IT@Intel White Paper

Intel IT

IT Best Practices

IT Business Efficiency and Employee Productivity

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Accelerating the Deployment of Intel® Solid-State Drives throughout the Enterprise

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Executive Overview

By aggressively deploying Intel® Solid-State Drives, we are enhancing user productivity and mobility, while reducing IT total cost of ownership.

As part of our mobile business PC strategy, Intel IT now requires all newly purchased laptops to be equipped with an Intel® Solid-State Drive (SSD) and an Intel® Core™ i5 vPro™ processor. To further accelerate deployment of SSDs, we also retrofit mobile business PCs whenever we perform a rebuild or update the OS to Microsoft Windows 7*. By aggressively deploying SSDs with both new platforms and OS upgrades, we enhance user productivity and mobility while reducing IT total cost of ownership (TCO).

An Intel SSD, especially when combined with the Intel Core i5 vPro processor and Microsoft Windows 7, provides a platform that offers benefits to employees and to Intel IT:

- **Employees.** SSDs provide Intel's highly mobile workforce with improved system performance, longer battery life, and greater mobility. For example, SSDs provide 4x faster I/O performance compared to a hard disk drive.[1]
- **Intel IT.** SSDs reduce TCO, primarily based on an estimated 90 percent reduction in the annual drive failure rate[2] and increased performance.

To date, we have deployed more than 36,000 SSDs. By the end of 2010, we will have deployed SSDs to approximately 55 percent of Intel's mobile business PCs, and we plan to deploy SSDs to the remaining mobile PCs—more than 72,000 total—in 2011.

While integrating Intel SSDs into our mobile business PC platform, we have refined our deployment strategy and identified key learnings and best practices in the areas of TCO, performance, and IT support to help ensure all Intel employees experience the benefits of SSDs.

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The IT@Intel program connects IT professionals around the world with their peers inside our organization – sharing lessons learned, methods and strategies. Our goal is simple: Share Intel IT best practices that create business value and make IT a competitive advantage. Visit us today at www.intel.com/IT or contact your local Intel representative if you'd like to learn more.

BACKGROUND

Intel IT is tasked with increasing employee productivity while decreasing IT total cost of ownership (TCO). To that end, we are constantly exploring technologies that complement our mobile business PC platform. We identified Intel® Solid-State Drives (SSDs) as one such technology.

Once we identified Intel SSDs as a performance-enhancing technology and verified the return on investment (ROI), we developed a four-phase plan that enables us to include SSDs in our standard mobile business PC configuration without experiencing increased support costs. We are currently in the third phase of our four-phase SSD deployment.

- **Phase 1: Early SSD introduction and funded upgrades.** In early 2008, we began investigating the use of Intel SSDs in our mobile business PCs with research, benchmarking, and pilot deployments.[3] We identified solid-state technology as a potential solution to significant support and performance problems with hard drive technology and as a potential breakthrough for mobile PC use cases.[4]

  Our pilot deployments helped make employees and business units aware of the benefits of SSDs, creating excitement and a strong demand for SSD retrofits. We deployed about 1,500 SSDs to highly mobile user segments—those employees who would benefit most from the enhanced performance, reliability, and mobility offered by SSDs. We also offered bulk deployment to groups and segments willing to fund the SSD procurement. These pay-per-view (PPV) projects involved from one or two laptops to hundreds.

- **Phase 2: Initial proliferation.** During Phase 2, primarily in 2009, we deployed approximately 8,000 units.

  In order to alleviate concerns about the higher initial cost of an SSD compared to a similarly sized hard disk drive (HDD), we conducted a refined assessment of TCO. We analyzed our historical HDD failure rate as well as the time required for typical IT and user tasks on mobile business PCs equipped with SSDs compared to PCs with HDDs. We used this information to estimate and compare the total impact over the useful life of a mobile business PC.[5] We concluded that SSDs did indeed reduce TCO, which led us to expand the deployment of SSDs.

  We began to deploy SSDs during mobile business PC refresh, and made SSDs the standard configuration for all new mobile business PCs. We also decided that whenever a mobile business PC needed an OS upgrade—but was not a candidate for refresh—we would retrofit that laptop with an SSD in addition to installing Microsoft Windows 7*. We also continued all Phase 1 deployment options.

