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Technology Paper

Cheetah 15K.3—Economies of Speed

Introduction

Businesses are constantly being asked to do more with less: achieve greater results in less time with fewer resources. As such, businesses have invested heavily in faster system processors and increased network bandwidth. However, if similar investments are made in *disc drive* performance, IT professionals can lower response times, while realizing a significant savings in overall system and infrastructure costs.

Seagate® has recognized the challenges facing today's IT professionals, and has been leading the way in developing and delivering highly reliable, state-of-the-art, cost-effective solutions—solutions that the server and storage industry have come to rely on.

The continual growth of IT performance demands, and thus the need for increased IOPS (Input/Output Operations Per Second), drove Seagate Technology to deliver the industry's first 15K-RPM disc drive. In subsequent generations, the leading Enterprise OEM hardware providers have grown to embrace Seagate 15K offerings. Soon, other disc drive producers began to develop their own 15K devices. Following the lead of Seagate, market acceptance of the 15K led to that product becoming a valuable asset to performance-minded IT professionals around the world.

Seagate is now shipping the third generation of their 15K-RPM Cheetah® offering—the Cheetah 15K.3. This product continues to improve upon the successes of earlier-generation Cheetah 15K products. Appendix A on page 9 provides a summary of the Cheetah 15K.3 specifications and features.

The wide acceptance of 15K-RPM technology can be attributed to a number of reasons, but the foremost reason is that today's IT professionals are successfully using the Seagate Cheetah 15K families to lower the total cost of ownership (TCO) of their storage solutions. While businesses strive to achieve economies of scale to leverage the breadth and depth of their product lines in order to increase efficiency and lower unit costs, Cheetah 15K products are now helping IT professionals realize *Economies of Speed* by lowering the TCO of their storage system investments.

Balancing the System

The capacity of hard disc drives has exhibited the phenomenal growth that is typical of the information technology industry, as the data density of the drive has increased year after year, surpassing many people's expectations. However, when considering the I/O performance of the drive and how quickly one can get to the drive's data, the generation-to-generation improvements have been less impressive—especially compared to other components in the system (see Appendix B on page 11). This lack of matched performance growth is due to the fact that the drive's speed is primarily dictated by the mechanics of the drive and the physics that constrain such mechanical parts. These mechanical factors include the movement of the spinning disc and the mechanical positioning of the arm across the disc.

Due to the slow performance of disc drives relative to other components of the system, most enterprise storage systems are configured with a large numbers of disc drives. These large populations are empowered with advanced interfaces that allow workloads to be distributed among many disc drives in the array. These configurations attempt to prevent the disc drives from becoming the performance bottleneck of the system. Unfortunately, the infrastructure required to support these large disc drive populations contributes to a significant cost increase for the overall system—not to mention the significant cost of the additional disc drives!

Rethinking Performance Planning: Higher Performance From Fewer Drives

In storage applications where the data is accessed in random patterns, the increased spindle speed of 15K-RPM drives can deliver tremendous benefits. For example, the Seagate Cheetah 15K.3 delivers an average of 35 percent more IOPS than 10K-RPM drives in a number of popular performance test configurations. This dramatic performance increase can be applied toward supporting a system requirement for a given number of IOPS, and maintaining a certain response time for a group of clients. In meeting that requisite system-level IOPS performance, fewer 15K-RPM disc drives are required than would be required if the same amount of I/O workload were to be handled by 10K-RPM drives. The cost savings realized by meeting system performance, capacity and reliability goals with fewer, faster 15K-RPM drives is what we call *Economies of Speed.*

Economies of Speed: **Cost savings realized by meeting system performance, capacity and reliability goals with fewer, faster 15K-RPM drives.**

What do fewer drives mean for the IT manager?

+ Greater reliability, because the system will have a lower spindle count

Reliability gains are due not only due to the reduction of disc drives, but due to the corresponding reduction in power supplies, host bus adapters (HBAs) and other components required for supporting the larger number of disc drives. Fewer components mean less opportunity for general failures to occur.

– Lower overall system cost

Fewer drives obviously means fewer HDAs, less cabling, and lower component costs—as well as lower overall drive cost!

– Less space

Of course fewer drives means less space required to hold the drives. This translates into denser performance: increased IOPS/ft2 and IOPS/ft3, as well as freeing up space for other hardware needs.

