



SOLID-STATE ADVANTAGE

Why your next data-storage drive should be an SSD

September 27, 2011

Executive Summary

Solid-state drives (SSDs) are becoming an increasingly popular choice for computer users who value the impressive speed, reliability and energy savings they provide. Although SSDs are likely to cost significantly more than hard disk drives (HDDs) on a per-gigabyte (GB) basis for the foreseeable future, a growing number of users are coming to the conclusion that the outstanding performance they provide is worth the extra cost, especially as prices fall and SSD technology continues to improve.

SSDs – which use NAND flash memory chips to store and retrieve data – allow computer systems to boot up, load applications and copy both large and small files dramatically faster than conventional HDDs. And because SSDs have no moving parts, they are much more energy-efficient and resistant to shock, vibration and accidental drops than HDDs – qualities that make them ideally suited for use in notebooks, tablet PCs, and other mobile devices.

As a result, gaming enthusiasts, corporate road warriors and other demanding PC users willing to pay a premium for higher performance are beginning to gravitate towards SSDs. PC makers are also fueling the shift towards SSDs by offering them as standard equipment in their latest ultra-slim and lightweight notebooks – including Samsung's Series 9, Sony's Vaio Z Series and Apple's MacBook Air – as a way to differentiate their performance.

"The market for solid state drives is red-hot," observed journalist Sean Portnoy in a recent *ZDNet* article.¹ Indeed, market research firm Gartner Inc. expects worldwide SSD shipments to surpass 21 million units in 2011, twice the 10.7 million SSDs shipped during 2010.² Gartner expects worldwide SSD shipments will reach nearly 145 million units, worth \$13.1 billion annually, by 2015.



"Newer SSDs' SATA 3.0 interfaces transfer data at up to 6 gigabits per second – twice the speed of previous SATA interfaces."

About this report

This report is intended to help readers, particularly consumers thinking about upgrading their own computers with an SSD, to better understand the advantages of solid-state storage. To assist with that evaluation process, we have collected highlights from a wide range of recent articles, reports and commentaries in a variety of leading English-language news publications and blogs. Samsung Electronics is grateful to the many journalists and technical evaluators whose articles and product reviews are summarized in this report.

A look inside

First, let's look at some of what goes into an SSD and how it works. NAND flash memory chips are the components that provide the actual memory storage in SSDs. These chips use electrical charges to store bits of digital data in rows of densely packed transistor cells, which retain stored information even when their power supply is switched off. Enterprise-grade SSDs used in commercial data centers often use single-level cell (SLC) memory chips, which store just one bit of data per cell, while most consumer SSDs use less-costly multi-level cell (MLC) chips, which store multiple bits of data per cell. Most MLC chips today store two bits of data per cell, but triple-level cell (TLC) chips capable of storing three data bits per cell have been developed and will soon be reaching the SSD market.

Flash memory chips are organized into groups of transistor cells called pages and blocks. A page contains 4 kilobytes (KB) of data, and is the smallest number of cells on which data can be written at once. A block typically contains 128 pages, which is the smallest number of cells that can be erased at one time.

Typically, the more flash memory chips an SSD has, the more data it can store. Samsung's 64GB SSDs, for instance, contain four 16GB flash memory chips, while the company's 128GB SSDs contain eight of these chips and its 256GB SSDs contain 16. Although only about the size of a postage stamp, each chip can hold approximately 300,000 pages of Microsoft Word documents, which is roughly equal to 9,000 photos, 1,000 MP3 music files or a dozen movies.

Storage capacity can affect an SSD's performance, since the number of memory chips helps to determine how many input/output (I/O) channels are available to carry data to and from the memory chips. Larger-capacity SSDs tend to have more I/O channels working in parallel, which allows them to handle a bigger stream of data, and thus perform more work faster.

Whether you're using an SSD or a HDD, one of the key factors in determining how well it performs is the type of interface used to transfer data between the computer's memory and its central processor(s). Until recently, most aftermarket SSDs have used a Serial ATA (SATA) 2.0 interface, which can transfer up to 3 gigabits per second (Gb/s) of data. The latest generation of drives, however, including Samsung's new SSD 830 series, is beginning to use SATA 3.0 interfaces, which can transfer up to 6 Gb/s.

