Tape Drive Comparison

- LTO-5 and LTO-4
- T10000B
- T9840D and T9940B
- TS1130

April 2010

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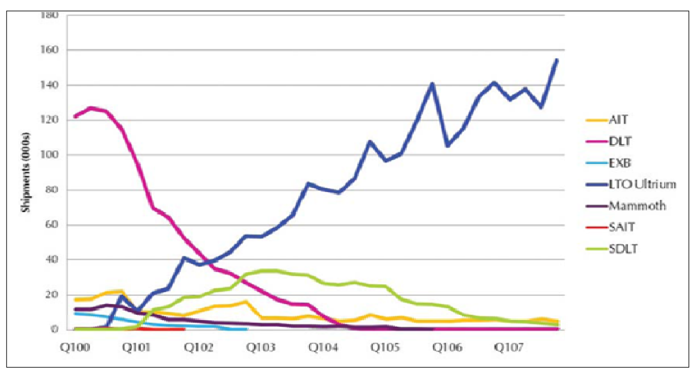
Introduction

With the Spectra Logic launch of LTO-5, the fifth generation of the successful LTO program, examining the range of the latest tape technologies helps customers select the right tape for their data backup environment. Tape is fast, affordable and reliable and increasingly important as data continues its steep growth trajectory. This growth has fueled tremendous advances in physical digital storage. Tape advancements, though steady and massive, have gone largely unnoticed.

Tape is resurging in importance not only because of its affordability, but also because of huge increases in tape reliability and speed, and because of the green IT emphasis on reducing energy consumption and carbon emissions. Other issues, too, such as regulatory compliance, have driven the use of tape. The IBM and Fujifilm announcement of a 35 TB (native) capacity tape demonstrates that tape has plenty of life left.

Tape dominates as the best removable media, and remains the hands-down leader in multiple additional categories. These include cost-for-capacity, and newly notable, the low energy cost per GB of data stored—after all, a tape on a shelf or in a library slot doesn't use any energy, while data on a disk requires constant power. The archival lifetime of tape for storing data securely, maintaining the data's integrity, is also unmatched, with an archival life of 30 or more years given an easily maintained environment.

Among tape technologies, Linear Tape Open (LTO) technology is the recognized leader in the market, with more than 3.3 million shipments to date[1]. The adjacent chart demonstrates the rise of LTO at the expense of all other formats, including Exabtye QIC, Mammoth, Travan, SAIT, DLT, AIT, and SDLT. LTO is the tape format of choice for medium-sized organizations up through huge enterprise customers storing petabytes of data, such as a number of the U.S. National Laboratories and multinational corporations.



This white paper examines the few tape technologies that still compete for the market that includes medium and enterprise organizations. The remaining tape competitors, out of a much larger field that had previously included helical scan technologies, now includes only LTO and proprietary Oracle/Sun/STK and IBM drives. Until recently theses proprietary drives were considered enterprise, but are now competing openly with LTO. LTO effectively serves the

[1] *IDC Worldwide Tape Qview*, IDC research, March 2010,

enterprise, as well as mid-range organizations. LTO's advantage is, in part, due to its cost-effectiveness. Proprietary drives are simply not cost-competitive.

Selecting a tape technology is typically driven by capacity, performance, reliability, and cost. However, this information may be obscured on specification sheets, each emphasizing certain aspects of technology, or using non-standard nomenclature in describing a wide range of features. Distinguishing the useful from the less useful requires some understanding of the technology and how tape has been used.

All of the drives reviewed are typically used in automated tape libraries, and are evaluated in that context. Some libraries provide automation features that play a significant role in maintaining data integrity through drive and tape health management.

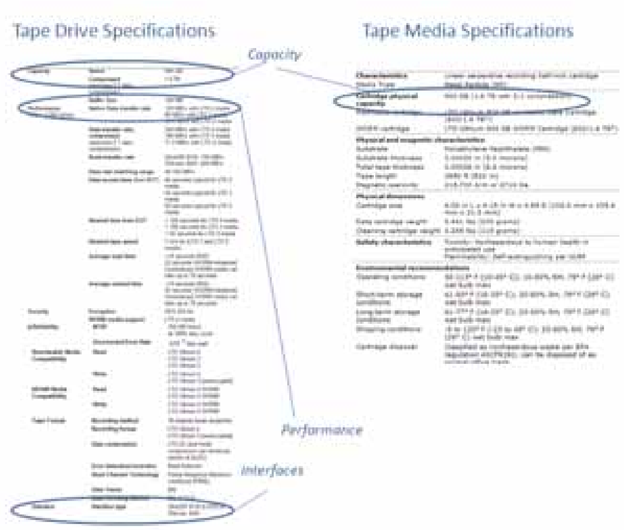
Methodology

Unless otherwise noted throughout this paper, these conventions have been used:

- The values in this paper reflect those specified for each technology's most recent generation/largest media—the largest tape cartridge, for example.
- When multiple values have been identified for any specification, the value from the most trusted source is used. For example, real world testing by a trusted source is used in place of vendor-supplied numbers, unless the delta between the values is large, in which case all values are shown and the discrepancy is discussed.
- Data used is typically for Fibre Channel drives and at maximum typical use.
- The industry standard multiplier of 1,000 is used rather than 1024 in converting bytes to megabytes, gigabytes, etc.
- All values are native (that is, no compression is assumed).
- Values have been rounded.

