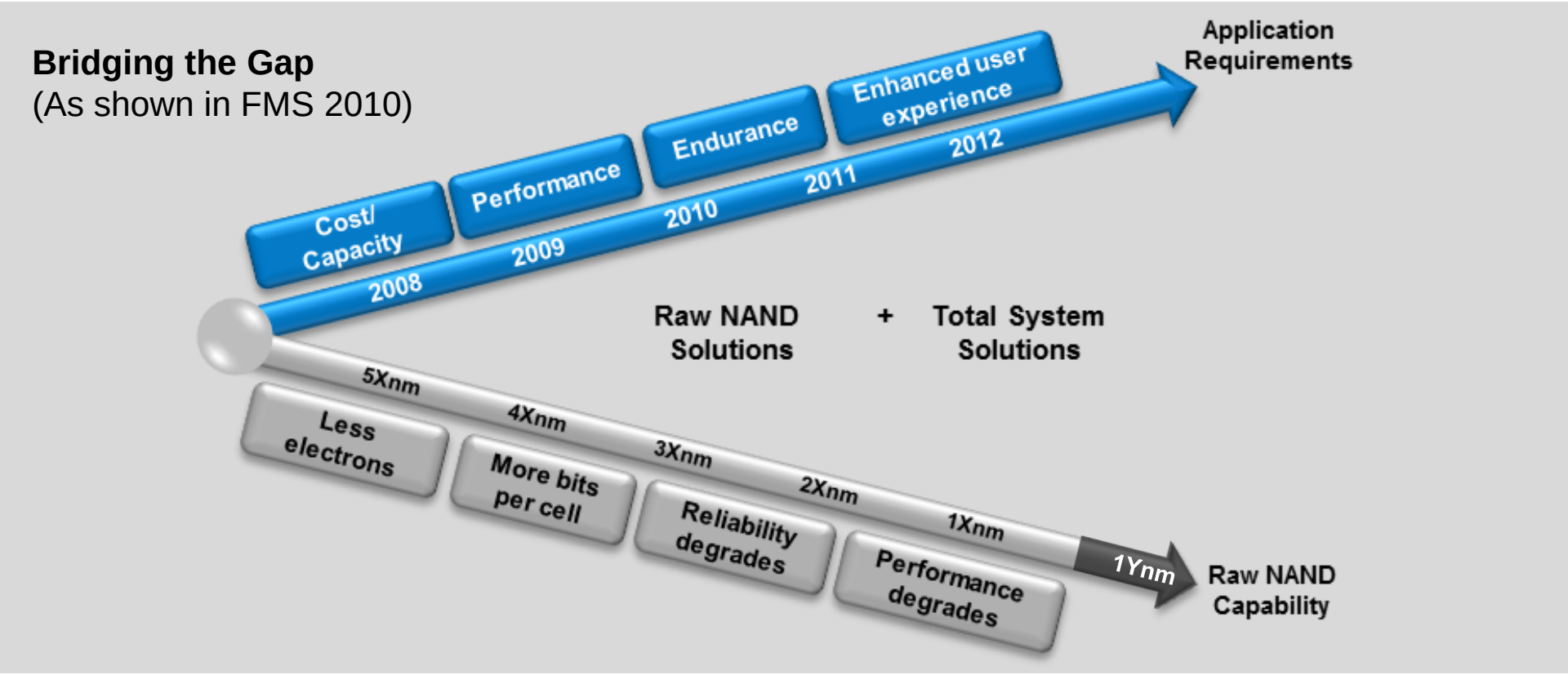
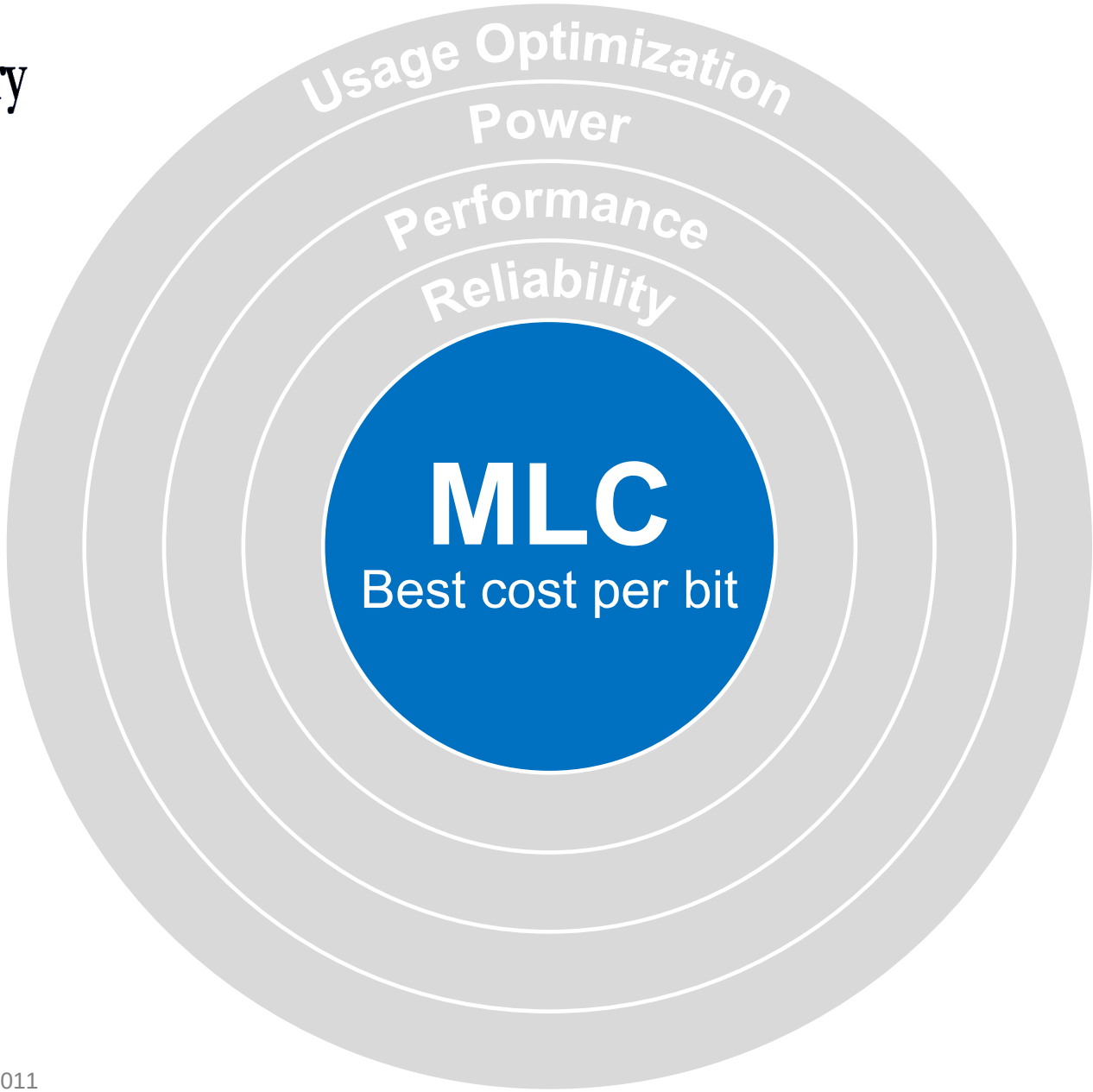
| **Fast Side Loading** | Fast sequential write, higher peak power | Parallel Multi die / Plane interleave Thermal throttling |
| **Instant On** | Multiple power off/on Access to first I/O | Quick mount Optimize single thread read |

