The purpose of this whitepaper is to:

• Describe current and future hard disk drive technologies

• Give HP’s customers some guidance in selecting their local disk technology to maximize their return on investment.

In optimizing the customer’s workstation investment, the impact of local disk performance and component reliability can vary, depending on the customer’s requirements for system-level performance and reliability, their workstation configuration, and the topology of their computing environment.

Some practical "Rules of Thumb" are suggested at the end of the paper.

This white paper will describe the current disk technologies in use today:

• SCSI (Small Computer System Interface)

• ATA (Parallel ATA, also known as E/IDE)
In addition, there are two new technologies on the horizon that promise major improvements:

• SATA (Serial ATA - deploying Mid-2003)
• SAS (Serial SCSI - future technology)

In order for a customer to obtain the best return-on-technology investment, the factors that should be considered are:

• performance
• reliability
• price

Note that these factors are changing quickly over time, and customers should re-evaluate them on a regular basis.

**hard disk technologies**

The most widely used hard disk technologies currently in use in workstations are SCSI and Parallel ATA (also known as E/IDE). See Table 1 for a summary of the SCSI and ATA technologies.

**SCSI**

The Small Computer System Interface, or SCSI, evolved from the first mini-computers. It was initially called SASI (pronounced “Sassy,” which stands for Shugart Associates System Interface), and it was later standardized by ANSI to promote wider adoption of the standard. The new standard was named SCSI.

Today, the most common use for SCSI is as a high-performance disk interface, although it was defined to be an interface to control many other types of computer-related peripherals. Today’s SCSI LVD (Low-voltage differential) bus can support up to 16 devices, but for all practical purposes that translates into a maximum of 15 disk drives and one controller.

From its roots as a peripheral interface for mini-computers, SCSI disk drives have been developed as a robust, fault tolerant, high-performance storage media for enterprise installations or performance-focused users. They are also more expensive than its equivalent capacity ATA devices for these reasons.

**ATA/IDE**

The ATA interface evolved from the IBM PC. It was originally called Integrated Drive Electronics, or IDE. It was mainly used in a home and business PC’s. It has only been recently that it’s been adopted into workstations as a low-cost alternative to SCSI. The meaning of ATA was also later revised to mean “Advanced Technology Attach” to make it more generic since today’s workstations and PC’s are no longer using the original IBM/PC AT form factor. The original IDE interface was actually a hard disk controller card with a 3.5” hard disk mounted directly to the card. Once this interface became widely accepted, the proprietary PC disk interfaces in use by various companies began to disappear and were replaced with the now nearly universal on-board IDE interface. Each IDE channel can support up to two disk drives.

**Table 1: Current technologies**

<table>
<thead>
<tr>
<th>disk type</th>
<th>interface type</th>
<th>bus</th>
<th>peak transfer rate</th>
<th>typical applications</th>
<th>cycle model</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATA</td>
<td>Parallel</td>
<td>16-bit</td>
<td>100 MB/s (Ultra ATA)</td>
<td>• home PC, non-critical business, desktop solutions, Performance-focused Design, Enterprise server, Business critical solutions, Always-on infrastructure</td>
<td>8hrs/day, 5 days a week</td>
</tr>
<tr>
<td>SCSI</td>
<td>Parallel</td>
<td>16-bit, 32-bit</td>
<td>160 MB/s to 320 MB/s</td>
<td></td>
<td>Continuous 24/7</td>
</tr>
</tbody>
</table>
The bandwidth available through existing parallel interfaces is becoming a bottleneck, so a new architecture was required for further performance enhancements. Fibre channel was the first storage architecture to successfully utilize a serial interface, and has resulted in both the ATA and SCSI markets evolving to follow suit.

**SATA**

Serial ATA is the evolution of Parallel ATA technology, and is aimed at overcoming the inherent limitations of the original IDE interface. Targeted to replace the desktop markets parallel ATA products, it uses a higher speed 1.5 Gb/s serial interface, provides hot-swap capabilities (SATA 2.0 specification), and point-to-point attach topology. SATA drives will also do away with the confusing and cumbersome "master-slave" configuration of current ATA devices and greatly reduce disk-related cabling in the chassis. Motherboard designs are expected to be available with up to four SATA connections.

The first generation of SATA drives are getting close to launch, and companies are beginning to introduce solutions utilizing SATA. There will be a price premium versus parallel ATA hard drives until desktop solutions begin to ramp in volume, at which point the industry will strive for price parity. There will also be new market opportunities for Serial ATA, including tape augmentation and nearline bulk storage for non-mission critical enterprise environments. The core SATA hard drive products offer more functionality than Parallel ATA, but still remain focused on the lowest acquisition price.