Understanding Specifications: Tape Technology Background

Specifications sheets include useful data, feathered in between layers of perhaps less useful data. The less useful data reflects a more historical perspective than a pragmatic perspective—that is, a value that was meaningful ten years ago but is no longer that meaningful, and is included as a matter of consistency. The following calls out significant data points in some specifications:



This paper evaluates tape drives as part of an automated system in which robotics move tapes in and out of drives. This is significant because a lot of specifications include facts such as the time it takes to get a tape in and out of a drive. Given that this value is calculated in seconds, this matters only if access time is critical. If access time is critical, it is a given that robotics are involved.

Access to Single File vs. Transfer Rate/Capacity

The issue of access time to data is important in understanding data included on specification sheets.

When tape was originally used with mainframes, tape was the only available media for storing information. Hard drives were too expensive at that time for simply storing data—they were used to run applications. In this circumstance, when you requested a file, the file was stored only on tape so the speed of data access was a significant factor.

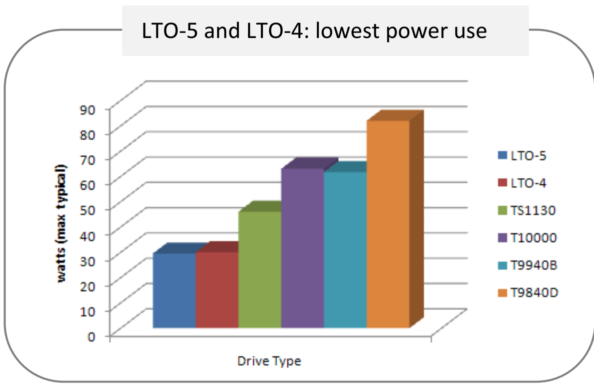
Typically, tape is no longer used as essentially online media, although it can serve well as nearline medium for some applications given current minimal latency. The change in tape use and the growth of data has led to high capacity data storage using drives that can read and write data quickly. The emphasis is on the rate of data transfer to and from tape, rather than on the speed of moving to a specific file on a tape.

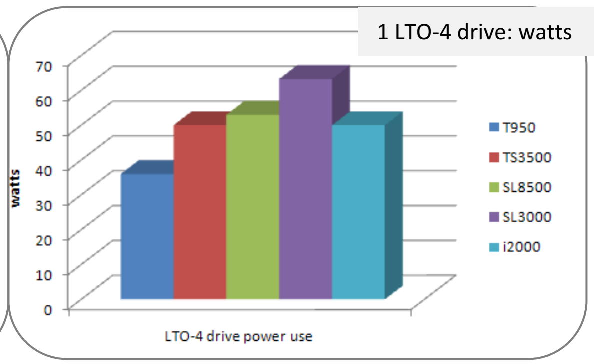
Contemporary tape use puts the emphasis on performance in terms of data transfer rate. Given that data growth is steady and significant, storing more data more quickly has become the typical measure of a drive, rather than accessing a single file quickly.

Power

Power use is an increasingly important topic in data center management. Some regions of the country and world are reaching the maximum power available in specific regions, such as the Northeastern United States. Everywhere, concerns about both costs and the environment are also emphasizing reduced power use. Data centers are significant users of power in the world. If data centers constituted their own industry, they would be the sixth largest of all industrial power consumers. Storage uses about 40% of data energy, a percentage that would be drastically reduced by making appropriate use of tape.

Power is best assessed by looking at how much power the drive in a specific library uses, and the overall library power use, rather than looking solely at drive power use. The following shows power use of specific drives and compares use of one LTO-4 drive across multiple libraries:





Even using an identical drive, power use varies considerably depending on how each library uses the drive. This has to do with how the library itself is constructed—each drive type is engineered to work with each specific library, and some of the sleds on which the drives are inserted in the library are more power-hungry than others. In the example above, the power use by an LTO-4 drive in the T950 library is considerably lower than the power used to run one LTO-4 drive in competing models. In every case, the LTO drives consume less power than proprietary drive technologies.

Automation's Role in Tape Reliability

Tape automation through robotic libraries affects tape drive and media along with power consumption. Some libraries, such as the Spectra Logic T-series family of libraries, provide additional support for maintaining healthy drives and media. By tracking errors and other data about drive technology, robotics can report on factors that range from the lifetime use of the tape to reporting on drive and tape errors, to help administrators identify problem tapes and drives before they affect operations.