- **Phase 3: Standardization.** During this, our current phase, we expect to deploy about 40,000 SSDs. Along with continuing Phase 1 and Phase 2 options, anytime a mobile business PC needs a break/fix rebuild (such as a drive failure), it is equipped with an SSD. The only exception is laptops that are at end of life.

  SSDs by themselves offer performance and productivity benefits, but when combined with the Intel® Core™ i5 vPro™ processor and Microsoft Windows 7, productivity and performance benefits are enhanced (see discussion below). Because of this, we are re-evaluating our practice of retrofitting older PCs, instead favoring aggressive replacement of older machines.

Table 1. Test System Specifications

	Gen 2010	Gen 2009	Gen 2008
Processor	Intel® Core™ i5 Processor M540 (2.53 GHz)	Intel® Core™2 Duo Processor T9600 (2.80 GHz)	Intel® Core™2 Duo Processor T7300 (2.00 GHz)
RAM	4 GB DDR3 1067 MHz	4 GB DDR3 1067 MHz	2 GB DDR2 667 MHz
Chipset	Intel® 5 Series/3400 Series Chipset Family	Mobile Intel® 4 Series Express Chipset Family	Mobile Intel® 965 Express Chipset Family
Graphics	Intel® Graphics Media Accelerator HD	Intel® Graphics Media Accelerator X4500	Intel® Graphics Media Accelerator X3100
SATA Support	SATA 3.0 Gb/s	SATA 3.0 Gb/s	SATA 1.5 Gb/s

- **Phase 4: Full deployment.** This phase will begin in 2011. Our goal is to have SSDs as the standard configuration for new desktop and mobile business PC purchases. We also plan to achieve SSD deployment to 100 percent of our mobile business PC fleet.

INTEL® SOLID-STATE DRIVE BENEFITS

We have found that an Intel SSD, especially when combined with the Intel Core i5 vPro processor and Microsoft Windows 7, provides a platform that offers benefits to employees and IT alike.

Faster system performance, lower energy consumption that extends battery life, and reduced TCO all underscore our commitment to deploying SSDs to every Intel employee.

Employee Benefits

Employees continually ask for improvements in PC system performance and mobility. For example, they would like applications to load faster and PCs to reboot and restore from sleep faster, and they don't want to shut down their PCs when moving from one location to another. Intel SSDs address many of these concerns.

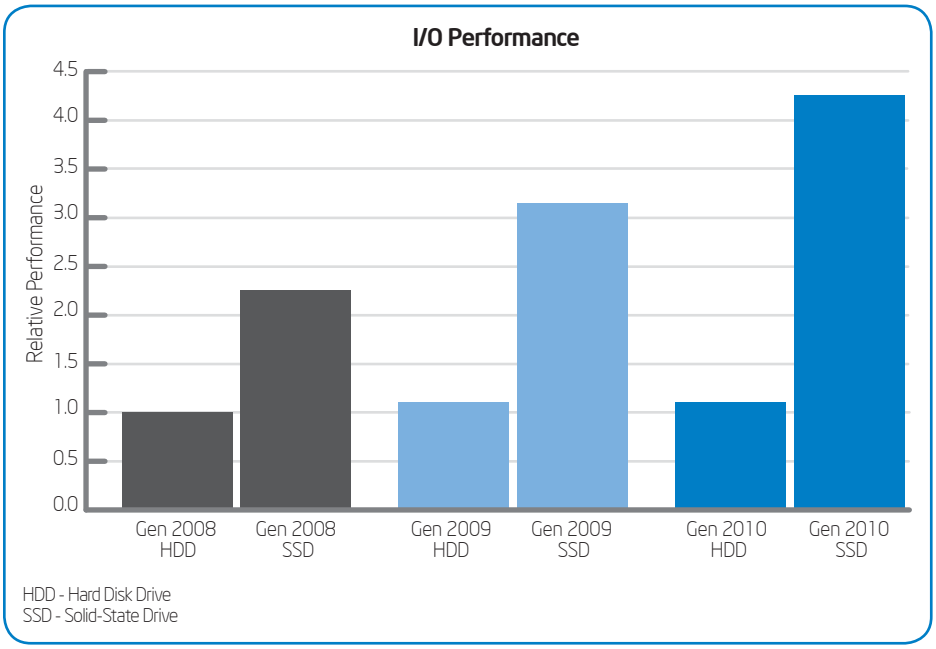

Figure 1. Solid-state drives provide an I/O performance increase on Intel® Core™ i5 vPro™ processor-based systems. With software-based encryption enabled, the I/O workload shows a 2.2x improvement on a three-year-old system, a 3x improvement on a two-year-old system, and a 4x improvement on an Intel® Core™ i5 vPro™ processor-based system. Intel internal measurements, June 2010.