Another key component that lies between the SSD's data interface and its memory chips is the controller chip, a microprocessor that manages the tasks of reading and writing data and distributing it evenly between the various flash memory chips. Controllers – which also handle a variety of other essential drive functions such as diagnostics, error correction, caching and security – play an important role in how well an SSD performs.

As of September 2011, Samsung is the only SSD manufacturer that designs and builds its own consumer SSD controller chips; others use controllers from third-party suppliers such as JMicron Technology, Marvell Technology and SandForce. While most SSD makers rely on generic single-core controllers, Samsung's proprietary triple-core MCX controllers excel in multitasking and provide superior performance under heavy I/O loads, allowing for more consistent performance on a wider variety of tasks.

SSDs' declining price

Cost has traditionally been the biggest barrier to widespread SSD adoption. While the price-per-GB of solid-state data storage has been declining for years, prices for HDD storage have fallen even faster. As a result, even though SSDs have grown steadily less expensive, they continue to cost more than mechanical HDDs and are not likely to close that gap anytime soon. Objective Analysis analyst Jim Handy predicted in a recent *CNET* article that "SSDs will remain from 10 to 20 times as expensive as HDDs of the same capacity."³

Yet despite the price differential, SSDs are becoming increasingly attractive to many buyers. When *Laptop* magazine Online Editor Avram Piltch evaluated the relative advantages of SSDs over HDDs in a December 2008 article, for instance, he praised the performance of solid-state data storage, but noted that it came at a steep price – typically costing \$500 to \$800 for even a medium-capacity 128GB SSD. For many users, he concluded, "the performance and power-saving benefits of an SSD may not be noticeable enough to justify its high price tag."⁴

By early this year, however, Piltch had reached a very different conclusion. In a February 2011 article evaluating four popular SSD models, Piltch noted that “for about \$220 you can replace your notebook’s hard drive with a 120GB SSD that is large enough to hold your operating system, all your programs, and plenty of media.”⁵

SSDs also can be a cost-effective way to extend the life of older PCs. A recent article by *Tom’s Hardware* editors Patrick Schmid and Achim Roos⁶ evaluated the benefits of upgrading several PC systems of varying ages by replacing their HDDs with Samsung SSDs. They found that SSDs, despite costing significantly more than HDDs, “are reasonable upgrades in older mainstream machines.” As long as your older system has sufficient RAM and a processor new enough to take advantage of the added speed, they noted, “an SSD could end up being the most significant upgrade available to you.”

“An SSD could end up being the most significant upgrade available to you.”

– Patrick Schmid and Achim Roos,
Tom’s Hardware

It helps that the cost of solid-state data storage has fallen dramatically in recent years, from nearly \$7.50 per GB in 2008⁷ to less than \$2 per GB today.⁸ And while that’s still more than 10 times the cost of HDD storage, buyers seem increasingly willing to consider SSDs as the cost of retrofitting a notebook PC falls into the \$200 to \$400 range.

Although most of today’s SSD buyers still fit the description of early technology adopters, Gartner analysts expect mainstream consumers to begin opting for SSDs over HDDs when prices fall into the \$1 per GB range,⁹ which could occur as soon as 2012.

Fundamentally faster

HDDs and SSDs rely on fundamentally different technologies to store and retrieve data. HDDs read and write data using a complex arrangement of motor-driven spindles, actuator arms and other mechanical parts to position a recording head over rapidly spinning magnetic-coated disks. SSDs, on the other hand, have no moving parts, and store information in the form of electrons within arrays of tiny transistors on a chip.

If there’s one thing SSD users agree on, it’s that SSDs dramatically speed up the computing experience. SSDs access stored information in microseconds, 10 to 100 times faster than even the speediest HDD. As a result, an SSD-equipped PC can perform thousands of operations while a HDD-equipped system is still waiting for its disk to spin to the proper location and its head to be positioned over the right sector.

In test after test, reviewers consistently report improved system performance after replacing HDDs with SSDs. Whether they’ve been re-booting system software, copying files or loading new software applications, switching from HDD to SSD storage has invariably allowed their PCs to complete those tasks much faster.