**SAS**

Serial Attach SCSI is the evolution of parallel SCSI. These drives are expected to retain the primary advantages of existing parallel SCSI drives - performance and reliability - and also to reap the benefits of a high speed serial interface. The first commercially available SAS systems are predicted to be available in early 2004.

The INCITS T10 working group, responsible for storage industry standards, has been focused on providing customers with a new level of flexibility in their storage deployment. As a result, the SATA and SAS interfaces are signal- and protocol-compatible, and customers deploying Serial SCSI in the system or storage solution will have the ability to plug Serial ATA devices into the same system. This will be the first solution that truly provides customers the ability to chose the right storage solution, on a drive-by-drive basis, without having to upgrade server or storage systems. SATA and SAS are summarized below. Note that the Operating Environment and Use Model may change significantly from the existing ATA / SCSI situation based on the new levels of price-performance and configuration flexibility.

<table>
<thead>
<tr>
<th>disk type</th>
<th>interface type</th>
<th>bus</th>
<th>peak transfer rate</th>
<th>typical applications</th>
<th>cycle model</th>
</tr>
</thead>
<tbody>
<tr>
<td>SATA</td>
<td>Serial</td>
<td>Serial</td>
<td>150 MB/s (SATA-II: 300MB/s)</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>SAS</td>
<td>Serial</td>
<td>Serial</td>
<td>300 MB/s</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>

**Performance**

Performance can be characterized in many different ways from very low level benchmarks to task-level benchmarks that directly represent the customer’s workload. We initially look at the relative performance of SCSI and ATA drives below, and will update this table when SATA and SAS drives become available.

As task level benchmarks are very customer-specific, many times the best one can do is to run industry standard benchmarks and project the customer benefit, with some knowledge of the customer environment. Some examples of the available benchmarks include:

- **SiSoft Sandra** - Low-level Benchmarks. Random Reads and Writes were measured.
- **Winbench 99 Disk Benchmarks** - Low-level Benchmarks. Disk access time and read rate measured.
- **High-End Disk Winmark 99** - Application Derived. Playback of Disk access of the High-End Winstone 99
We ran these tests on current system configurations and have included the results in Table 3. The systems were HP Workstation xw6000 with 2 x 2.4 Ghz Intel® Xeon™ processors, 512 MB PC2100 DDR memory, NVIDIA Quadro NVS 200 graphics, running Microsoft® Windows® 2000. The systems were identical other than the local storage. System A had a single 40 GB Maxtor D740-GL 7200 rpm UltraATA drive. System B had a Seagate ST336607LS 10,000 rpm 36.4 GB Ultra320 SCSI drive with HP A4 firmware. System C had a Seagate ST336752LW 15,000 rpm 36.4 GB Ultra320 SCSI drive with HP A3 firmware. The results are shown in Table 3 and graphically in Figure 1.

**table 3: disk performance comparison**

<table>
<thead>
<tr>
<th>Benchmark</th>
<th>System A 7200 rpm 40 GB UATA</th>
<th>System B 10K rpm 36 GB SCSI</th>
<th>System C 15K rpm 36 GB SCSI</th>
<th>SC SI 10K vs ATA</th>
<th>SC SI 15K vs ATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random Writes</td>
<td>8 MB/s</td>
<td>18 MB/s</td>
<td>20 MB/s</td>
<td>2.25x</td>
<td>2.50x</td>
</tr>
<tr>
<td>Random Reads</td>
<td>6 MB/s</td>
<td>11 MB/s</td>
<td>11 MB/s</td>
<td>1.83x</td>
<td>1.83x</td>
</tr>
<tr>
<td>Disk Access Time</td>
<td>12.5 ms</td>
<td>8 ms</td>
<td>6 ms</td>
<td>1.49x</td>
<td>2.07x</td>
</tr>
<tr>
<td>Disk Transfer Rate (end)</td>
<td>24.8 MB/s</td>
<td>39 MB/s</td>
<td>43 MB/s</td>
<td>1.57x</td>
<td>1.72x</td>
</tr>
<tr>
<td>Disk Transfer Rate (beginning)</td>
<td>40.8 MB/s</td>
<td>62 MB/s</td>
<td>59 MB/s</td>
<td>1.52x</td>
<td>1.44x</td>
</tr>
<tr>
<td>Business Disk WinMark '99</td>
<td>5.8 MB/s</td>
<td>8 MB/s</td>
<td>11 MB/s</td>
<td>1.35x</td>
<td>1.87x</td>
</tr>
<tr>
<td>High End Disk WinMark '99</td>
<td>22 MB/s</td>
<td>27 MB/s</td>
<td>33 MB/s</td>
<td>1.23x</td>
<td>1.45x</td>
</tr>
</tbody>
</table>