# From Our FMS 2010…

- What Changed?



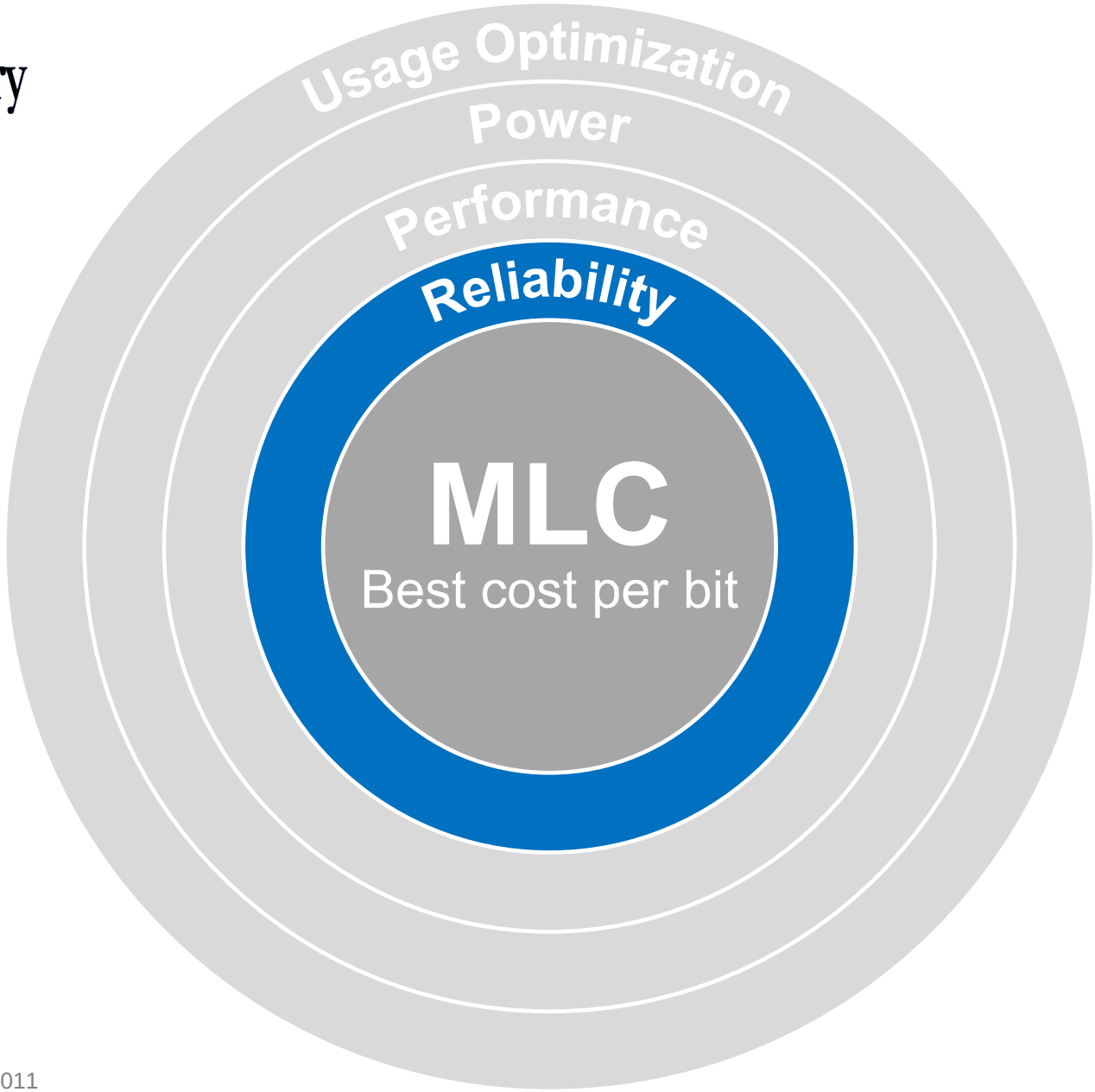
# NAND BASICS


Usage Optimization
Power
Performance
Reliability
MLC
Best cost per bit


# NAND Technology

## 3 Leveled Cost Reduction:

- **NAND Process**
  - 24nm in Mass Production
  - Migrating to 19nm in H2/2011
  - Expected to Continue Scaling
- **3-bits-per-cell**
  - Mature 4th Generation 3-bits-per-cell Technology
- **High Capacity Die**
  - 24nm 2-bit-per-cell – 64Gb
  - 19nm 3-bit-per-cell – 128Gb
  - Less Die Stacking for a Given Capacity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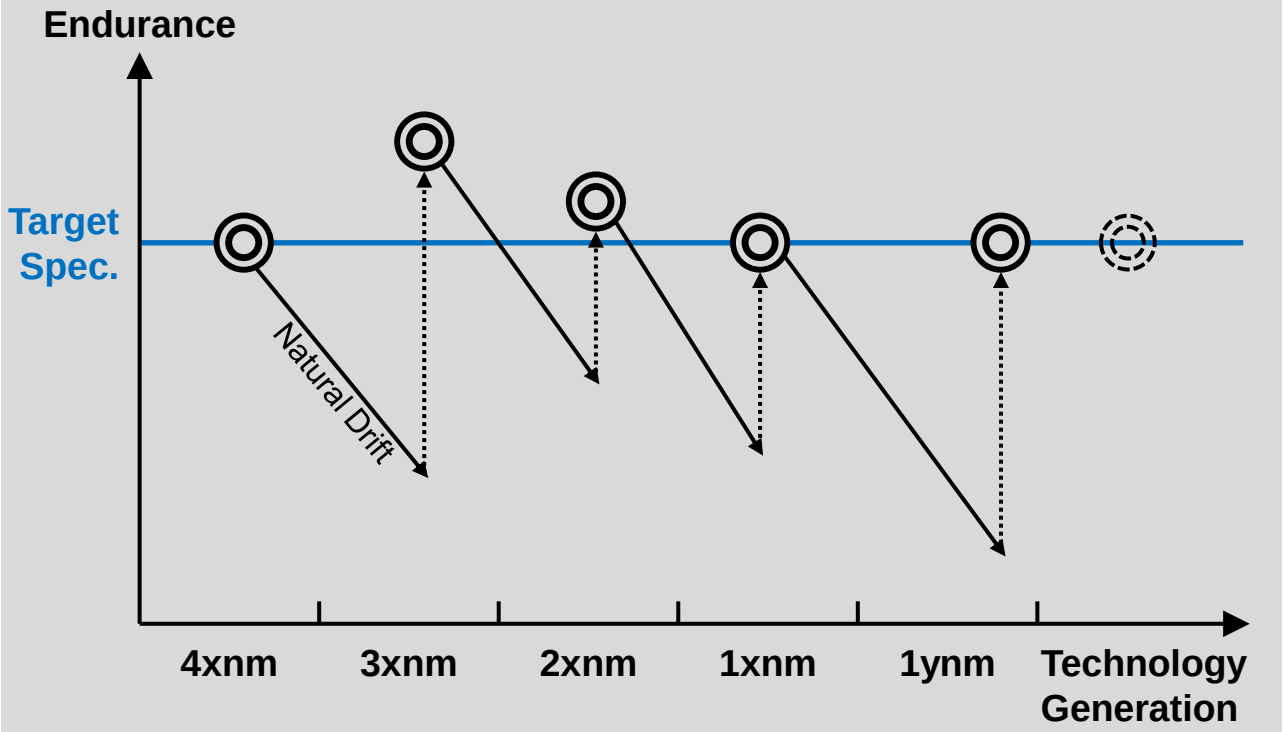
# Enhancing NAND Technology
## Reliability

