Tailoring SSD Architectures to Meet Evolving PC User Requirements

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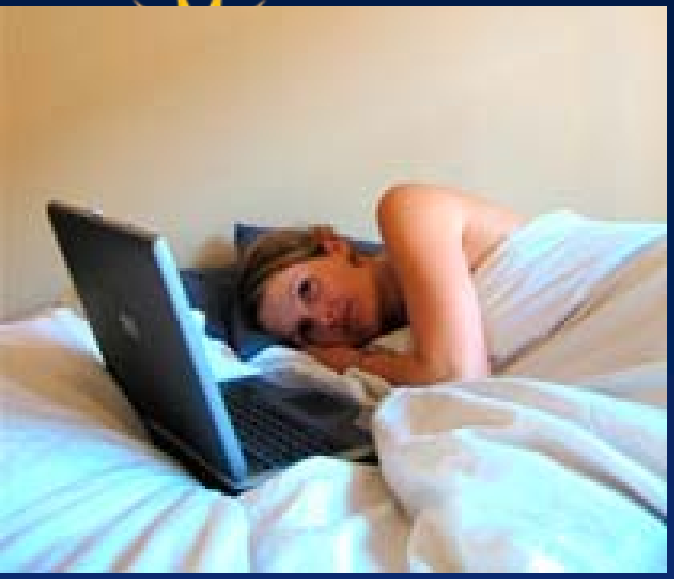
SanDisk



Everywhere, Anywhere, All the Time



Agenda

- SSD and the evolving usage scenarios
- Ecosystem collaboration
- Case study: The operating system & SSD
- Understanding the NAND challenge
- Directions & solutions to meet user needs

Forward Looking Statements

During our meeting today we will be making forward-looking statements.

Any statement that refers to expectations, projections or other characterizations of future events or circumstances is a forward-looking statement, including those relating to revenue, pricing, market share, market growth, product sales, industry trends, expenses, gross margin, future memory technology, production capacity and technology transitions and future products.

Actual results may differ materially from those expressed in these forward-looking statements including due to the factors detailed under the caption “Risk Factors” and elsewhere in the documents we file from time-to-time with the SEC, including our annual and quarterly reports.

We undertake no obligation to update these forward-looking statements, which speak only as of the date hereof.

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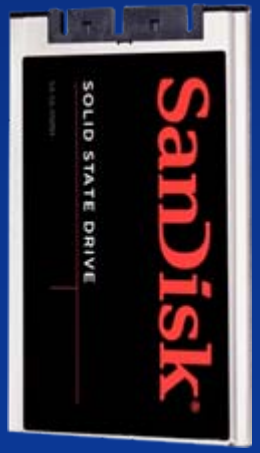
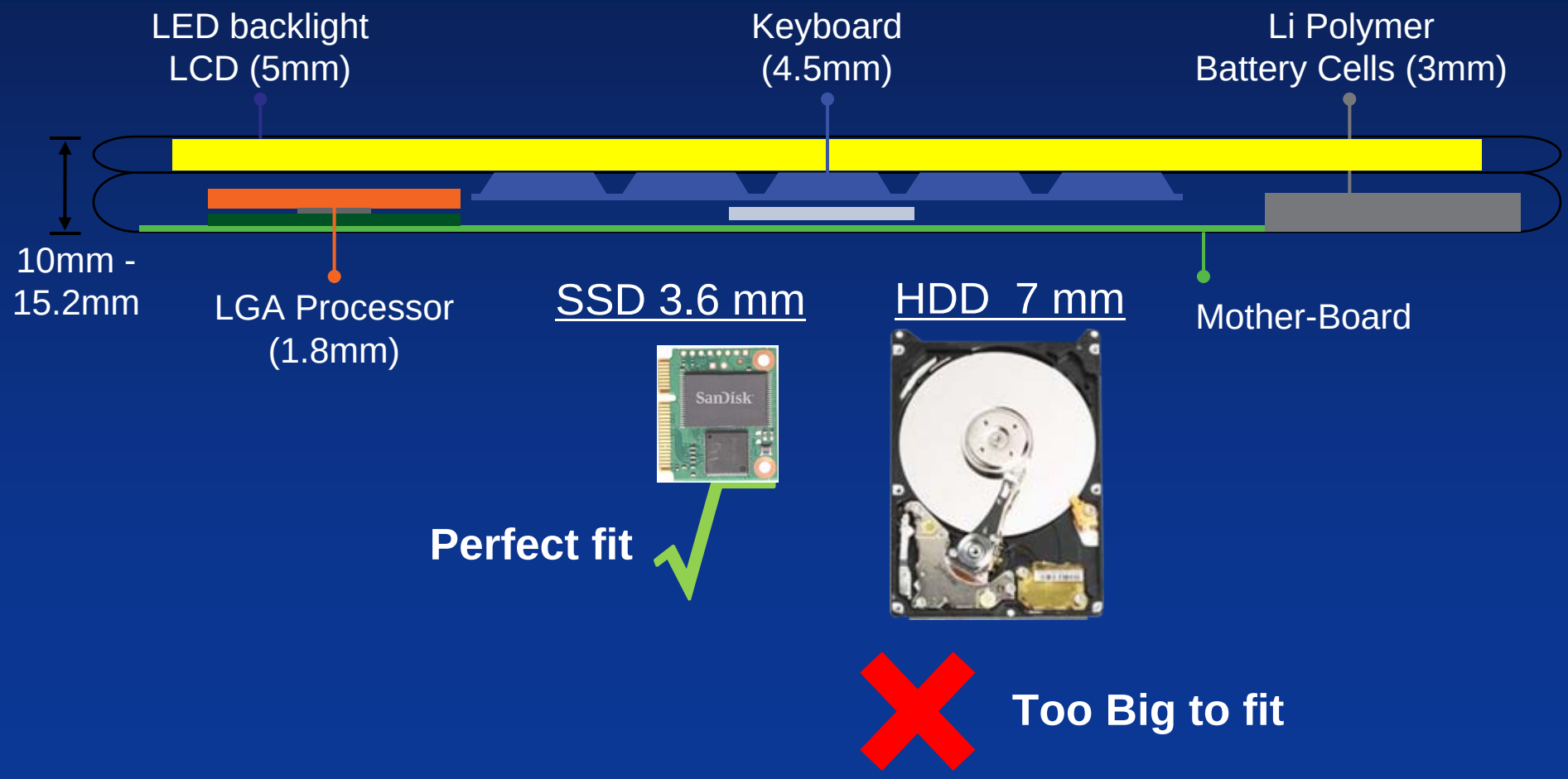
New SSD - as Different from an HDD as the Horseless Carriage from the Race Car

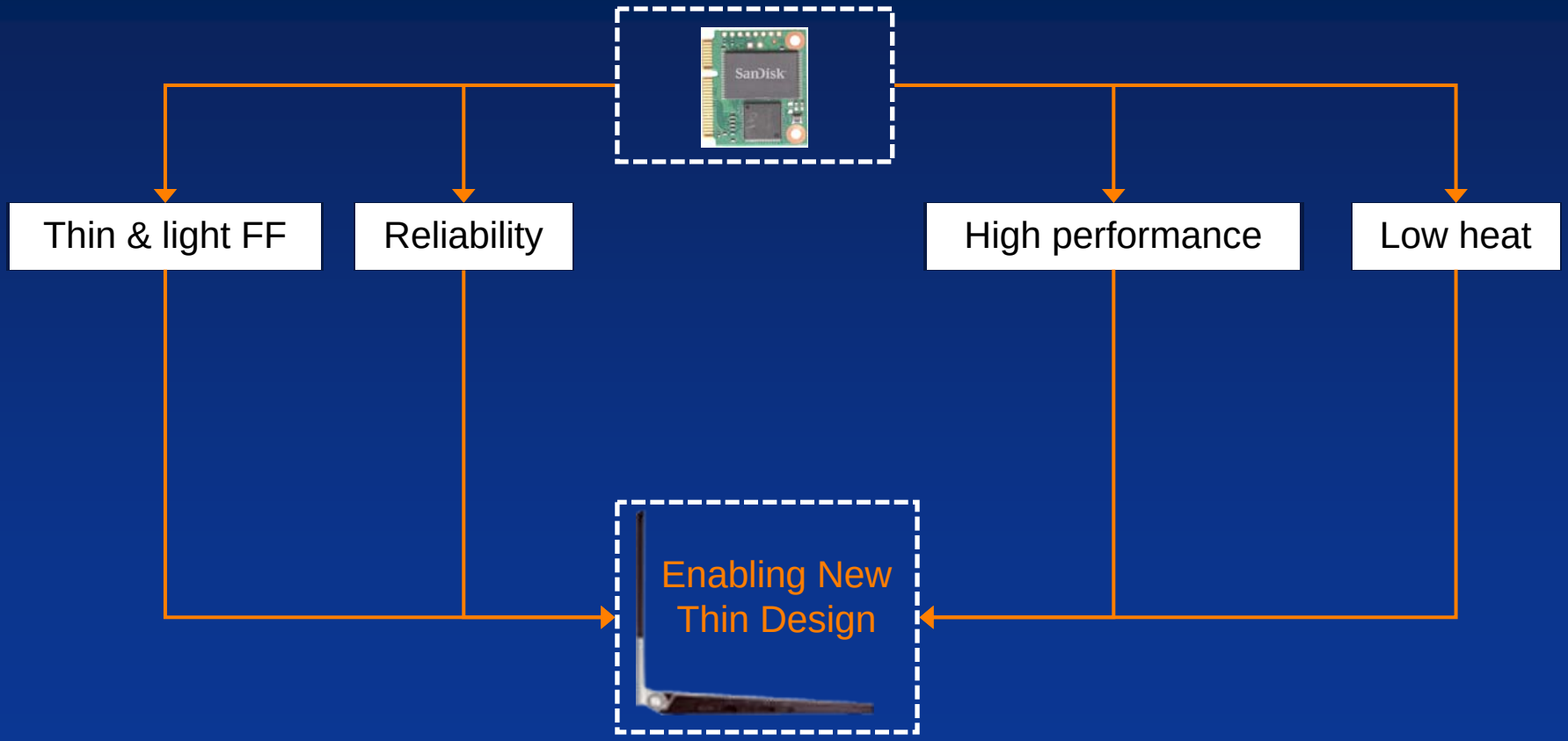


New Thin Designs – Enabled with SSD

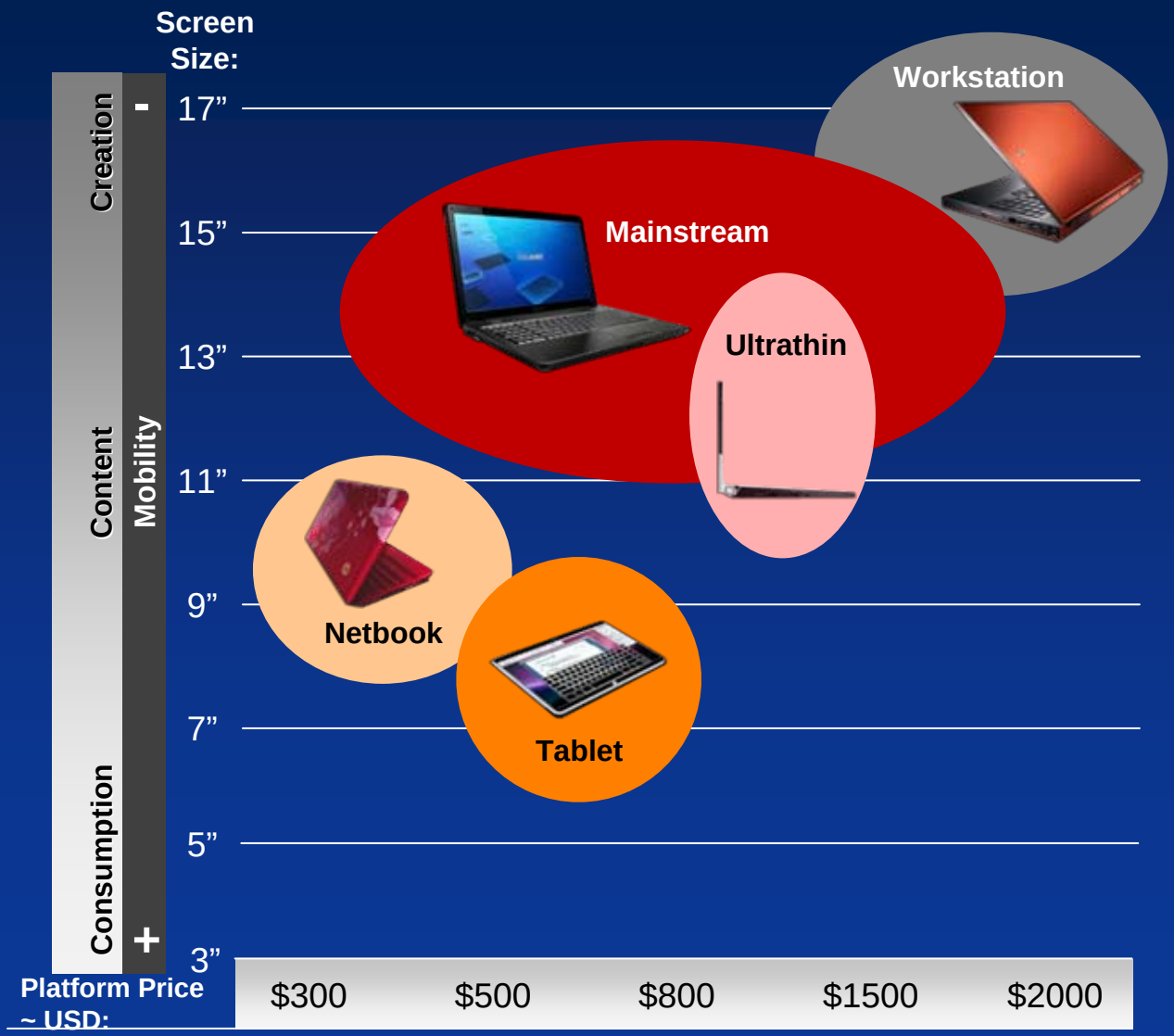
Laptop Side-View

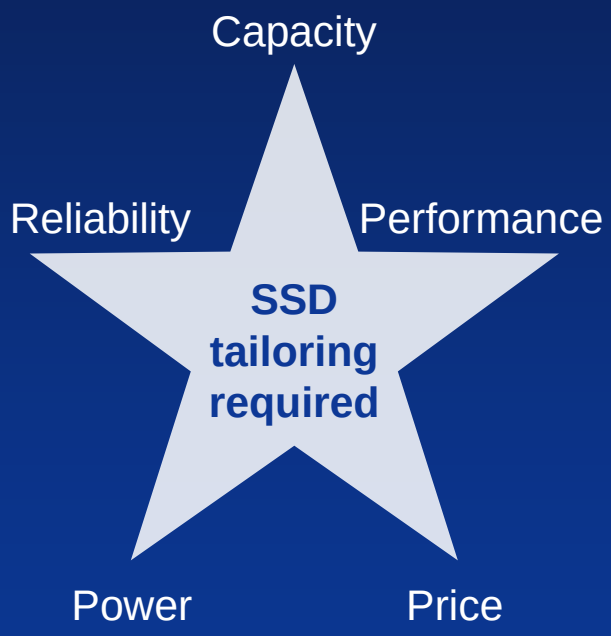


SSD Enabling - New Thin Mobile Computing Designs



Different SSDs for Different Computing Segments





Mainstream Computing Market

- **2014 NAND consumption mainstream PC market 13 Exabytes***
- Usage: Business & Consumer Apps
- Screen:15.4” – 13”
- Processor: Core2 Duo, CULV
- OS: Windows Professional, MAC OS
- Storage: 64GB – 256GB
- Price: $800-$1000