SYSTEM PERFORMANCE

To reflect our recent deployment of Microsoft Windows 7 and software-based whole drive encryption (WDE), we recently updated our performance benchmarks, which previously ran on Microsoft Windows XP* without WDE. We compared the performance of a mobile business PC equipped with an SSD against the same system equipped with a HDD, both using our standard IT build. We tested three different generations of systems, each with a 160-GB, 7200-rpm HDD, then with a 160-GB, second-generation SSD. These systems are described in more detail in Table 1.

In every test—overall workloads, productivity workloads, and I/O workloads—the SSD-equipped system significantly outperformed the HDD-equipped system. Figure 1 illustrates the I/O performance boost provided by the SSD on each system. While the I/O performance increased on older systems with

Table 2. Thermal Analysis

	Hard Disk Drive (HDD)		Solid-State Drive (SSD)	
Form Factor	Top	Bottom	Top	Bottom
Mobile Workstation (15-inch)	97.5°	85.6°	81°	80.2°
Mainstream (14-inch)	93.9°	97.5°	84.6°	82.6°
Small and Light (13-inch)	97.2°	93.2°	83.5°	81.3°
Average temperature difference between HDD and SSD: 12.2°				

Note: All measurements are in degrees Fahrenheit.

the SSD, the PC with the Intel® Core™ i5 vPro™ processor showed the largest increase—4x.

In boot tests, an SSD provided boot-time improvement of about 16 percent on a three-year-old system, but an impressive 46 percent improvement on an Intel Core i5 vPro processor-based system. Based on a study we performed in 2009, we anticipate that users will save an estimated 27 hours per year using SSDs instead of HDDs.[6]

MOBILITY

SSDs enhance mobility for our employees, providing efficiency, productivity, and physical comfort:

- **Freedom of movement.** SSDs provide greater freedom of movement and greater efficiency. There is no need to use standby mode when moving from one location to another because SSDs are not as fragile and sensitive to movement as HDDs. And, when it is necessary to shut down a PC or put it into standby or hibernate mode, SSDs provide faster response.
- **Longer use per battery charge.** Although the length of time a laptop equipped with an SSD can last without recharging varies dramatically based on configuration and use, many Intel employees report a noticeable improvement in battery life. Employees can be on the go for longer periods of time without worrying about finding a power outlet.
- **Cooler, quieter system.** Users often complain of the heat when trying to rest a mobile business PC directly on their laps. SSDs can decrease the overall thermal footprint of the platform. Overall, SSD platforms run about 12 degrees cooler than a system with a HDD. In addition, SSD-equipped systems run more quietly than PCs with HDDs because there is no noise from the SSD and less system fan noise due to the cooler system.

Table 2 shows temperature differences between systems with SSDs and systems with HDDs.[7]

IT Benefits

Although the unit cost for SSDs is currently higher than for HDDs, we do not make business decisions based on purchase price alone. When analyzing the use of SSDs, we considered the main factors that contribute to TCO, mainly support cost as a function of reliability and performance. Weighing these factors, we concluded that SSDs provide a substantial TCO benefit for IT and decided to install SSDs across the enterprise.

RELIABILITY

Early indicators show that Intel SSDs have a lower annual failure rate (AFR) compared to HDDs—possibly 90 percent or better.[8] A lower AFR is the key to reduced TCO, as reliability decreases user downtime as well as IT costs for troubleshooting and rebuilding laptops. Each drive failure can cost IT from 2 to 12 hours of repair time and can involve several support calls to answer user questions about the initial failure and the reconfiguration process.

Drive failures also incur varying degrees of business cost due to lost data. The cost of data loss depends on how robust the backup system is and on user compliance with regular backup policies.

