Technology White Paper

Tape Drive Technology Comparison: Super DLTtape™ Technology versus LTO Ultrium

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Introduction

This white paper is a comparison of Super DLTtape™ technology with the Ultrium technology developed by the Linear Tape Open ("LTO") technology providers, Seagate, HP and IBM. Its focus is on the merits of the two technologies from a customer point of view, and as such it compares the features and benefits of the SDLT 220 drive with the three different implementations of Ultrium technology, taking into account the key factors a customer considers when choosing a data protection solution. It draws on secondary data from respected industry analysts such as IDC and Dataquest, independent third party test data, as well as extensive primary research conducted with IT managers in departmental and enterprise IT environments.

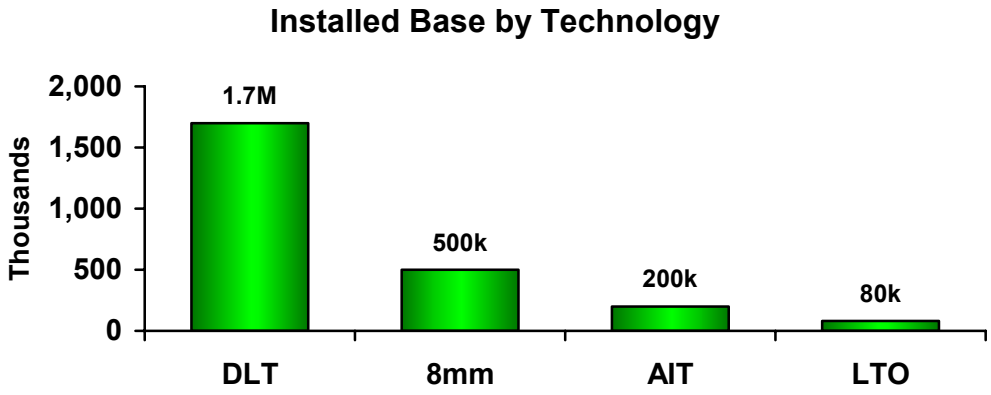
Technology Overview

Super DLTtape is the latest generation of the award-winning DLTtape™ technology. The SDLT 220 drive is a single reel, half-inch magnetic tape drive with a native capacity of 110GB a native transfer rate of 11 MB/sec. It is manufactured by Quantum Corporation and by Tandberg Data, and is sold and marketed by most leading vendors of servers and automated backup systems. It is backward read compatible with all DLTtape IV media written on DLT 4000, DLT 7000, and DLT 8000 tape drives.

Ultrium tape drives are the single reel implementation of LTO technology, a new platform developed by Seagate, HP and IBM. They also use half-inch magnetic media, have a native capacity of 100GB and are specified with transfer rates of 15 MB/sec or 16 MB/sec. They are sold by HP and IBM's captive server and automation divisions, as well as by a subset of other vendors. Ultrium drives are not compatible with any previous tape technology.

Open Standards

DLTtape drives and media have served the world's mid-range backup and archiving needs for much of the last ten years. With an installed base of over 1.7 million drives and over 70 million cartridges shipped to customers, DLTtape systems are recognized as the de facto industry standard for mid-range backup. IDC's latest reported market share numbers indicate that DLTtape had a market share of 73% in the mid-range tape segment[1]. The chart below summarizes the installed bases of various competing mid-range tape technologies.



Source: IDC, Quantum estimates

Super DLTtape technology, by virtue of its universal acceptance, provides end-users the advantages of an open industry standard. Specifically:

- *Super DLTtape technology does not impose limits on the choices open to users.* End-users can use the operating system, the hardware platform, and the software applications of their choice.
- *Super DLTtape technology is open to competition.* Every major computer system manufacturer and every major library manufacturer offers DLTtape as standard equipment. It is available through multiple national and international vendors and multiple drive and media manufacturing licensees. DLTtape media is available through multiple channels of distribution, ensuring a readily available supply and competitive pricing from a variety of sources.
- *Super DLTtape technology is open to external input.* Super DLTtape customers are the world's leading system builders and library manufacturers. Super DLTtape's development teams work closely with them, and maintain an ongoing dialog aimed at making sure Super DLTtape technology meets their customers' needs.