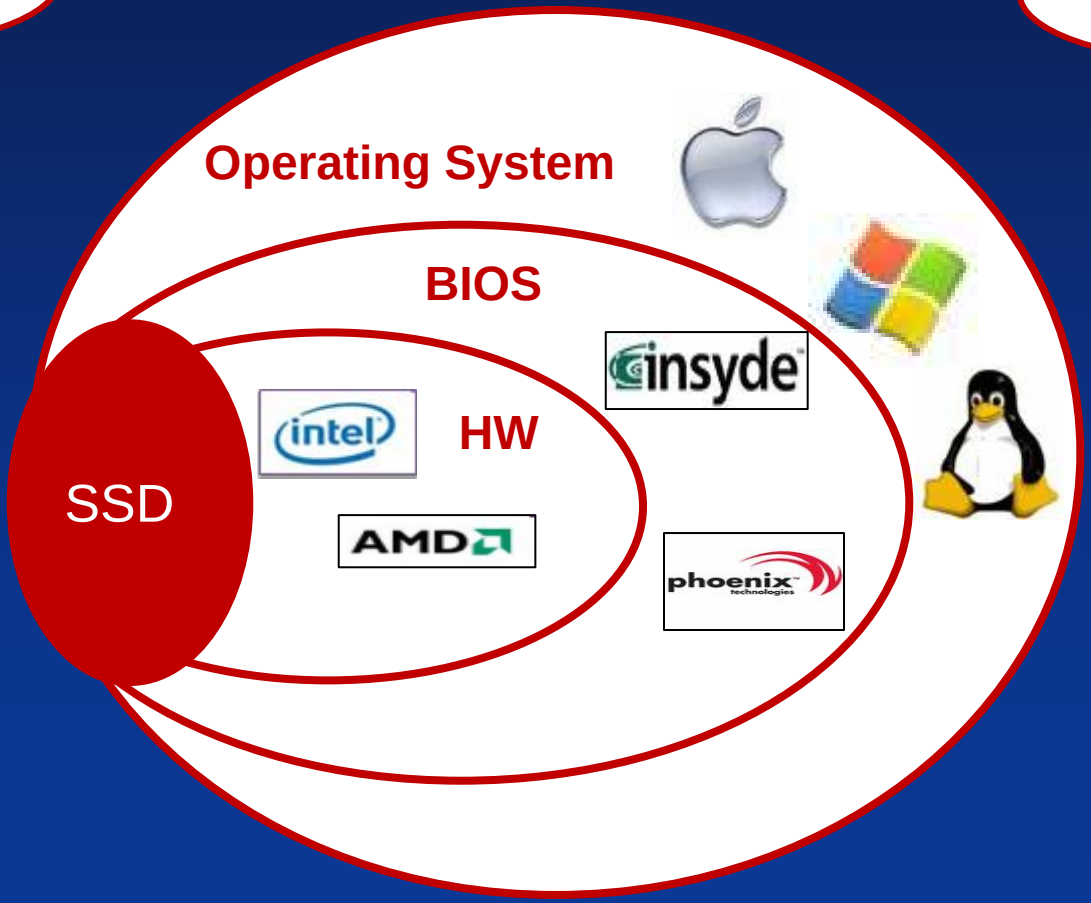
*Gartner, Inc., Semiconductor Forecast Worldwide: Forecast Database, N. Reilly et al, 1 June 2010

Ecosystem Engaged in an Enhanced User Experience

Thin & light

Instant on

All day battery



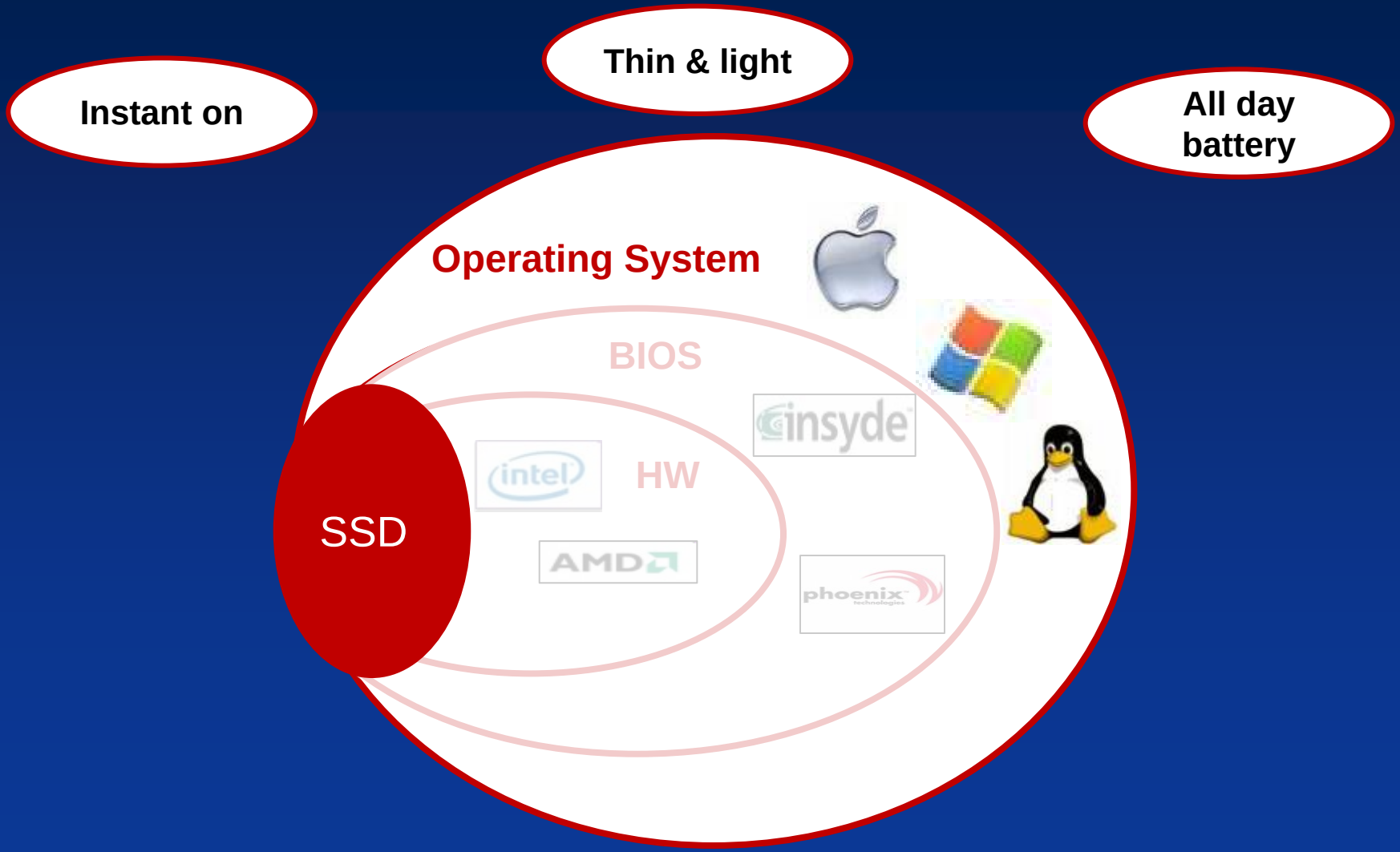
Innovation & Collaboration
Computex 2010

Microsoft

SanDisk

insyde

Ecosystem Engaged in an Enhanced User Experience



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The OS Home for Many Years
Access Takes Time

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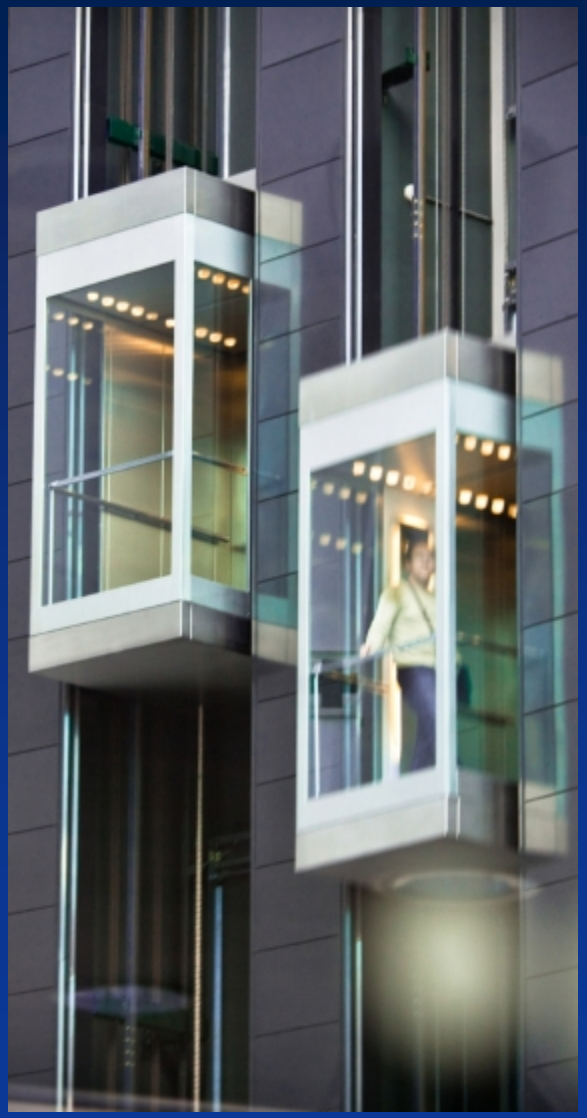
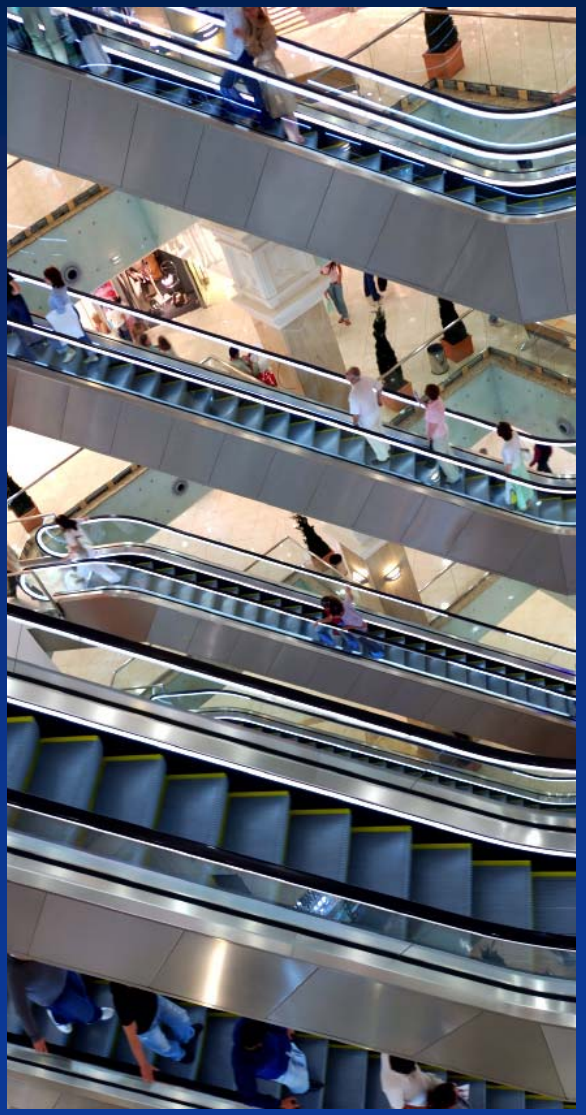
A New Home Offers New Challenges





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Different Architectures Different Behavior

