



**MEMCON08**  
DENALI SOFTWARE, INC.

JULY 21-24 • SAN JOSE, CA

## **Solid State Drives: The MLC Challenge**

By Don Barnettson  
Sr. Director of Marketing  
Sandisk Corporation

**SanDisk®**

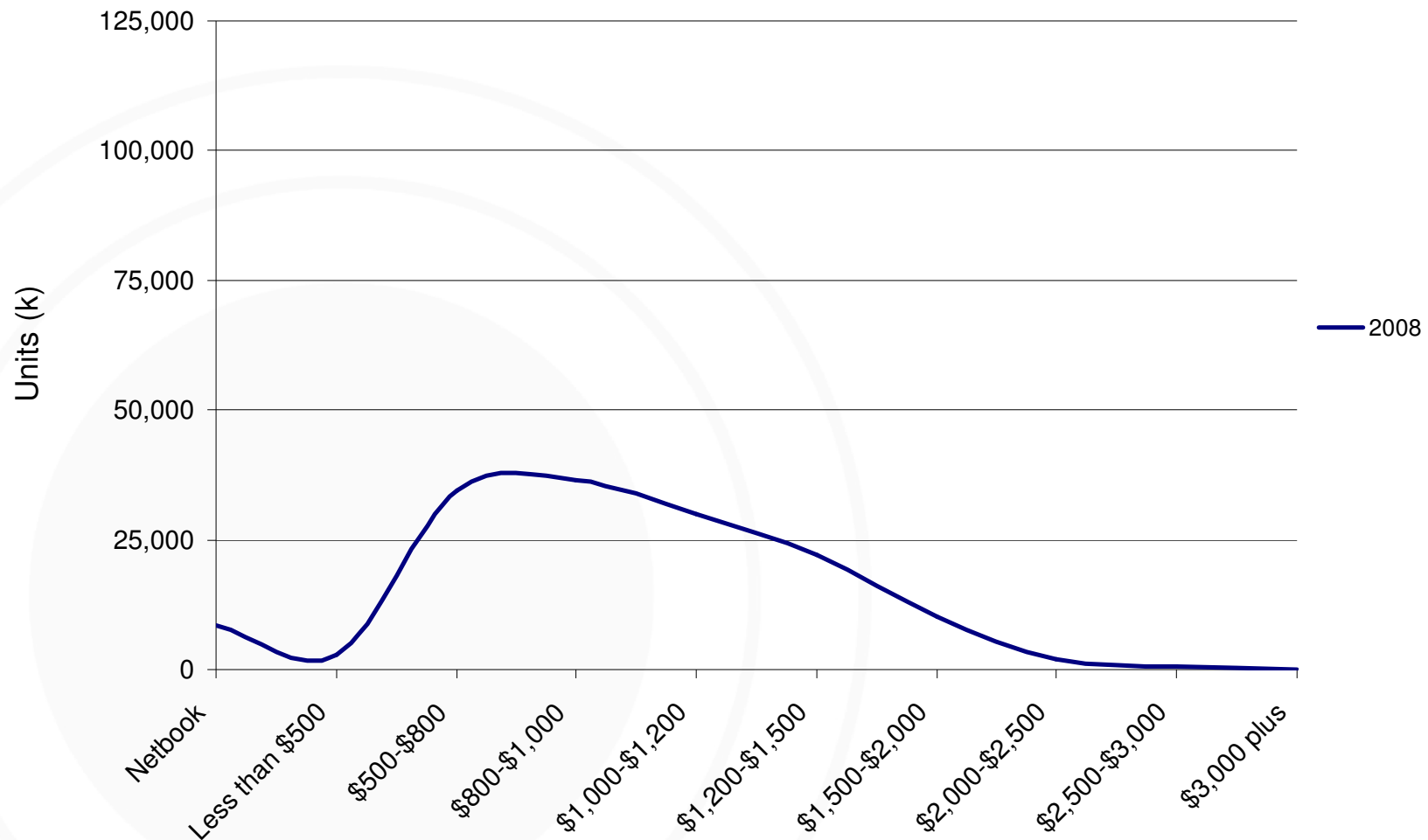
# Forward Looking Statements

During our meeting and presentation 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, production capacity, technology development, technology transitions and future products. Actual results may differ materially from those expressed in these forward-looking statements. Risks that may cause these forward-looking statements to be inaccurate include the risks detailed under the caption “Risk Factors” and elsewhere in the reports we file from time-to-time with the SEC, including our annual report on Form 10-K and our quarterly reports on Form 10-Q. We undertake no obligation to update the forward-looking statements that we make today and note that such forward-looking statements speak only as of the date hereof.