– Less total system power and heat

In enterprise applications, the energy efficiency savings from fewer disc drives results in dollar savings that can be easily monitored.

– Lower IT administration costs

As the costs of implementing and managing complex storage solutions become more heavily weighted toward human resource requirements, including integration and maintenance expenses, lower quantities of disc drives translates into lower costs of storage-management labor.

= *LOWER TOTAL COST OF OWNERSHIP!*

The Cheetah 15K.3 has enhanced the impact of 15K RPM on total cost of ownership, outshining the previous Seagate trendsetter, the Cheetah X15-36LP. Thus the Cheetah 15K.3 has established itself as the leader in lowering TCO—a critical goal for organizations faced with managing rapidly increasing volumes of information and rapidly increasing performance needs. The supremacy of Cheetah 15K.3 has been confirmed by the positive response that Seagate has received from customers and industry experts alike:

> *"The primary target market that Seagate is attempting to focus on is the enterprise environment; specifically companies that need speed while minimizing costs and space requirements. The 15K.3 meets these demands and justifies itself when compared to 10K drives by providing everything a server needs."* ***—GotApex.com***

"This drive does not disappoint at all in the performance arena and at maximum throughput beats the previous generation by about 15MB/sec! …We feel Seagate engineers have absolutely outdone themselves this time and we're once again awarding their product with our Top Honors Award." ***—LinuxHardware.org***

"The latest Seagate 15K product once again sets the standard against which this year's crop of drives will be judged. The 15K.3 scales new heights in single-user performance and sets a new standard for server-class speed. And, in a pleasant surprise, the heat and noise floors delivered by this 15,000-RPM drive rival that of 7200-RPM units!" ***—StorageReview.com***

How the Seagate 15K Family Does It

A drive's access time is an essential attribute in considering overall drive performance. Access time is defined as the time that it takes for the read/write head inside the drive to get to the location on the disc where the data resides. In current configurations, this access time is much greater than the time that it takes for the electronics of the device to actually read or write the data (referred to as data transfer time). The two major components of a drive's access time are seek time and latency. For an illustration of seek time and latency, refer to Figure 1

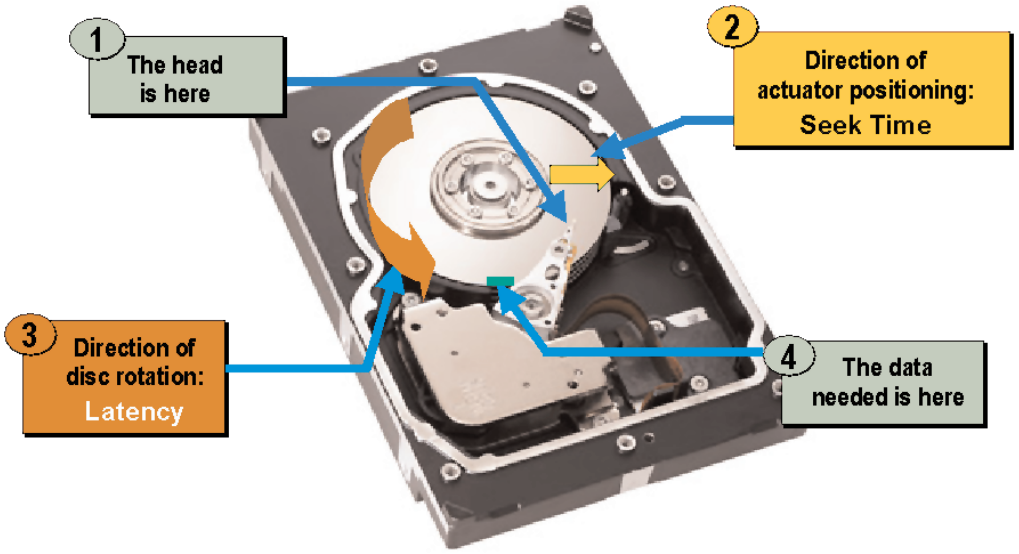

Figure 1. Seek time and latency

Seek Time: After the drive receives a command, the head moves, or seeks, across the disc to the track containing the data. The time it takes to move the head from its initial position to the track of the data is referred to as the seek time. Since Seagate 15K-RPM drives are designed with a smaller diameter disc than 10K drives, the distance that the head must travel is reduced, allowing for faster seek times.