"It's the single-most immediately noticeable system upgrade I've ever done."

– Alec Meer, *Rock, Paper, Shotgun*

"It's the single-most immediately noticeable system upgrade I think I've ever done," enthused gaming blogger Alec Meer of *Rock, Paper, Shotgun* in a recent post about replacing his PC's HDD with an SSD.¹⁰ "Windows, games, everything takes dramatically less time to load. Sticking one into my PC (without indulging any other upgrades) made it feel like someone had injected caffeine into its eyeballs," he said. "I truly believe that every PC gamer should make an SSD priority number one for their system upgrades, far above and beyond a new graphics card or processor."

Tom's Hardware editors Schmid and Roos noted after upgrading a variety of older PCs with SSDs that the new drives made a "night-and-day" difference in improving the systems' performance. Their SSD-upgraded PCs recorded twice the sequential read speeds of the fastest HDD versions tested, and were 40 times faster in random reads of 4 kilobyte (KB) data chunks. That kind of performance is important when working with small files, such as running an anti-virus program, installing applications or booting up system software.

In real-world application tests, *Tom's Hardware's* SSD-equipped PCs demonstrated triple the gaming data bandwidth, imported photos into Windows Photo Gallery three to five times faster and loaded other applications 10 times faster than comparable HDD-equipped systems. On the other hand, the SSD-enhanced systems did little to speed up video editing, Windows Media Center or Windows Media Player operations, which depend heavily on processor or graphics performance.

"Our test results demonstrate that it does make sense to install a fast solid-state drive, even in a several-year-old system," Schmid and Roos concluded. "It'll speed up the boot process, accelerate application loading times, and enable snappier responsiveness."

Larry Magid, technology columnist for the *Huffington Post* and the *San Jose Mercury News*, was similarly impressed with how fast his PC booted up after he installed a new SSD. "Until I installed this drive, it would take me about five minutes between the time I turned on the PC and the time I could actually start to use it by running programs," he said.¹¹ "Now it takes about 30 seconds from a cold start to loading Mozilla Firefox, and some of that time is taken up by the Intel hardware going through its initial boot process." Magid noted that the SSD also allows his PC to wake up much faster from sleep mode. "Before, from the time I touched the keyboard or moved the mouse while the machine was sleeping, I had to wait 30 seconds or more for the hard drive to spin up. Now it is usable a few seconds after I start waking it up. It's also faster to shut down a machine, because that often requires writing to the drive."

System boot up and application load times are among the performance areas that benefit most from installing an SSD. TechSpot editor Steven Walton compared how long it took to boot up the Windows 7 operating system and a variety of applications on an Intel Core i7-powered PC equipped first with a 1 terabyte Samsung Spinpoint HDD and then with a 256 GB Samsung 470 Series SSD. The SSD-equipped PC completed the task in just 9.5 seconds, 66 percent faster than the 27.9 seconds required by the HDD-equipped PC.¹²

TechSpot also tested the time required for the two drives to load Photoshop and the last level from the single-campaign Starcraft II game. While the performance advantage varied depending on the application, the SSD-equipped system was in all cases clearly faster than the HDD system (see chart below).

SSDs Enable Faster Bootups and Application Launches

	Samsung 470 Series SSD	Samsung Spinpoint F1 HDD	Performance increase with SSD
Windows 7 bootup	9.5 seconds	27.9 seconds	+66% faster
Photoshop CS4 launch time	1.2 seconds	8.2 seconds	+85%
Starcraft II launch time	16.2 seconds	24.6 seconds	+34%

Source: TechSpot.com test results, Nov., 2010

For another SSD versus HDD test, *Fox Business News'* Erik Berte compared how long it took to copy about 1GB of music files between two folders on a laptop PC equipped first with a 500GB Seagate Momentus HDD and then with a Samsung 470 Series SSD. On the Seagate drive, this took 33 seconds. On the Samsung SSD: just 9 seconds. "If you tend to move files around a lot on your computer, this drive will significantly cut down your wait time," Berte concluded.¹³

SSDs vs. HDDs – which fits your needs?

