

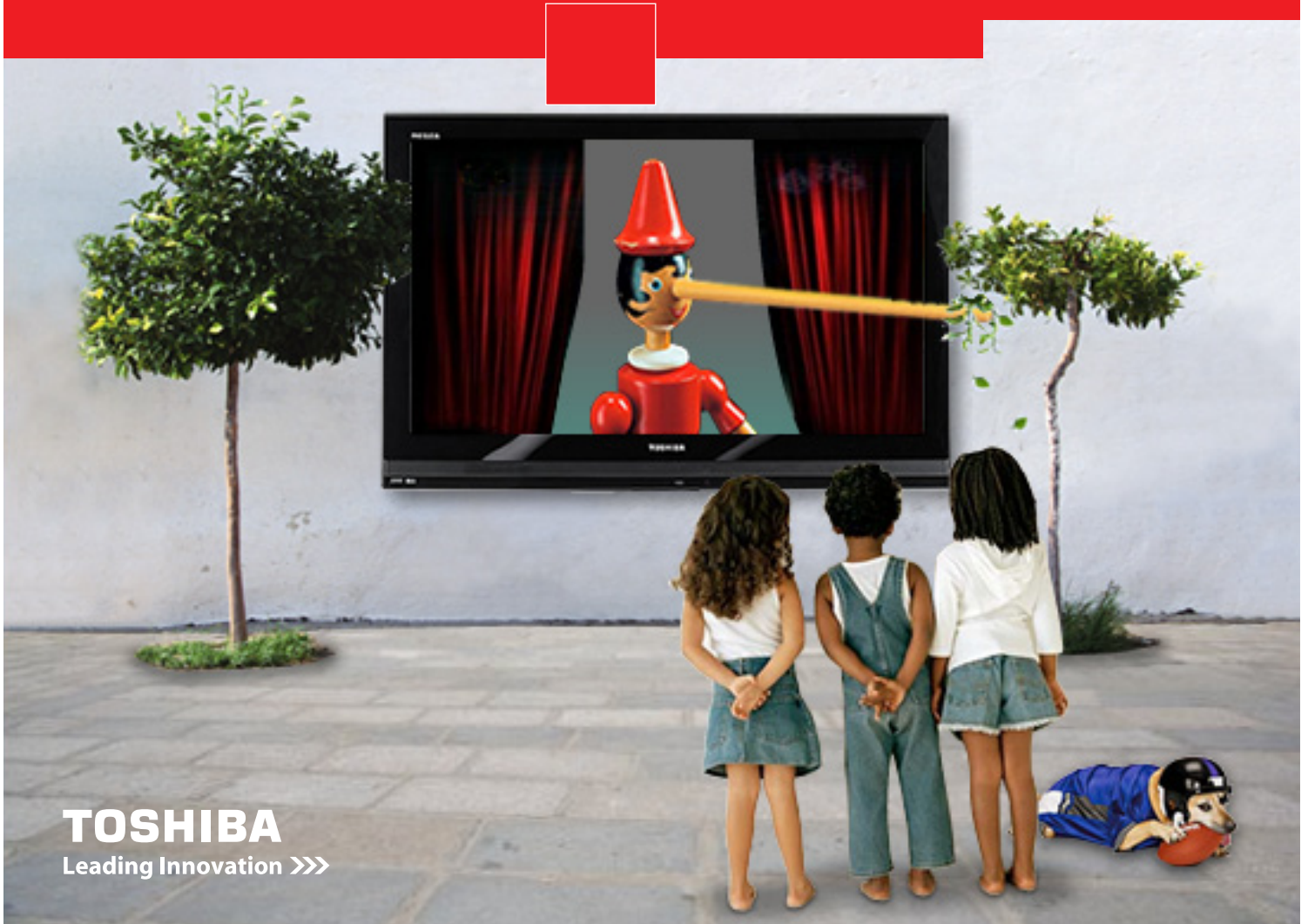
Solid State Drives

Separating myths from facts



SSD vs HDD? MLC vs SLC?

Determine the right technology for the right application. Choose the right performance, endurance, capacity and reliability for your mobile computing needs.