The Spectra BlueScale features make it particularly easy to identify problem tapes and drives through the use of icons that display on the graphical interface, which is on the library's front panel and available anywhere through a web browser.

The media is in good condition.

The media tape health is average: for maximum reliability use the tape for restores only.

The media tape health is poor: retire this tape.

In-Depth Comparison

This paper covers the following information regarding each tape drive technology:

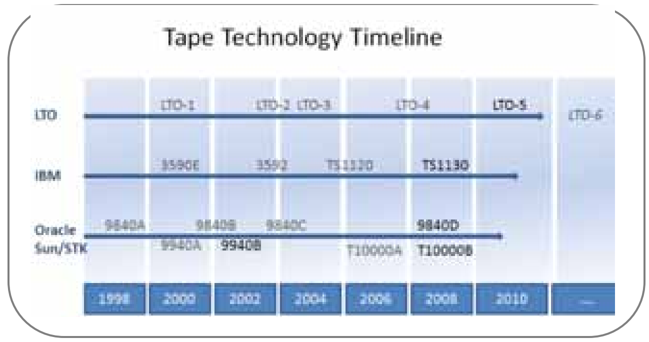
- Drive Types: technology introduction
- Mechanics
- Performance/transfer rates and capacity
- Data streaming to optimize performance
- Price
- Connectivity
- Power use
- Read/write compatibility with earlier generations of tape
- Reliability of media and of drives
- Media Load/Access Times
- Technology /vendor longevity and roadmaps

In each of these sections, this paper examines the following tape technologies:

- Linear Tape Open/LTO-4 and -5
- TS1130
- T10000B
- T9840D and T9940B

Open and Proprietary Technologies

These tape drive technologies all employ a serpentine recording method, but with varying results in performance, cost, and other measures.



Ultrium LTO

Linear Tape Open technology is built on open tape standards developed in a joint venture by Hewlett Packard (HP), IBM, and Seagate. That group created LTO technology in 1997 to provide more choices to users in what had been previously a closed-development arena. The LTO consortium of HP, IBM and now Quantum oversee LTO technology development and roadmap.

LTO is an open format technology with multiple sources for the drives and tapes. Also, because LTO licenses manufacturing to multiple vendors, LTO ensures compatibility between different vendors' tape and drives. The LTO format is also referred to as the Ultrium format. Ultrium LTO-5 format, the fifth generation of LTO, continues to offer the encryption feature introduced in LTO-4. It is worth noting that in almost every case, unless Spectra libraries are used, a separate key management package, non-trivial to install and use, must be implemented before the encryption is usable at any site. The newest drive generation implements a Giant Magneto Resistive (GMR) head to reduce wear on media; this technology is also available in IBM TS1130 drives. The sixth generation of LTO is under development for a tentative 2013 release.

IBM TS1130

The TS1130 continues as the third generation of the drive technology that originated with the 3592 technology, where the second generation was labeled TS1120. The newest drive generation implements a Giant Magneto Resistive (GMR) head to reduce wear on media. TS1130 uses existing 3592 tapes and provides backwards compatibility supporting both read and write for 3592 generation 2 and read only for 3592 generation 1. Older tapes can be reformatted for re-use, although of course this removes all data from those tapes. The next generation of this drive technology may be released as soon as 2011.

Oracle-Sun-STK T10000B

Oracle/Sun/STK released the T10000B drive in 2008, as a follow-on to the T10000 released in 2006. Note that this drive does not accept 9940 media. The drive supports encryption (although again, please note that external encryption key management applications are required before the encryption can be used). The T10000B drive uses a dual-head technology to lessen wear on tapes. The drive is backward compatible with only T1000 drives, but not with any previously released Oracle/Sun/STK tape formats.

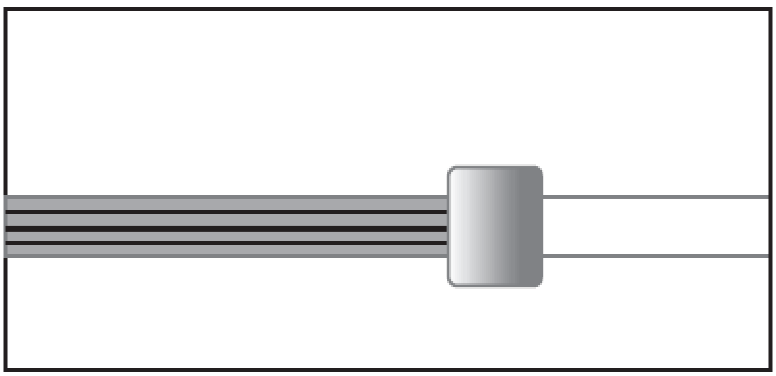
Oracle-Sun-STK T9940B and T9840D

The T9840D drive, which STK released in 2008, is included in this analysis. The T9940B drive is also reviewed; it was introduced in 2002 but apparently no longer available through Oracle. The T9840D drive is targeted to a specific niche market that elects to use short media, exchanging high capacity for rapid access, unlike the other tape drives described in this analysis. No future generations of this line of drives have been identified.