	HDD	SSD	Advantage of SSD
Access time		✓	SSDs access data 100 x faster
Read / write speed		✓	SSDs read and write data 3x faster
Noise		✓	With no moving parts, SSDs operate silently
Durability		✓	SSDs can survive up to 8x more shock
Power use		✓	SSDs use half as much electricity
Heat dissipation		✓	SSDs generate much less waste heat
Reliability		✓	SSDs average 3x longer mean time between failures (MTBF)
Maximum capacity	✓		HDDs offer higher storage capacities
Cost	✓		HDDs cost 10x less per GB of storage

Source: Samsung, June 2011

In a more exhaustive series of tests,¹⁴ *Laptop* magazine's Avram Piltch compared a 256GB Samsung 470 Series SSD with a 640GB 7,200-rpm Hitachi HDD, and several other SSDs. The performance difference was especially pronounced when reading and writing smaller data blocks, in which the Samsung SSD's average read-write speed of 194.2 megabytes per second (Mbps) when handling 512 kilobit (Kb) blocks was more than four times faster than the HDD's 45.3 Mbps. The difference between SSDs and HDDs was even more startling when reading and writing extremely small 4Kb data blocks. *Laptop's* reviewers used two different CrystalDiskMark tests to calculate an average 4Kb read-write speed of 51.2 Mbps for the Samsung SSD, more than *60 times* faster than the HDD's meager 0.8 Mbps.

The Samsung SSD also outperformed the HDD across the board on a variety of other real-world comparison tests. It was more than twice as fast as the HDD, for instance, in copying 5GB of mixed-media files from one folder to another (26 vs. 59 seconds). In compressing 5GB of miscellaneous files into a ZIP archive and then unzipping the same archive, the Samsung SSD was more than 20 percent faster than the HDD. And when opening a variety of Windows® applications – Adobe Reader 9, Excel 2010, Firefox 3.63, Photoshop CS5 (64-bit) and Word 2010 – the SSD was more than twice as fast on average as the HDD (4.1 vs. 9.5 seconds).

Where the Samsung SSD really showed its superiority, however, was when asked to perform a second task – such as opening an application – while a drive-intensive process was already underway. To evaluate this kind of stress, the reviewer timed how long it took to open each of the five Windows applications mentioned above while zipping 5GB of files in the background. Samsung's SSD responded to this torture test with flying colors, opening all five applications in an average 6.1 seconds, more than five times faster than the HDD's 31.6 seconds.

Multitasking Open Times (in Seconds)

Drive	Adobe Reader	Excel	Firefox	Photo-shop	Word	Average Open
Samsung 470 Series (256GB)	6.5	5.9	2.0	15.3	1.0	6.1
Crucial RealSSD C300 (256GB)	6.2	5.7	1.9	16.9	0.9	6.3
Intel X25-M (120GB)	8.2	6.4	6.4	16.1	1.5	7.7
OCZ Vertex 2 (120GB)	7.0	6.1	1.8	15.5	0.8	6.2
Hitachi 7,200 rpm	45.8	16.6	33.1	52.3	10.4	31.6

Source: Laptop magazine, Feb. 11, 2011

While test results can vary widely depending upon their specific parameters and the drives and systems used, *Laptop* magazine's combination of theoretical and real-world test results lends further support to the conclusion that SSDs can significantly accelerate the performance of many common PC applications.

Energy savings

Although speed is a compelling reason to consider switching from HDDs to SSDs, solid-state storage offers many other performance advantages, including lower energy use and heat generation, silent operation, and better resistance than HDDs to shocks, drops and other accidental damage.

Energy efficiency is one of the key reasons why SSDs are making rapid inroads into many corporate data centers, which the U.S. Environmental Protection Agency estimates will use 3 percent of all the electricity consumed in the United States by this year.¹⁵ Analyst Krishna Chander noted in an IHS iSuppli report¹⁶ that, because SSDs consume only about half as much power as HDDs, "even a small penetration of SSDs in enterprise data centers could result in massive power savings." He estimated that by 2013, SSDs could replace 10 percent of the high-performance HDDs used for rapid transaction processing in U.S. data centers, reducing the centers' cumulative electricity consumption by more than 160,000 megawatt hours.