Despite the emphasis in LTO marketing materials on being an open tape format specification, the reality is that unique characteristics outside the LTO specification have created drive and media incompatibility among LTO vendors. The LTO licensing system allows cartridge and drive manufacturers "substantial flexibility"[2], and differences such as varying media slot heights, power consumption and chassis length complicate the open standard claims. From a customer point of view, the drives are essentially three different products from three different vendors. The drives are not interchangeable and should one of the drive vendors cease manufacturing Ultrium products, customers will be left without a drive migration path.

Additionally, the process of achieving compatibility between multiple drives and media from multiple manufacturers (as is the case with Ultrium technology) is extremely complex. The read/write head on each of the Ultrium drives is unique, the tape-head interface is different and the drives employ different search speeds. Furthermore, the media formulations of each media supplier are unique. One consequence of these differences is that each drive's cleaning cartridge is different and can be used only in its respective drive. As end-users review the alternative data protection solutions offered by the Ultrium vendors they should be aware of the risks associated with attempting to achieve compatibility between three unique drives and media from five different media suppliers. Potential risks include:

- Inability to recover data written by another manufacturer's drive
- Damage to the read/write head caused by variations in media abrasiveness
- Tape edge damage caused by differences in head design and tape-head interface

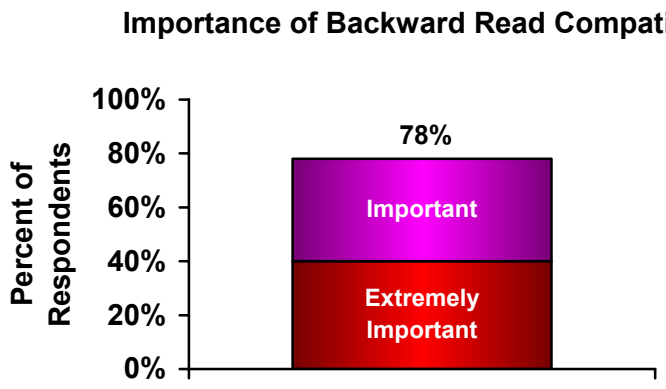
In fact, in their respective user documentation each Ultrium drive manufacturer recommends the use of their own branded media to ensure reliability standards are met. By contrast, the Super DLTtape drives manufactured by Quantum and Tandberg are identical, and thanks to Quantum's rigorous manufacturing and qualification processes all brands of Super DLTtape media are fully interchangeable with all Super DLTtape drives.

Investment Protection

Over the years, Quantum has made a strong commitment to preserving its customers' investments in media and drives by maintaining a high level of compatibility across generations of DLTtape media and drives. Since acquiring the DLT business in 1994, Quantum has maintained media compatibility across all generations of DLTtape products. DLTtape IV media can be written and read by DLT 4000, DLT 7000, and DLT 8000 drives. In addition, it is read compatible with Super DLTtape drives.

So IT managers can continue to access the data stored on millions of DLTtape IV cartridges with Super DLTtape drives. That means they do not need to go to the great expense of transferring all their older tapes to new media just to make them readable. And it means that users with a mix of DLTtape drives today can seamlessly migrate to the Super DLTtape platform as and when their storage needs grow.

Quantum's primary research with end-users indicates that backward compatibility is one of the most highly valued features of a tape technology. The graph below shows that 78% of IT managers rated backward compatibility as either very important or important, a powerful endorsement of Quantum's commitment to compatibility across generations.



Source: Quantum end-user research

Media incompatibility is a significant problem for users considering buying a new technology such as LTO. It is not possible to jump from one technology to another without a great deal of pain and expense. Not only do users have to transfer their data to new media - they have to make a leap of faith that the new technology will be around in 2-3 years. In the case of LTO there may well be a change of strategic direction at one of the LTO drive manufacturers. If one of the LTO vendors withdraws from the market, there is no guarantee that their installed base will continue to be supported.

Product Features

Capacity

Super DLTtape drives are currently available with a capacity of 220GB (compressed). They use an innovative optical servo that employs the best of magnetic and optical technologies, combining high-density magnetic read/write data recording with laser servo guiding on the previously unused backside of the media. This enables Super DLTtape to maximize the number of tracks per inch on the magnetic side of the media. LTO, by contrast, suffers from the fundamental problem shared by all traditional magnetic servo methods: a portion of the recording surface has to be used to store the servo track information. As a result, Super DLTtape is able to write 448 data tracks on its half inch tape, compared with only 384 for Ultrium. Today Super DLTtape drives enjoy a 10% capacity advantage over Ultrium. This advantage will jump to 60% when the enhanced SDLT 320 drive (320 GB compressed) is launched in early 2002.