Latency: After the head is positioned on the appropriate track on the disc, the head waits on that track until the desired sector of data moves underneath the head due to the rotation of the disc. The time it takes for the data to reach the head is the latency time. Of course, the faster the disc is spinning, the shorter the latency time. For a 15K-RPM disc, the total time required for a disc to make one revolution is 4 msec. For a 10K-RPM disc, the total time is 6 msec.

When the head reaches the track, the data may already be immediately under the head, resulting in an actual latency of 0 msec. On the other hand, the data may have just passed the head, in which case the head must wait a full revolution (4.0 msec) before reading the data. Therefore, on average, the latency will be 2.0 msec for a 15K-RPM drive.

When considering the effects of both average latency and average seek time, the average data access time of a Seagate 15K drive is approximately 5.8 msec—about 2.1 msec faster than that of an average Seagate 10K drive.

Data Transfer Time: For the majority of performance applications, the time required for the electronics to read the data and transfer it to the bus (referred to as the data transfer rate) is very small compared to the access time, resulting in the data transfer time having relatively little impact on the drive's performance. Figure 2 compares the overall time-to-data between 10K and 15K drives.

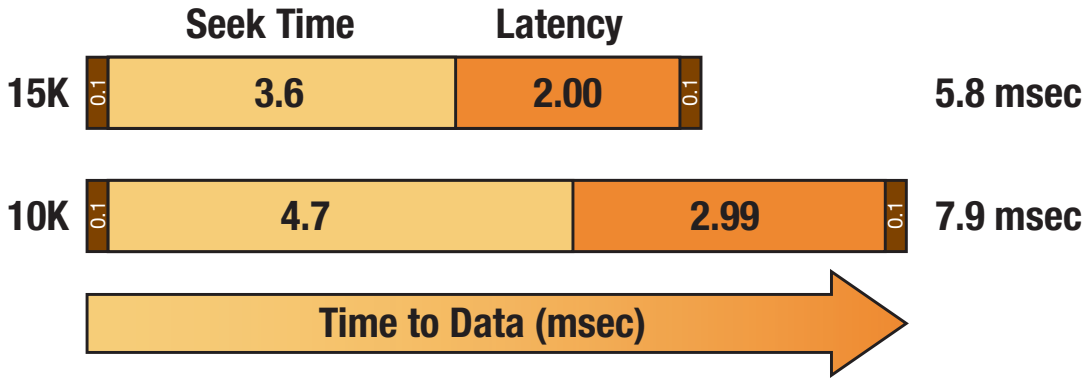

Figure 2. Data access times

Optimizing Systems for Performance

To ensure that the disc drive is not a bottleneck in the system, IT administrators often configure their disc drives in a manner that minimizes the influence of the drives' access times on system performance. Access times for 10K-RPM drives can be minimized by storing data only on the outermost portion of the disc. This minimizes seek time because the data is spread out over a smaller area of the media. As one can guess, this process lowers the capacity of the disc. Reconfiguring a disc drive in this way is referred to as destroking, or short-stroking, the disc.

As destroking is shown in Figure 3, data is stored on the shaded region on the outer diameter of the disc. The lighter area in Figure 3 is available data storage that remains unused to keep the seek time to a minimum. The underutilized media that is characteristic of short-stroking results in a very expensive cost-per-usable-gigabyte and cost-per-IOPS solution for the end user.

As one can guess, 15K-RPM drives decrease the access time without forcing users to give up the capacity on the disc. By using 15K-RPM products, fewer drives of a given capacity are needed to meet the performance requirements of the system. This is the fundamental concept behind Economies of Speed.