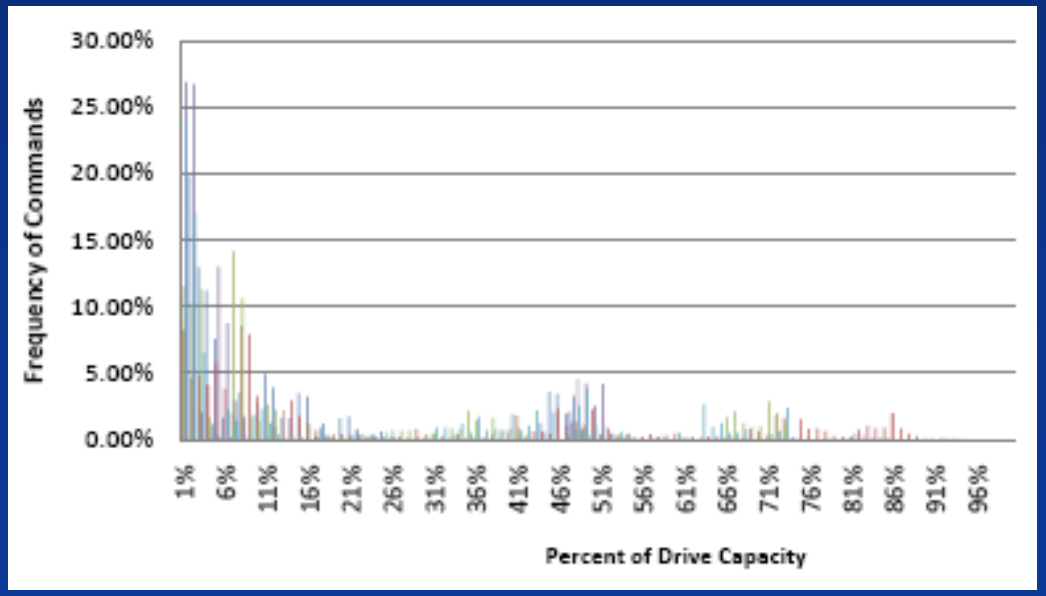
OS Storage Awareness Makes a Difference

SanDisk Internal Windows 7 Study

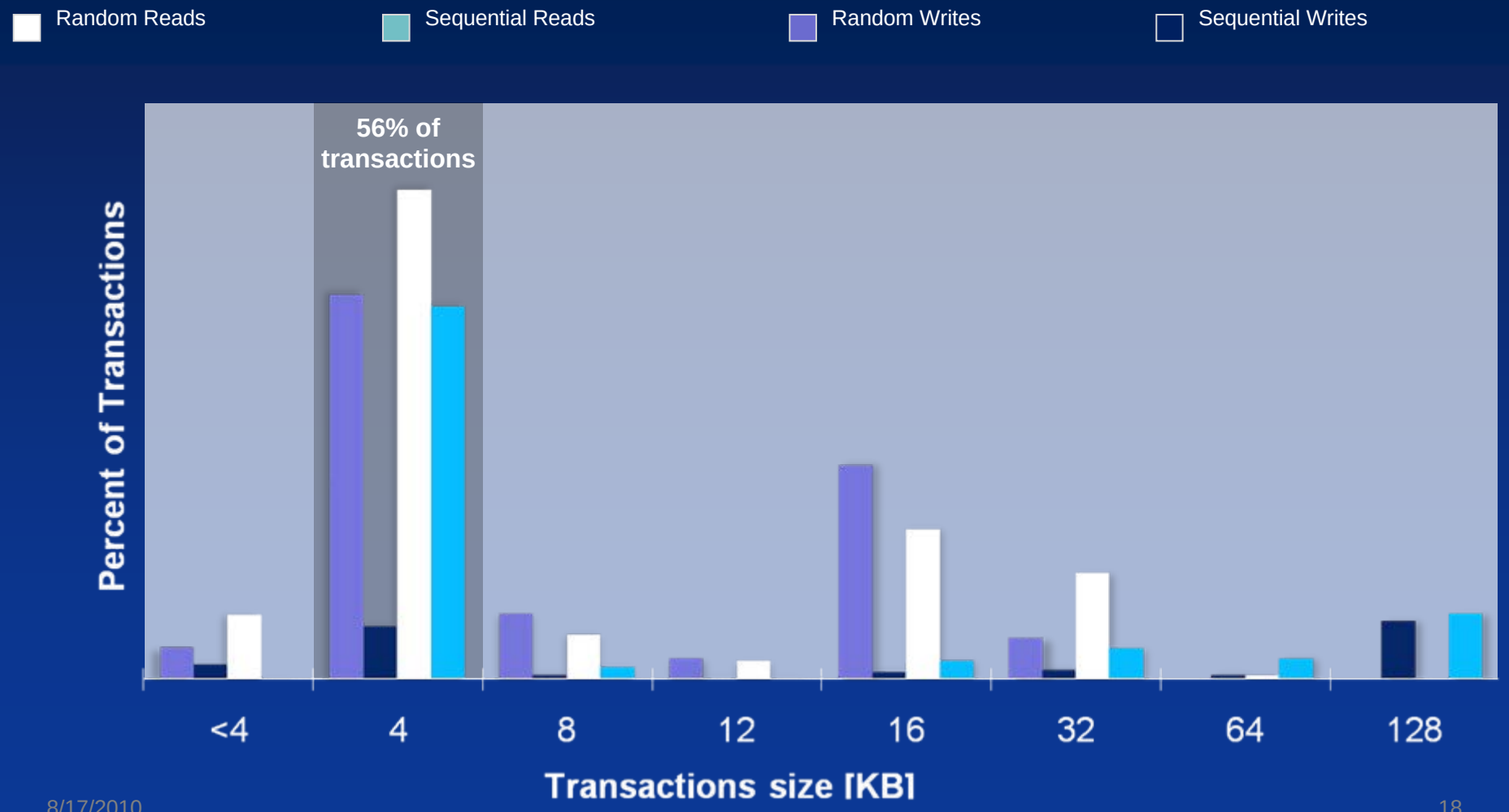
- Purpose: Analyze and characterize:
  OS I/O interface with the storage device
- Various corporate user groups observed running Windows 7 Ultimate
- Data traces from the host to the device were captured
  - SATA analyzer - individual tasks traced
  - High-level filter driver - real user activity, recording realtime I/O operations

Footprint of Corporate Usage

- Examination of variety of different corporate user's behavior and different disk size
- Found recurrence of hot spots in specific locations (not evenly distributed over the media)
- SSD designer must be take into account the flash wear-out implication