Interface Variants

Super DLTtape drives are currently offered with two alternative SCSI interfaces: Low Voltage Differential (LVD) Ultra 2 SCSI running at 80 MB/second, and High Voltage Differential (HVD) Ultra SCSI running at 40 MB/second. These are the standard interfaces for the connection of high performance storage devices.

Interfaces offered on the Ultrium drive vary by vendor. Seagate and IBM offer the drive with both SCSI LVD and SCSI HVD interfaces. HP only offers the drive with a SCSI LVD interface. In addition, IBM makes the claim that its Ultrium product is available with a Fibre Channel interface, although the product is not readily available (as of Q4 2001).

While Fibre Channel has established itself as the connection standard between SAN devices, such as switches, routers and tape libraries, the standard for internal tape library connections remains SCSI. The

principal benefit to Fibre Channel connectivity on the tape drive itself is simplified connectivity, albeit at an increased cost. Fibre Channel offers no gains in drive performance since SCSI standards already exceed the highest performance levels of LTO and Super DLTtape drives. As SAN architecture matures, tape libraries will increasingly be able to take advantage of tape drives with native Fibre interfaces, and to meet this need the SDLT 320 drive will be offered with a Fibre Channel interface.

Performance

The SDLT 220 drive is specified with a native transfer rate of 11 MB/sec, while the LTO Ultrium drives are specified with native transfer rates of 15-16 MB/sec. In the real world, however, tape drives rarely perform at their maximum specified transfer rate. Network bandwidth and disk subsystem limitations are the two most common causes of tape drives not meeting their specified data transfer rates. Since every end-user's system is unique it is difficult to incorporate these variables into a lab test of tape drive performance. However, there are other factors that have a significant impact on real-world transfer rates, and these can be measured: the mix of files that an end-user typically backs up, as well as the ability of the tape drive to match the flow of data from the host.

National Technical Systems (NTS), an independent third party test lab, recently conducted tests of the real world performance of the SDLT 220 drive versus that of Ultrium drives from the three LTO vendors. Benchmark testing was conducted at NTS' labs during September 2001.

Testing was conducted on the following server test platform:

Model	Dell Power Edge 6400 Server
Processor	Pentium III Xeon, 866/133
Memory	512 MB
Operating System	Windows 2000 AS
Backup Software	ARCserve 2000
SCSI controller: (Internal)	40 MB/sec Perc 2/Single Channel Wide Ultra 2 LVD
SCSI controller: (External)	320 Mb/sec Ultra160/m SCSI

To simulate typical use conditions the following data sets were utilized:

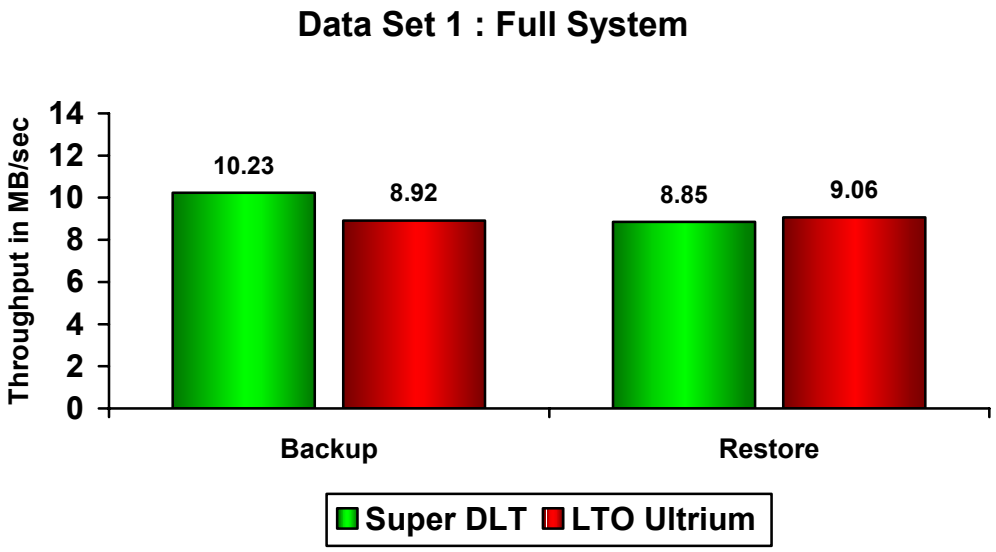
1) Full System – including operating systems and applications (795MB)*.
2) Typical user data found on a network server such as Microsoft Office user files, archived e-mail, and multimedia files (4GB).
3) Medium-sized Oracle database (4GB) (Not including the application itself).