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Here's How to Recognize Solid State Drive Myths

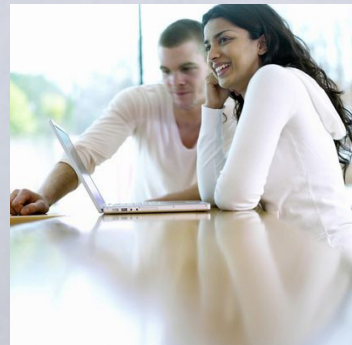
There are a lot of myths and misconceptions circulating about solid state drives. As an innovator and industry leader in NAND Flash as well as in 1.8-inch and 2.5-inch hard disk drives for mobile computing, Toshiba would like to provide information to help you separate the reality from the myths.

Flying saucers and UFOs have their place, just not in the SSD world.

8 Common SSD Myths

- 1 Solid state drives are too expensive for mainstream computing [Fact ▶](#)
- 2 There's no clear advantage to SSDs [Fact ▶](#)
- 3 All SSDs have similar performance [Fact ▶](#)
- 4 MLC NAND-based SSDs can "wear out" if you write a lot of data [Fact ▶](#)
- 5 Hard disk drives store data more safely and are more dependable than solid state drives [Fact ▶](#)
- 6 SSD capacities are too small..... [Fact ▶](#)
- 7 SSDs don't reduce power consumption enough to make a difference..... [Fact ▶](#)
- 8 SSDs will replace all hard disk drives [Fact ▶](#)

SSD MYTHS



Toshiba's SSD products are a collaborative effort developed with expertise from both storage and semiconductor businesses, designed to meet the requirements of the mobile PC OEM and the ultimate end user.

SSD Myth 1

Solid state drives are too expensive for mainstream computing

Myth Busted Today, the proven performance of MLC NAND-based SSDs is enabling more consumer-oriented prices. SSDs for notebook computers are most suitable for users who value increased reliability, ruggedness and performance.

The facts: Like many new technologies, SSDs for mainstream computing applications carry a price premium in comparison to the standard solution, in this case, hard disk drives.

However, as SSD prices continue to decline, this price premium will decrease, too. Use of Multi-level Cell NAND, which stores two or more bits per cell, advances in NAND process technology and the expected price curve for semiconductor memory products will continue to improve the value/performance of MLC SSDs. In 2009 and 2010, the notebook computing market is expected to show increased adoption of SSDs, growing to approximately 17% of the notebook market by 2013¹.

The important thing when choosing MLC vs. SLC SSD is to have the right technology for the right application. Based on our usage modeling, Toshiba finds that MLC-based SSDs are a good fit for most mobile computing applications, while SLC-based SSDs are usually better suited for high performance enterprise applications.

¹Forward Insights, "Solid State Drives: A Closer Look." Oct. 2008.

SSD Myth 2

There's no clear advantage to SSDs

Myth Busted SSDs outperform HDDs in boot-up time, random read and write, and when opening and saving files.

The facts: Compared to hard disk drives, SSDs realize a number of advantages that address needs in the mobile computing market for performance, ruggedness, and lightweight, compact form factors. Boot time is typically about half that required for an HDD. The time to find a file on the drive is measured in millionths of a second for SSDs and in thousandths of a second for HDDs, so the difference adds up.

The benchmark scores (lower left) for Toshiba MLC NAND SSDs¹ show the performance advantages of our 43nm SSDs compared to 5400 rpm and 7200rpm HDDs. These SSDs excel Windows® XP boot speed, application loading, general usage and virus scan.