Scenario Distribution by Block Size

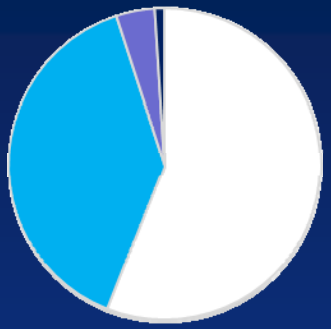


IO Count for Various Applications

Boot

Wake from Hibernate

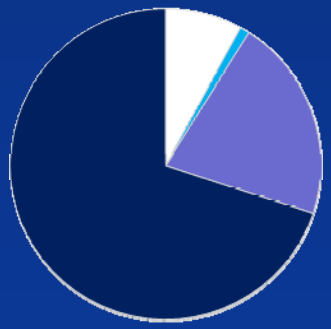
Launch Application



Random Reads Sequential Reads Random Writes Sequential Writes

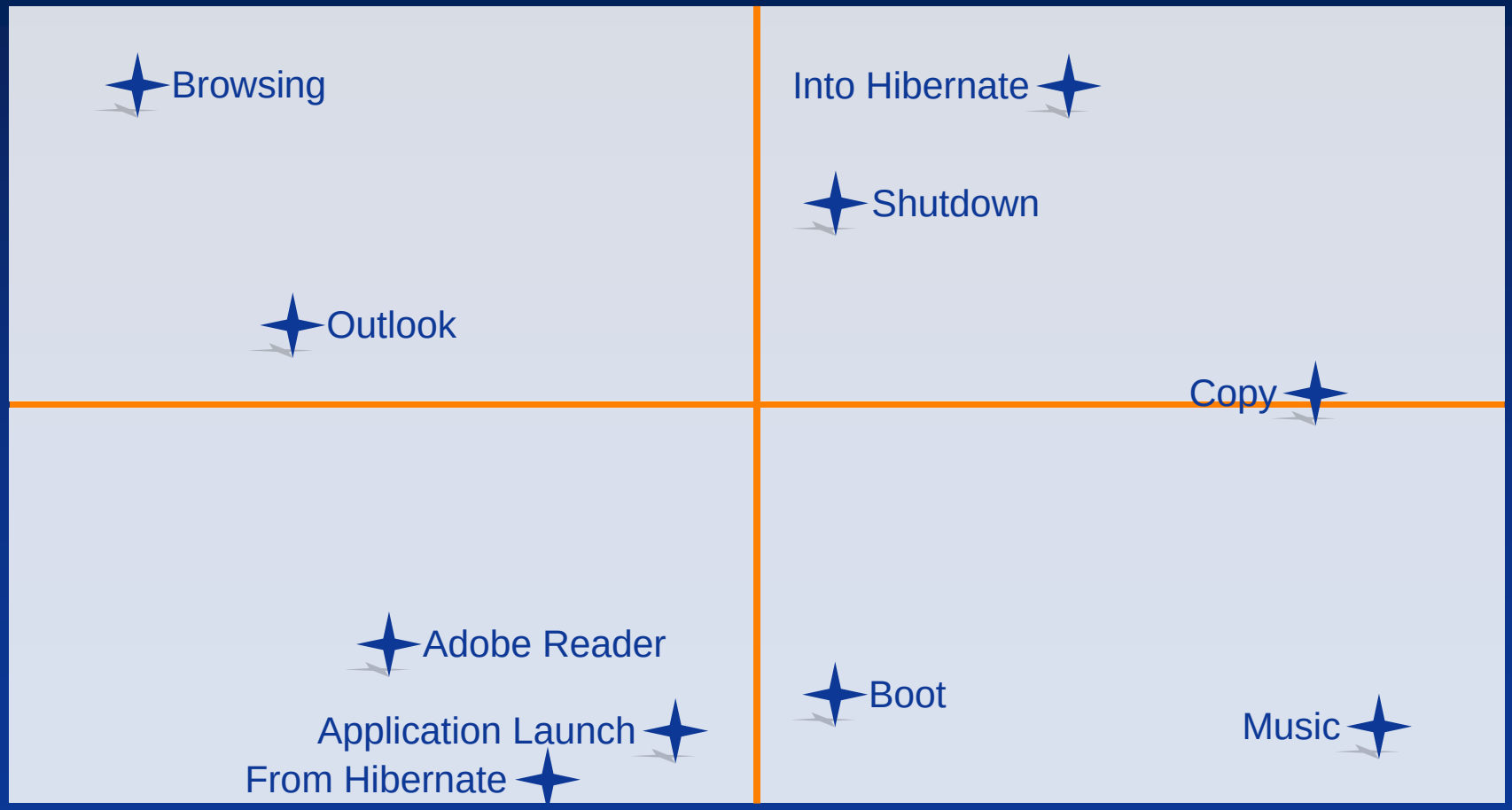
Copy

Down to Hibernate

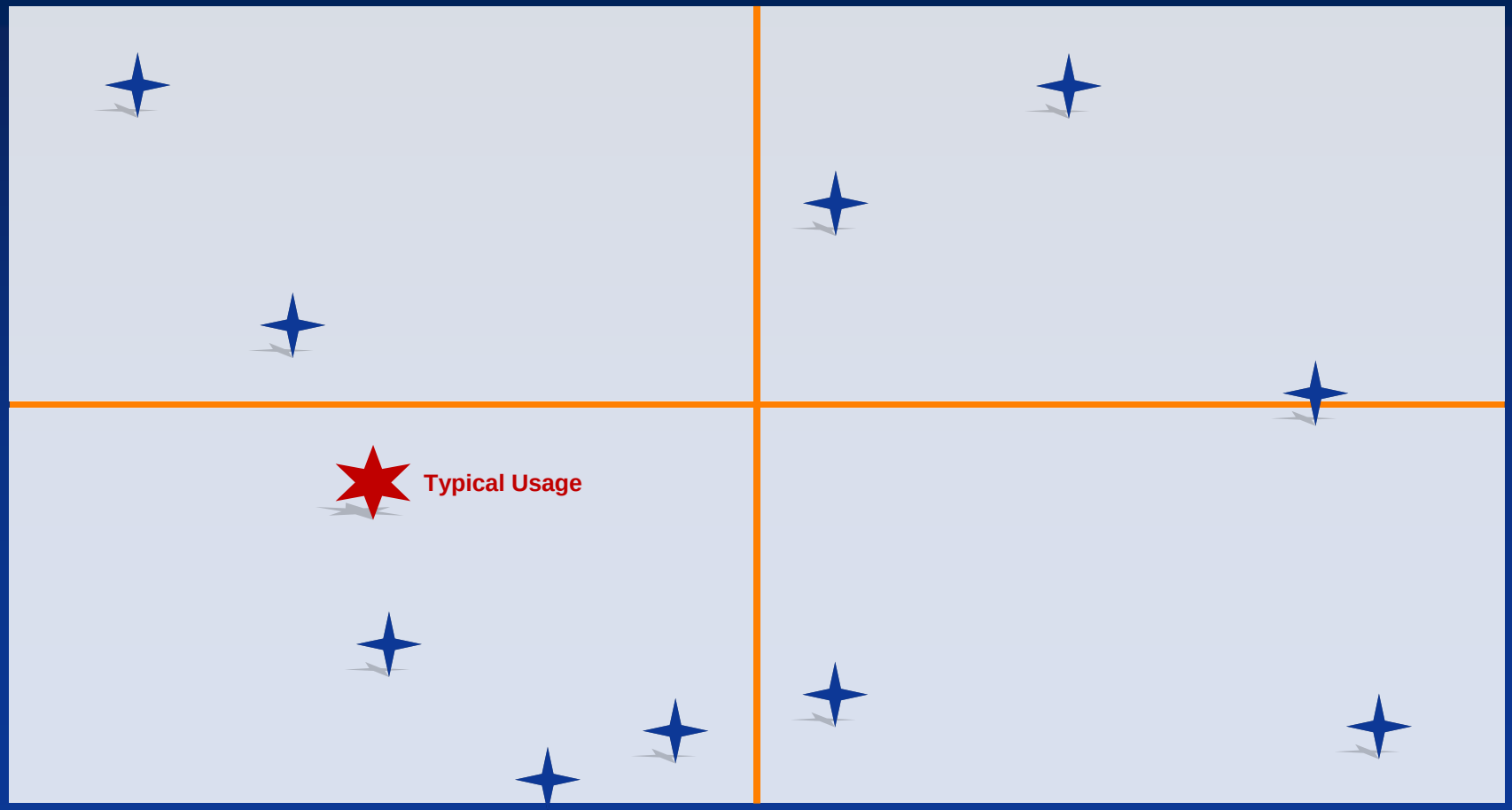


Shutdown

Applications – R/W, Sequential / Random Disk Activity Distribution



Applications – R/W, Sequential / Random Disk Activity Distribution



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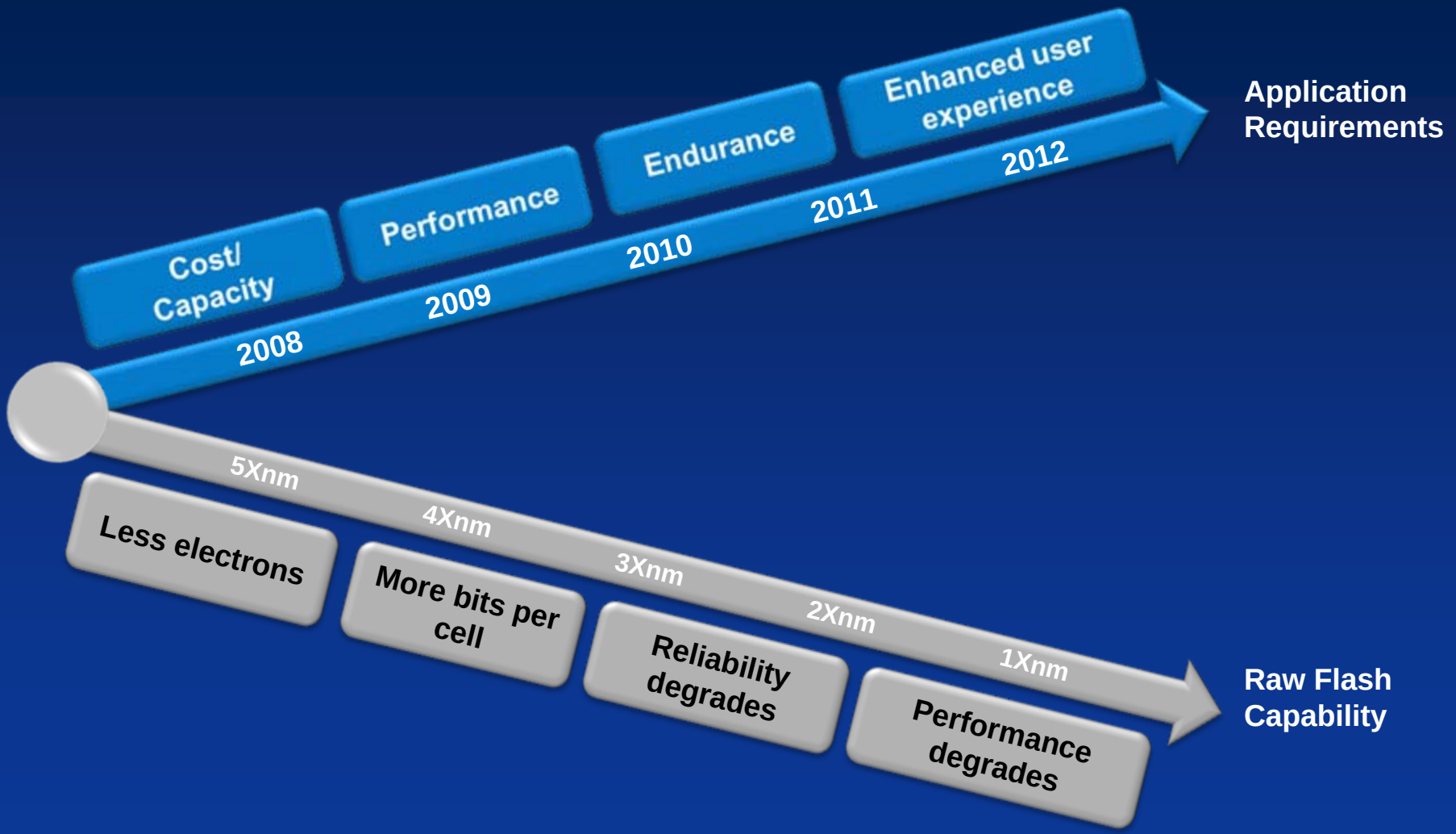
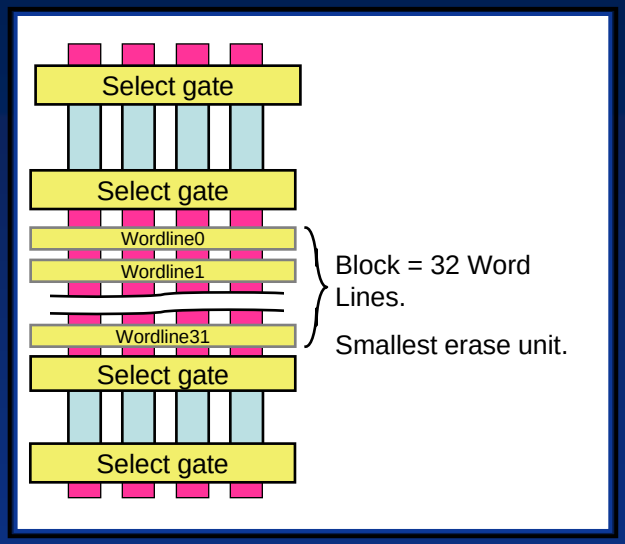
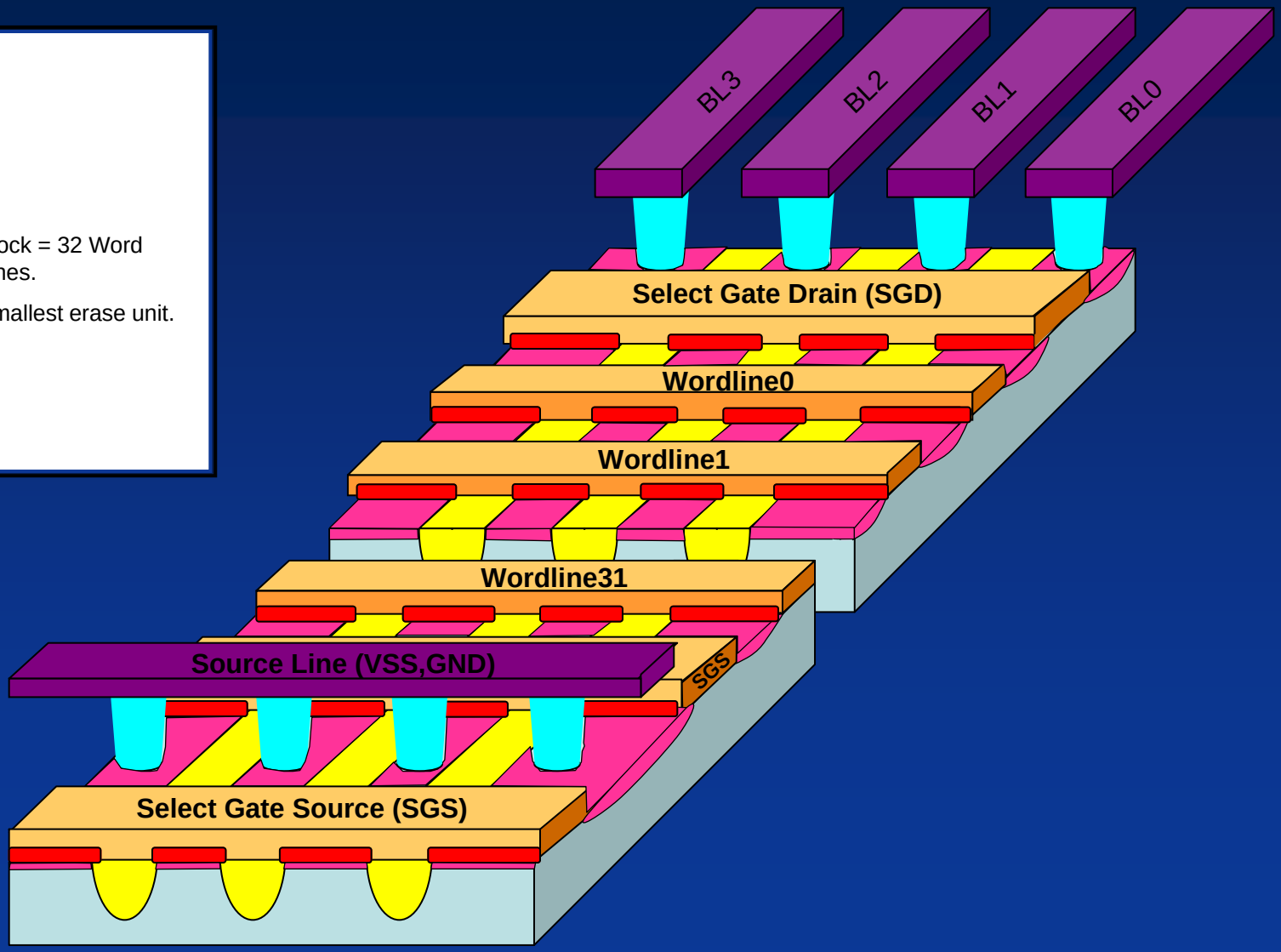
It's All About Cost…….



NAND Basics (Array Structure)





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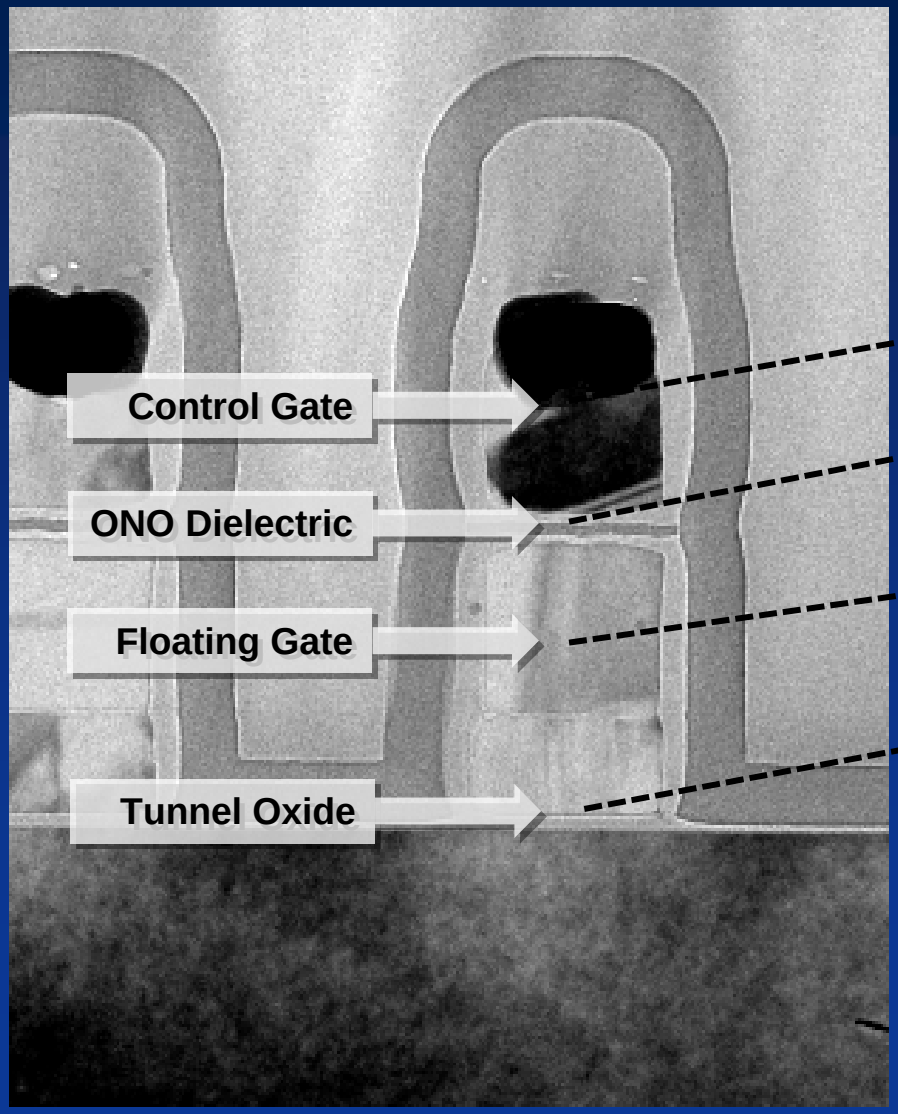
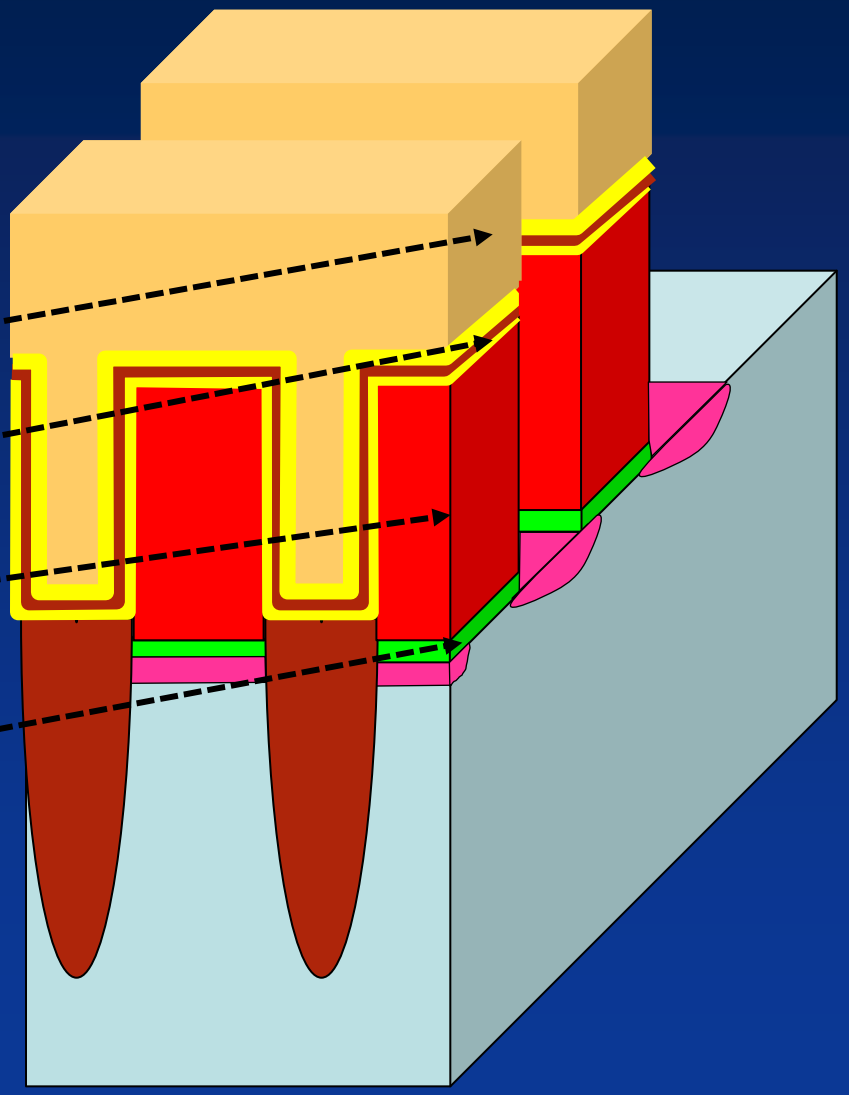
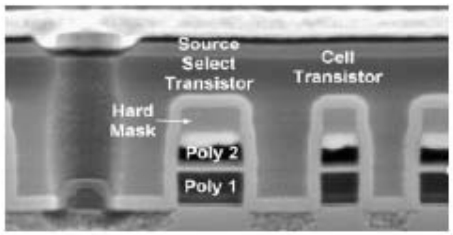
NAND Basics (Memory Cell)