The low-level benchmarks show significant advantages of SCSI over ATA, in some cases by over 100%. The differences are even more pronounced with 15,000 rpm SCSI drives. Several aspects of SCSI design are responsible for these advantages:

- Higher platter rotational speeds: 10,000 rpm/15,000 rpm vs 5400rpm/7200rpm. These result in shorter access times and higher data transfer rates.
- Larger internal buffers: 8 MB vs 2 MB, although ATA drives are starting to show up with 8 MB caches.
- Higher raw bus transfer rates: A theoretical peak of 160 MB/s or 320 MB/s vs. about 100 MB/s for today’s Parallel UltraATA interface.
- A more efficient protocol that allows blind transfers, request queuing or stacking, and request optimizations. These features can provide benefit in multi-disk or multiple simultaneous file access requests.

**figure 1: disk performance comparison**

These differences are still very visible, but tend to be diluted, as we move to the “higher-level” benchmarks such as the Business Disk Winmark 99 and the High-End Disk Winmark 99.
Based on these results alone, one might conclude that SCSI has a decided performance advantage in all situations. This is true in many cases, but there are many factors that can determine the correlation of these benchmarks to customer benefit. In some situations these factors can dilute the performance advantages of SCSI vs ATA. These elements are highlighted graphically in Figure 1.

workstation configuration:

- Number of processors and processor frequency: In general, the faster the processor, the more important local disk performance becomes.
- Amount of RAM: A very important factor. Too little RAM increases the amount of swapping which amplifies local disk performance as a factor. There is a significant difference in typical swap performance between SCSI and ATA.
- Network interface: When important data files and applications are being served over TCP/IP, the network interface performance and network design can significantly affect system performance. In those cases the local disk is typically being used for OS, and performance may be less critical.

environment:

- Software: Applications vary widely in their treatment of local storage. Some applications have been written to minimize or optimize storage access as it is an extremely slow part of the memory hierarchy, relative to RAM and processor cache. Other applications are truly pathological (e.g., writing scratch files a block at a time on to the disk, backwards). In the latter case, or in a mixed environment, local disk performance can have a huge effect on overall performance. In addition, the Operating System and particular file system can significantly affect the correlation of local disk performance to overall performance.
- Topology: This can be one of the strongest determiners of the need for high performance local disk. In some scenarios, the bulk of the user’s data and applications reside on local storage during most of the working day. Disk performance can be a major factor for the customer in this case. In other scenarios data and applications are stored on a central shared server and data and applications are transferred over the network. Local disk is primarily used for an OS Boot image and swap space. In this case local disk performance is a secondary concern.

reliability

There are several ways to evaluate the reliability of hard disk drives. Most manufacturers, however, characterize their drive reliability with "Mean Time Between Failure" (MTBF) and "Annual Failure Rate" (AFR).

Based on quoted MTBF, SCSI drives have a decided edge in reliability vs. ATA drives. This stems from the fact that SCSI drives are specifically designed for 24/7 operation, more demanding environmental conditions, and extended service lifetimes. ATA drives are designed primarily with lowest cost in mind, with more modest service and environmental goals.
The typical manufacturers’ specs for SCSI and ATA are:

• **SCSI** - 1,200,000 - 1,500,000 hours statistically derived MTBF based on 24/7 continuous use duty cycle – AFR of approximately 0.40%

• **ATA** - 500,000 - 600,000 hours statistically derived MTBF based on 8.33 hours/day, 5 days per week duty cycle – AFR or approximately 0.80%

While the translation of this low level data into reliability in the customer’s environment is difficult to do analytically, some important factors are:

• Duty Cycle (hours of use per day)

• Environmental
  — Temperature
  — Physical conditions (e.g. vibration)

• Expected service life

For a medium to large installations, using SCSI drives can potentially save a customer significant amounts of money (see Table 4 below). However, each customer must carefully evaluate their own cost structures, software applications, system configurations, and use models to determine the benefit of using SCSI drives in their workstations. With the emergence of SATA and SAS, customers will be able to choose the serial architecture that delivers the best balance between acquisition cost and long term reliability. In the meantime, please ask your HP representative for the most up to date information on which core technology is best suited to your specific environment.