Recording Methodology and Mechanics

Linear Serpentine Recording

LTO, T9940, T9840, T10000, and TS1130 technologies write linear serpentine data tracks parallel to the edge of the tape, shown below.



Linear serpentine recording

Using linear serpentine recording, a half-inch tape moves linearly past a head that houses the carefully aligned read and write heads. To create the serpentine pattern on the tape, the head assembly moves up or down to precise positions at the ends of the tape. Once the head assembly is in position, the tape motion is resumed and another data track is written parallel to and in between the previously written tracks.

Tape Drive Mechanics

In all tape drive systems, the tape is pulled from the cartridge, guided through the tape path, and then pulled across the read-write head assembly. All tape mechanics have improved significantly, with extra error checking and media handling sophistication that largely eliminates concerns about tape handling.

Linear Drive Mechanisms

When the tape cartridge is inserted into a linear tape drive, a load mechanism inside the drive engages with a positioning tab at the beginning of the tape. The tab pulls the tape out of the cartridge and onto a take-up hub inside the drive compartment. As the drive reads or writes, the drives spools the tape between the take-up hub inside the drive and the cartridge supply reel inside the media cartridge.

T9840D cartridge tapes have supply and take-up reels inside the cartridge to permit midpoint loading; this provides fast access to data.

Speed Mechanical Control

In all drives, the tape must be precisely moved through the tape path and across the heads during read and write operations. Also, the relative speed between the tape and the heads must be precisely controlled.

Linear recording technology controls tape speed using a servo mechanism and pick-up and take-up spools. These linear mechanisms employ a very tight and positive control of the spool-to-deck mechanism, which forces the spool gears into the corresponding deck gears.

New improvements in tape technology have lead to more than 700 percent reliability increase over last 10 years[2]

Performance and Capacity

Data transfer rate is defined as the speed at which data is written to tape from the drive's internal buffer. This is usually measured in megabytes per second (MB/sec). If the data transfer from the host system to the drive is significantly slower than the drive's transfer rate, a great deal of start-stop tape motion occurs while the drive waits for more data. Through speed-matching, available in some technologies, and data buffers, stop-start is minimized.

Tape capacity is measured by the amount of data that can be recorded on a single tape cartridge. Tape manufacturers maximize capacity by increasing the bit density on a given area of tape—the ideal method. Some manufacturers simply increase the length of the tape in the cartridge. Hardware data compression is also used to increase capacity.

Native and compressed capacities and transfer rates for each tape technology are shown in the table below.

[2] Beech, Debbie. "Best Practices for backup and long-term data retention" Sylvatica Whitepaper. *The evolving role of disk and tape in the data center*. June 2009

Drive Technology	Data Transfer Native	Data Transfer Compressed	Native Capacity	Compression Ratio
LTO-5	140 MB/s	280 MB/s	1.5 TB	2:1
LTO-4	120 MB/s	240 MB/s	800 GB	2:1
TS1130	160 MB/s	Not available	1 TB	3:1
T10000	120 MB/s	240 MB/s	1 TB	*compressed value not given*
T9940B	30 MB/s	70 MB/s	200 GB	2:1
T9840D	30 MB/s	70 MB/s	75 GB	2:1

Data Streaming's Role in Performance

A tape drive's ability to continuously read or write data, or "stream" data, is a key performance and reliability differentiator. A drive's performance suffers dramatically if the drive is not supplied with data at a rate sufficient to keep it streaming. In cases where these conditions are not met, the drive stops the forward tape motion, reverses the position, brings the tape back to speed, and then restarts the write operation. This is sometimes referred to as shoeshine.

The amount of time spent performing a stop-rewind-start motion dramatically impacts the overall tape system's throughput. To minimize this, high-performance linear technologies employ powerful reel motor systems. The reel-motor system results in linear drives having larger physical footprints and higher power consumption ratings than helical-scan devices. Helical-scan drives perform the stop-rewind-start sequences more quickly because of the slower tape speeds. All of these tape drive technologies use data buffers to minimize stop/start motion.

Each drive has a buffer to help in keeping a drive operating at an optimal speed—caching data that can be used to keep the tape streaming through the drive. The tape stops only when the buffer contains no data to be written (buffer underflow), or when it is full of data during reading (buffer overflow).

In addition, some drive technologies operate at multiple speeds rather than a fixed linear speed. For example Spectra's IBM LTO drive provides 14 different speeds which can track to variable data rate from the host and ensure optimal throughput from the host and virtually eliminate mechanical repositions. The drives match the speed of the tape to the rate of data streaming into the drive. For example, the LTO-5 drive can drop to any of 14 speeds to optimize throughput.