NAND Technology Evolution

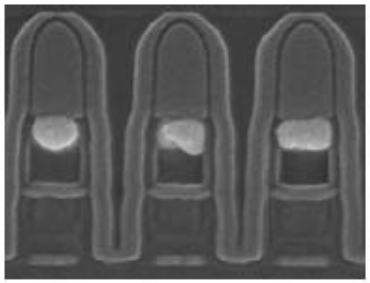
2002 - 160nm



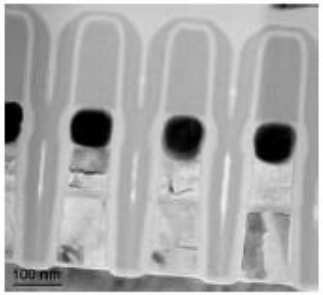
-Nitride SWS

- 16 cell string

2003 - 130nm



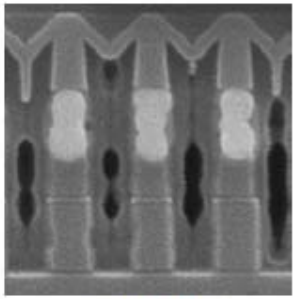
2004 - 90nm



-Self-aligned STI

- 32 cell string

2005 - 70nm



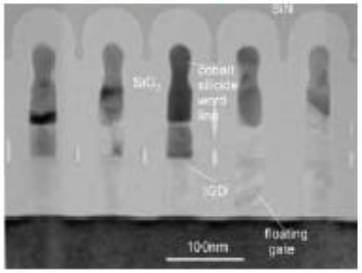
- Oxide SWS

2007 - 56nm

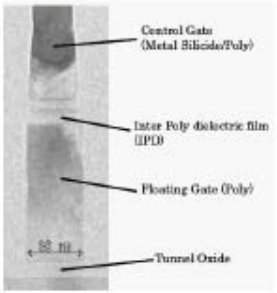
- CoSix WL, Cu BL

- 64 cell string

2008 - 43nm

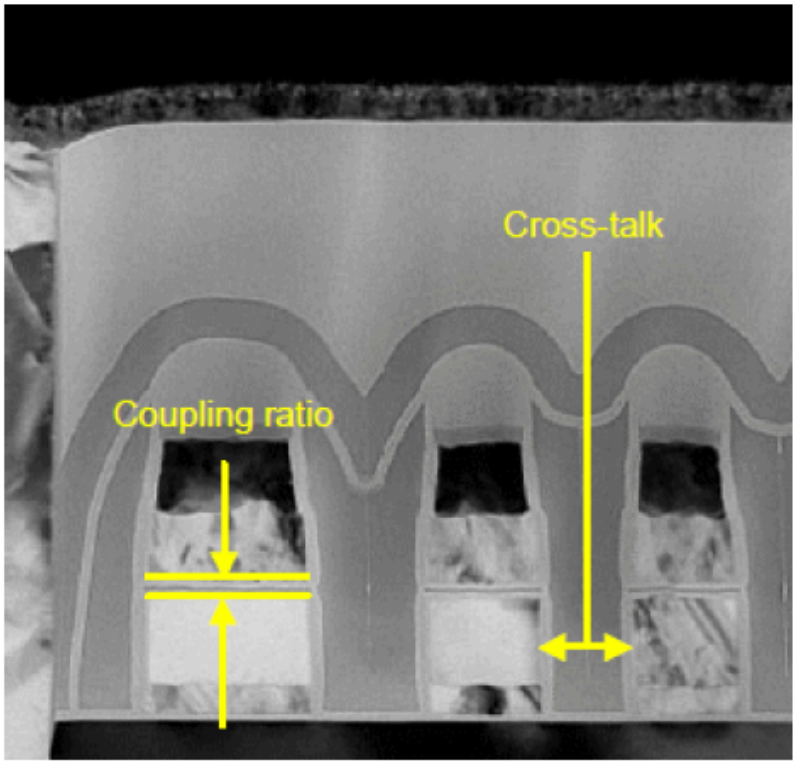


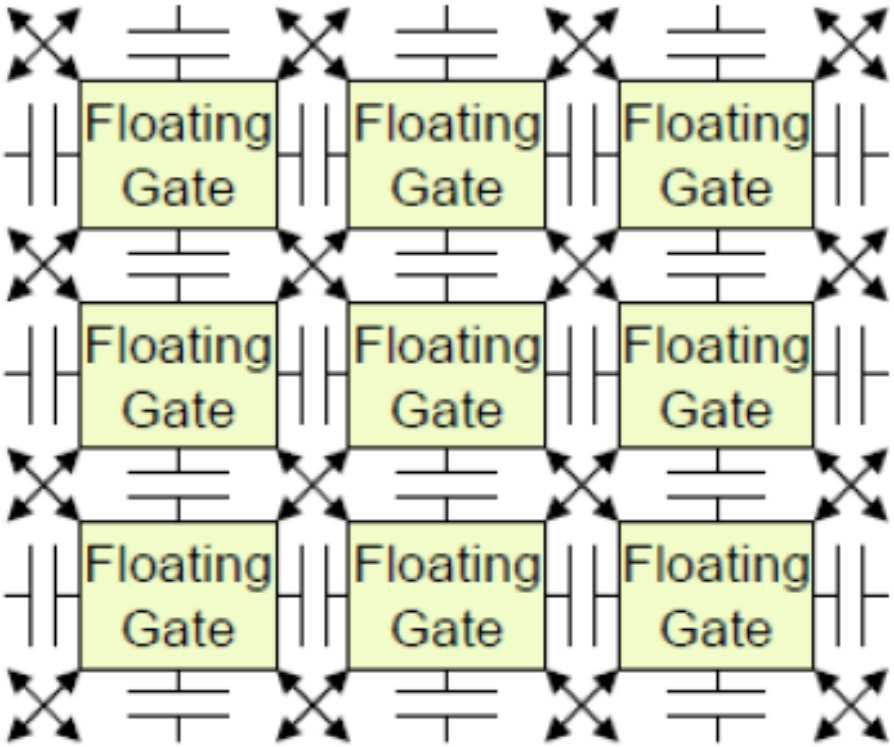
2009 - 32nm



Source: Chipworks, Semiconductor Insights, Toshiba
(Forward Insights Dec 2009)

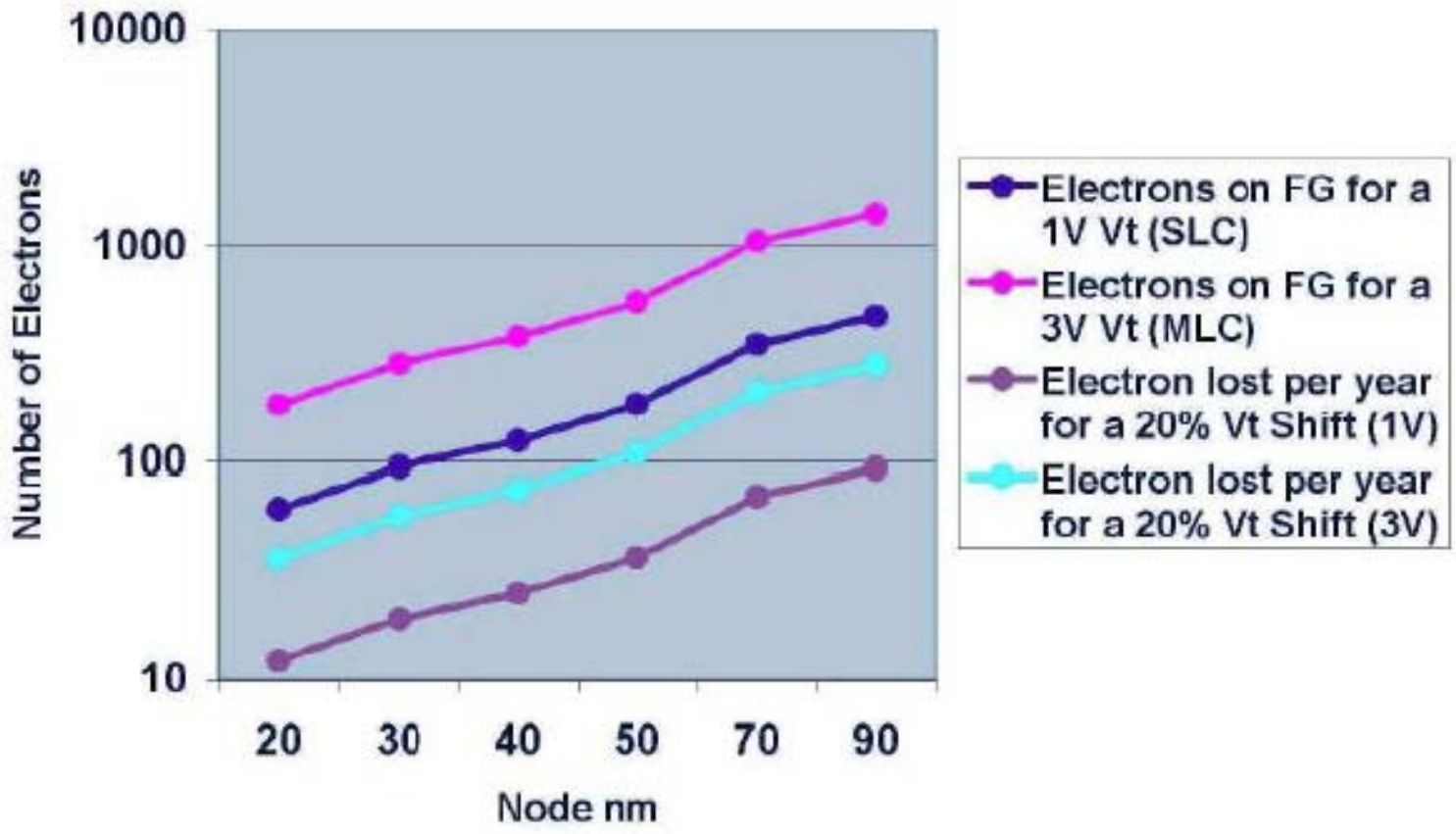
NAND Scaling Challenges – Interferences





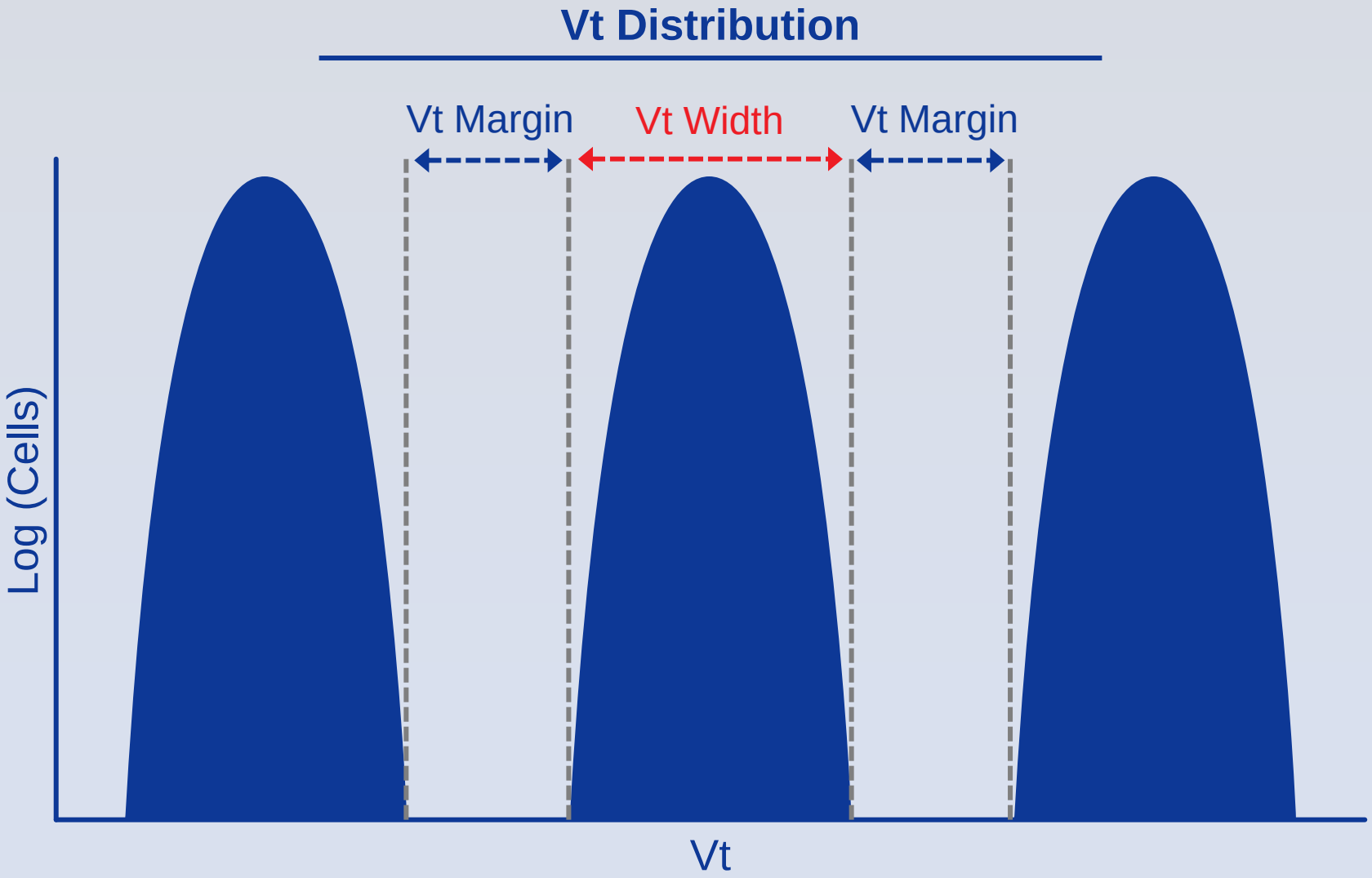
Source: Semiconductor Insights

NAND Scaling Challenges – Less Electrons



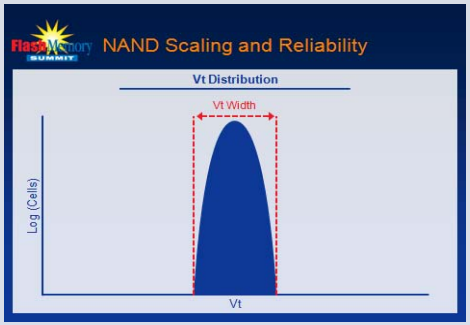
(Source: Prall, NVSMW 2007)

