

## Validating the Reliability of Intel® Solid-State Drives

### Benefits of Intel® Solid-State Drives

- 87 percent reduction in annualized failure rate decreases IT total cost of ownership.
- 4x faster I/O performance increases employee productivity.

To enhance employee productivity while reducing IT total cost of ownership (TCO), in 2009 Intel IT made a strategic decision to standardize on mobile business PCs equipped with Intel® Solid-State Drives (Intel® SSDs). Early TCO calculations using data from solid-state drive (SSD) manufacturers indicated that we could reduce TCO due to greater reliability compared to hard disk drives (HDDs).<sup>1</sup> In a yearlong study of more than 45,000 SSDs deployed in our mobile business PC fleet, we validated that Intel SSDs provide an 87 percent reduction in the annualized failure rate compared to HDDs—which supports our early TCO analysis. See Figure 1.

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

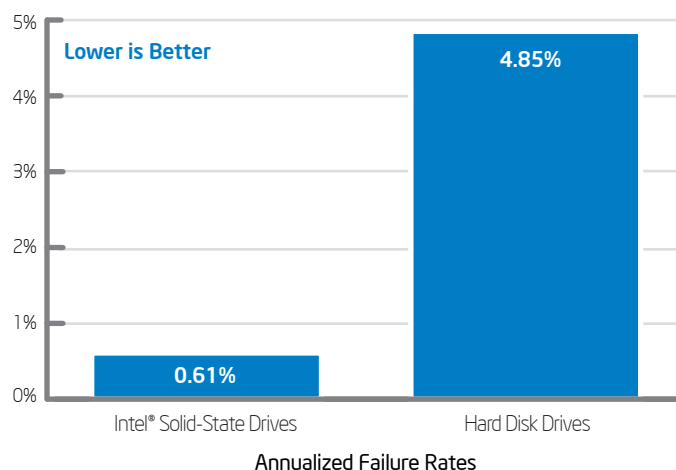


Figure 1. Analysis of Intel® Solid-State Drive failure data shows an 87 percent reduction in the annualized failure rate compared to hard disk drives, directly reducing IT total cost of ownership. Intel internal measurements, 2008 and February 2011.

## Benefits of Improved Drive Reliability

Reducing drive failures significantly increases employee productivity and reduces IT costs. For this reason, Intel IT proactively monitors and then repairs or replaces drives that exhibit signs of potential failure.

For employees, improved drive reliability results in:

- Fewer unpredictable and inconvenient outages
- Increased productivity and task completion
- Reduced potential for data loss
- Less time spent recovering data and reconfiguring mobile business PCs

For IT, improved drive reliability leads to:

- Fewer support calls
- Less Service Desk time spent on drive repair and replacement
- Decrease in costs for drives with expired warranties
- Reduced costs for data recovery on failed drives

We consider lowering the annualized failure rate to be the primary factor in reducing TCO. To help us determine how much we could reduce TCO by replacing HDDs with Intel® Solid-State Drives (Intel® SSDs) in our mobile business PCs, we worked with the Intel SSD product group to develop the Client IT TCO tool, which is now available online at [www.intel.com/design/flash/nand/index.htm](http://www.intel.com/design/flash/nand/index.htm). IT organizations can enter their own data into the tool to get a sense of how much they could reduce their TCO by transitioning to Intel SSDs.

## Background

In 2007, Intel IT evaluated replacing HDDs in our mobile business PC fleet with Intel SSDs. As a new technology, Intel SSDs required higher upfront costs compared to HDDs. However, we anticipated that improved employee productivity and mobility plus reduced TCO could justify these costs.

We assumed that SSDs would deliver better reliability because, unlike HDDs, they don't include fragile moving parts. To validate this assumption and to justify the higher upfront costs, we calculated TCO as part of a proof of concept (PoC). In our calculations, better reliability was the primary factor in reducing TCO, while faster performance was a secondary factor.

At the time we calculated TCO, we had not accumulated enough internal data to analyze reliability, and no long-term studies of SSD reliability were available. As a result, we relied on the best data available—from SSD manufacturers. Comparing manufacturer estimates with actual 2007 HDD failure data indicated that SSDs could offer a 90 percent reduction in annualized failure rates.

As part of the PoC, we also deployed 1,500 first-generation Intel SSDs to our sales force in 2008. In 2009, we deployed an additional 7,000 first-generation Intel SSDs to employees through upgrades, OEM adoption, and PC refreshes.

Our TCO calculations, along with strong employee demand, led us to commit to deploying Intel SSDs in 100 percent of

Intel's mobile business PCs. We provided second-generation Intel® X25-M and X18-M Mainstream SATA Solid-State Drives (80 GB and 160 GB) to employees through new PC deployments, OS rebuilds and upgrades, and department-funded deployment projects. By early 2011, we had deployed 45,384 second-generation Intel SSDs in our environment, which allowed us to calculate reliability using actual failure data.