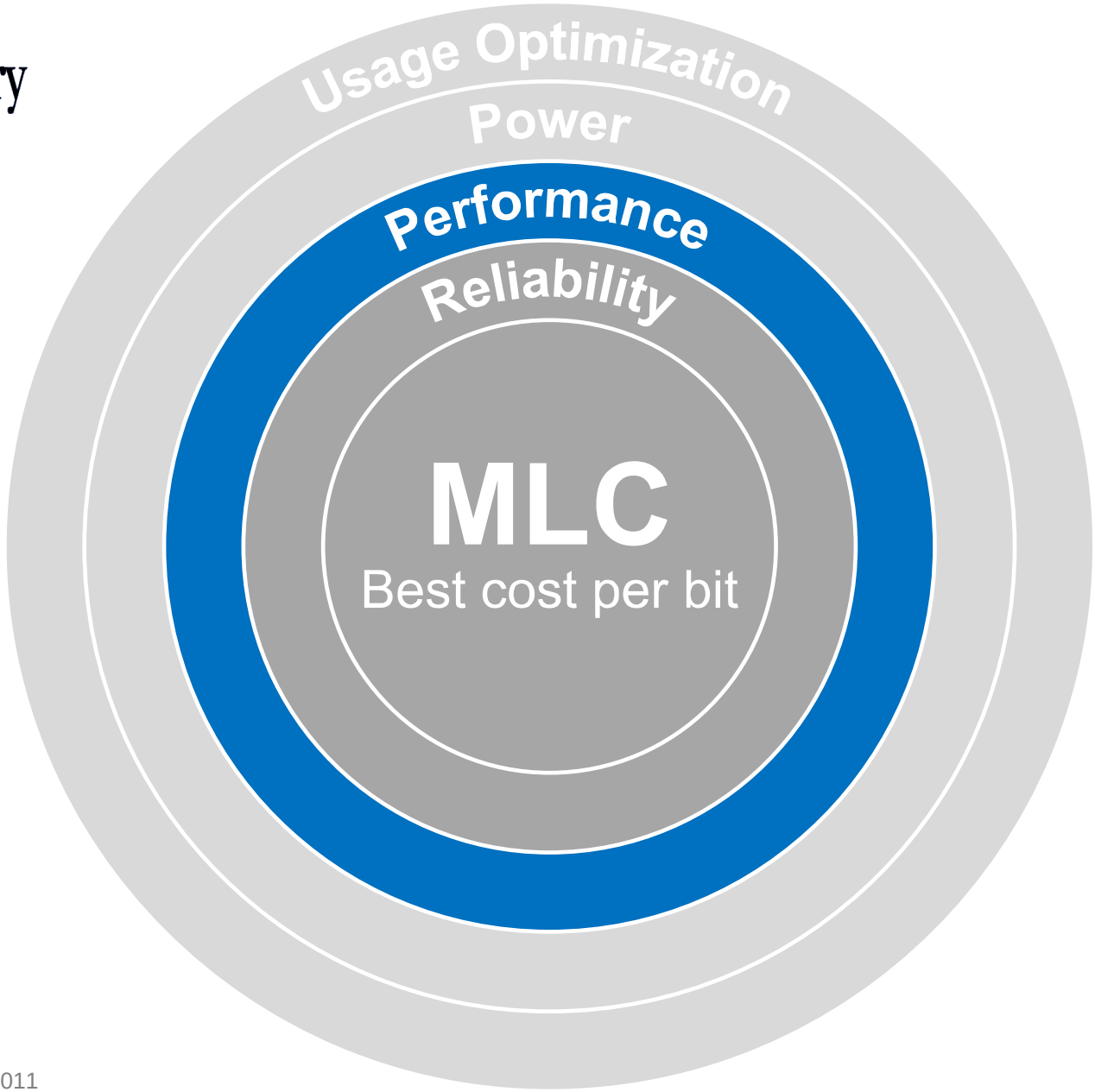
*Based on SanDisk Internal Evaluation*

**Goal:**

Maintain ***Endurance*** Target while Scaling – Overcome Natural Drift




1) Increase VT Window
2) Dynamic Read
3) Air Gap
4) Proprietary Process, Cell & Programming Scheme Optimization
5) Data Randomization / Scrambling
6) nCache™
7) Hybrid FG Cell Design
8) StrongECC™ + DSP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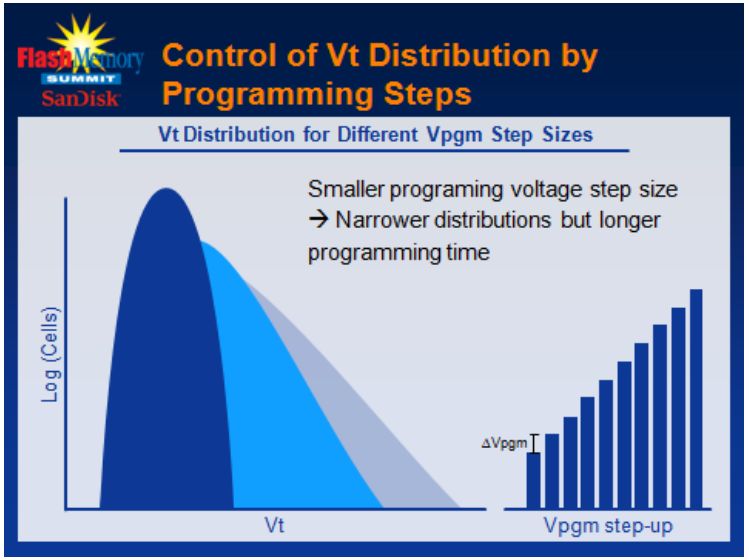
# Enhancing NAND Technology – Sequential Performance

**Goal:**
Maintain ***Performance*** while Scaling – Overcome Natural Drift

- Larger Page Size
- All Bit Line Architecture (ABL)
- Parallelism:
  - Multi-Plane in a Die
  - Multi Die in a Product
- Bus performance (e.g. Toggle Mode)
- StrongECC™+ DSP