Reliability Margins



Control of Vt Distribution by Programming steps

Vt Distribution for Different Vpgm Step Sizes



Log (Cells)

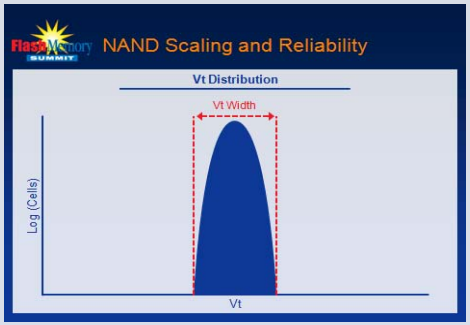
Vt

ΔVpgm

Vpgm step-up

Control of Vt Distribution by Programming steps

Vt Distribution for Different Vpgm Step Sizes



Log (Cells)

Vt

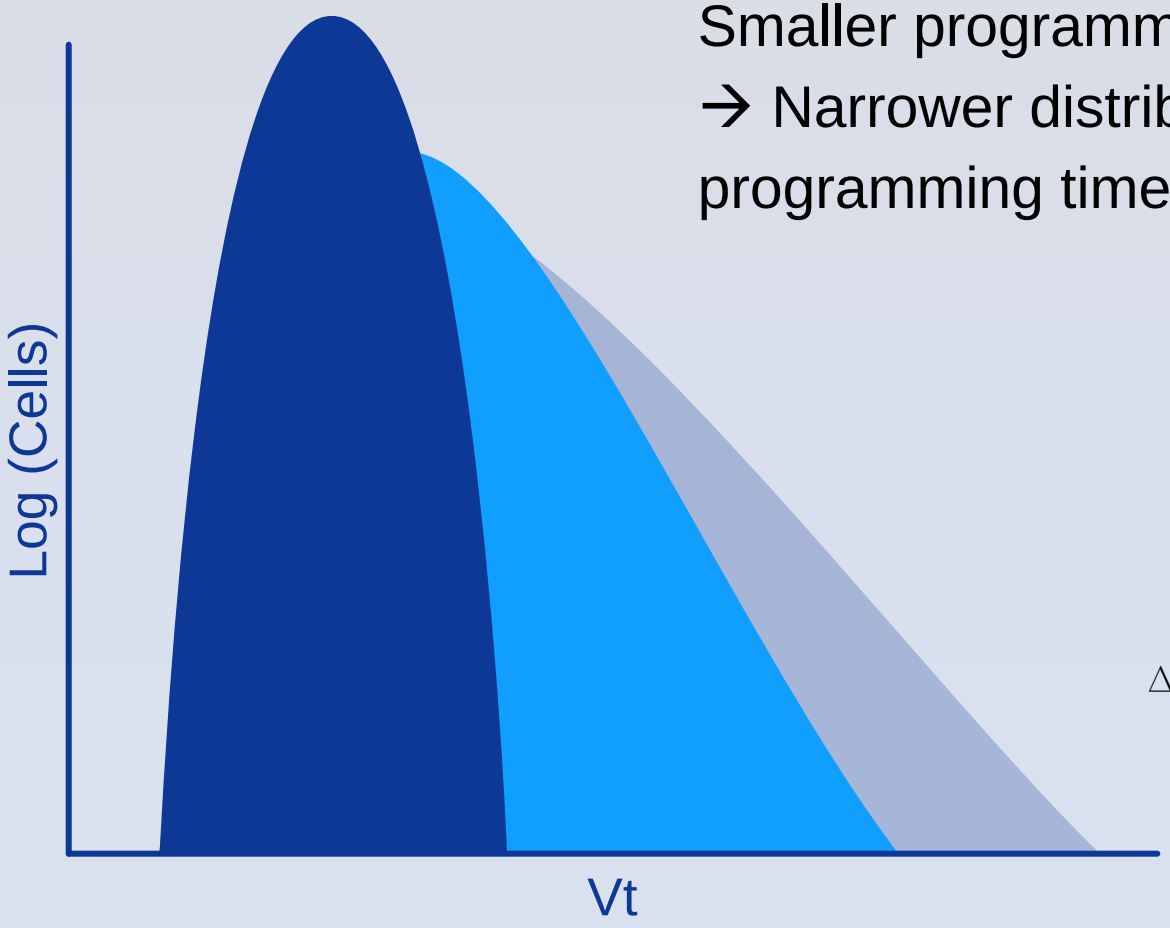
ΔVpgm

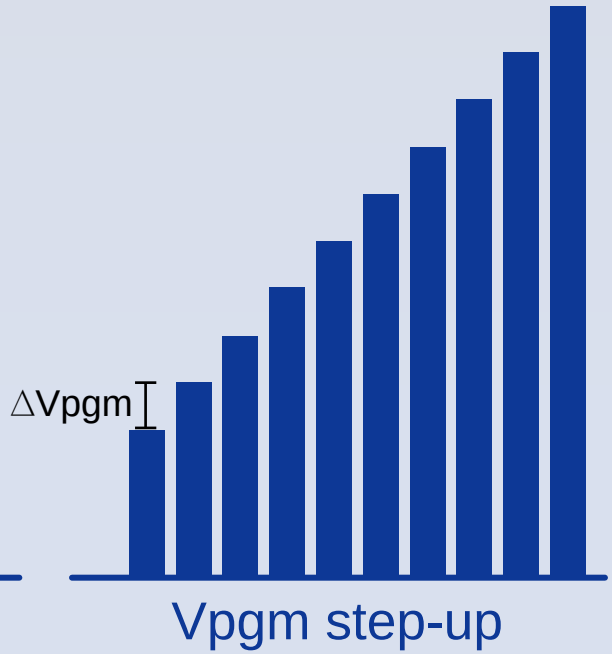
Vpgm step-up

Control of Vt Distribution by Programming Steps

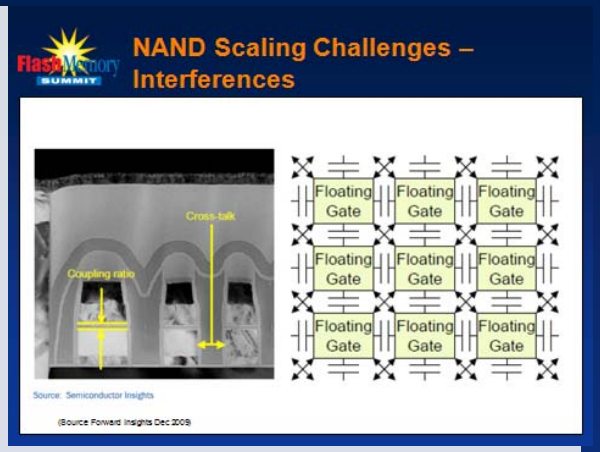
Vt Distribution for Different Vpgm Step Sizes

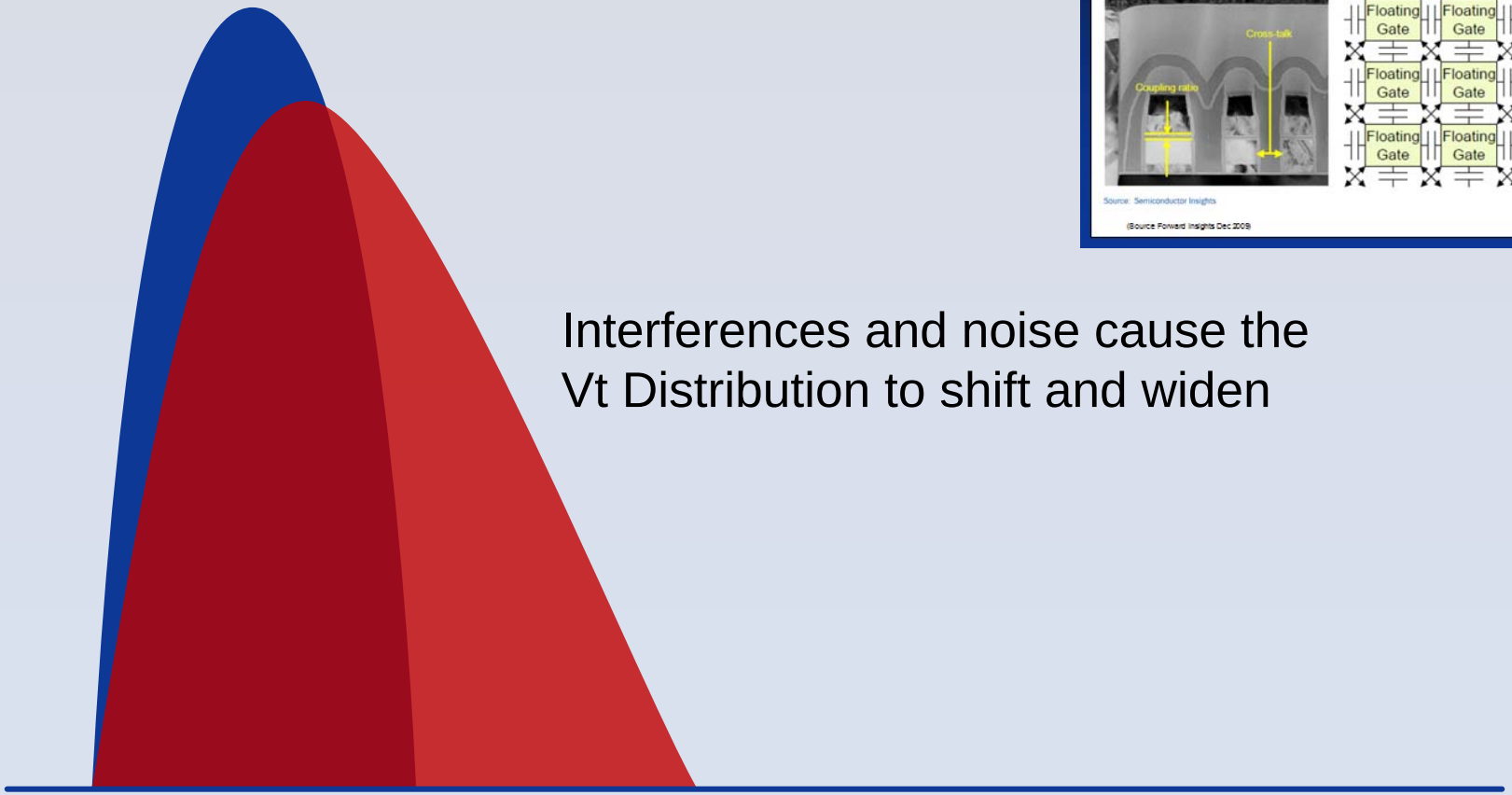
Smaller programming voltage step size
→ Narrower distributions but longer programming time