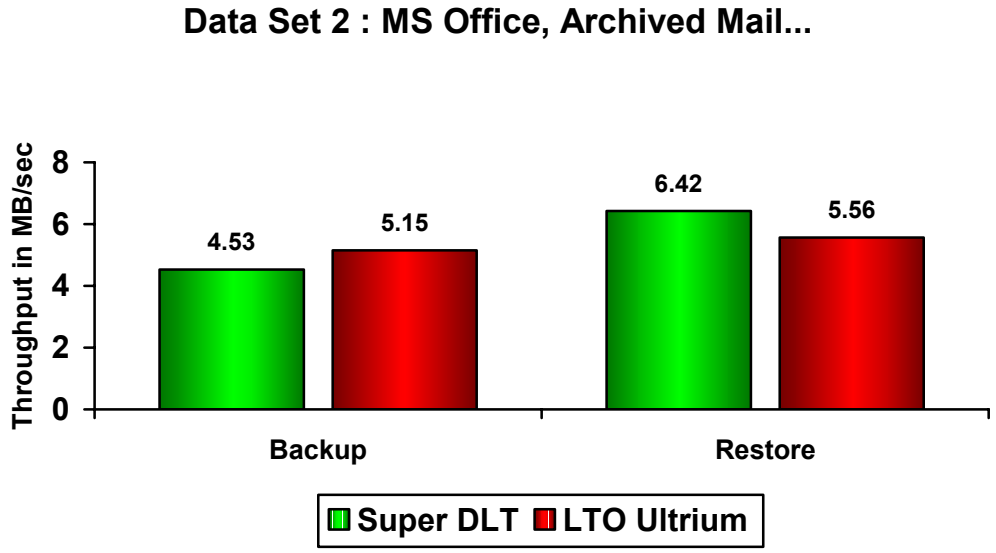
* The size of data set number (1) was determined by the actual size of the existing files on the test servers.

NTS exercised benchmark test procedures as appropriate to insure fair competitive analysis. Prior to the start of testing, NTS contacted each of the respective competitive vendors in turn, informing them that NTS was performing a benchmark with their product while giving them a chance to submit the latest available released software and firmware revisions applicable to the benchmark.

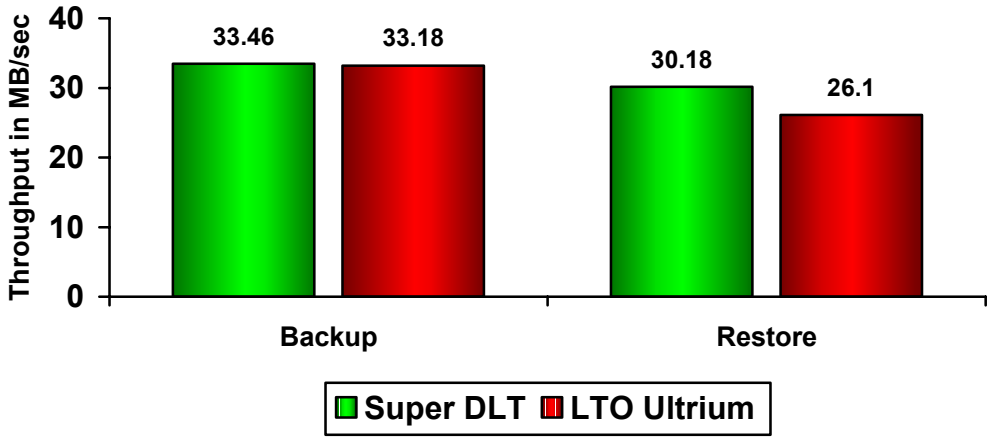
All backups were done with hardware compression enabled as typical in real world use. NTS repeated testing three times for accurate results. Data throughput and timing were recorded from the log files created during the backup and restore procedures.