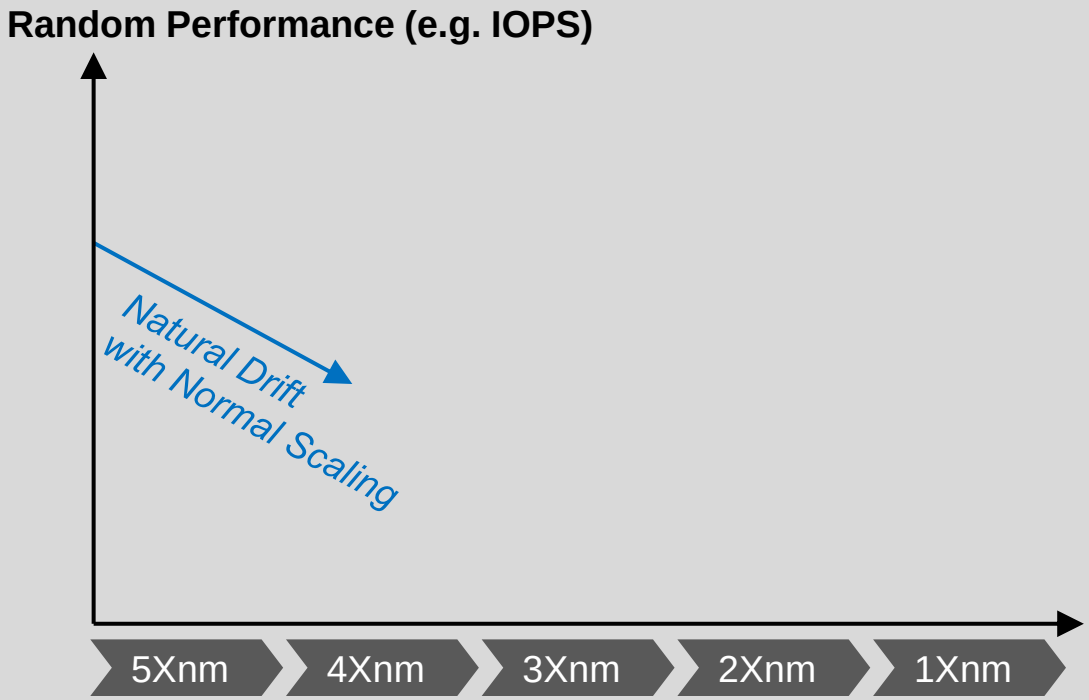

Source: Klein/Oren FMS 2010

**Enable Higher Performance Level**

# Enhancing NAND Technology – Random Performance

*Based on SanDisk Internal Evaluation*

**Goal:** Maintain ***Random Performance*** while Scaling – Overcome Natural Drift

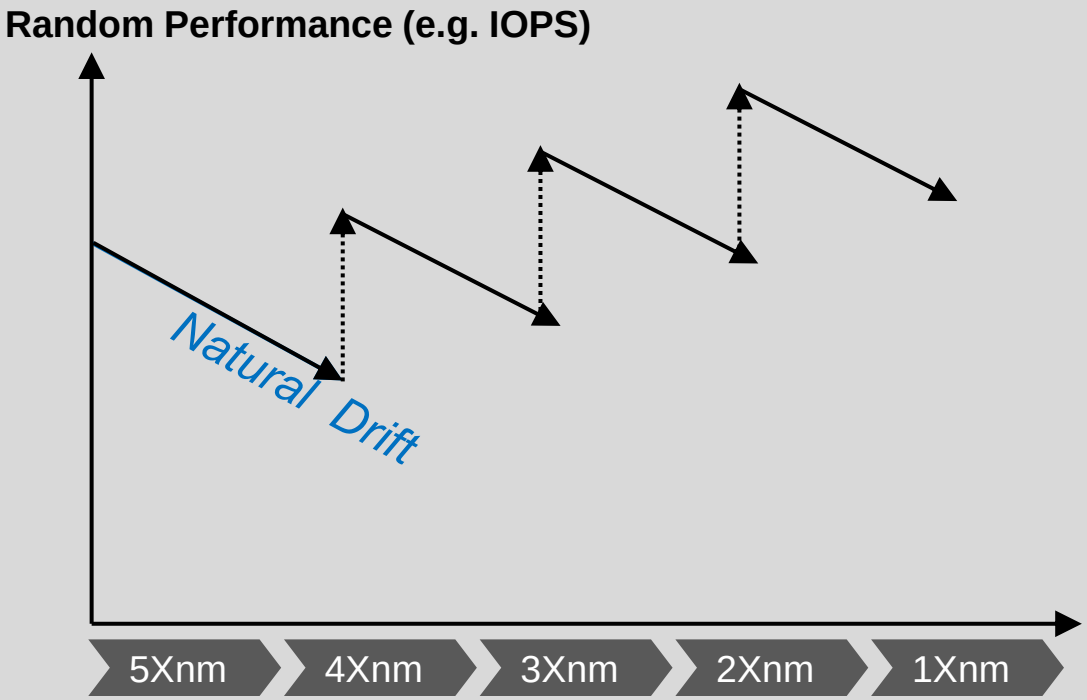



Natural Drift of t-Prog capability
Negative Impact of increase in page size

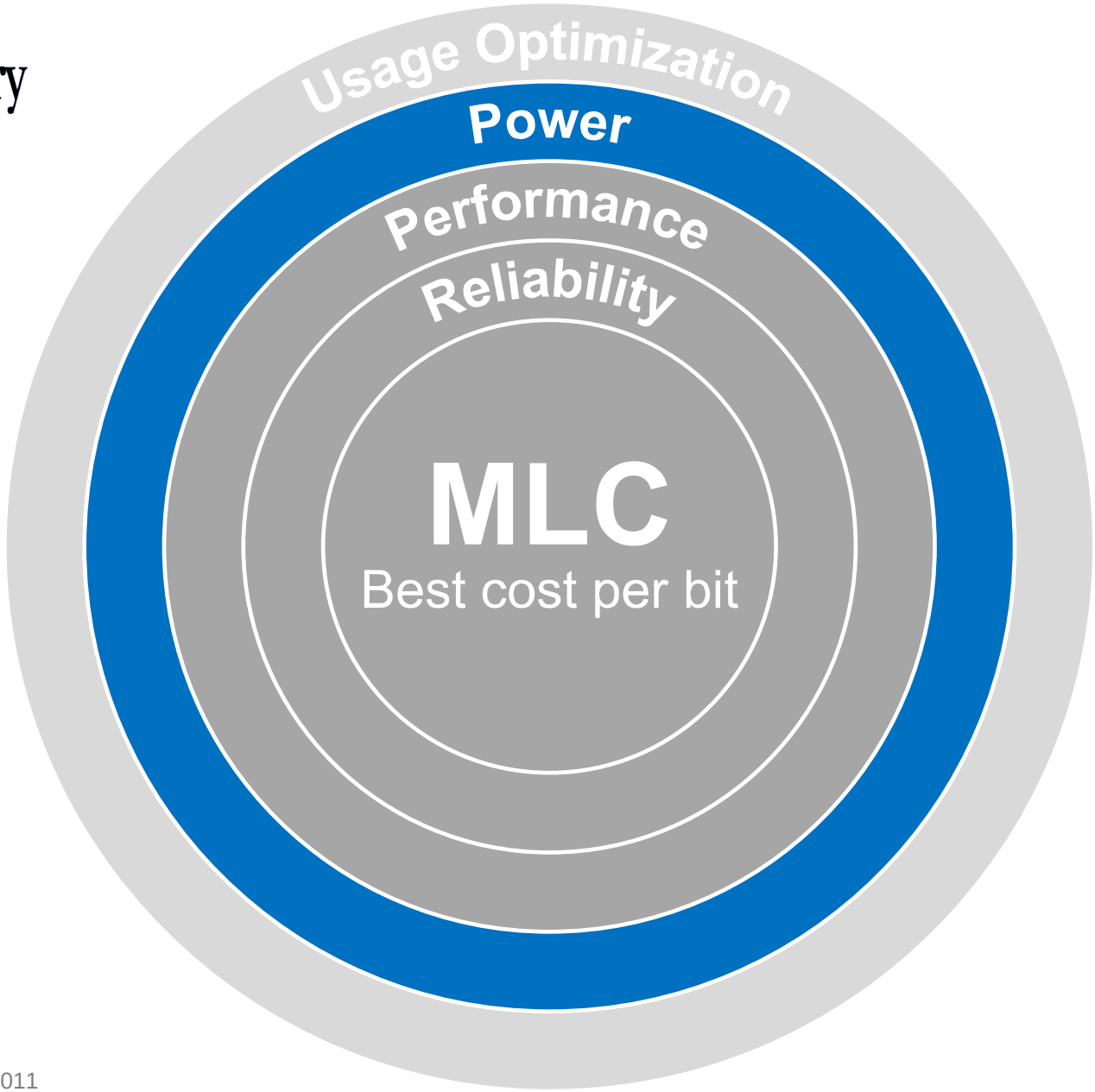
# Enhancing NAND Technology – Random Performance