The Effect of Interferences



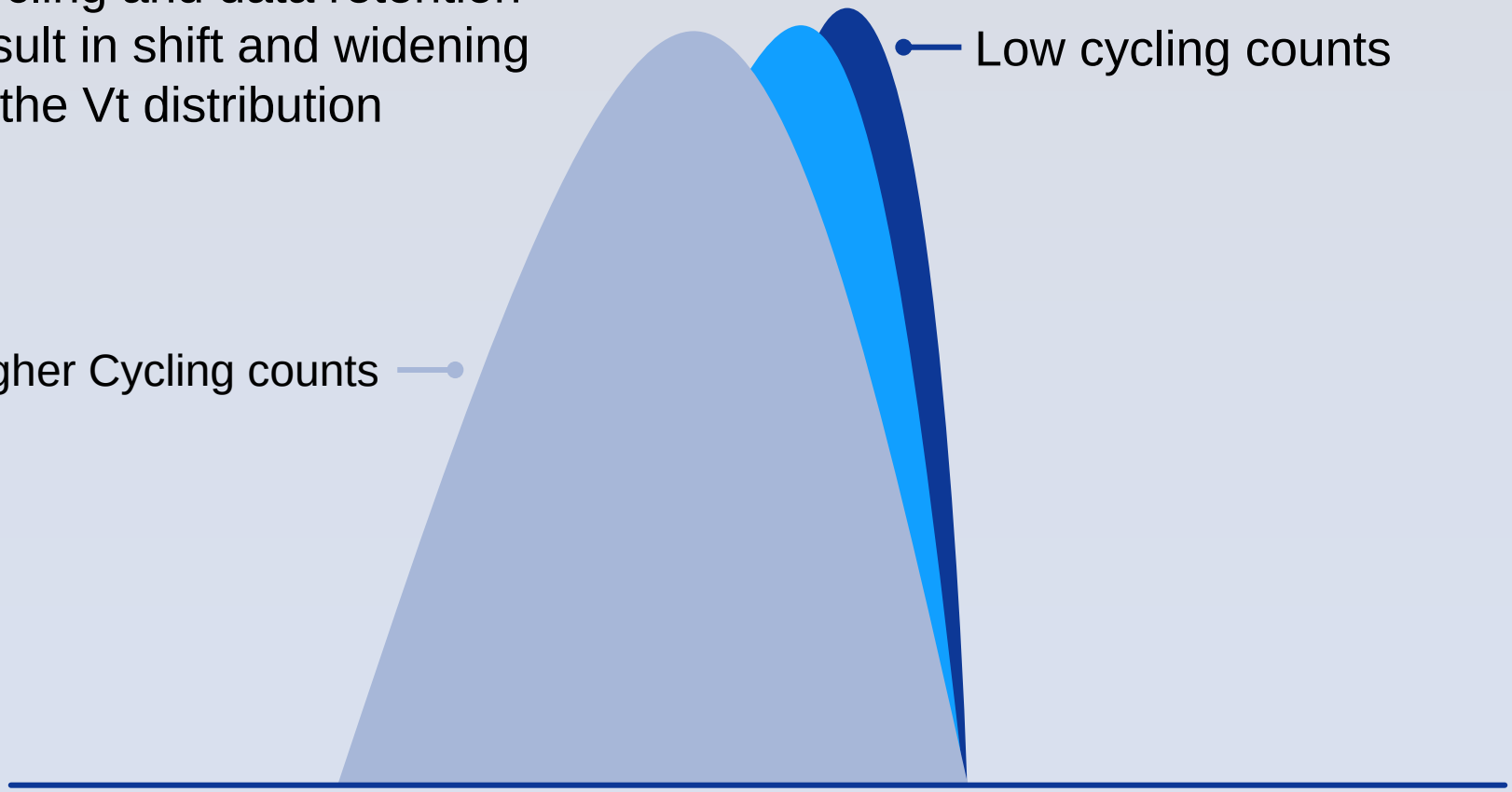


Interferences and noise cause the Vt Distribution to shift and widen

The Effect of Cycling + Data Retention

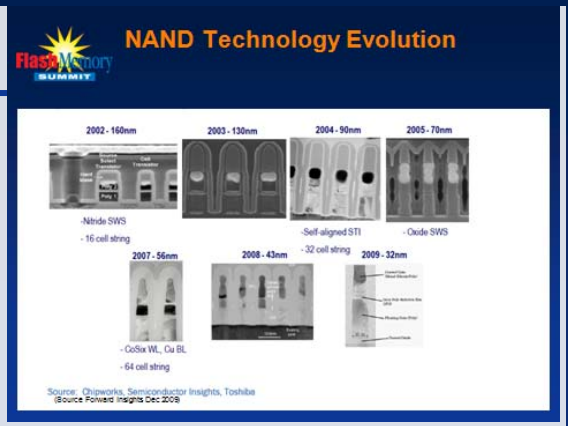
VT Shift after Data Retention

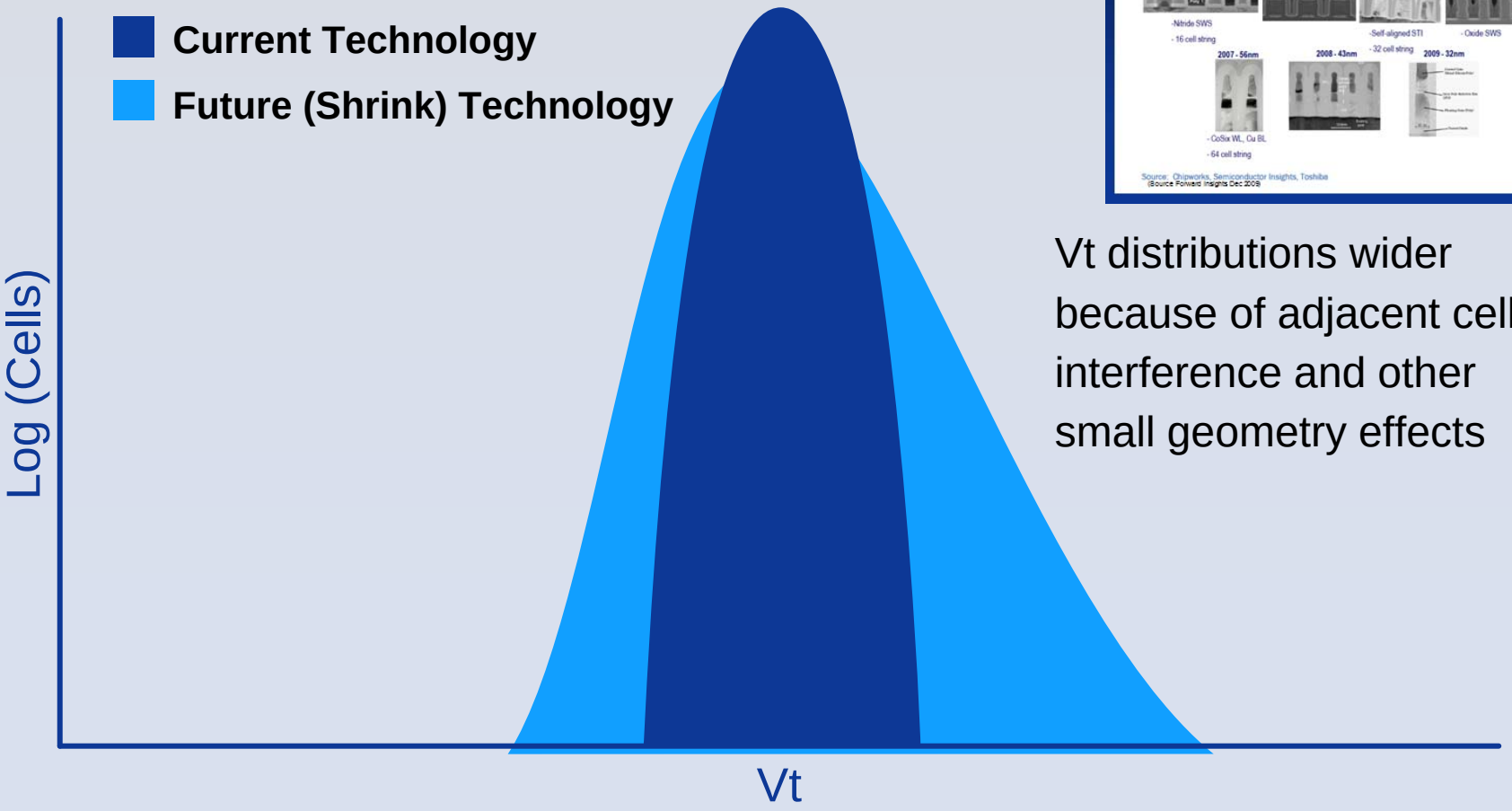
Cycling and data retention result in shift and widening of the Vt distribution



The Effect of Scale Down (Technology Shrink)

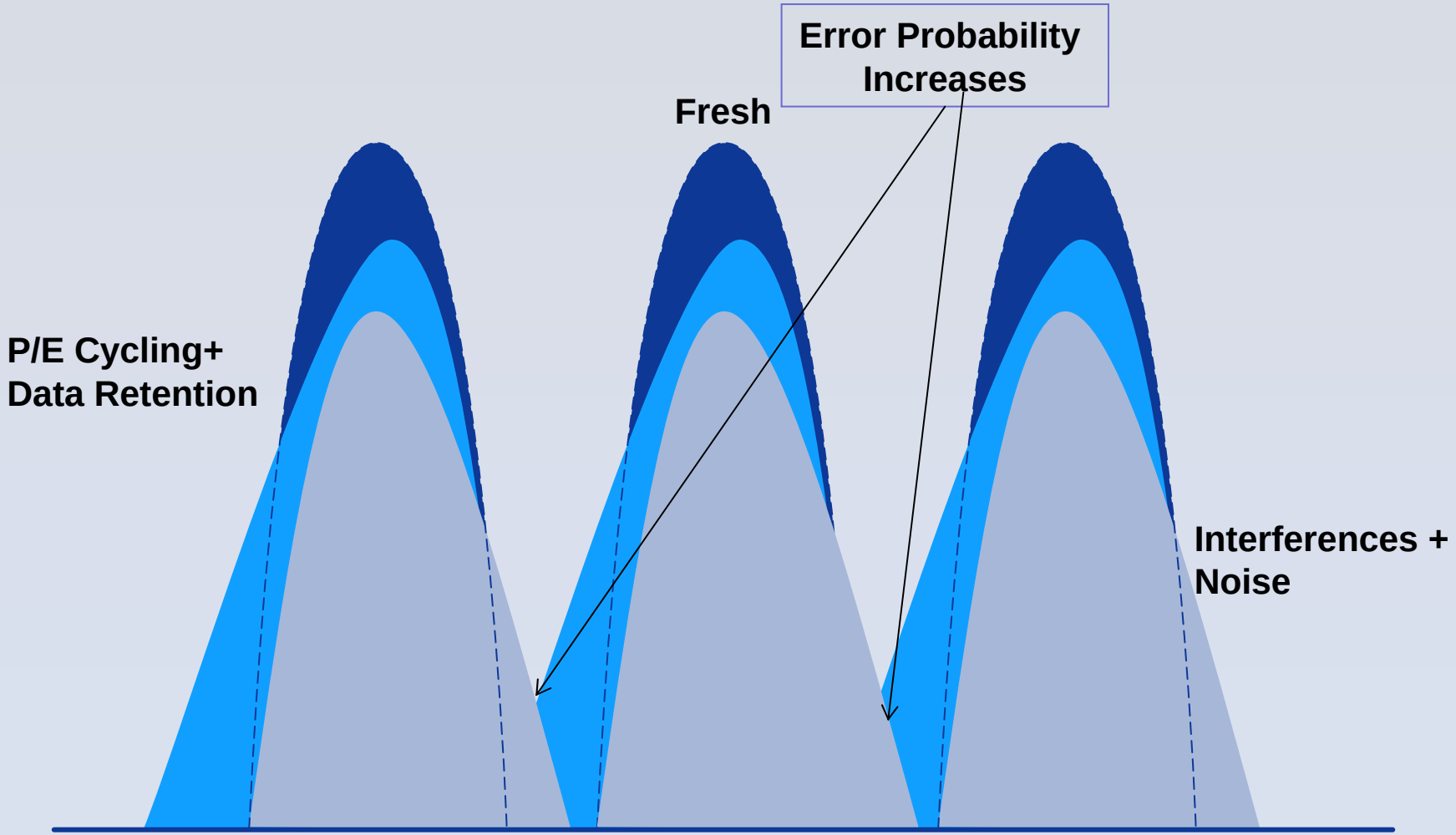
Vt Distribution Comparison



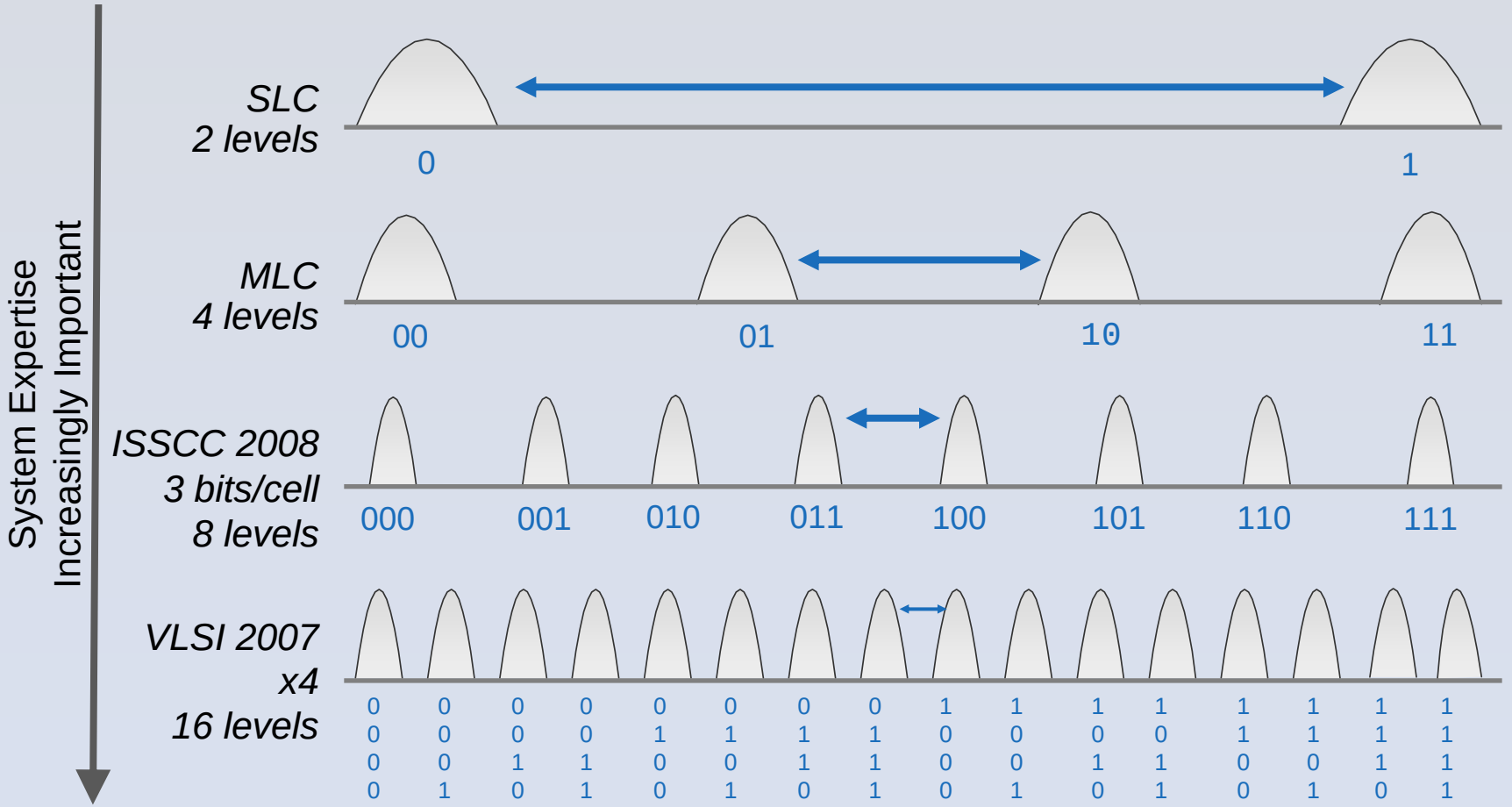


Vt distributions wider because of adjacent cell interference and other small geometry effects