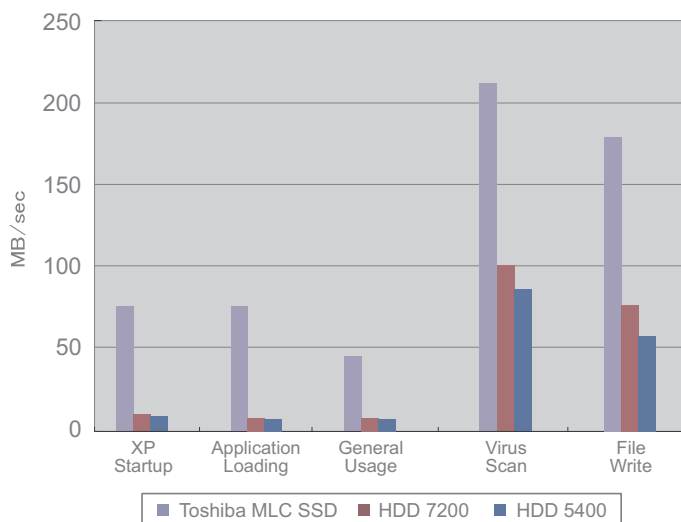
Perhaps even more important to the mobile user are the advantages in terms of higher reliability and ruggedness. Because they have no moving parts, SSDs can withstand greater shock and vibration, and have the added benefit of quieter operation. According to Web-Feet Research², 2.5-inch hard drives for computing applications can withstand 350Gs of operating shock and 900Gs of non-operating shock, while NAND-based SSDs can withstand >1500Gs for both operating and non-operating shock. For vibration resistance, 2.5-inch drives can withstand 0.7Gs vibration, while both MLC and SLC NAND-based SSDs can withstand 20Gs or more.

As an added benefit, SSDs can also be configured to smaller form factors and reduced weight compared to hard drives.

¹Based on internal tests by Toshiba America Electronic Components. Conditions and configurations: Benchmark tests PCmark 05, using Intel Core2Duo 2.2GHz E4500 CPU with 2MB L2 cache, 2GB DDR SDRAM with 800MHz FSB, Intel GMA3100 graphics, and Windows® Vista OS.

²Market data on SSD and HDD from Web-Feet Research, SSD Markets and Applications Quarterly Series: 1Q 2008, based on average performance of products available as of the date of the report.

Benchmark by PCmark05



Performance. Endurance. Reliability.

Compared to hard disk drives, solid state drives offer several advantages for the mobile computing market – performance, ruggedness, and lightweight, compact form factors.



SSD Myth 3

All SSDs have similar performance

Myth Busted Many benchmarks have shown that there can be a significant difference in performance from one SSD to another. Buyers should carefully consider the drive manufacturer's experience in NAND manufacturing and technology as well as the specific features and performance of the drives they consider.

The facts: Not all SSDs are created equal. Just taking a controller and NAND and putting it in a drive enclosure does not make a successful SSD. The early market indications that not all SSDs are meeting expectations can be attributed in part to this concern.

We believe that three factors are critical: the design of the controller, proven NAND flash technology and experience with the hard disk drive market. The architecture of the controller can have a significant impact on endurance, wear-leveling and performance, and SSD architectural features such as DRAM cache and parallel design are critical to better performance, but are not apparent to the end user. As an innovator of NAND flash since the 1980's, Toshiba has found that experience plays a significant role in maintaining quality and yield with each process migration as well as in moving to multi-level cell technologies to store more than one bit per cell. Toshiba's SSD products are unique in the industry as they are a collaborative effort developed with expertise from both storage and semiconductor businesses, designed to meet the requirements of the mobile PC OEM and the ultimate end user.

MLC NAND Leadership

- World's most experienced producer of NAND Flash
- World's second largest Flash memory supplier¹
- Principal innovator of NAND and NOR Flash
- 32Gb² NAND chip fabricated with cutting-edge 43nm process
- 32Gb³ NAND and controller in a single package
- Japan's largest 300mm wafer fab



¹Suppli NAND Flash Supplier Rankings, 2007.

²When used herein in relation to memory density, gigabit and/or Gb means 1,024x1,024x1,024 = 1,073,741,824 bits. Usable capacity may be less. For details, please refer to specifications.

³When used herein in relation to memory density, gigabyte and/or GB means 1,024x1,024x1,024 = 1,073,741,824 bytes. Usable capacity may be less. For details, please refer to specifications.

SSD Myth 4

MLC NAND-based SSDs "wear out" if you write a lot of data

Myth Busted The five-year estimated write capacity of a 128GB¹ Toshiba MLC SSD is 80 Terabytes², well beyond the typical usage of a mobile computer user. Users with unusually large write requirements can increase write capacity by choosing a larger capacity SSD.