### Table 4: Reliability Implications†

<table>
<thead>
<tr>
<th>Disk Type</th>
<th>Reliability (AFR)‡</th>
<th>Number of Seats</th>
<th>Estimated Downtime</th>
<th>Potential Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCSI</td>
<td>~0.40%</td>
<td>1,000</td>
<td>16hrs/yr</td>
<td>$16k/yr</td>
</tr>
<tr>
<td>ATA</td>
<td>~0.80%</td>
<td>1,000</td>
<td>32hrs/yr</td>
<td>$32k/yr</td>
</tr>
</tbody>
</table>

† Assumptions:

• 1,000 seat installation

• Workstations under continual use throughout the year (24/7)

• 4 hour response time to replace the drives

• $1,000/hour downtime cost

‡ Definitions:

• MTBF—Mean-time between failure (usually in hours)

• AFR—Annual failure rate (usually in percent)

Naturally, uptime is important to all customers. However, in cases where uptime is absolutely critical and there are no topology-level redundancies, SCSI drives are a better bet as they are engineered for greater inherent reliability. A customer with a workstation performing a multi-day or -week financial, mechanical, electrical or chemical analysis might be a good example of the need for this level of reliability.

In cases where uptime is critical but there are topology-enabled redundancies, ATA drives can be a very reasonable tradeoff. An example here might be a centralized data topology where all important data and applications are kept on a highly available central server and local failures are handled by timely local drive and/or workstation replacement.
Due to the enhanced performance and engineered reliability of SCSI drives, manufacturers command a premium. This premium is necessarily reflected in the pricing to end customers, and can be quite significant for the highest performance and/or capacity drives - sometimes as high as 300% vs. similar capacity ATA drives. Each customer must decide whether the additional cost makes sense, likely in the context of an ROI evaluation.

It is desirable to make a well-informed decision by weighing salient factors in the context of a Return on Investment (ROI) analysis. As mentioned above, for the SCSI vs. ATA decision, the factors would likely be centered around Performance, Reliability and Cost:

- Initial purchase cost and budgetary constraints
- Storage subsystem performance and capacity requirements
- Impact of performance and reliability on user productivity
- Customer value of user’s productivity
- Impact of reliability on downtime
- Cost of downtime
- System lifetime

Many customers are not equipped to do a formal analysis, however, so we suggest some rules of thumb below. Additionally, HP is very interested in understanding details about specific customer’s needs to help them make an informed choice.

While a customer-specific analysis is preferable, that is often not possible for a variety of reasons. Below we suggest some typical scenarios and suggest SCSI or ATA local storage in those cases.

- **power design work**: Models are large (100s of MegaBytes or GigaBytes). Maximum and predictable performance is required. The end user works on a local copy of their models. Uptime is important, but secondary to performance. The added performance of SCSI or even RAID 0 (Striped) SCSI translates directly to end user productivity and is typically well worth the incremental cost.

- **centralized data**: Data and applications are loaded from a remote server. Local disk is used primarily for swap space and some scratch data. Reliability can be addressed by the pre-planned replacement of a failed disk drive or Workstation offline. ATA drives provide adequate performance and a very cost-effective solution. Note: it is very important to configure systems with enough RAM to minimize occurrence of swap.

- **streaming data focused**: Quick seek and continuous real time (isochronous) data access is a must. Typical of many DCC environments. RAID 0 (Striped) SCSI is required in many cases to meet the interactivity needs of the user. Cost is secondary.

In optimizing the customer’s workstation investment, the impact of local disk performance and component reliability can vary significantly, depending on a large number of factors. This paper has suggested some of the factors and offered some Rules of Thumb to help the customer evaluate and choose between SCSI and ATA local disk solutions.

A simplified way of characterizing the different disk technologies is as follows:

- **SCSI** — mission critical applications, highest reliability and overall performance
- **ATA** — most cost-effective storage for non-critical applications
- **SATA** — successor to ATA with performance and enterprise application features
- **SAS** — successor to SCSI with system compatible with SATA drives

Other workstation and system infrastructure components, including memory, processor speed, chipset, graphics, and networking, are worthy of similar ROI calculations. Customer environments and workloads will determine what role these factors play in the overall performance, reliability, and price equation.

HP is very interested in understanding details of specific customer’s needs to help them make an informed choice and to help refine our product offering. Customer input along those lines is welcomed, on an ongoing basis.
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