Quantifying the energy-saving benefits of SSDs outside the data center is more complex because usage patterns can vary widely, while a variety of system variables – processors, displays, cooling fans, etc. – can also affect

energy use. Nonetheless, it's evident that SSDs, on average, use much less energy than HDDs, typically consuming an average of 1.3 watts or less during active operation compared with 4 watts or more for HDDs.¹⁷ SSDs use less power when idle, averaging 0.5 watts or fewer. Samsung's 470 Series SSDs' power use is even lower, averaging 0.24 watts when active and a mere 0.14 watts when idle.

"Expect your SSDs to last two to three times longer than mechanical drives."

- Kenneth Hess, ServerWatch

On an individual user level, the cost savings from an SSD's superior energy efficiency are likely to be minimal, since storage devices (whether HDD or SSD) account for less than 10 percent of most PCs' overall power use. Yet SSDs' efficient energy use can provide a significant advantage to mobile PC users, who typically report about 20 percent longer battery life from SSD-equipped systems. So a laptop PC user whose system normally runs for five hours on a charge might reasonably expect to gain another hour of battery life by swapping his or her HDD for an SSD. That could make the difference between being able to work through an entire cross-country plane flight and having to shut down prematurely.

Other SSD Advantages

Another key advantage of SSDs over HDDs is their greater tolerance for shock, vibration and other mechanical abuse. Although great strides have been made over the years in making HDDs resistant to such potentially harmful environmental challenges, they are still susceptible to catastrophic failure when a sudden jostle or fall brings their read-write heads into contact with their spinning disk platters.

So how much more shock-resistant are SSDs? Shock, the physical consequence of sudden acceleration or deceleration, is measured in multiples of the standard acceleration resulting from free fall in the Earth's gravity, signified by the symbol g. Most SSDs are rated to withstand at least 1,500 g during operation, while the most rugged HDDs are rated at only about 300 g.¹⁸ Computer maker Dell counsels potential buyers that its factory-installed SSDs offer "over 8x the shock tolerance of a standard notebook HDD."¹⁹

No technology is completely indestructible, of course. But when it comes to overall reliability, most industry analysts give SSDs a distinct edge over HDDs. TechnoQWAN storage analyst Robin Harris, for instance, noted in a recent *Data Center Knowledge* article that although HDD technology has had much longer to mature, SSD technology is improving rapidly. "Over a five-year life I would expect an SSD to offer a 30 to 40 percent lower annual failure rate than a mature disk drive," he concluded.²⁰ Technical analyst Kenneth Hess is even more optimistic in a recent *ServerWatch* column, stating: "Expect your SSDs to last two to three times longer than mechanical drives."²¹

Cool, quiet operation is yet another benefit of SSDs. *Examiner* technology writer Andrew Weiner recently observed after installing an SSD in his PC that, aside from the increased speed, the biggest change with the new drive was its silence. "There is no vibration of the typical HD platters or clicking of the read/write heads. You press the power button and it silently starts up. At first you may think it is not working, but in fact it is, and very well at that," he wrote, adding: "One other quality I noticed is that without moving parts spinning and whirring around, the overall temperature of the PC was about 10 degrees cooler."²²

Conclusion

SSDs aren't for everyone. For those on a tight budget or who don't require the highest PC performance or who need to store terabytes of data on a single drive, HDDs are probably still the best option. But for those who want to accelerate their gaming, video editing or other demanding applications, or who need an extremely rugged mobile system with extra-long battery life – and who are willing to pay a premium for those attributes – an SSD is definitely worth consideration.

SSDs are just beginning to gain significant traction with mainstream consumers. But with SSD-equipped Apple and Samsung notebooks reported to be approaching 500,000 units per quarter,²³ they certainly appear to be establishing a solid foothold. Clearly, demanding PC users are already developing a healthy appetite for solid-state storage. And with flash memory prices expected to continue falling, ordinary consumers' hunger for this fast, dependable and energy-efficient storage technology seems only likely to increase.