PERFORMANCE

Another important aspect of SSDs from the IT perspective is their workload and I/O performance improvements over HDDs. Our tests indicate that SSDs can reduce build time by more than 20 percent. Because we perform 30,000 to 40,000 builds per year, SSDs can significantly reduce IT support costs. In addition to speeding builds, SSDs also enable us to perform other support activities more quickly, such as backup and restore, patching, and application installations.

Other considerations related to TCO are included in the Developing IT Best Practices section.

DEVELOPING IT BEST PRACTICES

Our experience deploying SSDs to mobile business PCs has led to a number of best practices, including configuring PCs to maximize SSD performance, addressing data protection issues, and reducing IT support issues.

As we progress into Phase 4 of deployment, our observations will help us increase efficiency.

Total Cost of Ownership

SSDs have a higher initial price than comparably sized HDDs. We have justified paying the higher initial price by analyzing the TCO across the following areas:

- **Annual failure rate.** As previously stated, a lower AFR is the key element of reducing TCO. Because of this, we are carefully tracking our SSD failures. We currently have more than 36,000 SSDs deployed, some with up to 30 months of use. Although we don't have long-term data, our preliminary data shows a dramatic failure rate reduction compared to HDDs—very much in line with our early estimates and the failure rate specified by the manufacturer.
- **Longevity.** An early concern with SSDs was whether the drive would reliably last for the useful life of the PC. Having to replace an SSD due to wear would obviously increase TCO. To assess this risk, we monitored the write volume of a sample group of users for several months. The average write volume observed for the group was well below the write limit specified by the manufacturer. We also performed our own stress testing on a small group of SSDs, demonstrating that even drives that were well beyond the manufacturer's write limit specifications were still healthy and operating properly. We have concluded that the Intel SSDs should easily outlast the useful life of a mobile business PC in all but the most extreme uses.
- **Standard configuration.** We evaluated the TCO of mobile business PCs holistically and re-evaluated our standard configuration to prioritize SSDs over less important components and capabilities, such as optical drives and fingerprint readers. This approach helped to offset the additional upfront cost of using SSDs. We will continue to consider other configuration changes, as well.
- **Pricing.** Changing the standard configuration of PCs in the middle of our refresh cycle allowed us to take advantage of market conditions and pricing. To control costs, we do not always replace a HDD with an SSD of equal capacity. Instead, we optimize the SSD's capacity to business needs and user segment. Some user segments store much of their data remotely, such as on a shared drive. We have found that users willingly sacrifice local capacity to gain the performance boost that SSDs offer. We've also observed that there is a trend toward using 1.8" form-factor drives in the lighter and smaller footprint mobile business PCs. The price difference between an SSD and a HDD in the 1.8" form-factor is typically smaller than in the 2.5" form-factor.
- **Standardization.** Component standardization reduces costs and eases support costs. Intel SSDs are pervasively available, in multiple form-factors, from the OEMs we use. This allows us to stock fewer parts as well as define training and processes for a single product family.
- **Reuse value.** Because we expect that an SSD will have a longer useful life than a mobile business PC, we can find additional uses for it when the PC is refreshed or retired—such as moving it to a new mobile business PC or using it to upgrade an old PC that has a HDD but still has additional useful life.
- **Warranty.** Replacing a laptop's drive—HDD or SSD—doesn't void the laptop's warranty. However, it may create a situation where the system's warranty expiration and the drive's warranty expiration are out of sync, which implies additional overhead in tracking and managing warranty dates—a potential cost that requires us to track dates carefully.
- **Battery replacements.** Because SSDs can go longer between battery recharges, it is reasonable to assume that a mobile business PC equipped with an SSD will use fewer batteries during its useful life. We anticipate that fewer battery replacements per PC will reduce our costs.

Performance Considerations

During the two and a half years that we have been installing SSDs on Intel's mobile business PCs, we have learned that the configuration and technical specifications of the PC can affect SSD performance.

- **Benchmarks.** In general, SSDs perform faster than HDDs, as illustrated by benchmark results easily found on the Internet. But while results from others can be used as guidance, we believe that it is important to perform benchmark testing on our own mobile business PCs, with our own software configurations, representing common Intel usages. Through internal benchmark testing and feedback from

users, the performance benefits of using Intel SSDs are readily apparent.