The following charts summarize the performance test results by comparing the performance of the SDLT 220 with the performance achieved by the Ultrium drives: [3]





Data Set 3 : Oracle Database



The performance benchmarking results clearly show that in terms of real world performance there is very little difference between the SDLT 220 and the Ultrium drives. In some cases the Super DLTtape drive offers superior performance on backup, while the Ultrium drives are marginally better on restores. In other cases, the reverse is true. The bottom line is that the results are sufficiently close to show that end-users can expect similar levels of performance from both Super DLTtape and Ultrium drives.

PRML vs. RLL Recording Code

Super DLTtape technology uses a new high-efficiency PRML (Partial Response Maximum Likelihood) channel developed jointly by Quantum and Lucent Technologies. It applies proven PRML disk drive technology to high-performance tape drives, enabling higher recording densities. Due to the complexity of applying this technology to tape, Ultrium vendors opted to deploy the older RLL 1,7 (Run Length Limited) read channel technology.

RLL 1,7 uses a read technique called peak detection. Peak detection focuses on peak voltage levels for interpreting data from the drive head. But as bits are packed more densely on the tape, it becomes harder to distinguish data from background noise or to detect separate peaks for individual bits. As bit density increases, so does the possibility of inter-symbol interference (ISI). ISI results from the overlap of analog signal peaks now streaming through the read/write head at higher and higher rates.

PRML technology solves these problems by first converting the head's analog signal to a digital signal, then uses the digital signal to detect data bits. The principal effect is that PRML can handle more tightly packed bits than can peak detection, while improving noise rejection. The benefits are higher bit densities, faster transfer rates and fewer errors per megabyte stored. The use of PRML means that Super DLTtape can achieve higher recording densities that than LTO Ultrium. The SDLT 220 has 7% higher bit density than LTO while the soon to be released SDLT 320 will have 56% higher bit density.

Compression Algorithm

Super DLTtape drives use the DLZ (Digital Lempel Ziv) compression algorithm. LTO Ultrium drives use the ALDC (Adaptive Lossless Data Compression) algorithm. Both are so-called adaptive lossless compression techniques and variants of the LZ1 (Lempel-Ziv 1) class of data compression algorithms, first proposed by Abraham Lempel and Jacob Ziv in 1977. The patents to LZ1 are now owned by Hi/fn, the world's leading vendor of compression technology. DLZ is Hi/fn's implementation of the LZ1

algorithm, based on improvements made to the original Lempel Ziv work by Stac Electronics[4]. ALDC is IBM's proprietary implementation of the LZ1 algorithm, which it licenses from Hi/fn[5].

All compression programs work on the same basic principle – they replace long redundant strings with shorter ones. Adaptive data compression techniques try to construct models, or look for data sequences derived in some fashion from recent experience. The algorithms thus *adapt* dynamically to different types of data. The ALDC and DLZ algorithms define a fixed-size sliding window, conceptually a history of the previous data processed (the "history buffer"), which is used to perform pattern matching against the incoming data stream.

The compression ratio is a result of two key factors: the actual data being compressed, and the size of the history buffer. The larger the history buffer, the better the chances of being able to compress the data, but at the cost of slower performance. Research has shown that the optimal history buffer size is 2048 bytes. The ALDC algorithm supports history buffer sizes of 512, 1024, and 2048 bytes. The DLZ algorithm supports a history buffer size of 2048 bytes. Sequences of bytes that match sequences maintained within the history buffer are represented in the coded data as copy-pointer and match-length code words. Bytes that cannot be matched are encoded as literals with a flag bit.

In practice, given the two algorithms' shared heritage, compression results achieved by ALDC and DLZ are very similar. Hi/fn's research indicates that the DLZ compression algorithm is marginally better than ALDC at compression ratios of 3:1 and below, and slightly worse at higher compression ratios of 4:1 and above. DLZ is optimized for compression ratios of 3:1 or less since this represents the vast majority of real-world situations. Both compression techniques are widely used in the computer and networking industry and have been around for a number of years. DLZ compression is found in many products, including those sold by Quantum, Cisco, Lucent, IBM and Novell. The ALDC algorithm is used by 8mm helical scan technologies and was adopted as a compression standard for the QIC (Quarter Inch Cartridge) tape drive industry in 1994.