*Based on SanDisk Internal Evaluation*

**Goal:** Maintain ***Random Performance*** while Scaling – Overcome Natural Drift




1) Cache Technology and Optimization per usage
2) Page Based Mapping
3) Proprietary WL/BL RC reduction
4) StrongECC™ + DSP Optimized for Random Performance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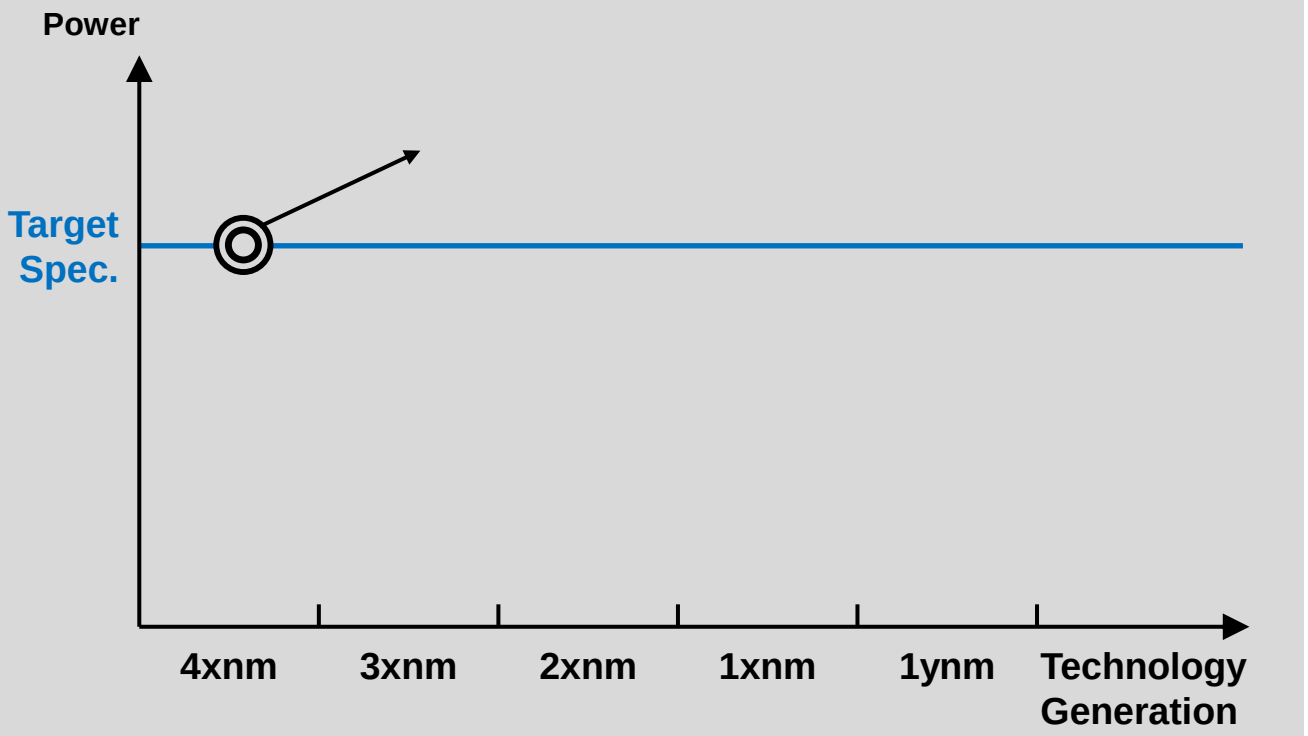
# Enhancing NAND Technology – **Power**