Buffer and Speed Matching

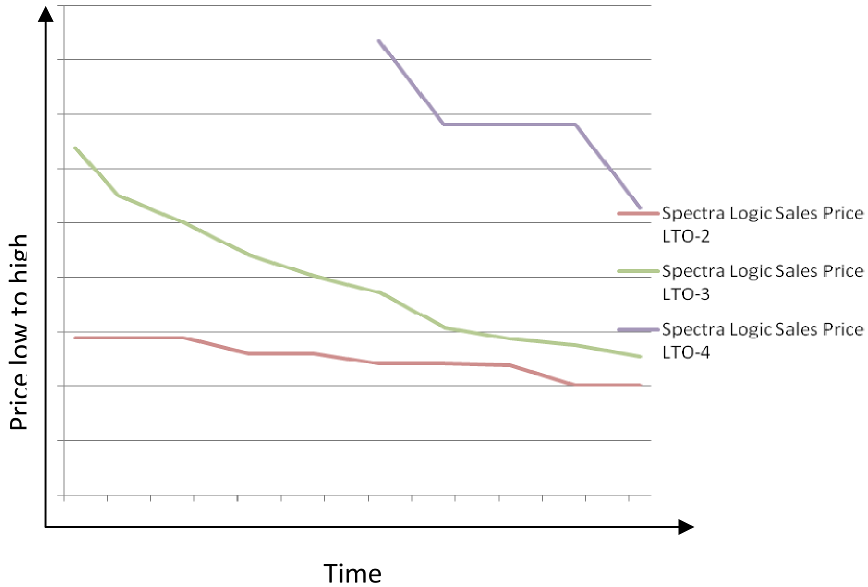
Drive Technology	Buffer	Speed-Matching
LTO-5	512 MB	14
LTO-4	256 MB	7
TS1130	1 GB	7
T10000B	256 MB	2
T9940B	64 MB	n/a
T9840D	n/a	n/a

Price

Consider whether it is worthwhile to invest in a proprietary format, especially given the open-source format LTO, which is available from multiple vendors and decreasingly expensive. LTO-4 technology provides virtually the same performance and capacity—and at a significantly lower cost. LTO-5 tapes provide the highest capacity of the available tape technologies discussed in this paper—at 1.5 TB. At the same time, proprietary drives costs six times as much as LTO drives, so you are paying more for less capacity.

Given the dominance of LTO technology, it's clear that it's an advantage to have a choice of vendors, with competition that leads to lower media and drive costs.

Spectra Logic LTO Media Pricing



Connectivity/Interfaces

Drive Technology	Interface
LTO-5	Open systems: • Serial-attached SCSI (SAS) at 6 Gbit/sec • 8 GB Fibre Channel , dual port • 3Gb/s and 4Gb/s backward-compatible for SAS • 2Gb/s 1Gb/s backwards-compatible FC •
LTO-4	Open systems: • LVDS Ultra-wide SCSI-2 • 4 GB Fibre Channel with 2Gbit/sec interface, 4Gbit/sec interface, and Fibre Channel direct connect (automation) • 3Gb/s SAS
TS1130	Open systems: • 4 GB Fibre Channel Mainframe: • FICON • ESCON Requires a controller to use FICON
T10000B	Open systems:

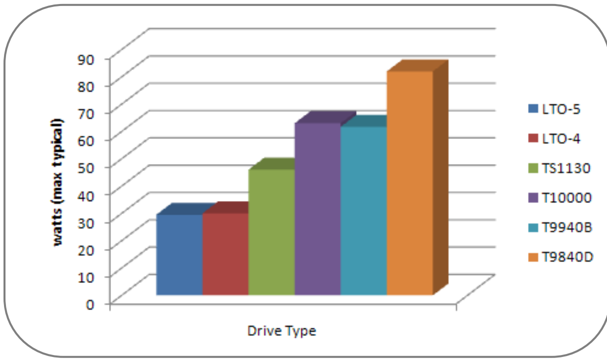
Drive Technology	Interface
	• 4 GB Fibre Channel Mainframe: • FICON
T9940B	Open systems: • 2 GB Fibre Channel Mainframe: • FICON • ESCON
T9840D	Open systems: • 2 GB Fibre Channel Mainframe: • ESCON for VSM 2-GB • FICON

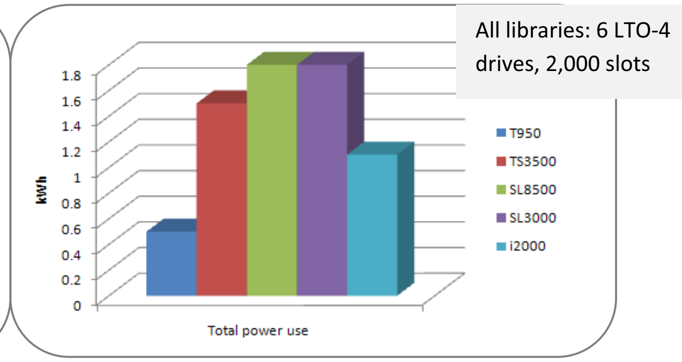
Power Requirements

The power required by the drives spans a considerable range. To compare power use so that the results can be easily compared, typically energy use divided by quantity of data capacity (for example, watts/TB).