The facts: It's true that MLC NAND drives are rated for a smaller number of write cycles than SLC NAND-based drives, but the important thing when choosing MLC vs. SLC is to have the right technology for the right application. Based on our usage modeling, Toshiba believes that MLC-based SSDs are a good fit for most mobile computing applications, while SLC-based SSDs may be better suited for high-performance enterprise applications.

Absent any industry standard usage model, Toshiba developed an internal model and studied usage patterns for normal and heavy, or write-intensive, users. To even begin to reach a conservative endurance limit of a 64GB MLC NAND-based SSD with wear-leveling technology, a mobile user would have to write approximately 40 Terabytes (forty trillion bytes) of data over the expected five-year life of the drive. That's equal to approximately 22GB of new data per day, every day – or enough to fill 4.6 DVDs, or 32 CDs daily. With a 128GB drive, for example, the wear would be spread over a larger storage area, effectively doubling the average daily write limit to 44GB, or more than 9 DVDs. In the Toshiba usage modeling study*, typical users wrote approximately 1.4GB/day, and heavy users wrote about 5.2GB/day. Further analysis showed that auto-save and hibernate features could increase total data written per day to 2.4GB for the typical user and 9.2GB for heavy users. Although the specifications of Toshiba 64GB MLC SSDs exceed the 40 Terabyte example provided, it may help demonstrate that the endurance limit is so far beyond the likely usage of a typical mobile computer user that it isn't a realistic cause for concern.

Toshiba also compared the daily write volume for PC-class SSDs using MLC and SLC technology. For a 128GB SLC NAND drive, the daily write volume increases to approximately 500GB per day over a 5-year life, while the 256GB and 512GB drives could support write volumes of 1 and 2 Terabytes per day, respectively.

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*Toshiba internal study involving 237 mobile computer users.

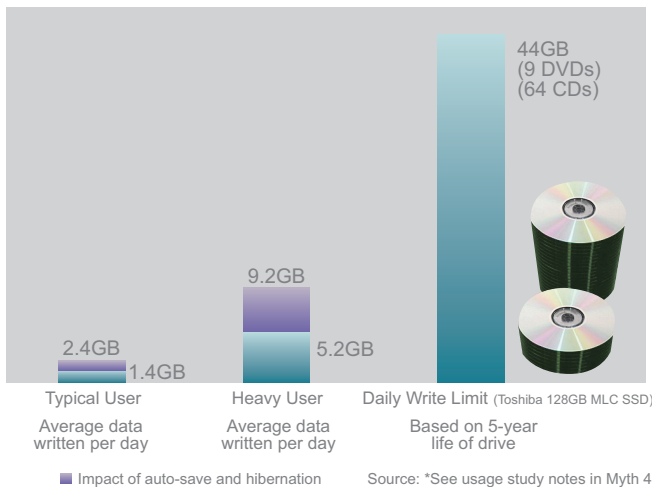
SSD Myth 4 (continued)

Endurance: MLC vs. SLC
Estimated Average Daily Write Limit

	MLC	SLC	Notes
512GB	176GB ¹	2TB ²	<ul style="list-style-type: none"> Average GB/day write limit based on 5-year product life Manufacturers typically warrant HDDs for 3-5 years Estimate assumes 1,400 W/E MLC and 50,000 W/E SLC and write amplification factor
256GB	88GB	1TB	
128GB	44GB	500GB	
64GB	22GB	250GB	

This comparison demonstrates that the endurance limit of an MLC NAND solid state drive is so far beyond the likely usage of a typical mobile computer user that it isn't a realistic cause for concern. Users who write a great deal of data can choose a higher capacity drive.

Toshiba Usage Model Study*
Average Data Written Per Day



¹When used herein in relation to memory density, gigabyte and/or GB means $1,024 \times 1,024 \times 1,024 = 1,073,741,824$ bytes. Usable capacity may be less. For details, please refer to specifications.

²When used herein in relation to memory density, terabyte and/or TB means $1,024 \times 1,024 \times 1,024 \times 1024 = 1,099,511,627,776$ bytes. Usable capacity may be less.