*Based on SanDisk Internal Evaluation*

**Goal:** Maintain ***Power / Energy*** Target while Scaling

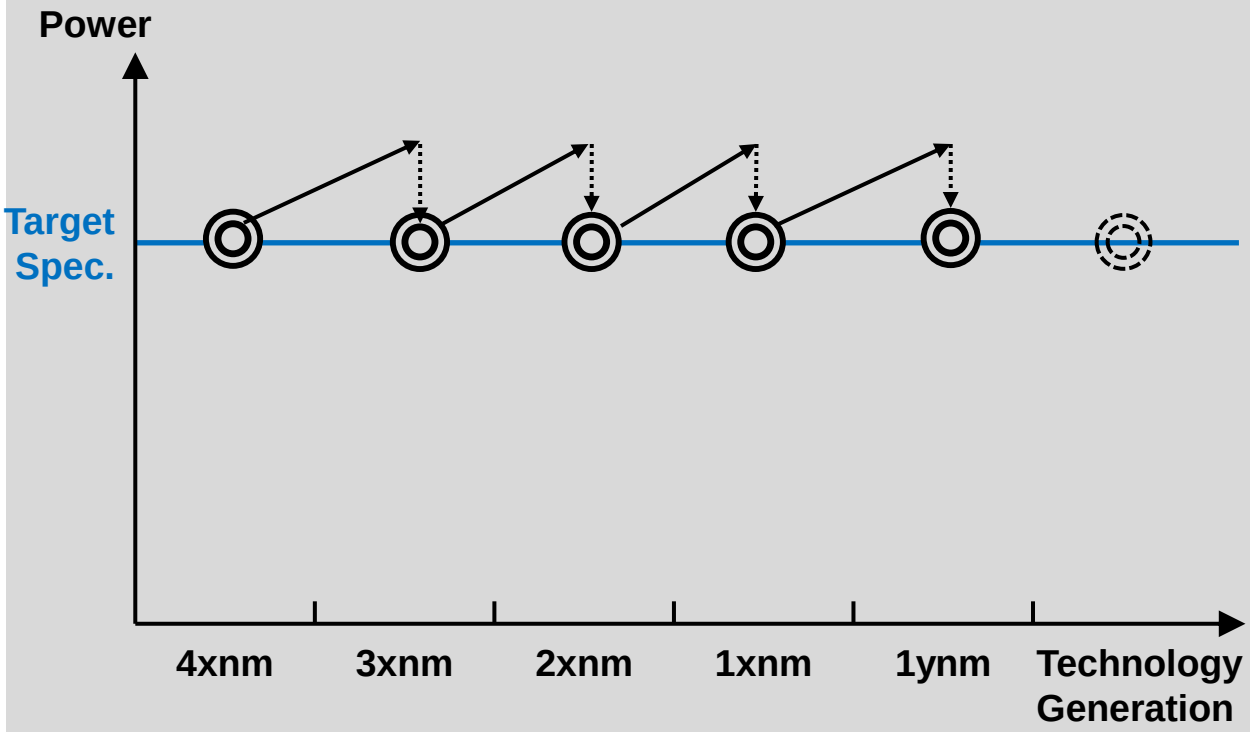



**Capacitance Increases Resulting in Power Increase**

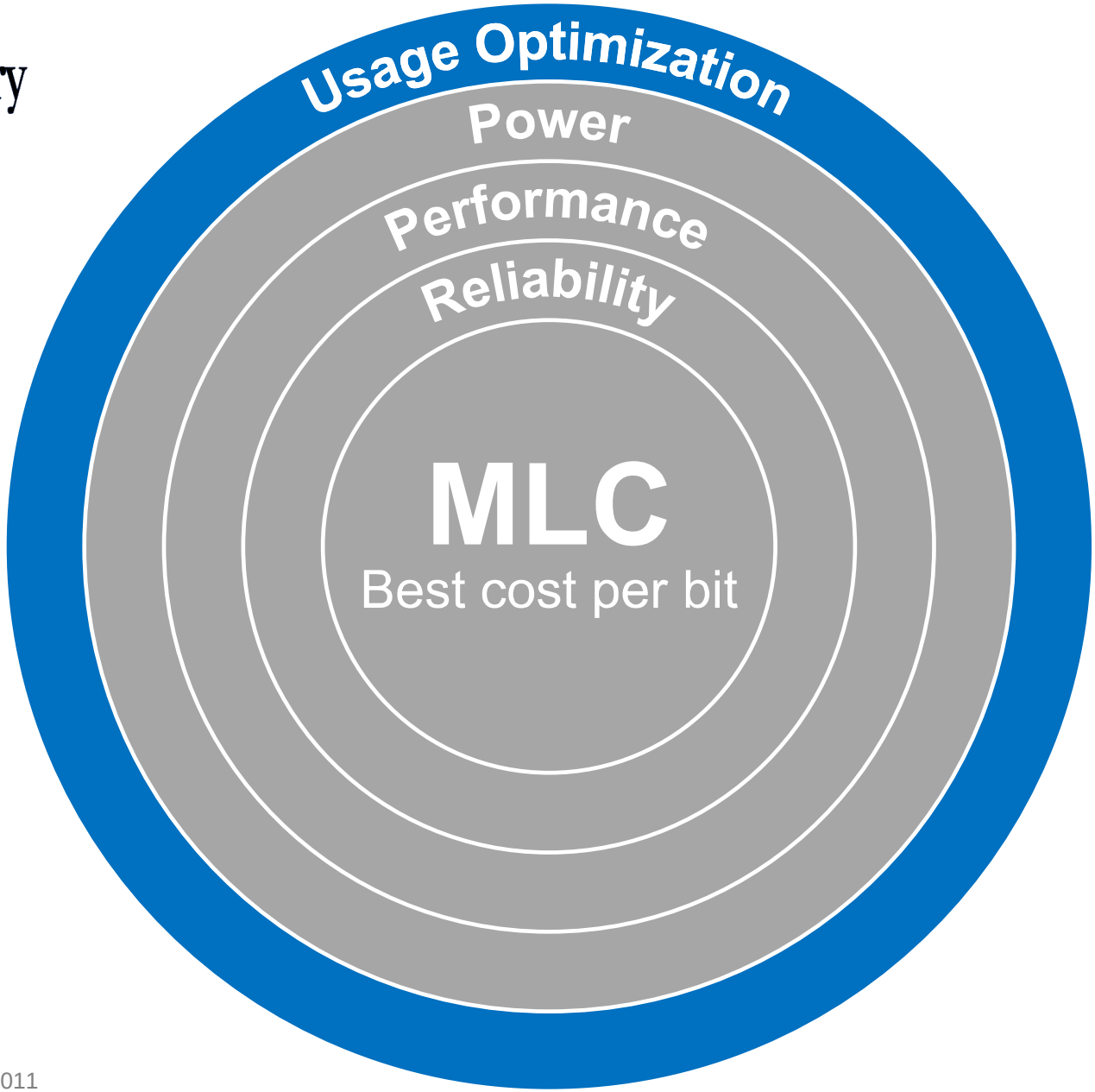
# Enhancing NAND Technology – **Power**

*Based on SanDisk Internal Evaluation*

**Goal:** Maintain ***Power / Energy*** Target while Scaling




1) Proprietary ICC Optimization
2) ABL (All Bit Line) Design Enables Lower Energy per bit
3) Dynamic Power Conscious Parallelism