Drive Technology	Power Use (typical, not maximum)	Native Capacity	Watts/TB
LTO-5	29.5 watts	1,500 GB	19.7w/TB
LTO-4	30 watts	800 GB	37.5w/TB
TS1130	46 watts	1 TB	46w/TB
T10000	63 watts	1 TB	63 w/TB
T9940B	61.7 watts	200 GB	308w/TB
T9840D	82 watts	75 GB	1,093w/TB

** 9840 drives also consume more than twice the power of LTO-4.*





LTO-5 drives automatically seek the lowest possible power use. When the drive is idle, with no tape mounted and handling no commands, the drive can use as little as 5w. Power saving mode is automatically initialized by the drive, and requires no user interaction. .

Media and Backward Compatibility

As tape technologies evolve, a drive manufacturer must weigh the size of its installed base and the willingness of that base to switch to a new media type as the manufacturer introduces new tape drives. In general, new tape drives use new media types to take advantage of the latest head and media materials. Once the drive technology is established, the drive typically provides some backwards read/write compatibility—it can read from and write to older generations of media.

Drive Technology	Media supported
LTO-5	Reads LTO-3, LTO-4, and LTO-5 tapes Writes to LTO-4 and LTO-5 tapes
LTO-4	Reads LTO-2, LTO-3, and LTO-4 tapes Writes to LTO-3 and LTO-4 tapes
TS1130	Reads 3592 Gen-1, (3592 J1A) Gen-2, (TS1120 E05), Gen-3 (TS1130 E06) tapes Writes 3592 Gen-2 and Gen-3 tapes 1 TB storage through the use of *3592 Extended Data cartridge (JB)* Built on 3592 technology
T10000	Reads and writes to T10000 and T10000B tapes; incompatible with preceding 9840/9940 technology
T9940B	Reads and writes T9940A, T9940B tapes
T9840D	Backwards compatible with all T9840 media

The Future: Migration, Stability, and Roadmaps

At some point, every IT administrator faces the issue of whether to migrate data to a new generation of technology or a new technology overall. With the increasing regulatory vigilance required by many organizations, this can have long-term consequences, since old media must be usable even years from now.

One way to manage the problem of technology upgrades in data storage is to identify a tape technology that has a long roadmap *and* to select an automated tape library that supports partitioning. This way, you can store older media generations, still with read access to the data, while writing data using the newest and highest performance drive with the highest capacity media. Partitions are each a part of the library that is designated as its own virtual library and appears to the outside network as its own library. Each partition can hold a specific drive generation and its media. Logical partitioning such as this can prevent the need for data migration and preserve the site's original investment in older media.

Further, consider whether you need to maintain multiple types of technology. If you do, evaluate whether it is most efficient and cost-effective to keep a smaller, older library or stand-alone drive to read the older tapes, along with using a new library with the fastest and highest capacity technology, or whether to invest in an automated tape library that supports multiple types of technology and its media.

When considering tape technologies, evaluate the number of tape automation manufacturers—this helps ensure long-term support of the technology and availability of drives and tapes. Note that seven manufacturers make LTO -compatible libraries, while only one manufacturer supports 9940, 9840, T1000 (Oracle/Sun) and TS1130 (IBM).