# Agenda

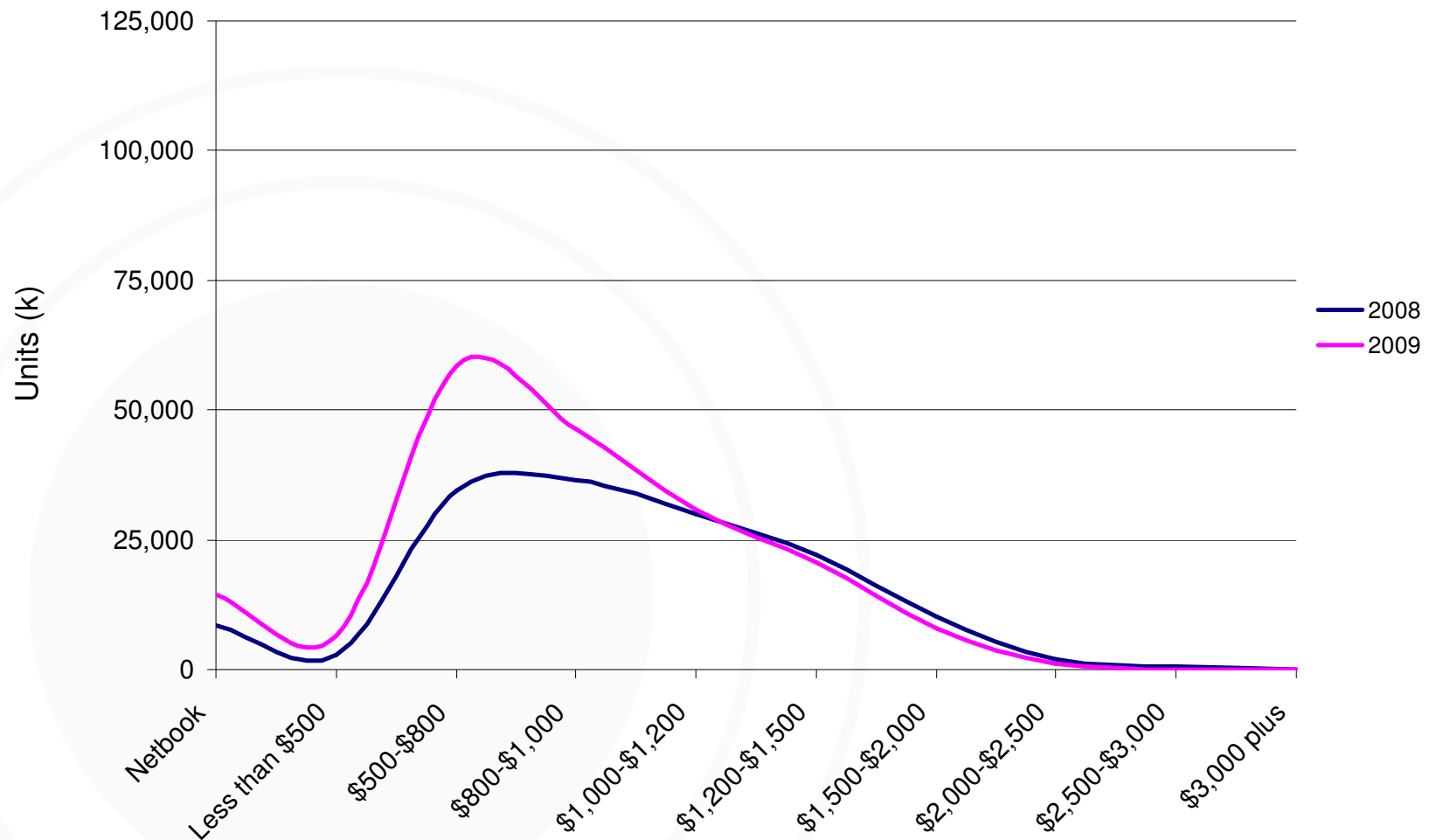
- The SSD Opportunity
- The Challenge of MLC in a PC Environment
- Key SSD Figures of Merit
  - Performance: Bapco
  - Endurance: Introducing the first metric
- Conclusions