4) Proprietary Low Power StrongECC™ + DSP
5) Proprietary Low Leakage CMOS
6) AirGap Reduces Capacitance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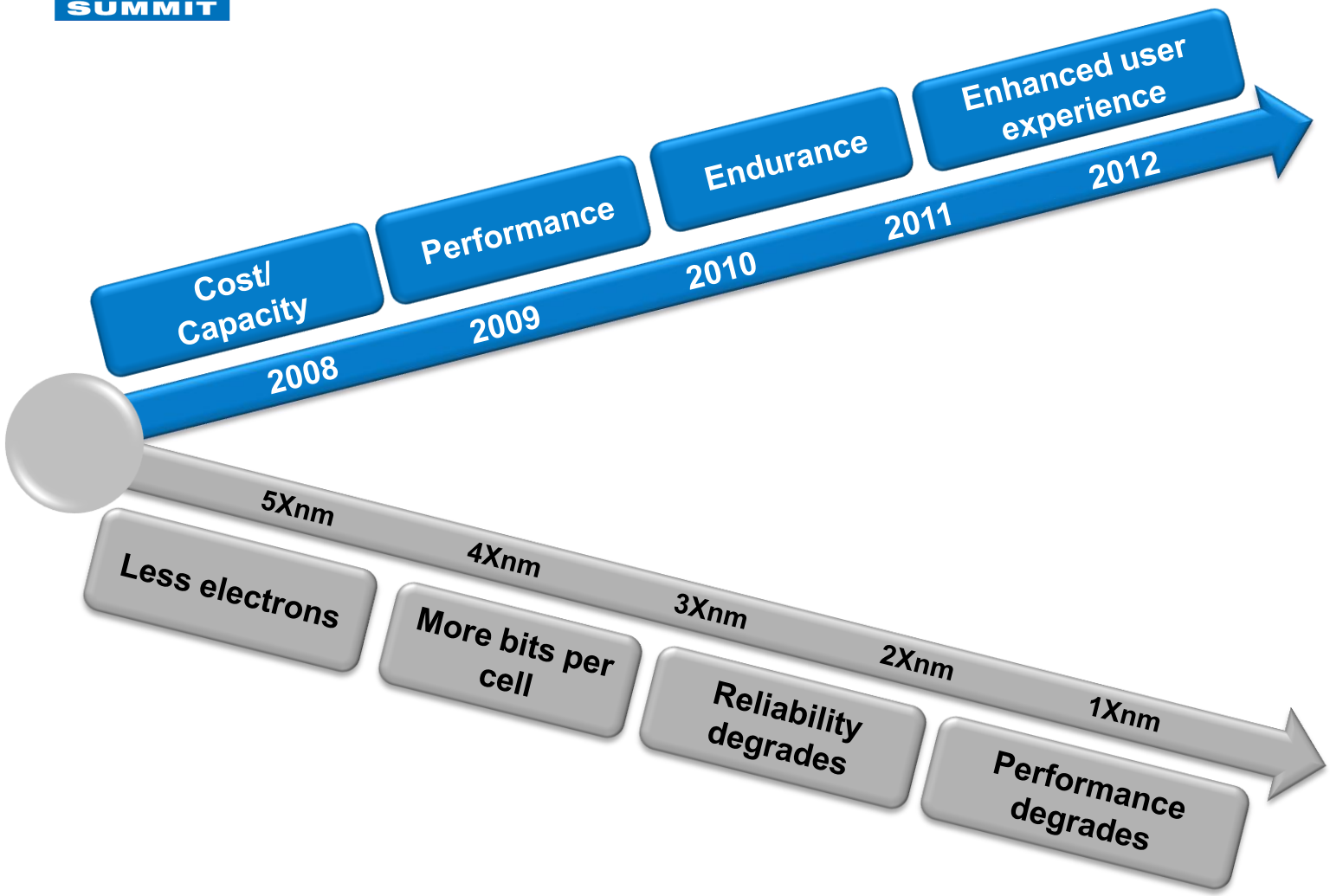
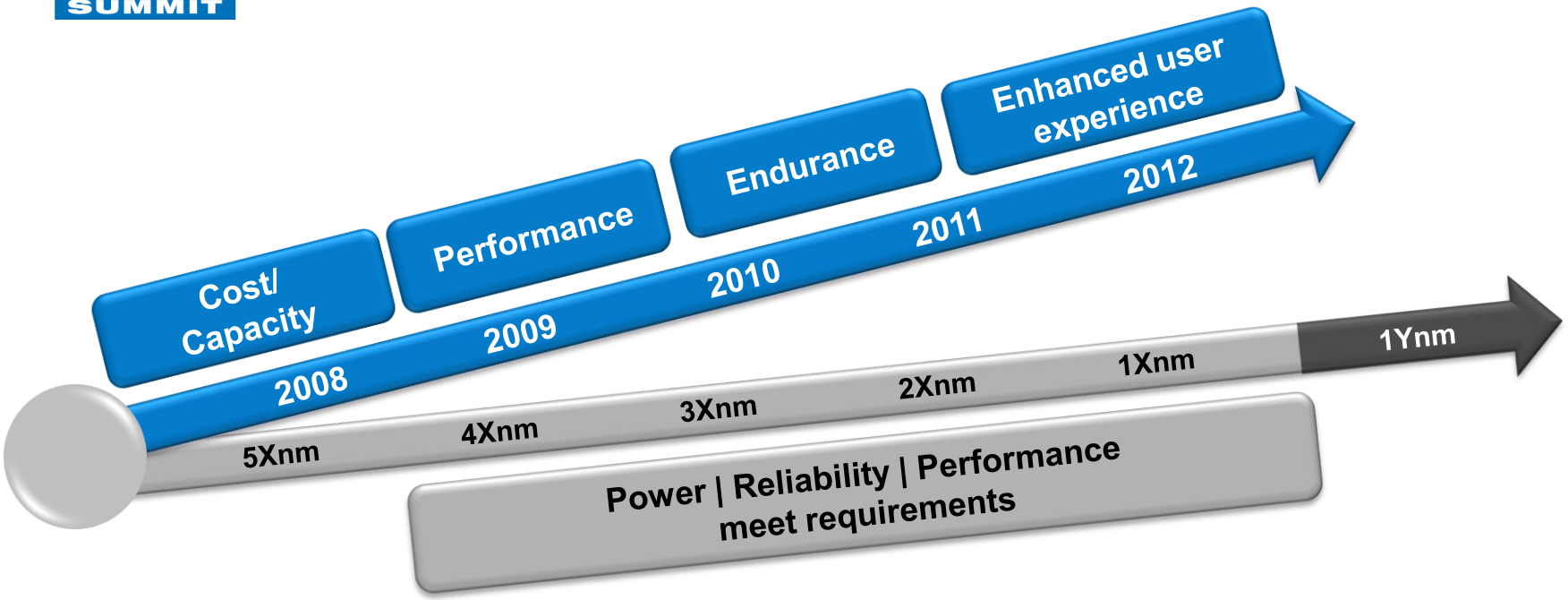

Cost/ Capacity
Performance
Endurance
Enhanced user experience
2008
2009
2010
2011
2012
5Xnm
4Xnm
3Xnm
2Xnm
1Xnm
Less electrons
More bits per cell
Reliability degrades
Performance degrades

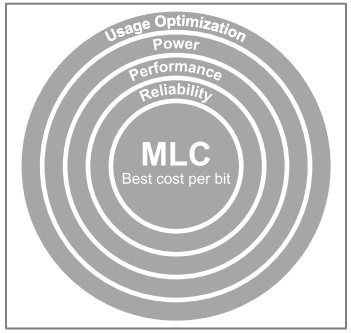
# Summary

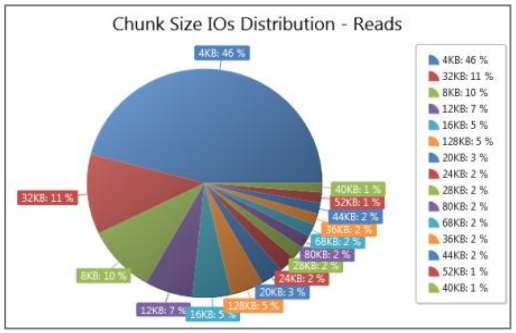