Drive and Media Management Tools

SDLT offers users two sets of diagnostic tools to help them manage their drives:

1) DLTtools™, a software application that facilitates drive maintenance, testing and diagnostics. DLTtools allows the system administrator to update firmware, edit mode pages, and EEROM parameters.
2) GS LinkTM software allows administrators to access diagnostic information from the front panel of the tape drive via a portable handheld device, streamlining the diagnostic process for a Super DLTtape drive.

Ultrium drives offer varying levels of diagnostic tools. IBM drives ship with a similar application to DLTtools, but Seagate and HP drives do not. Nor do any Ultrium vendors offer an IR enabled device to perform rapid diagnostics.

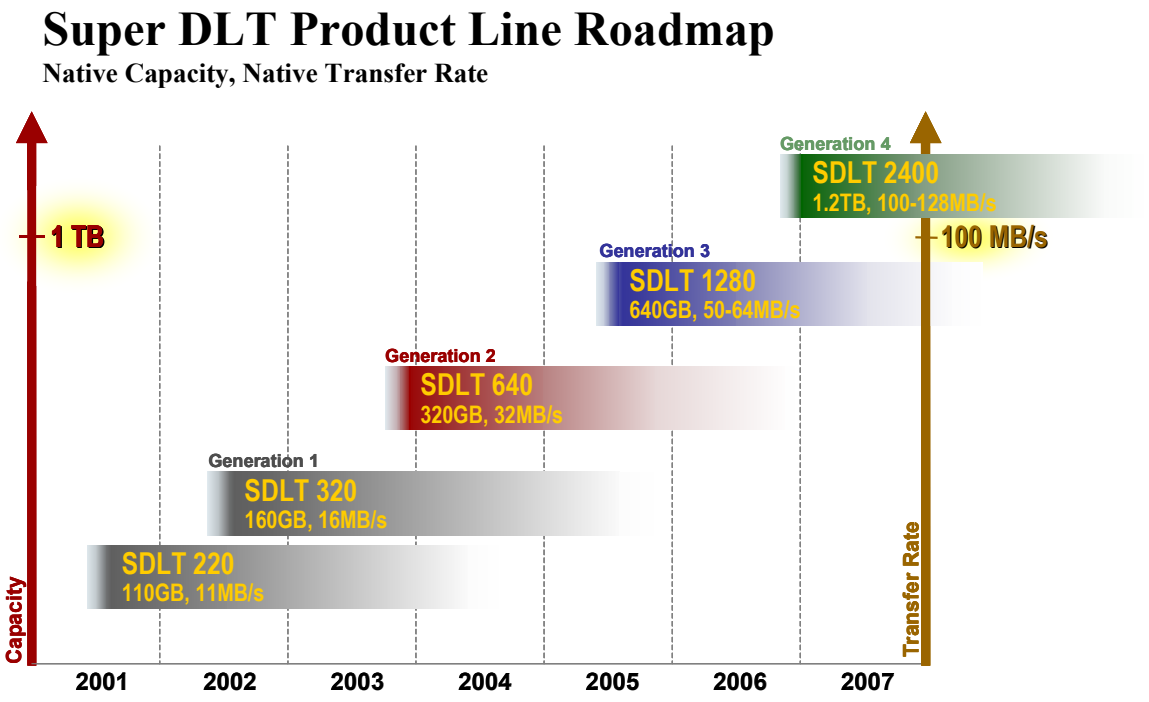
Memory in Cartridge

Ultrium cartridges are required by the LTO interchange specification to include a memory chip on the cartridge, adding cost with little real user benefit. The memory chip provides the drive with essential information that allows it to read cartridges that were written by other vendors' drives: calibration information, manufacturers' data and information about initialization. This is necessary because of the potential interchange problems with LTO. However, if the cartridge memory is damaged, or malfunctions, the drive can no longer write to the cartridge. Ultrium vendors claim that the media becomes read-only, although independent testing indicates that in some cases the cartridge cannot be read at all[6].

Ultrium vendors also plan to store media usage information on the unused portion of the memory chip, although this feature requires support from backup software applications to be of any use. Today, no software applications support this feature.