Noted, and Quoted

"The days of the old-fashioned mechanical disk are numbered. If you haven't been hiding under a rock for the past few years, you know SSDs offer greater durability and significantly faster performance than their magnetic counterparts... There is no better way to improve the speed of your notebook. Whether your system is three years old or straight out of the box, with an SSD upgrade, you'll see dramatic performance improvements in the activities that matter most: launching applications, multitasking, and copying files." ²⁴

- Avram Piltch, *Laptop* magazine
<http://blog.laptopmag.com/ssd-battle-royale-which-drive-will-speed-up-your-notebook-the-most>

"I do a lot of graphic work and work with large files, and prior to having the SSD in my system I would open a file, walk away and by the time I got back it's open. I used to have enough time to get a donut and a drink. Now I don't." ²⁵

- Michael Reyes, *Hardware Geeks*
http://www.hardwaregeeks.com/index.php/GadgetBlog/comments/samsung_470_series_ssd_review/

"I now have four SSD-equipped systems – two desktops and two laptops – running full time... I am officially spoiled. Sitting down in front of a PC that uses a conventional hard disk drive is almost painful." ²⁶

- Ed Bott, ZDNet
<http://www.zdnet.com/blog/bott/how-do-you-make-an-ssd-even-faster/3223?pg=1>

"Going SSD is life changing." ²⁷

- Joe Wilcox, Beta News
<http://betanews.com/2011/08/17/samsung-ssd-s-speed-up-with-new-830-series/>

For more information, please visit: www.samsung.com

This white paper is provided for information purposes only. All information included herein is subject to change without notice. Samsung Electronics is not responsible for any direct or indirect damages, arising from or related to use of this white paper.

References

1. Sean Portnoy, "Intel's upcoming 2011 SSD lineup leaked," ZDNet, May 1, 2011, <http://www.zdnet.com/blog/computers/intels-upcoming-2011-ssd-lineup-leaked-five-new-series-include-pcie-based-drive/5674>
2. Joseph Unsworth, "WW Semiconductor Forecast Database 2Q11 Update" Gartner Inc.
3. Brooke Crothers, "SSD vs. HDD: How low will hard drives go?" CNET, March 9, 2011, http://news.cnet.com/8301-13924_3-20041259-64.html#ixzz1GD3WEGXA
4. Avram Piltch, "Are SSDs Worth the Money?" Laptop magazine, Dec. 1, 2008, <http://www.laptopmag.com/advice/expert/are-ssds-worth-the-money.aspx?page=1>
5. Avram Piltch, "SSD Battle Royale: Which Drive Will Speed Up Your Notebook the Most?" Laptop magazine, Feb. 11, 2011, <http://blog.laptopmag.com/ssd-battle-royale-which-drive-will-speed-up-your-notebook-the-most>
6. Patrick Schmid and Achim Roos, "Could An SSD Be The Best Upgrade For Your Old PC?" Tom's Hardware, August 5, 2011, <http://www.tomshardware.com/reviews/ssd-upgrade-hard-drive,2956.html>
7. Anand Lal Shimpi, "2010 Value SSD (~\$100) Roundup: Kingston and OCZ take on Intel," Anandtech, June 3, 2010, <http://www.anandtech.com/show/3756/2010-value-ssd-100-roundup-kingston-and-ocz-take-on-intel>
8. Dong Ngo, "Review: OCZ Vertex 3 Series solid-state drive - 480 GB - SATA-600," CNET, April 11, 2011, http://reviews.cnet.com/internal-hard-drives/ocz-vertex-3-series/4505-9998_7-34542032.html#ixzz1JM5uthBB
9. Agam Shah, "Consumer SSDs to Break out in 2012, Gartner Says," IDG News, May 11, 2011, http://www.pcworld.com/businesscenter/article/227593/consumer_ssds_to_break_out_in_2012_gartner_says.html
10. Alec Meer, "If You Buy One PC Upgrade This Year," Rock, Paper, Shotgun, April 4, 2011, <http://www.rockpapershotgun.com/2011/04/04/if-you-buy-one-pc-upgrade-this-year/>
11. Larry Magid, "Flash Drives Speed up PC Start Times," Huffington Post, Nov. 14, 2010, http://www.huffingtonpost.com/larry-magid/flash-drive-speeds-up-pc_b_783331.html
12. Steven Walton, "Samsung 470 Series 256GB SSD Review," TechSpot, Nov. 22, 2010, <http://www.techspot.com/review/340-samsung-470-series-ssd/page6.html>