Here's an example: Assume that a system administrator wants to store 360 Gbytes of data and meet a set performance expectation. If this amount of data is stored on ten 15K-RPM drives, the user will have increased performance due to the faster seek and latency times of the 15K-RPM drives. Now if an administrator sought to achieve similar performance on a 10K-RPM configuration, the user would have to compensate

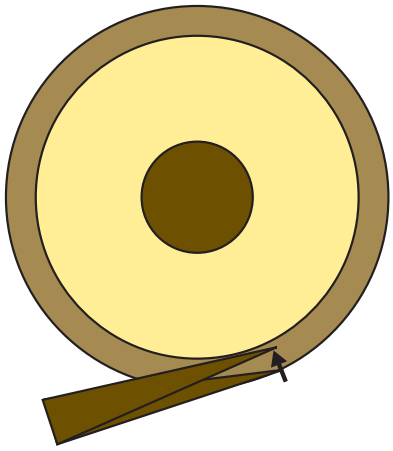

Figure 3. Disc Drive Short-Stroking

By using 15K-RPM products, fewer drives of a given capacity are needed to meet the performance requirements of the system. This is the fundamental concept behind Economies of Speed.

for the slower access times of the 10K-RPM drives. Thus the 10K drives would have to be short-stroked to drop their seek times down to that of the 15K-RPM drives, resulting in a reduction in the total capacity of the array. Due to the short-stroking and the resulting reduced capacity, additional 10K drives would be required to store the same 360 Gbytes of data, while maintaining the system performance expectation. Figure 4a shows how purchasing only ten 15K-RPM drives can achieve very similar performance to fourteen 10K-RPM drives and provide the administrator with other Economies of Speed savings.

		Drives Required	Capacity (Gbytes)	Total IOPS	Response Time (msec)	MTBF (hours)	Drive Power Consumption (W)
10K ST336607LC		14	*366.85	687	17.5	85K	196
15K ST336753LC		10	367	670	17.1	120K	140
		29% Fewer	**Equiva-lent**	**Only 2% Different**	**2% Faster**	**41% Greater**	**29% Less**

*Destroked capacity

Configuration: *Dell PowerEdge 2500 Server, PERC 3/QC RAID Controller, PowerVault 220S, running Iometer performance analysis tool with RAID 0, 8-Kbyte stripe size, 8-Kbyte transfer length, transaction-based workload, 67 percent read, 100 percent random access, queue depth 16*

Figure 4a. Comparison of Number of Drives Required

Figure 4b explores a similar situation where 400 Gbytes of data is to be stored. Here the 15K-RPM drives outperform the 10K-RPM drives in every category, while only requiring the user to purchase eleven drives.

		Drives Required	Capacity (Gbytes)	Total IOPS	Response Time (msec)	MTBF (hours)	Drive Power Consumption (W)
10K ST336607LC		14	*403.8	912	17.5	85K	196
15K ST336753LC		11	403.7	977	16.4	109K	154
		21% Fewer	**Equiva-lent**	**7% Greater**	**6% Faster**	**28% Greater**	**21% Less**

*Destroked capacity

Configuration: *Dell PowerEdge 2500 Server, PERC 3/QC RAID Controller, PowerVault 220S, running Iometer performance analysis tool with RAID 0, 8-Kbyte stripe size, 8-Kbyte transfer length, transaction-based workload, 67 percent read, 100 percent random access, queue depth 16*

Figure 4b. Comparison of Number of Drives Required

Performance Benchmark Results

So how does the Cheetah 15K.3 perform in terms of industry standard performance benchmarks? Below is a comparison between the Seagate Cheetah 15K.3 and the highest rated 10K-RPM products. StorageReview.com, a third-party performance evaluator of disc drives, published the results found in Figure 5. In each of StorageReview.com's Iometer patterns (File Server, Database, and Workstation), the Seagate 15K.3 outperformed the 10K-RPM drive by at least 24 percent.