Product Roadmaps

One of the primary concerns of most IT Managers is choosing a tape technology with a future. The roadmap for Super DLTtape drives and media is the most impressive technology vision in the data protection industry. It lays out, step-by-step, how Super DLTtape systems will continue to meet or exceed data protection needs for the coming decade. In doing so, Super DLTtape technology will become the first tape technology to achieve over one terabyte (TB) of uncompressed storage capacity on a single cartridge, along with a transfer rate of over 100 megabytes per second (MB/sec). Just as important, the Super DLTtape roadmap delivers investment protection by providing backward read compatibility to each prior generation of DLTtape products.

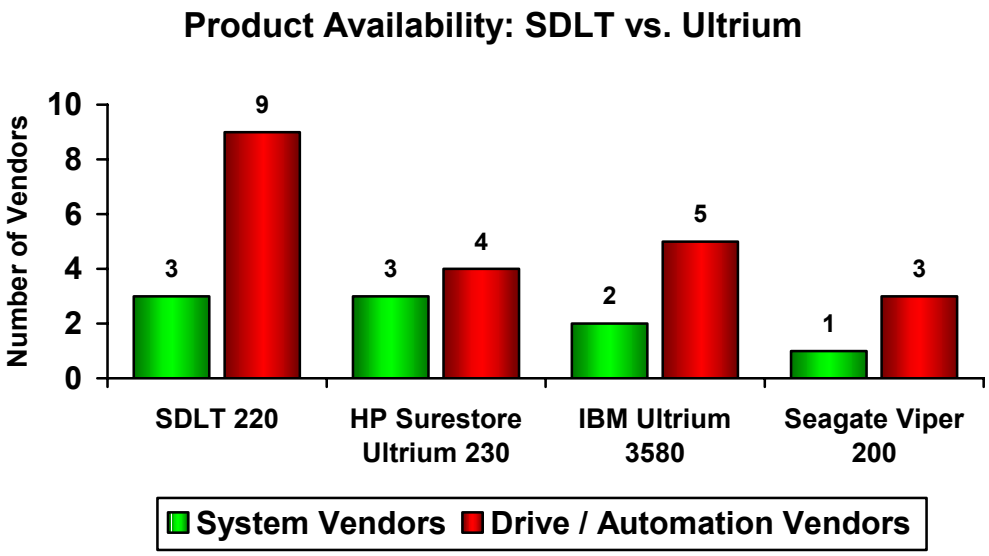


The roadmap for Ultrium charts a path to 800GB and 80MB/sec in the same time frame. So by 2006 Super DLTtape drives will have a 50% capacity advantage and a 25% transfer rate advantage over Ultrium. Significantly, Ultrium will rapidly start to lose touch with end-users' growing storage needs. Research by IDC and Forrester Group projects corporate data storage needs will grow at a rate of 70%-80% per year. By choosing to double capacity only once every two years, Ultrium will effectively be growing at a rate of only 41% per year. The implications for the end-user are that by 2004 they will require three times the amount of LTO media and three times the number of Ultrium tape drives to backup their data (assuming their data needs grow at an average rate and that their backup window remains constant). This hidden cost means the Total Cost of Ownership for Ultrium drives ends up being significantly higher than for Super DLTtape drives. Super DLTtape, by contrast, plans to double capacity and transfer rate every 18 months, thus keeping more in line with end-users' needs. The greater concentration of Super DLTtape technology's R&D resources makes this possible, whereas Ultrium's resources are effectively diluted between three competing vendors. So contrary to the LTO Ultrium vendors' claims that their approach leads to shorter technology development cycles, in fact the opposite is true.

Product Availability

Vendor preference is a key driver of end-user purchase decisions. Some companies have IT or procurement policies that limit choices to one or two specified vendors; others simply prefer to standardize on a single vendor. It is important, therefore, for a tape technology to be widely available. Most leading vendors of midrange computer systems or workstations offer Super DLTtape products, including Compaq, Dell, and IBM. Each of these manufacturers offers Super DLTtape products as factory installed backup systems and libraries for their high performance servers. Super DLTtape technology is also available from the leading manufacturers of tape storage libraries and autoloaders.

The chart below shows the number of vendors offering Super DLTtape compared with the number of vendors offering the different versions of Ultrium. Most system and automation vendors have chosen to offer only one of the versions of Ultrium, with the result that the market for the Ultrium drive suppliers is effectively split three ways. Given the significant investment required to develop, market and sell high end tape drives, it is questionable whether there is a viable long-term business for all three Ultrium suppliers.



Note: Based on publicly available data, Q4 2001