13. Erik Berte, "FOXBusiness.com Review: Samsung 470 Series Solid State Drive," Fox Business, Jan. 6, 2011, <http://www.foxbusiness.com/technology/2011/01/06/foxbusinesscom-review-samsung-series-solid-state-drive/>
14. Avram Piltch, "SSD Battle Royale: Which Drive Will Speed Up Your Notebook the Most?" Laptop magazine, Feb. 11, 2011, <http://blog.laptopmag.com/ssd-battle-royale-which-drive-will-speed-up-your-notebook-the-most>
15. U.S. Environmental Protection Agency ENERGY STAR Program, "Report to Congress on Server and Data Center Energy Efficiency Public Law 109-431," Aug. 7, 2007, http://www.energystar.gov/ia/partners/prod_development/downloads/EPA_Datacenter_Report_Congress_Final1.pdf
16. Michael Yang, "Solid State Drive (SSD) Electricity Savings Could Power an Entire Country," IHS iSuppli, May 6, 2009, <http://www.isuppli.com/memory-and-storage/news/pages/solid-state-drive-ssd-electricity-savings-could-power-an-entire-country.aspx>
17. Kenneth Hess, "10 Reasons Why SSDs Are Better Than Mechanical Disks," ServerWatch, Feb. 24, 2011, <http://www.serverwatch.com/trends/article.php/3926131/10-Reasons-Why-SSDs-Are-Better-Than-Mechanical-Disks.htm>
18. "Taking Storage to Extremes," Seagate Technology white paper, Aug. 2008, http://www.seagate.com/docs/pdf/whitepaper/tp594_storage_extremes.pdf
19. Munif Farhan, "Benefits of Solid State Drives in Dell Precision Workstations," Dell Inc. white paper, Sept. 2010, <http://i.dell.com/sites/content/business/solutions/whitepapers/en/Documents/solid-state-drives-workstation.pdf>
20. Robin Harris, "SSDs vs. Disks: Which Are More Reliable?" Data Center Knowledge, Jan. 27, 2011, <http://www.datacenterknowledge.com/archives/2011/01/27/ssds-vs-disks-which-are-more-reliable/>
21. Kenneth Hess, "Ten Reasons Why SSDs Are Better Than Mechanical Disks," ServerWatch, Feb. 24. 2011, <http://www.serverwatch.com/trends/article.php/3926131/10-Reasons-Why-SSDs-Are-Better-Than-Mechanical-Disks.htm>
22. Andrew Weiner, "The Crucial M4 SSD; quiet as a mouse, strong as an ox," Examiner, May 12, 2011, <http://www.examiner.com/internet-and-technology-in-national/the-crucial-m4-ssd-quiet-as-a-mouse-strong-as-an-ox-review-1#ixzz1Oovir26X>

23. Neil Hughes, "Strong sales make Apple's 'quasi-tablet' MacBook Air a \$2.2B-per-year product," *Apple Insider*, April 3, 2011, http://www.appleinsider.com/articles/11/04/04/strong_sales_make_apples_quasi_tablet_macbook_air_a_2_2b_per_year_product.html
24. Avram Piltch, "SSD Battle Royale: Which Drive Will Speed Up Your Notebook the Most?" *Laptop magazine*, Feb. 11, 2011, <http://blog.laptopmag.com/ssd-battle-royale-which-drive-will-speed-up-your-notebook-the-most>
25. Michael Reyes, "Samsung 470 Series SSD Review," *Hardware Geeks*, Jan. 30, 2011, http://www.hardwaregeeks.com/index.php/GadgetBlog/comments/samsung_470_series_ssd_review/
26. Ed Bott, "How do you make an SSD even faster?" *ZDNet*, May 3, 2011, <http://www.zdnet.com/blog/bott/how-do-you-make-an-ssd-even-faster/3223?pg=1>
27. Joe Wilcox, "Samsung SSD's speed up with new 830 series," *Beta News*, Aug. 17, 2011, <http://betanews.com/2011/08/17/samsung-ssd-s-speed-up-with-new-830-series/>

#