# The SSD Opportunity



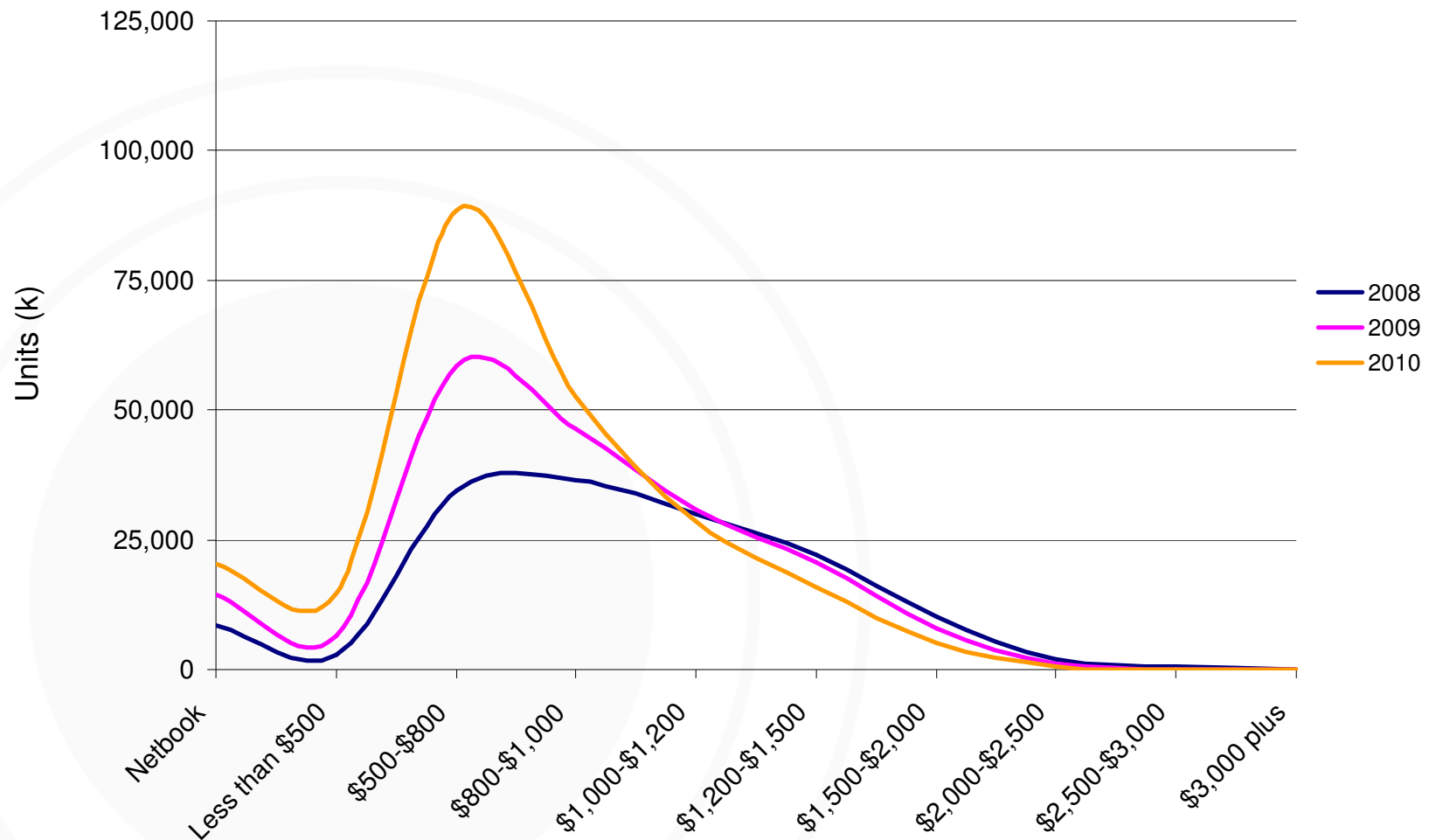
Gartner, Inc. "Forecast: PCs, Worldwide and North America" by George Shiffler, Raphael Vasquez and Mikako Kitagawa, July 1, 2008  
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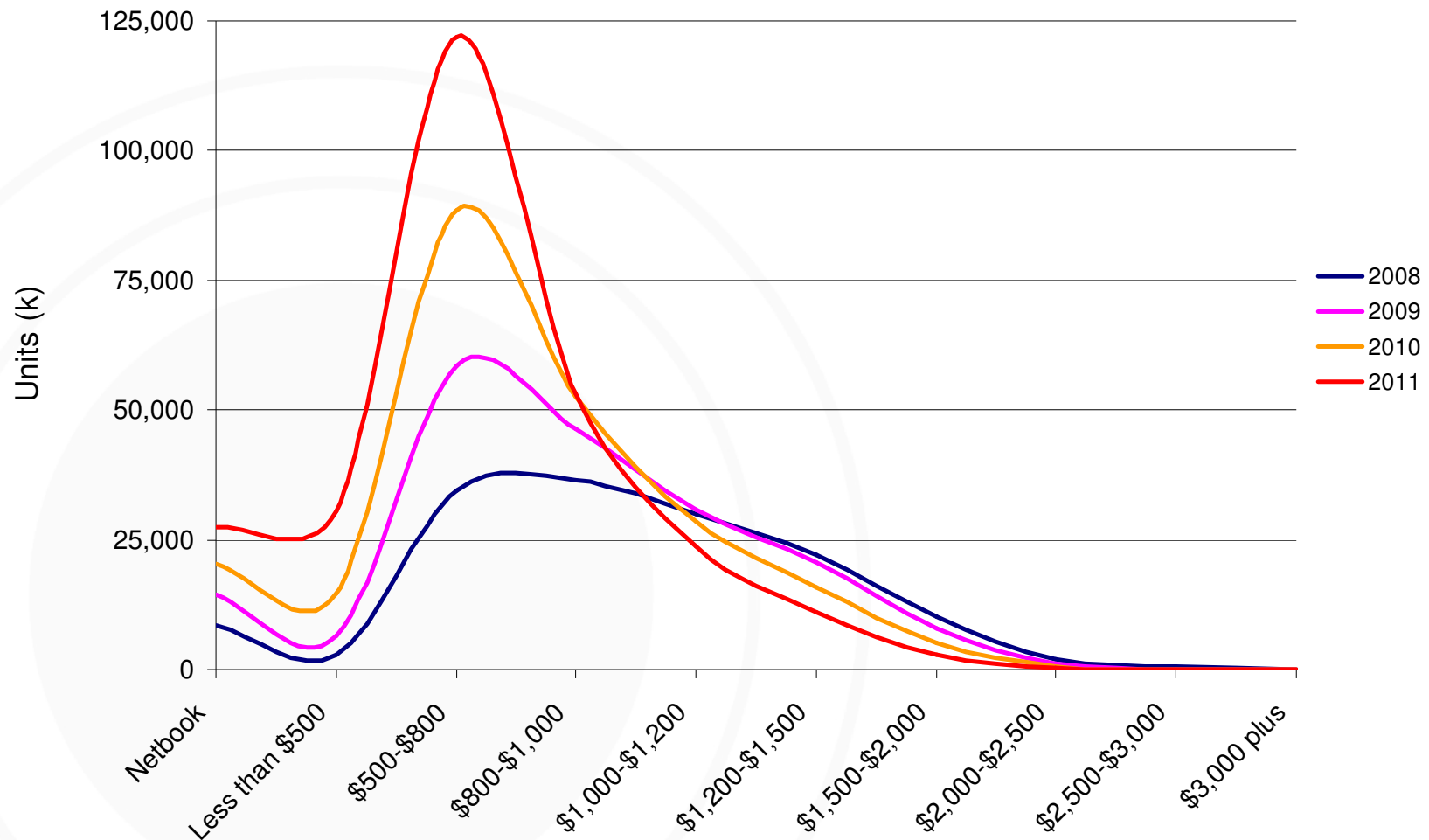