- **Encryption.** We have deployed software-based WDE. Because the SSDs provide such high data transfer rates, we found that the use of WDE has impacted raw I/O performance of SSDs to a greater extent than on HDDs. By deploying SSDs and WDE at the same time, we are able to meet our information security objectives and provide better overall system performance than with an unencrypted HDD. We are assessing the benefits of Intel® Advanced Encryption Standard-New Instructions (Intel® AES-NI) support in select Intel Core i5 vPro processors for software-based encryption and are also excited about the potential of drive-based encryption.
- **Performance over time.** The Trim attribute of the Advanced Technology Attachment (ATA) Data Set Management Command, often referred to simply as Trim, synchronizes the OS's view of deleted files with those that are deleted but not erased on the drive. This helps stabilize the performance and health of the SSD over time.

  Without Trim, write performance is reduced over time to some degree. We analyzed the out-of-box performance of Intel SSDs compared to that of several drives that had been used for 12 to 18 months, and concluded that Trim was useful, but not required for the user to get the performance benefits from the Intel SSD. We initially deployed our 36,000 SSDs without Trim support, and only recently, with our deployment of Microsoft Windows 7 and the Intel® Rapid Storage Technology (Intel® RST) driver version 9.6, are we enabling native OS Trim support. For systems without native OS Trim support, users have the option of running the "Optimize" feature in the Intel® SSD Toolbox.
- **BIOS – SATA controller mode.** Advanced Host Controller Interface (AHCI) mode is a common and desired setting for the SATA controller mode in the BIOS of current laptop PCs. AHCI mode provides Native Command Queuing (NCQ) support for better performance. We found that when AHCI mode is not enabled, there can be a slight performance impact on HDDs, but there is significant performance degradation for certain operations on SSDs.
- **SATA support.** Although SSDs support Serial Advanced Technology Attachment 3.0 Gb/s (SATA 2), laptops that are two to three years old may support only SATA 1.5 Gb/s (SATA 1). Therefore, when retrofitting older laptops with SSDs, the performance gains are not quite as good as for newer laptops that support SATA 2. However, we still retrofit SSDs into older systems and see significant performance benefits compared to systems with HDDs.

IT Support Considerations

Although SSDs are a plug-and-play alternative to HDDs, they are a new technology and have raised some support questions.

- **OS-specific tuning.** Defragmentation is not required for Intel SSDs, nor are tools that pre-load software into memory to reduce load times. Microsoft Windows 7 is SSD-aware and automatically disables these features when it detects an Intel SSD; on PCs running other OSs, we disable or uninstall these features during the build.
- **Other software tuning.** Shock-sensor software is not required with SSDs; therefore, we either use SSD-aware shock-sensor software, or disable or uninstall it. We also confirm that other drive optimization tools are SSD-aware. For example, file placement utilities are ineffective on Intel SSDs.
- **Firmware.** Firmware is an important component of the SSD, impacting performance, reliability, and security. During our testing and pilot deployments, we actively updated the firmware on SSDs prior to initial installation and on deployed systems. Now that we buy systems with OEM-qualified Intel SSDs, we no longer proactively update firmware versions on deployed systems; we will only perform firmware updates if a supplier issues guidance to upgrade due to a major defect. If required to perform SSD firmware updates, we would provide this service in our PC Service Centers, where employees bring their PCs to us at their convenience. We have also demonstrated the ability to remotely update the SSD firmware using the integrated drive electronics redirect (IDE-R) capability of Intel vPro™ technology.
- **Data recovery.** The substitution of SSDs for HDDs in our standard platform has required us to revalidate our data recovery capabilities and reinforced the importance of diligently enforcing regular system

backups. We have found the following to be the two most significant SSD data recovery issues:

  - Although they have a low AFR, SSDs do fail—and when they do, we have observed that they fail very differently from HDDs. The failures we have seen have generally occurred without warning, and we currently have limited data recovery options. Recovering and rebuilding data based on HDD platter scan services is not currently feasible for SSDs.
  - Recovering data from a failed SSD is already challenging; the addition of software-based encryption adds another layer of complexity to potential data recovery processes.