SSD Myth 5

Hard disk drives store data more safely and are more dependable than solid state drives

Myth Busted With no mechanical parts, SSDs are less likely to suffer unexpected drive failure than HDDs. Both SSDs and HDDs use error correction to provide virtually error free storage. The defacto industry standard for SSDs is to correct bit errors to a level comparable to that of HDDs.

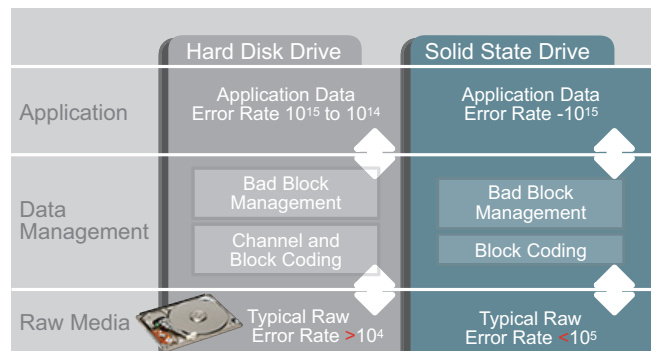
The facts: Some reports have questioned SSD reliability. Overall, both MLC and SLC types of SSD have no mechanical parts so they are not prone to mechanical failure, and typically have a higher rated MTTF than HDDs¹. This additional ruggedness and reliability is the reason flash-based SSDs have been used since the mid-1990's in military and mission-critical applications and are now gaining in popularity for mobile computer users.

Another misconception is that hard disk drives require less error correction than SSDs. Both HDD and MLC NAND SSD drives utilize error correction algorithms to ensure that data is stored safely. Just as a hard disk drive is widely accepted with little concern about bad sectors, the NAND flash memory in a SSD works in a similar way in that the controller maps around bad memory areas and error correction code (ECC) is used to correct bit errors. Controllers for NAND flash have built-in ECC to automatically correct bit errors. The defacto industry standard is to correct any bit error to a level comparable to that of hard disk drives. System designers have long been aware of using ECC to detect and correct errors. Historically, memory subsystems have used Hamming code, while Reed Solomon ECC is common in hard drives and CD-ROMs.

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SSD vs. HDD Bit Error Rates

SSDs Require Less ECC than HDDs by a Factor of 10x



SSD Myth 5 (continued)

MLC NAND-based SSDs do require more complex error correction than those using SLC NAND, but this function is taken care of by the integrated controller, and is transparent to the user.

Industry observers have noted that Total Cost of Ownership may be reduced with SSDs, with savings coming from lower support and replacement costs, as well as reduced costs for recovering data from a failed hard drive, and reduced productivity losses due to time without a PC.

For more information on drive endurance, or estimated write capacity, please see Myth 4.

HDDs are generally expected to last three to five years, and Toshiba SSDs are designed to match this level of performance, both in endurance and data retention. For all storage solutions, best practices for data management recommend backing up your data.

For more information on this subject, please visit our website ssdfacts.toshiba.com for informative videos on SSD performance, reliability and endurance.

¹Forward Insights, "Solid State Drives – A Closer Look", Oct. 2008, pg. 52.

SSD Myth 6

SSD capacities are too small

Myth Busted SSDs are now available in many capacities, including high-capacity drives of 256GB and 512GB for mobile computer users.



Toshiba 512GB SSD

The facts: As one of the first companies to enter the solid state drive market with a family of products based on MLC NAND technology, Toshiba offers SSDs for mobile computers in 128GB,

256GB and 512GB capacities, in 1.8-inch and 2.5-inch form factors. Capacities for SSDs are not expected to be a limiting factor as value/performance improves with advances in NAND technology combined with the historical price decline in semiconductor storage.

SSD Myth 7

SSDs don't reduce power consumption enough to make a difference

Myth Busted SSDs provide a noticeable reduction in power consumption, but because the system processor and display use much more power, the difference may not extend the battery life of a mobile computer in all cases. In enterprise applications, however, use of SSDs as hard drive replacements can result in significant power savings.

The facts: There have been articles and blog posts that claim SSDs reduce power significantly compared to HDDs, and can therefore help extend battery life in mobile computing. On the other hand, other commentators have said that the power difference isn't significant.