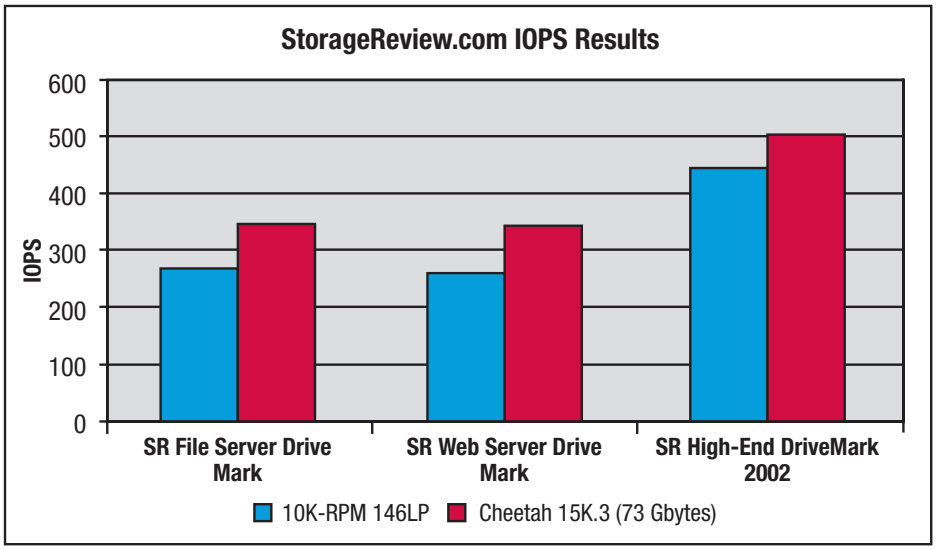

Figure 5. StorageReview.com Performance Comparison

The Cheetah 15K.3 performs at a higher level of IOPS, enabling the system to support more clients and have a faster response time for each client. As businesses push an ever-increasing amount of information upon Intranets, the Internet and Local Area Networks, the need to improve response times is critical. Figure 6 illustrates the faster response time of the Cheetah 15K.3 over the latest 10K-RPM drives.

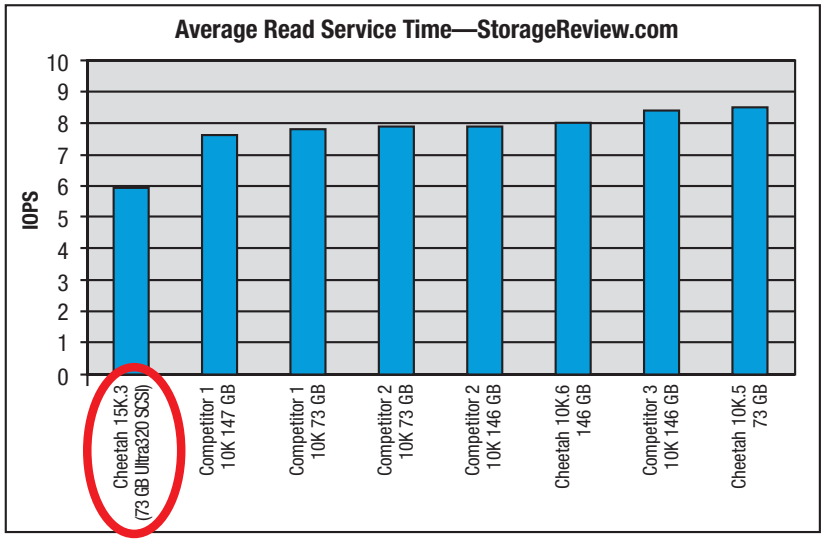

Figure 6. Response Time Comparisons

The Cheetah 15K.3 also demonstrates superior performance versus 10K-RPM drives in the ZD WinMark performance suites. Figure 7 shows the results as measured by StorageReview.com.

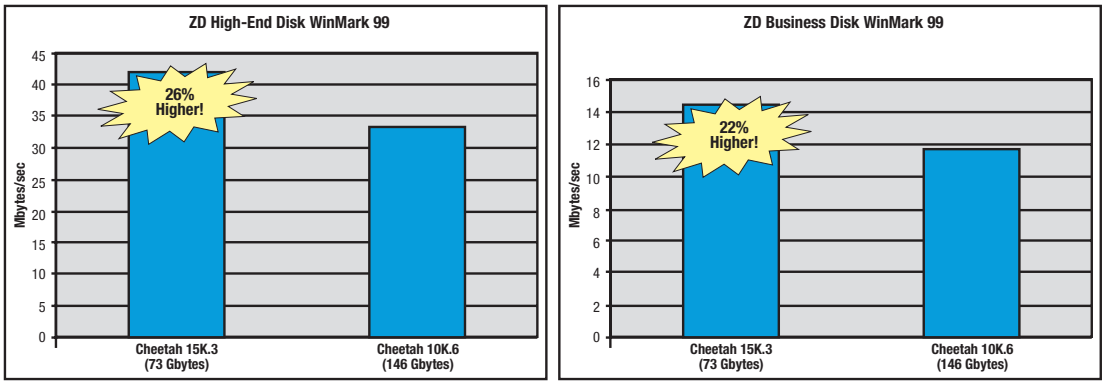

Figure 7. StorageReview.com ZD Winmark Performance Comparison

Applications

The Cheetah 15K.3 fulfills the need for exceptionally high reliability and faster access times in the vast majority of performance applications. As the mainstream has shifted to 15K RPM, these drives can be found in large numbers in a wide variety of hardware platforms:

- Midrange servers
- High-end enterprise servers
- Workstations
- SANs

Examples of these applications include HP's ProLiant servers, AlphaServer systems and StorageWorks enterprise storage solutions; HP's SureStore E FC 60Disk Array and SureStore E SC10 and HVD10 Disk Systems; LSI's MetaStor storage systems; and XIOtech's MAGNITUDE SAN.