## Methodology

We calculated SSD reliability using two industry-standard measures, the annualized return rate (ARR) and the annualized failure rate (AFR). To perform these calculations, we first determined the total number of weeks each Intel SSD was deployed and then added these totals for all drives to determine the total number of drive weeks that Intel SSDs were deployed in our environment.

A "returned" drive is any drive replaced due to suspected logical or physical failure. We performed a rigorous evaluation of each returned drive using a proprietary toolset that the Intel SSD product group provided. If the analysis detected a failure, we logged the cause. If a drive passed, we logged it as a return, but not as a failure.

We calculated the ARR using a simple formula:

- $ARR = \frac{\text{Total Number of Returned Drives}}{\text{Total Drive Weeks} \times 52 \text{ Weeks per Year}}$

Similarly, we calculated the AFR:

- $AFR = \frac{\text{Total Number of Failed Drives}}{\text{Total Drive Weeks} \times 52 \text{ Weeks per Year}}$

## Results

Table 1 compares failure data for Intel SSDs with that of HDDs. We calculated 1,109,399 Total Drive Weeks from 45,384 second-generation Intel SSDs. During the yearlong study, employees returned 227 drives. Using the Total Drive Weeks denominator, we calculated an ARR of 1.06 percent.

Of the 227 returned drives, 130 had detected failures. Using the Total Drive Weeks denominator, we calculated an AFR of 0.61 percent and compared this to the 2007 AFR for HDDs of 4.85 percent.

Based on analysis of the failure data we collected on Intel SSDs, we determined that:

- The second-generation SSDs we deployed in our mobile business PCs resulted in an 87 percent reduction in the annualized failure rate compared to the HDDs we used in our mobile business PCs in 2007.

- The 0.61 percent AFR for second-generation Intel SSDs reasonably aligns with the assumption of a 0.50 percent AFR that we used in our original TCO analysis and therefore validates our TCO calculations.

The lower AFR for Intel SSDs is the key to reduced TCO, as improved reliability decreases user downtime as well as IT costs for troubleshooting and rebuilding laptops. Each drive failure can cost IT from two 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 back-up system is and on employee compliance with regular back-up policies.

## Collaborating with the Product Group to Improve the Design of Intel® Solid-State Drives

Because reliability plays a key role in reducing total cost of ownership and therefore the rate of enterprise adoption of Intel® Solid-State Drives (Intel® SSDs), Intel IT collaborated with the Intel SSD product group to analyze all returned drives. We ran a set of failure analysis scripts on returned drives to determine if they failed and, if so, the causes of failure. The product group then used the results to understand the most common causes of failures in our environment—including power-loss issues, NAND cell defects, and firmware-related issues—to make improvements in the next generation of Intel SSDs.

Table 1. Annualized Failure Rate Comparison of Intel® Solid-State Drives and Hard Disk Drives

	Hard Disk Drives	Intel® Solid-State Drives
Total Drive Weeks	4,160,000	1,109,399
Number of Drives	80,000	45,384
Average Weeks per Drive	52	24.4
Number of Returns	N/A	227
Number of Failures	3,881	130
Annualized Return Rate (ARR)	N/A	1.06
Annualized Failure Rate (AFR)	4.85%	0.61%
	Annualized Failure Rate Reduction	87%

## Conclusion

Intel SSDs offer greater reliability and lower overall TCO than we experienced with HDDs. Intel SSDs also provide Intel's highly mobile workforce with improved system performance, longer battery life, and greater mobility. These benefits underscore why we are committed to deploying SSDs throughout our enterprise. Intel SSDs are now part of the standard configuration for all the mobile business PCs we purchase. Rather than limiting deployment to our standard two- to four-year PC refresh cadence, we are taking advantage of every opportunity to deploy Intel SSDs—including OS upgrades, PC rebuilds, and PC refreshes—to realize the benefits of Intel SSDs more rapidly.

## For More Information

Visit [www.intel.com/it](http://www.intel.com/it) for additional papers detailing our investigations of SSDs.

- "Improving the Mobile Experience with Solid-State Drives"
- "Enterprise-wide Deployment of Notebook PCs with Solid-State Drives"
- "Accelerating the Deployment of Intel Solid-state Drives"

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## ACRONYMS

AFR	annualized failure rate
ARR	annualized return rate
HDD	hard disk drive
Intel® SSD	Intel® Solid-State Drive
PoC	proof of concept
SSD	solid-state drive
TCO	total cost of ownership

<sup>1</sup>"Enterprise-wide Deployment of Notebook PCs with Solid-State Drives." Intel Corporation, August 2009.

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