There are elements of truth to both sides of this argument. According to a study by market analyst firm Web-Foot Research¹, SSD drives with SATA interfaces for PC applications typically consume 0.5W during read and 1.0W during write operations compared to 2.0W read/1.8W write for 5400 rpm 2.5-inch HDDs, and 2.3W read/2.1W write for 7200 rpm 2.5-inch SSDs. This means that for read operations, SSDs consume about 75% less power than HDDs, and for write operations, about 50% less. However, there are very low power 1.8-inch hard drives on the market that reduce these differences.

On a system level basis, which is what the user can most easily observe, the storage system typically uses only 5 to 15% of the total power required by a mobile PC. As a result, the additional battery life may only turn out to be a few additional minutes per charge, depending on the individual notebook, battery and drive. The display and processor account for the largest percentage of the power use.

However, for enterprise applications, solid state drives offer the potential to reduce power consumption significantly compared to HDDs. In some cases, where short stroke HDDs are used for very fast read and write applications, SSDs that use approximately 7W of power can replace one or more HDDs that use approximately 14W². iSuppli forecast that the worldwide power savings from replacement of short-stroke HDDs by SSDs could increase from 6,986 megawatt hours in 2008 to 166,643 megawatt hours in 2013, or enough to power a small country².

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SSD Myth 7 (continued)

In addition, IDC analyzed the power consumption in data centers, and determined that for every watt used to power the actual drive, one additional watt is typically needed to cool the data center and another watt is required to power related electronic equipment (e.g. controllers, fans, host bus adapters and power supplies)³. With no moving parts, SSDs require less power and generate less heat, as shown in the chart⁴ below. SSDs are attractive for enterprise applications because of faster random read and random write performance, and the ability to reduce related energy costs in the data center.

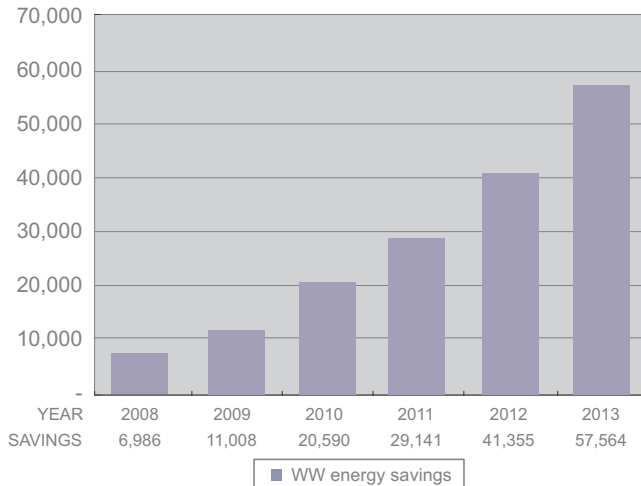
¹Web-Foot Research, *SSD Markets and Applications, Quarterly Series: Q1 2008*.

²iSuppli, "Solid-State Drive (SSD) Electricity Savings Could Power an Entire Country," news release May 6, 2009.

³IDC, "The Real Costs to Power and Cool All the World's External Storage," May 2008.

⁴HDD data from IDC, "The Real Costs to Power and Cool All the World's External Storage," May 2008; SSD data from "Toshiba calculations."

Forecast of worldwide data center energy savings attained by using enterprise SSDs in place of short-stroked HDDs (MWH)



Source: see footnote 4, Myth 7

SSD Myth 8

SSDs will replace all hard disk drives

Myth Busted SSDs and HDDs will coexist.

The facts: There is a definite market opportunity for the performance and reliability advantages of SSDs. However, we expect SSDs to coexist with HDDs for the foreseeable future because there is a role for both storage technologies.

Toshiba and market analysts expect SSDs to begin to gain significant traction in the market in 2009, growing to approximately 17% of the notebook market by 2013¹. Toshiba expects the value/performance of its MLC NAND-based SSD line-up to help speed the acceptance of solid state storage among early adopters of notebooks and ultra-mobile PCs (UMPCs).