Within many of these systems, the benefits of 15K span a broad array of applications requiring faster access times:

- Database queries and transaction updates (transactional by definition)
- Data mining/warehousing (allows quick manipulation of data)
- File and print (helps ensure fast response time as clients are added)
- E-mail (helps handle time to copy and updates individual messages of copied e-mails)
- Internet (aside from caching on the front end, 15K-RPM drives allow for the e-commerce transactions on the back end, similar to a database application, but without the ability to schedule peak use)
- A/V editing

Conclusion

A surge of interest by IT managers in 15K-RPM disc drives has pushed these leading-edge products into the mainstream market, making 15K-RPM drives the enterprise drives of choice. This is can be seen in the high-volume adoption by major OEMs, distributors and resellers. With the ability to achieve much greater IOPS and rapid response time while using fewer drives than 10K-RPM configurations, the Cheetah 15K.3 family of disc drives enable successful and focused solutions for the end user. The net benefit of these Economies of Speed is reduced total cost of ownership—a key requirement in today's enterprise environment.

Appendix A. Cheetah 15K.3 Specifications and Features

Specifications	73 GB[1]	36 GB[1]	18 GB[1]
Model Number	ST373453LC/LW/FC	ST336753LC/LW/FC	ST318453LC/LW/FC
Capacity			
Formatted 512 Kbytes/Sector (Gbytes)	73.4	36.7	18.4
Interface	Ultra 320 SCSI	Ultra 320 SCSI	Ultra 320 SCSI
External Transfer Rate (Mbytes/sec)	320	320	320
Interface	2 Gbit/sec FC	2 Gbit/sec FC	2 Gbit/sec FC
External Transfer Rate (Mbytes/sec)	200	200	200
Performance			
Spindle Speed (RPM)	15K	15K	15K
Average Latency (msec)	2.0	2.0	2.0
Seek Time			
Average Read/Write (msec)	3.6/3.9	3.6/3.9	3.6/3.9
Track-to-Track Read/Write (msec)	0.2/0.4	0.2/0.4	0.2/0.4
Transfer Rate			
Internal (Mbits/sec)	609 to 891	609 to 891	609 to 891
Internal Formatted (Mbytes/sec)	57 to 86	57 to 86	57 to 86
Sustained (Mbytes/sec)	49 to 75	49 to 75	49 to 75
Cache, Multisegmented (Mbytes)	8	8	8
Configuration/Organization			
Discs	4	2	1
Heads	8	4	2
Nonrecoverable Read Errors per Bits Read	1 sector per 10^{15}	1 sector per 10^{15}	1 sector per 10^{15}
MTBF (hours), AFR	1,200,000, 0.73%	1,200,000, 0.73%	1,200,000, 0.73%
Power Management			
Typical Op (amps) +12V/+5V SCSI	1.03/0.87	1.03/0.87	1.03/0.87
Fibre Channel	1.03/0.87	1.03/0.87	1.03/0.87
Power Idle (watts) SCSI	12	10	9
Fibre Channel	12	10	9
Environmental			
Temperature, Operating (°C)	5 to 55	5 to 55	5 to 55
Temperature, Nonoperating (°C)	-40 to 70	-40 to 70	-40 to 70
Shock, Operating: 2 msec (Gs)	60	60	60
Shock, Nonoperating: 2 msec (Gs)	250	250	250
Acoustics Idle (bels—sound power)	3.5	3.2	3.1
Vibration, Operating: <400 Hz (Gs)	0.5	0.5	0.5
Vibration, Nonoperating: <400 Hz (Gs)	2.0	2.0	2.0
Physical			
Height (in/mm)	1.0/25.4	1.0/25.4	1.0/25.4
Width (in/mm)	4.0/101.6	4.0/101.6	4.0/101.6
Depth (in/mm)	5.75/146.6	5.75/146.6	5.75/146.6
Weight (lb/kg)	1.9/0.8	1.8/0.8	1.8/0.8
Warranty			
Limited Warranty (years)	5	5	5

[1]1 Mbyte = 1,000,000 bytes. For additional details, go to cheetah.seagate.com.