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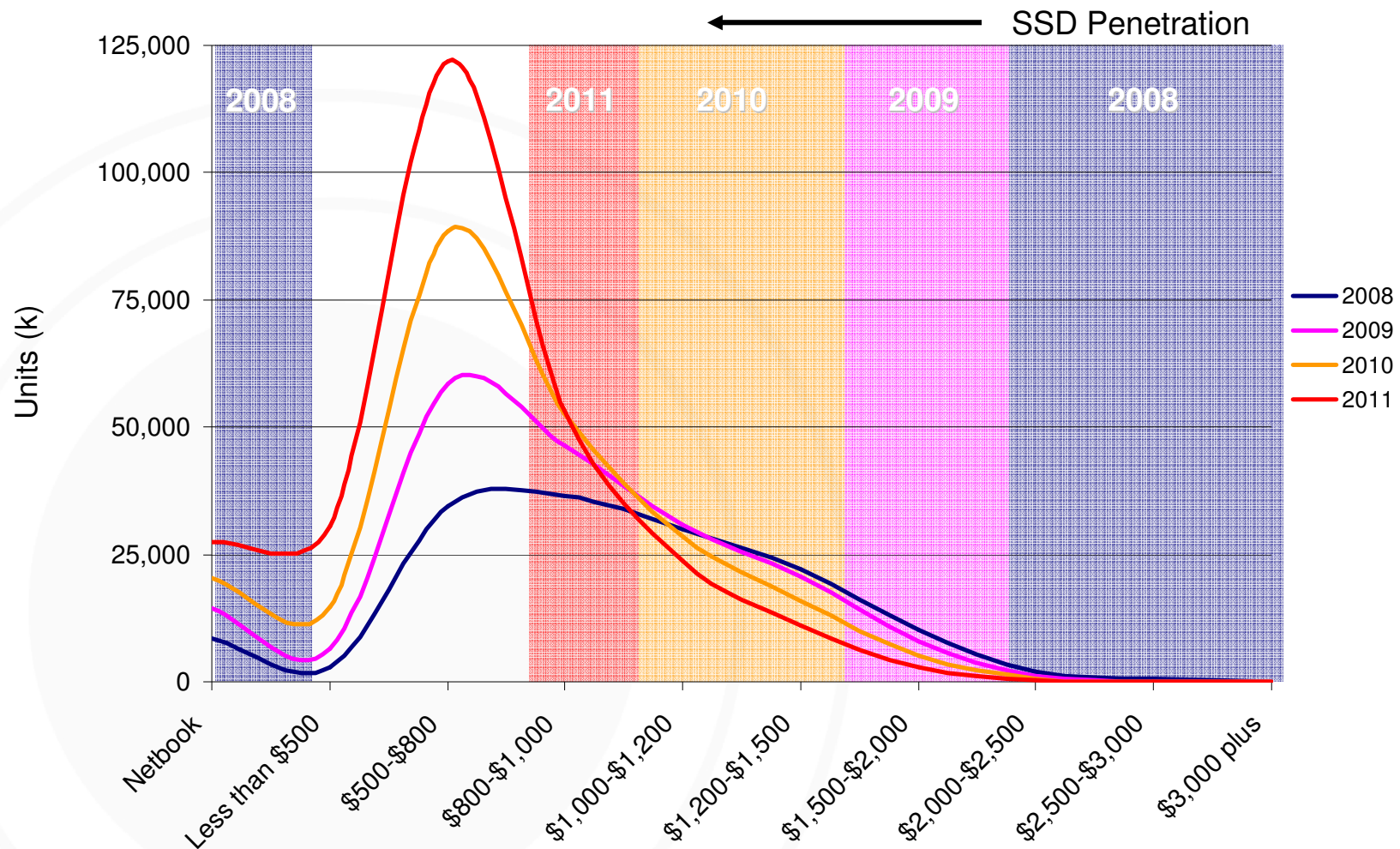
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 Gartner, Inc. "Semiconductor Forecast Worldwide: Forecast Database" by Nolan Reilly, Joseph Unsworth et al, May 29, 2008  
 SSD at 10% of Notebook ASP.