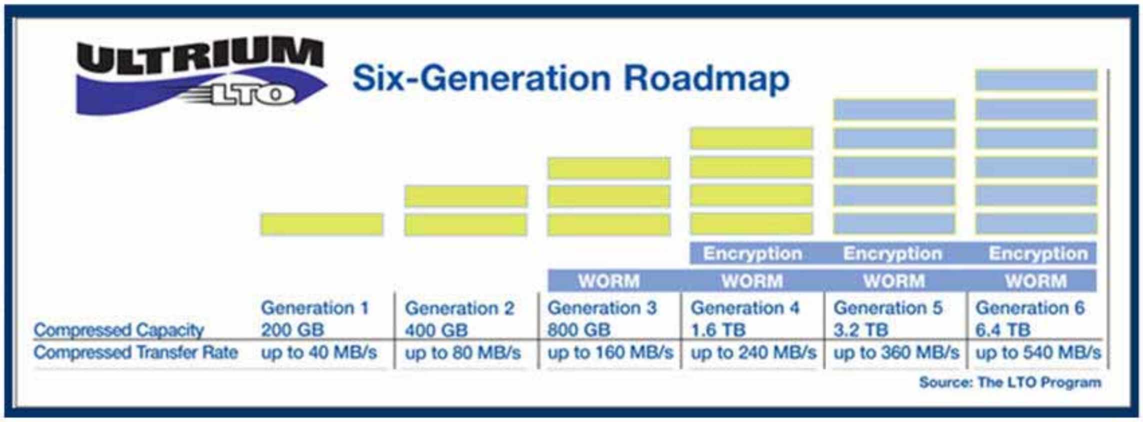
Manufacturing Viability

The TS1130 shares its core technology, production line and volume components with IBM's LTO line which in combination delivers around 210,000 drives per year. This drives up quality and drives down open-source LTO technology pricing. Oracle/Sun/STK is limited to very low volumes in enterprise drives that work with mainframes. Oracle/Sun/STK has only 40% of all mainframe installs, and is in a steady decline. IBM, manufacturer of both LTO and TS1130, owns 60% of the mainframe market, and that percentage is growing. Along with IBM, LTO drives are manufactured by three other vendors, and LTO media by multiple manufacturers. This compares very favorably to all other drives, which have one drive manufacturer and, at most, two tape manufacturers.

Further, note that proprietary drives are available in only a few library automation systems, while LTO is widely available across the spectrum of tape automation systems.

Roadmaps

When choosing a tape drive technology, consider the future of the technology. Succeeding generations typically offer higher performance and capacity while ensuring backward-read compatibility with previously written tapes. You may want to avoid new investments in a technology that is near the end of its life cycle. Currently, only LTO has a published roadmap that is openly accessible. Please note that discussion about continuing LTO past the sixth generation is said to be underway.



Reliability

It's not easy to measure tape and drive reliability, because so many factors are involved. Note that there is no single metric to establish drive and tape reliability. Because of this complexity, it's important to note that a simple analysis is an incomplete analysis. For example, the following are some of the metrics you may want to take into account when calculating tape and tape drive reliability and overall lifespan.

- Error statistics, where more recent errors are weighted more heavily and errors from which the drive could not recover are also more heavily weighted.
- Number of tape mounts and dismounts.
- Number of bytes written and read.
- Mean time between failure (MTBF), a statistical measure of the average time between drive failures, which for example, can be heavily skewed in data centers with high air-borne particulate counts.
- Head life specifications (typically measured in hours).
- Design attributes contribute to increased reliability. For example:
    - LTO drives (by IBM, a member of the LTO consortium) improve read/write reliability by storing IBM's statistical media read/write analysis on every use of the cartridge when using IBM LTO tape drives.

  - TS1130 drives use a special head overcoat technology that lengthens overall product life expectancy.
  - T10000 drives use a dual-head technology which reduces the number of tape passes.
- The materials used in the physical tape for each drive technology, which are variations of the Metal Particulate (MP) and the Advanced Metal Evaporated (AME), factor into reliability analyses. Regardless of the variation, the MP recording layer is composed of magnetic material mixed with a binder and other additives, such as lubricants. AME media's recording layer is made entirely of magnetic cobalt material.
- Data integrity is specified as the bit error rate, which gives the number of permanent errors per total number of bits written. Uncorrected bit error rate is used in this analysis, rather than the undetected error rate.
- The media-use specification by the manufacturer indicates how much the tape has been passed over the drive heads. The number passes differ depending on the technology. To assess these values, the passes must be compared in an apples-to-apples manner—for example, the number of passes required to write to all tracks on an entire tape differ, depending on the technology. For example, LTO drives have a life span of 260 complete backups (completely filling the tape 260 times), which equals 20,000 passes of the tape over the drive's heads.
- The number of media loads and unloads, each a stressor on the tape, is another way to measure tape lifetime

- MTBF is largely irrelevant, given that most drives are sold with on-site service contracts.

The usability of each tape can be calculated using internal drive analyses or using media lifecycle management—a Spectra library method of tape uses and tracking error rates when writing to or reading from tapes. Errors may be due to drive problems or to media problems. Some systems, such as Spectra's Media Lifecycle Management, help you distinguish between the two types of failure, so you can remove the tape or identify the problem drive and clean it or deal with it proactively, as appropriate.

Measures of tape drive reliability

Drive Technology	**MTBF** power-on hours	**Uncorrected Bit Error Rate**	**Head life**
LTO-5	250,000	Less than 10^{-17}	60,000 hr
LTO-4	250,000	Less than 10^{-17}	60,000 hr
TS1130	237,000	Less than 10^{-19}	not available
T10000	290,000	Less than $1x10^{-19}$	5 years

Drive Technology	MTBF power-on hours	Uncorrected Bit Error Rate	Head life
T9940B	290,000	Less than 10^{-18}	8.5 years at 70% duty
T9840D	290,000	Less than 10^{-18}	8.5 years at 70% duty