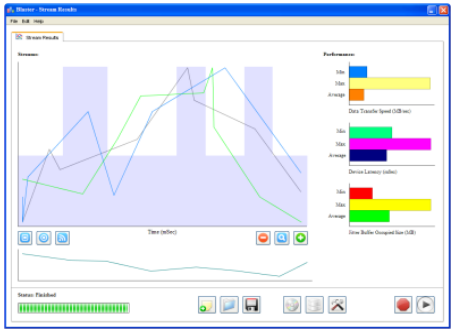

*NAND + System solutions enable continuation of NAND scaling while maintaining reliability, performance & power requirements*

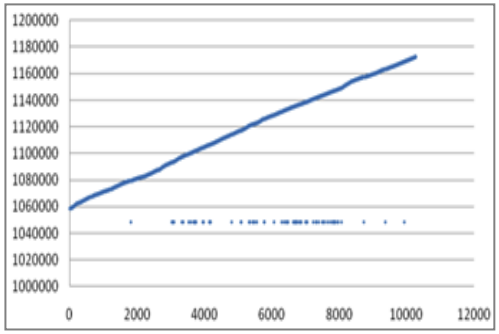
# Summary

- SSD enables a multitude of opportunities in mobile computing
- It is up to us to bring the SSD technology to mainstream
- This is achievable by:
  - Continuous process shrink
  - Tailoring solutions to use cases






*System design based on real life usage data for enhanced real life user experience*

# Thank You