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# Challenge of NAND in the PC Environment

Mismatch between  
Sector size & block size

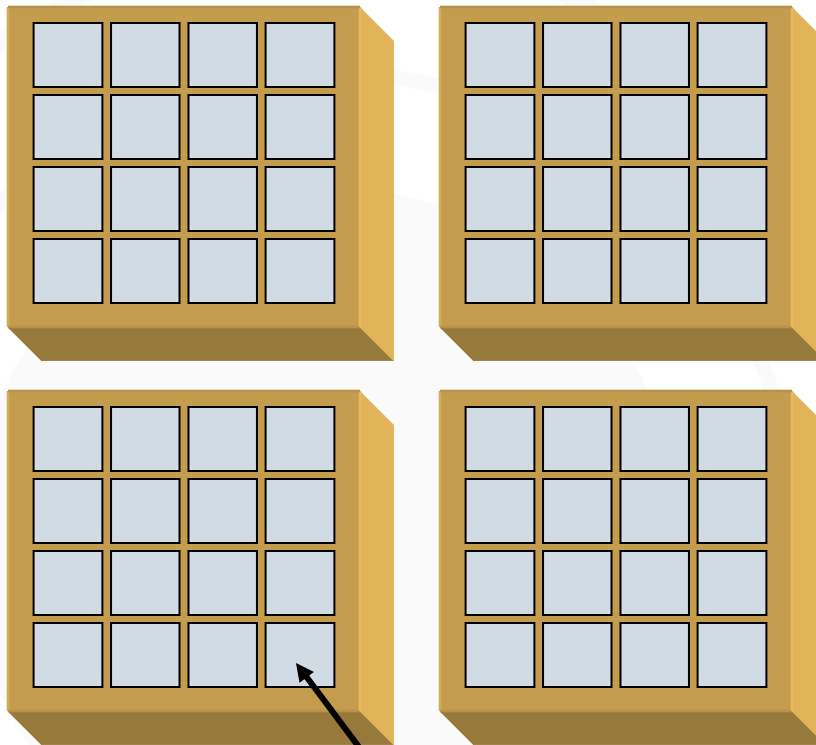
Windows: large quantity of  
Small background writes