According to IDC, digital storage is growing at a phenomenal pace. In 2008, 486 exabytes (that's 486 billion gigabytes) of digital data was created, captured and replicated, generated by over one billion devices including digital cameras, camera phones, medical scanners and surveillance cameras, as well as computers. By 2012, digital data is expected to grow five-fold to approximately 2,502 exabytes². Major contributors to this growth include film to digital image capture, analog to digital voice, analog to digital TV, Internet, email and IM. In this vast storage market, there's plenty of room for both hard disk drives and SSDs, to provide choices for optimal retrieval of stored data.

Toshiba is an industry leader in both small form factor HDDs and in NAND flash-based SSD technology, and offers a broad selection of digital media products based on different storage technologies. The breadth of products and markets in which these solutions play shows Toshiba's insight into the requirements, possibilities and future directions of the quickly changing landscape for storage technologies. In the end, we see HDD and SSDs as critical storage solutions with long term viability and attributes specific to different applications.

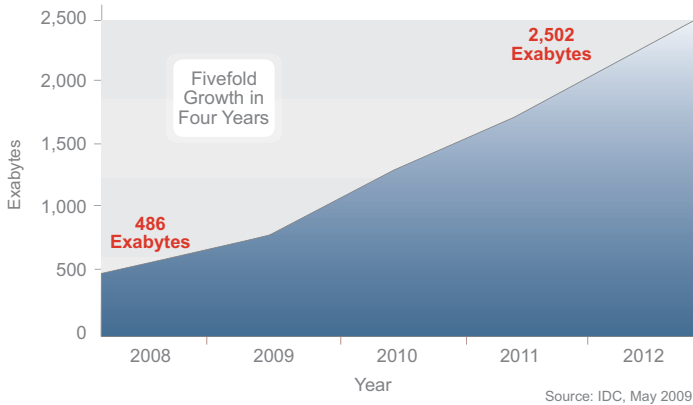
¹Forward Insights, "Solid State Drives: A Closer Look." Oct. 2008.

²Source: IDC White Paper, "As the Economy Contracts, the Digital Universe Expands," May 2009.

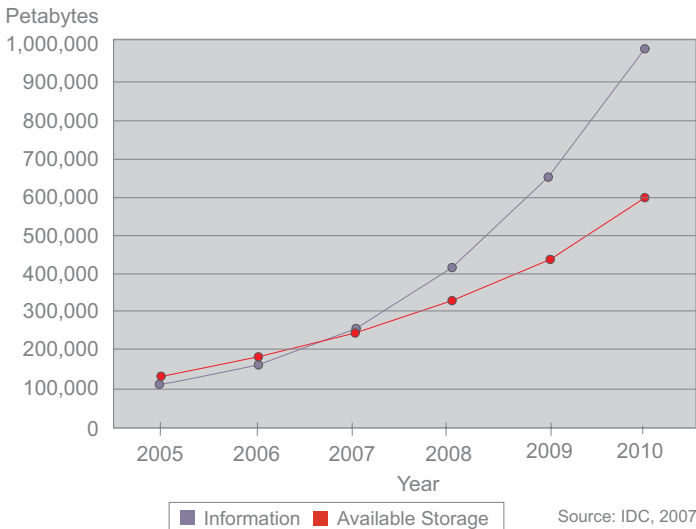
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SSD Myth 8 (continued)

Digital Information Created, Captured, Replicated Worldwide



Information vs. Available Storage



Storage and Semiconductor Expertise

Products in Every Major Brand of Notebook Computer



Toshiba is an industry leader in both small form factor HDDs and in NAND flash technology, and offers a broad selection of digital media products based on different storage technologies. Toshiba storage products are used by every major brand of notebook computer.

Toshiba's SSD products are a collaborative effort developed with expertise from both storage and semiconductor businesses,

designed to meet the requirements of the mobile PC OEM and the ultimate end user.

The breadth of products and markets in which these solutions play shows Toshiba's insight into the requirements, possibilities and future directions of the quickly changing landscape for storage technologies. In the end, we see HDD and NAND Flash as two critical storage solutions which each have long term viability due to their individual attributes and which will be adopted in applications for which each is best suited.

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