Reliability

The highest reliability rating in the industry is underpinned by proven reliability leadership based on the first- and second-generation Seagate Cheetah X15 product families. These drives have all led by example, establishing a standard of excellence in reliability and providing customer confidence.

CRT and RDT Testing: The Cheetah 15K.3 carries on the high reliability of the previous generation Cheetah X15-36LP product with high, demonstrated MTBF.

Field Data: The Cheetah 15K.3 average field return (AFR) data indicates that it is also carrying forward the quality of the previous-generation X15-36LP.

Reliability and Spindle Speed: Reliability data over current and previous generations shows that there is no correlation between increased spindle speed and changes in reliability.

The Cheetah 15K.3 has the highest reliability rating of any drive at any RPM in the industry. The Cheetah 15K.3 incorporates the most advanced elements of the 3D Defense System™, enabling an MTBF of 1,200,000 hours and an AFR of 0.73 percent.

Power and Cooling Requirements

The Cheetah 15K.3 has exceptionally low power and cooling characteristics—comparable to those of 10K-RPM drives. In addition, as with other Seagate enterprise disc drives, the Cheetah 15K.3 is equipped with a temperature sensor that sends a warning in advance to the host when the temperature exceeds limits either specified by the product manual or by the customer.

Cheetah 15K.3 Advanced Features

In addition to the fast access time of the Cheetah 15K.3, Seagate has designed into this drive advanced technology that ensures this drive will maintain maximum performance in a variety of applications. Performance is maximized with the Seagate advanced caching and command queuing algorithms, superior adjacent-track seek performance, Nonlinear Optimized Formatting, and SAMS— the Seagate Advanced Multidrive System™.

NONLINEAR OPTIMIZED FORMATTING

Seagate takes advantage of its superior adjacent-track seek performance in formatting its high-performance drives by using a patent-pending design with a layout that optimizes the trade-off between one-track seeks and head switches. This format method allows for superior sustained transfer rates.

ZERO ACCELERATION PATH TECHNOLOGY

Our Seagate-exclusive patent-pending Zero Acceleration Path technology allows higher track densities by employing algorithms using prewritten track position information to maximize head track-following accuracy. This allows for high track density, which translates into shorter seek distances and allows for a lower disc and head count, bringing greater reliability.

SAMS

The Seagate Advanced Multidrive System (SAMS) is a set of designs that keeps performance on track by reducing the effects of rotational vibration (RV) generated from multiple drives operating simultaneously in a cabinet. RV can hamper performance by making it difficult for the head to stay on track.

SAMS maintains performance in two ways. First, SAMS helps minimize the amount of RV energy emitted from the Seagate drive, thus minimizing the amount of overall RV in the cabinet. Second, SAMS reduces the impact that the cabinet's RV has on the heads and media within the Seagate drive. An example of a SAMS design element is Cheetah 15K.3 Inertia Weights. These weights add mass to limit the transfer of drive-chassis RV to the Seagate drive and maintain peak performance by the Seagate drive, despite forces that would cause competitor drives to suffer.

Interfaces

The Cheetah 15K.3 offers up to and including 2-Gbit-per-second Fibre Channel Arbitrated Loop (FC-AL) and up to Ultra320 SCSI interfaces. These cutting edge interfaces allow for fast data transfer and system performance in the very large systems where they have the most impact.

Appendix B. Balancing the System

Because of the slow speed of disc drives relative to the other components in the system, most enterprise solutions require large numbers of disc drives. The infrastructure to support these discs is a significant cost of the system.

	1987	2001	Increase
CPU Performance	1 MIPS	2000 MIPS	2000x
Memory Size	16 Kbytes	16 Mbytes	1000x
Memory Performance	100 μsec	50 nsec	2000x
Disc Drive Capacity	20 Mbytes	72 Gbytes	3600x
Disc Drive Performance	60 msec	6 msec	10x

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