2008: PC treats SSD exactly like an HDD

# Mismatch – Sector & block Size

Flash Erase Blocks

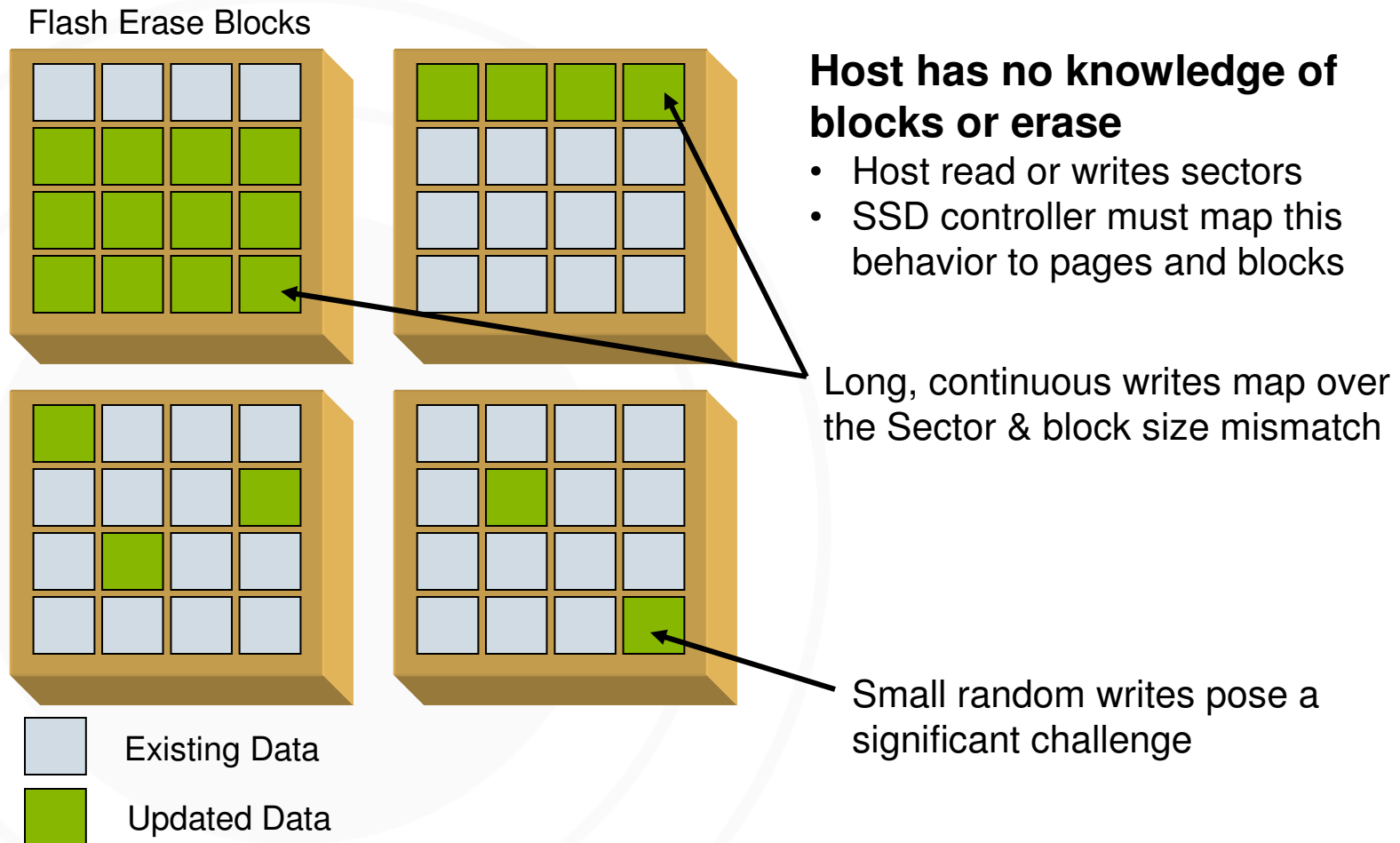


Individual logical sectors  
mapped to NAND pages

**Host has no knowledge of  
blocks or erase**

- Host reads or writes sectors
- SSD controller must map this behavior to pages and blocks

# Mismatch – Sector & block Size



# Mismatch – Sector & block Size

Flash Erase Blocks



## Host has no knowledge of blocks or erase

- Host read or writes sectors
- SSD controller must map this behavior to pages and blocks

## In digital consumer apps

- Dominated by large, continuous writes -> mismatch presents a minimal issue

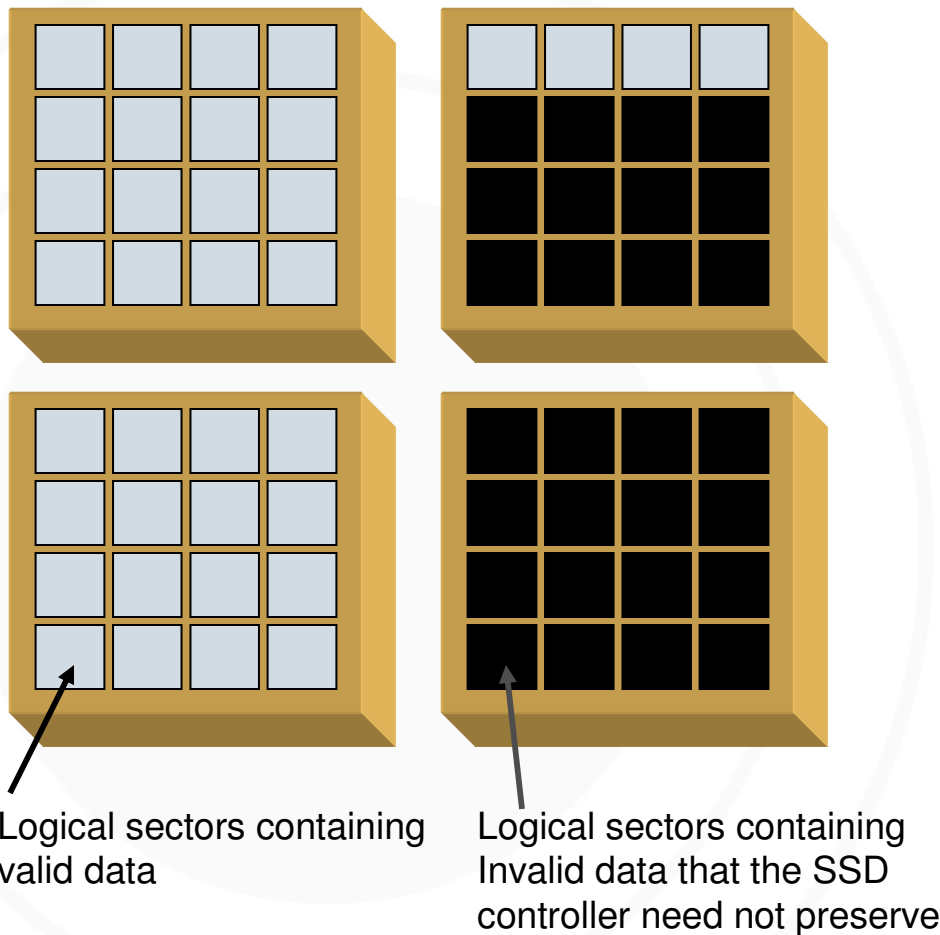
## In computing apps:

- Dominated by small, random writes -> mismatch is critical

Hence the SSD challenge

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# Trim Command – How will it help?