- **Drive reuse and disposal.** Our information security policies mandate that drives, both HDDs and SSDs, be wiped before internal reuse. We currently use a traditional tool that works similarly for both HDDs and SSDs. We are investigating using the secure erase capability for SSDs in the future to reduce the time required to wipe data from the drives. Although SSDs can be reused internally for quite some time, our information security policy demands that when a drive—SSD or HDD—reaches its end of life, it must be destroyed. We accomplish this by shredding the drive.
- **Technician training and tools.** To maintain a continued level of quality support, we trained our IT technicians in SSD technology, including installation, upgrade, and troubleshooting processes. Our IT technicians' main job is diagnosing users' PC problems. It remains to be seen whether, in all cases, we can continue to use the same diagnostic tools we use with HDDs; we may need to modify some tools or develop new ones.
- **Build method.** We discovered that when retrofitting a PC with an SSD, it was better to rebuild the OS instead of cloning it. A new build provides a fresh start, eliminating legacy issues from long use, such as software patches, re-installed applications, and unused files and registry settings.

FUTURE PLANS

As we accelerate the deployment of Intel SSDs in our mobile business PC fleet, we will continue to investigate how we can best take advantage of their performance benefits.

Data encryption is one area in which we will actively pursue performance enhancements. Currently, we use software-based WDE. Although WDE is necessary to protect Intel data and intellectual property, it can negatively affect drive performance. In contrast, hardware-based encryption has less performance overhead because the drive controller does the encryption and decryption.

Select Intel Core i5 vPro processors feature Intel AES-NI, which can help lessen the performance impact of encryption. We are currently testing the performance benefits of Intel AES-NI support in our encryption software. In addition, we want to evaluate drive-based encryption to determine when we should begin incorporating it into our environment.

Currently, we are focused on deploying SSDs to 100 percent of our mobile workforce. We also plan to deploy SSDs to desktop PCs. More study is needed to determine whether the TCO benefit of SSDs is as compelling in the desktop environment as it is for mobile business PCs.

CONCLUSION

Intel SSDs offer significant performance and support benefits, particularly when combined with the Intel Core i5 vPro processor and Microsoft Windows 7. Users appreciate enhanced system performance, greater mobility, and enhanced productivity and efficiency. From the IT perspective, Intel SSDs offer greater reliability, better build performance, and lower overall TCO than we can achieve with HDDs.

We take advantage of every opportunity to deploy Intel SSDs—such as OS upgrades, PC rebuilds, and PC refreshes—rather than limiting deployment to our standard three-and-a-half-year PC refresh cycle. This helps Intel more quickly realize the benefits they offer.

The experience we've gained over the two and a half years enables us to deploy and support Intel SSDs in a more efficient and cost-effective manner.

ACRONYMS

AFR	annual failure rate
AHCI	Advanced Host Controller Interface
ATA	Advanced Technology Attachment
HDD	hard disk drive
IDE-R	integrated drive electronics redirect
Intel® AES-NI	Intel® Advanced Encryption Standard-New Instructions
Intel® RST	Intel® Rapid Storage Technology
NCQ	Native Command Queuing
PPV	pay-per-view
ROI	return on investment
SATA 1	Serial Advanced Technology Attachment 1.5 Gb/s
SATA 2	Serial Advanced Technology Attachment 3 Gb/s
SSD	solid-state drive
TCO	total cost of ownership
WDE	whole-disk encryption

For more information on Intel IT best practices, visit www.intel.com/it.

[1] Intel internal measurements, June 2010.

[2] "Enterprise-wide Deployment of Notebook PCs with Solid-State Drives." Intel Corporation, August 2009.

[3] See "Enterprise-wide Deployment of Notebook PCs with Solid-State Drives" and "Improving the Mobile Experience with Solid-State Drives." Intel Corporation, January 2009.

[4] We discuss our initial analysis and performance comparisons in "Improving the Mobile Experience with Solid-State Drives."

[5] We discuss our analysis in "Enterprise-wide Deployment of Notebook PCs with Solid-State Drives."

[6] "Enterprise-wide Deployment of Notebook PCs with Solid-State Drives"

[7] "SSD Thermal Analysis: Technology Evaluation." Intel Corporation internal publication, June 2009.

[8] "Enterprise-wide Deployment of Notebook PCs with Solid-State Drives"

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