Putting It All Together : The Cumulative Effect

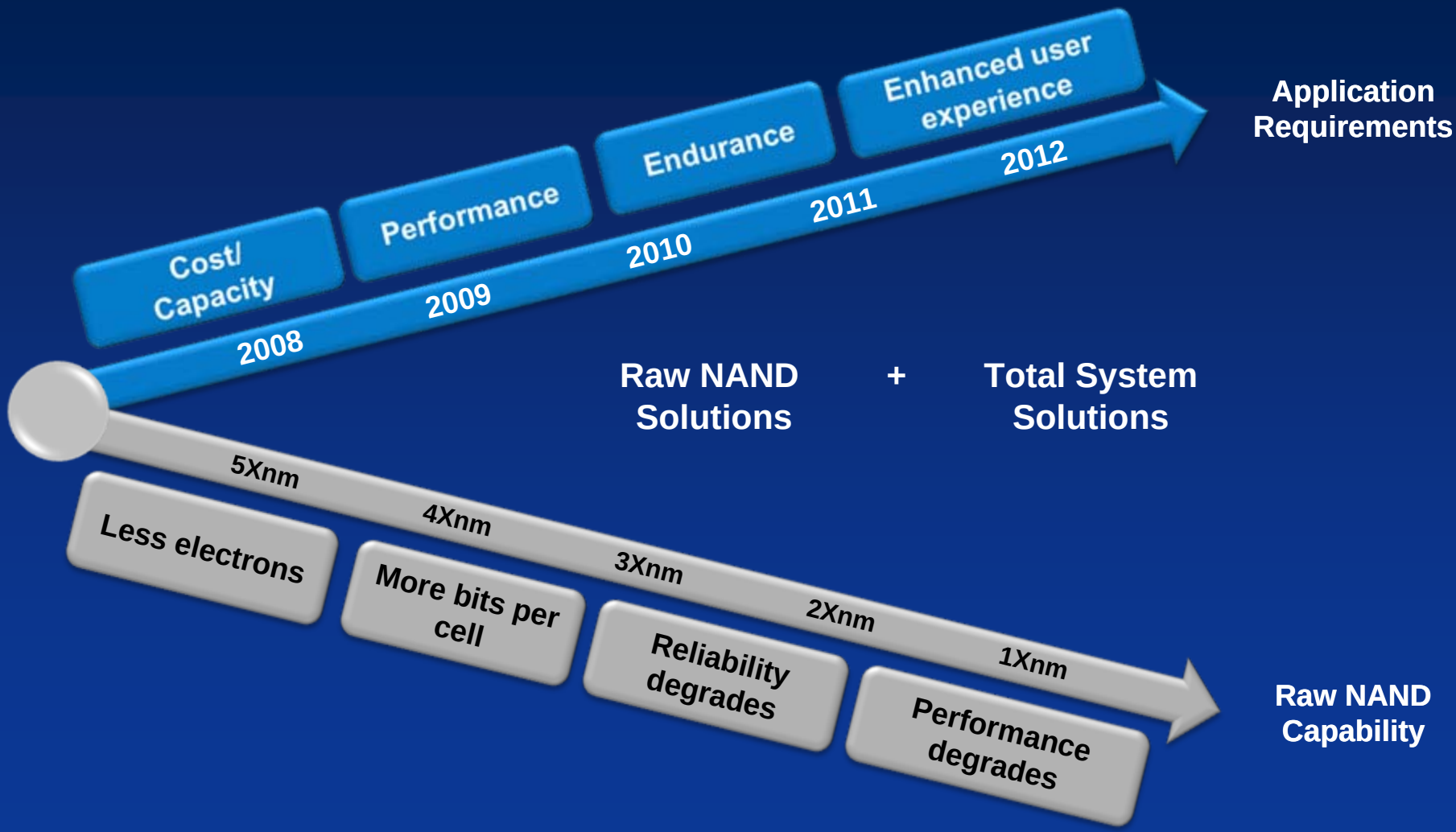


Going Beyond 2 Bits Per Cell

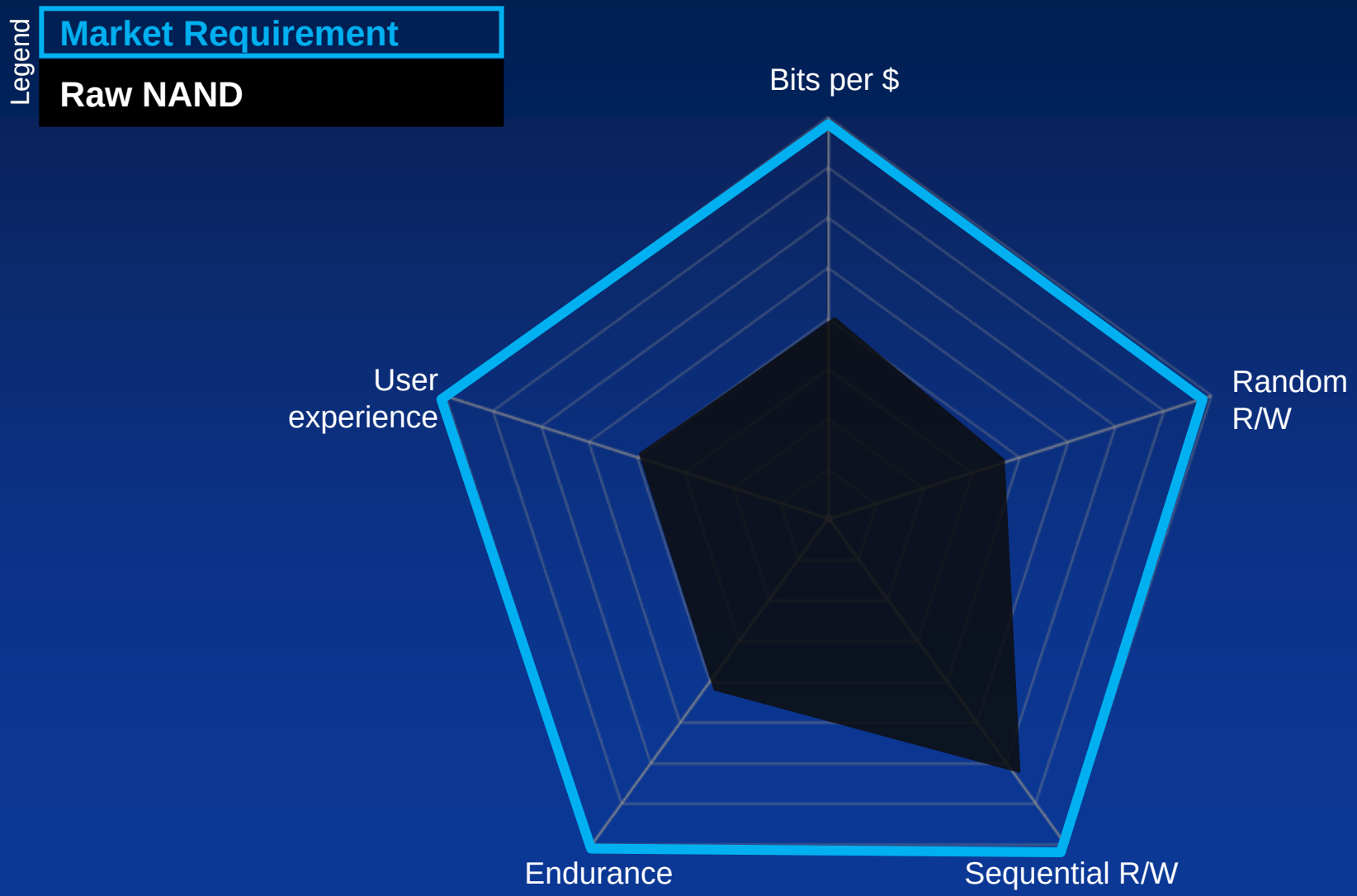


- Distance between adjacent voltage levels is significantly shorter
- Error probability increases (overlap) due to Vt distribution shift and widening.

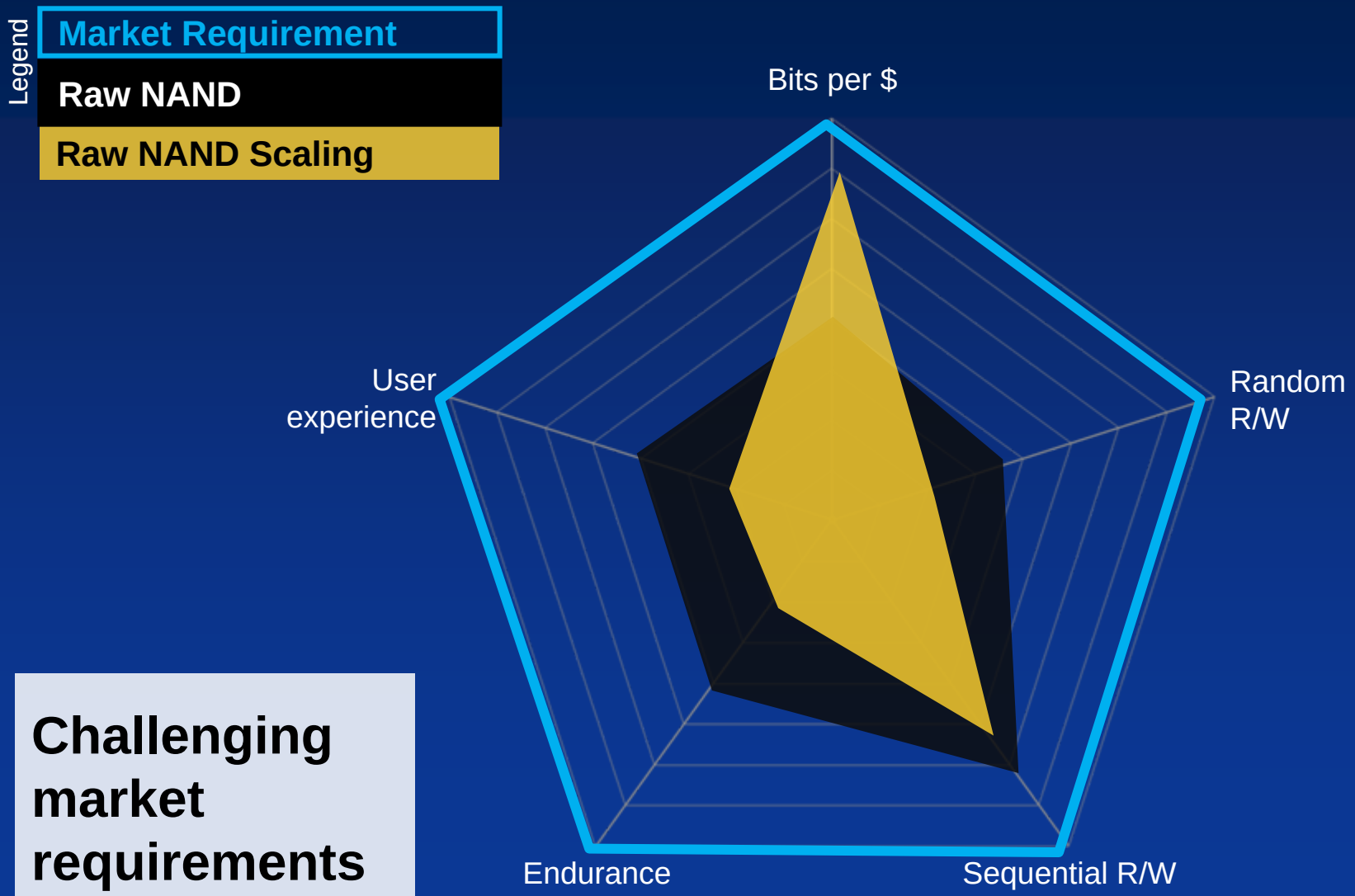
Bridging the Gap



Raw NAND Vs. Market Requirements



Cost Benefit of Raw NAND Scaling

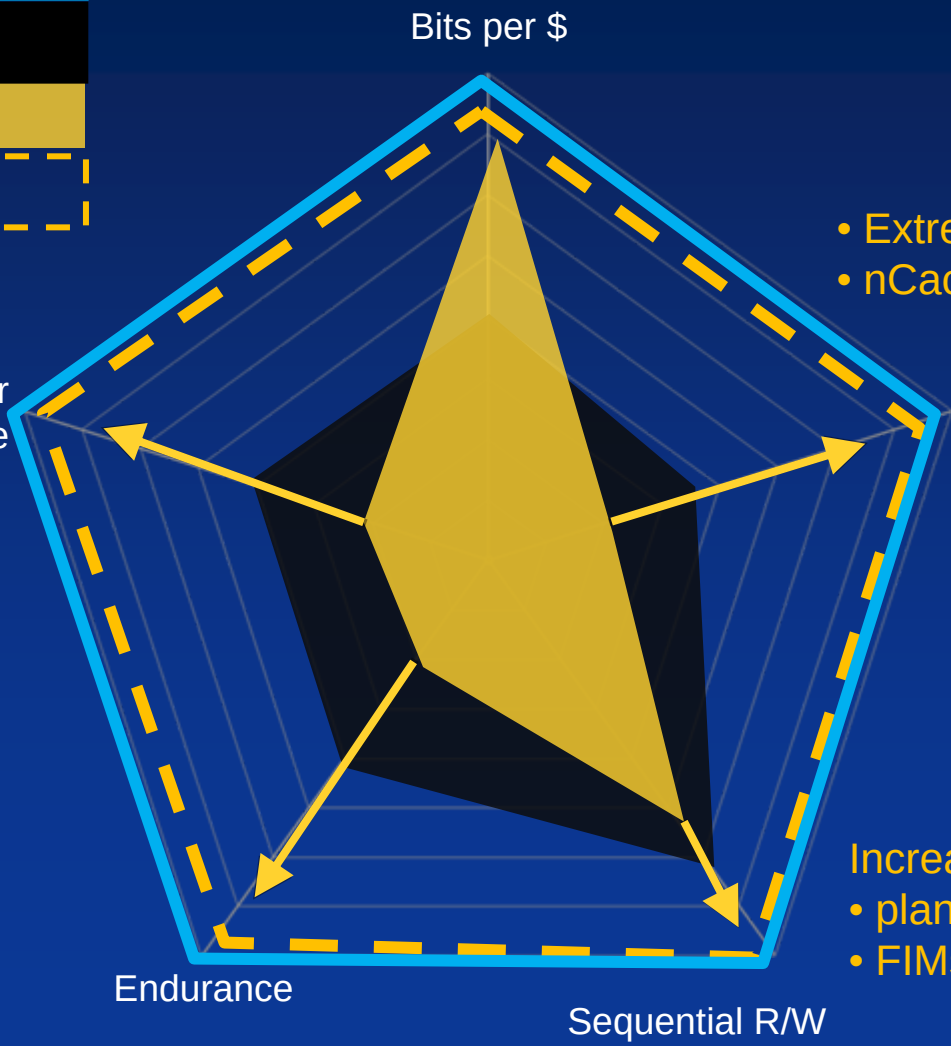


Challenging market requirements

SanDisk Bridging the Gap with Adaptive Flash Management (AFM)

Legend

- Market Requirement
- Raw NAND
- Raw NAND Scaling
- SanDisk AFM



- ExtremeFFS
- nCache

Increased parallelism
- planes per die
- FIMs per system

Thank You!