## Trim

Allows the host to communicate to the SSD which sectors no longer contain valid data

- First time PC treats SSD uniquely

Trim gives the SSD controller room to operate

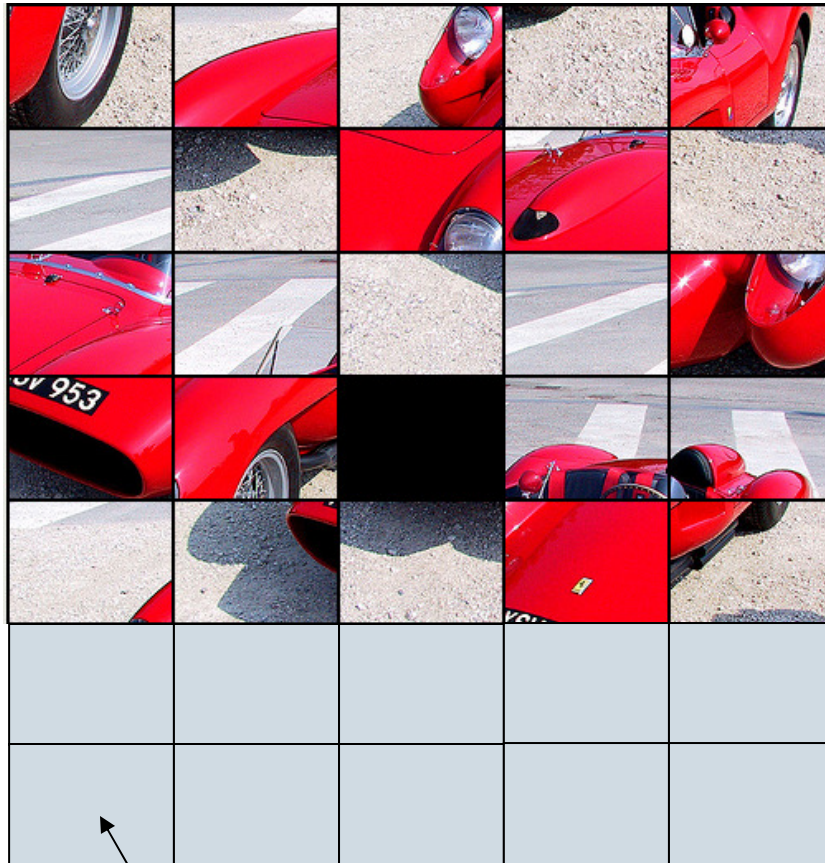
- Freeing up 20-50% of the blocks

Once eco-system supports trim, expect a significant improvement in SSD performance

- Random write performance
- SSD Endurance

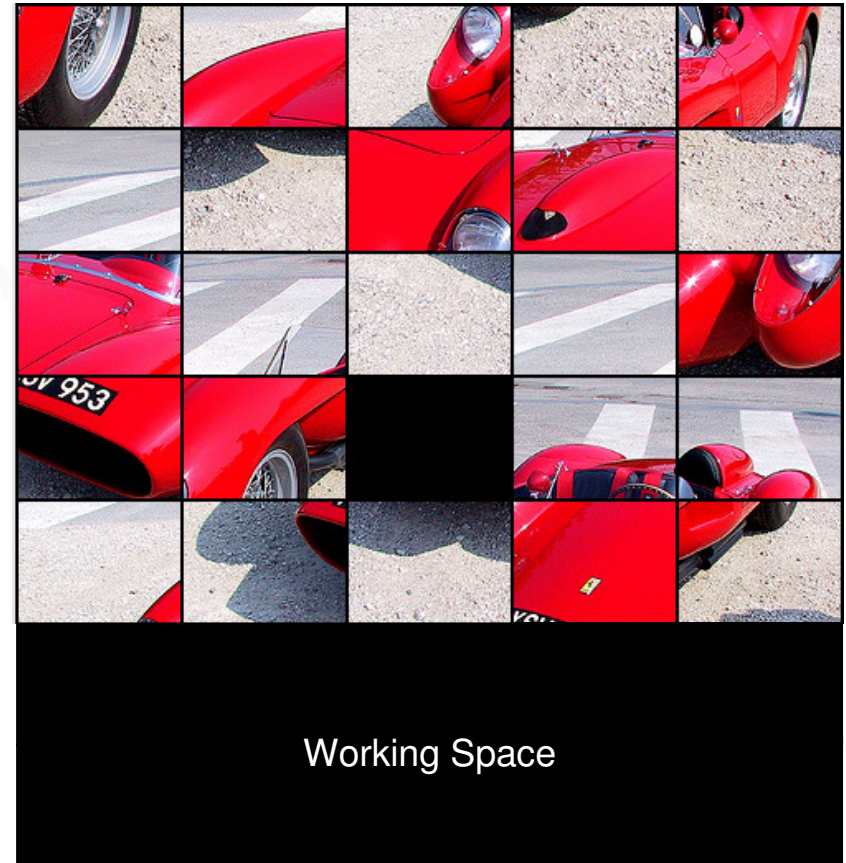
# Trim Command – How will it help?

Without Trim



Data that is dead to host, but SSD must preserve

With Trim



Working Space

# What does an SSD do for a Customer?

- SSDs make systems significantly faster
  - Speed is the focus of significant R&D in industry today
  - Early adopters will buy speeds and feeds
  - Mainstream – need a clear “What does it mean for me?”

# Performance – Relevant Metrics Exist

- For Enthusiast Users
  - Speeds & feeds from raw SSD data sheet
    - Promotion of sequential performance, but random performance is key
  - PC Mark HDD scores (up to 4x faster than HDD)
- For Mainstream Users
  - Simple metric on what SSDs mean to them
    - Bapco's Sysmark provides this metric for business applications
  - SSDs deliver up to a 50% improvement in Sysmark performance vs. HDD
- SanDisk is extremely well positioned – our ABL technology creates a surplus of raw NAND speed
  - pSSD introduced at Computex nearly 2x as fast as competing devices



# What does an SSD do for a Customer?

- SSDs make systems significantly faster
  - Speed is the focus of significant R&D in industry today
  - Early adopters will buy speeds and feeds
  - Mainstream – need a clear “What does it mean for me?”
- SSDs make systems significantly more reliable
  - Nothing is more precious than our customers’ data
  - SSDs are clearly more reliable in traditional metrics (MTBF) due to solid state nature
  - Industry has not been clear on metrics for endurance – leaving consumers with an unanswered “Will it last?” question

# Endurance & Bapco Usage Models

- Bapco defines (3) typical user profiles (professional, student, personal)
  - Which applications? How many hours per day?

	<b>Writes (GB/week)</b>	<b>3 Year Writes</b>	<b>5 Year Writes</b>
<b>Professional</b>	87.0	13.5 TBW	22.6 TBW
<b>Student</b>	37.2	5.8 TBW	9.6 TBW
<b>Personal</b>	30.9	4.8 TBW	8.0 TBW

TBW = Terabytes written  
Vista with MobileMark 2007

**Bapco Write  
Pareto**

<b>Write Size</b>	<b>Percent of of x-fer requests</b>
<b>4K</b>	<b>57.8%</b>
<b>8K</b>	8.8%
<b>16K</b>	8.3%
<b>32K</b>	0.3%
<b>64K</b>	0.5%
<b>128K</b>	24.5%

- Majority of data requests are 4kB at a time to the SSD
- Contemporary NAND flash has 512kB – 1MB blocks (erase)
- Mismatch in write size & block size is THE key SSD challenge

# How to measure SSD endurance?


$$\text{Cycles} = \frac{\text{Data Written by Host}}{\text{Capacity}}$$

**Incorrect: Ignores the sector / block size mismatch**

$$\text{Cycles} = \frac{(\text{Host writes}) * (\text{Write Amplification Factor}) * (\text{Wear Leveling Factor})}{\text{Drive Capacity}}$$

?

# Analysis of Competitors Endurance Claims

## ■ All of these methods look from the NAND up

- Equations are too complex to be broadly used, yet too simple to yield correct results
- Rated endurance of 20GB/day for 5 years

## To the end customer, the SSD is a system

- Need an endurance specification for the system as a whole
- A single, simple “Gas Gauge” that everyone can use

## Introducing... ***Longterm Data Endurance (LDE)***

- Poses two possibilities:
1. Competitor's MLC is only rated to 552 cycles
  2. Equation is incorrect, in addition to being overly complex

# ***Longterm Data Endurance (LDE) Definition***

- Def'n: Total amount of data writes allowed in SSD lifespan = ***LDE***
  - Write pattern: Typical business PC user (Bapco Write Pareto)
  - Lifespan: Data is written equally over system life
  - Retention: Data is retained for 1 year after ***LDE*** is exhausted
  - Tested by limiting available density & running to ***LDE*** exhaustion
- ***LDE*** can then be used to calculate SSD lifespan
  - For example, if a drive has a ***LDE*** of 80TBW
  - With 20GB of writes per day, ***LDE*** is not exhausted in the first 10 years
  - The ***LDE*** is directly dependent upon the SSD's capacity
- ***LDE*** provides the first useful measure of SSD endurance
  - SanDisk will standardize ***LDE*** through the appropriate body
  - SanDisk will spec ***LDE*** on all future PC SSD products
  - We strongly encourage our competitors to do the same

# In netbook Space – *LDE* is already key

- System specifications
  - UMPC running WinXP -> Personal user model, 3 year product lifespan
- Some OEMs would like a 4GB MLC SSD for entry level
  - Major SSD suppliers reluctant to guarantee 3 year lifespan for 4GB MLC under WinXP
  - Major SSD suppliers pushing OEMs to start at 8GB to support endurance



# In Notebook Space - *LDE* will become key



- ***LDE*** will be **THE** key differentiator between SLC, MLC and x3 based SSDs (examples only)
  - 250MB/s 32GB SLC SSD 400TBW ***LDE***
  - 250MB/s 64GB MLC SSD 100TBW ***LDE***
  - 200MB/s 64GB x3 SSD 40TBW ***LDE***
- OEM Marketing opportunity for ***LDE*** as a measure of SSD Quality
  - Nothing is more important to Sandisk than our customers' data
  - Perhaps some users will only choose to consume 20% or 50% of the SSD's rated ***LDE***

# Conclusions

- Key SSDs values are performance & reliability
  - Early adopters: Buy based on speeds and feeds
  - Mainstream adopters & business buyers: “What it means to me?” in a simple and useful way
- To drive mainstream adoption the SSD industry needs to embrace useful & simple measures of performance AND reliability
  - **Bapco** simplifies performance into a single number
  - **LDE** simplifies endurance into a single useful number
- SanDisk will lead the SSD industry to mainstream adoption
- Parties interested in collaborating to release the **LDE** standard, please email Sandisk at [LDE@sandisk.com](mailto:LDE@sandisk.com)