**not explained further*

Measures of tape cartridge reliability

Tape Life Technology	Durability	Full File Passes	Media Uses (end-to-end passes)
LTO-5	100,000 cartridge load, unload cycles	260 full backups	20,000
LTO-4	100,000 cartridge load, unload cycles	260 full backups	20,000
TS1130/3592 tape media	300,000 cartridge load, unload cycles	(extended media) 72 full file passes	*not available*
T10000	Minimum 100,000 load, unload	300 full file passes	n/a
T9940B	10,000 load/unload minimum	*n/a*	Tape load @ 10/day (100k loads) 240,000 hours Long-life durability 6,500 read/write passes minimum
T9840D	10,000 load/unload minimum	*n/a*	

Load, File Access, and Rewind

Media load and file access times can be considered decreasingly important factors as per-tape capacities rise or when tape drives are integrated into robotic tape libraries. This is because the tape is now used primarily for accessible storage rather than a replacement for disk access speeds, as in the case with mainframes.

When tapes contained very little data (e.g., the 9940B with only 200 GB of data), and were used to access data continuously, load time was very important. However, in the post-mainframe era, and with disk space affordable, tape no longer functions as ‘almost-disk.’ Instead tape is used for secondary storage—occasional access. Load times and file access times are relatively insignificant compared to the time it takes to read and write large data sets, even given the ever increasing performance of next-gen drives. The "mid-tape" load drives, such as the 9940, provide fast access but with serious penalties of high cost, low capacities and complex (and therefore more fragile) mechanics are most subject to obsolescence by disk-based solutions for open-systems applications.

Media load time is defined as the amount of time between cartridge insertion and the drive becoming ready for host system commands. File access time is defined as the time between the point at which the drive receives a host-system command to read a file and the point at which the drive begins to read the data.

File access times are typically averages, since the requested file might be located in the middle of the tape or at either end. Drive vendors typically state specifications for both tape load and file access.

Media Load and File Access Time

Drive Technology	Tape Load *	Average First file Access	Rewind
LTO-5	12 seconds	62 seconds	75 seconds
LTO-4	17 seconds	57 seconds	57 seconds
TS1130	13.5 seconds	48 seconds	37 seconds
T10000B	16 seconds	62 seconds	48 seconds
T9940B	16.5 seconds	41 seconds	48 seconds
T9840D	n/a	9 seconds	8 seconds

**load to ready; phrased variously; unclear that all identify same set of tasks*

Conclusion

The backup and archive market is currently dominated by LTO technology. Of the drives discussed here, LTO provides an incredible combination of high capacity, high performance/transfer rate, low cost, fast media load and file seek time, lowest power requirement, high reliability, data integrity specifications and long term market viability.

Spectra Logic T-series libraries support LTO technology, and take advantage of LTO drive features to provide unique methods of managing tapes to help administrators track the usage and health of the tape. In addition, the Spectra T-Finity library supports TS1130 drives with the same superior set of management features.

Given the many factors you can take into account, the key is to prioritize the factors that are most important to your unique data storage requirements, and choose the technology that best meets your priorities.

Appendix: Specification Tables

The more recent the release of the technology, the more elusive the specifications appear to be. This appendix provides publicly available specifications in chart form. Text describing LTO-5, TS1130, and T1000B was also used in this analysis, but is not included in this appendix.

Summary

The values in the chart summarize the data reviewed in this paper. NA is used if the data was contradicted in several places or simply not available. Italicized data shows the best value in each category. Note that LTO leads this in terms of un-weighted categorical superiority, best in 5 of 11 categories; TS1130 follows with best in 2 categories and tied for best in 1 category.

Drive	Transfer rate MB/s nat/comp	Capacity Native- nat/comp	Buffer MB	Speed match	watts max-avg	w/TB	MTBF power-on hr	Uncor-rected Bit Error Rate	Head life	Load / First file / rewind (sec)	Inter-faces (Gb/sec)
LTO-5	*140 / 280*	*1.5 - 3 TB*	512	*14*	*29.5*	*19.7*	250,000	10^{-17}	60,000 hr	12 / 62 / 75	8 FC/ 6 SAS
LTO-4	120 /240	.8 - 1.6 TB	256	7	30	37.5	250,000	10^{-17}		17 /57 / 57	4 FC/ SCSI
TS1130	160 /na	1 - 3 TB	*1000*	7	46	46	237,000	*10^{-19}*	na	13.5 /48/37	*4 FC/ FICON/ ESCON*
T10000	120 /240	1 TB - (na)	256	2	63	63	*290,000*	*$1x10^{-19}$*	5 years	16/62/ 48	4 FC / FICON
T9940B	30 / 70	200 -400 GB	64	n/a	61.7	308	*290,000*	10^{-18}	8.5 years at 70% duty	16.5 /41/48	2 FC / FICON/ ESCON
T9840D	30 /70	75-150 GB	n/a	n/a	82	1,093	*290,000*	10^{-18}		*n/a/9/ 8*	

LTO

The following specs describe LTO-4 technology:

Tape Cartridge Capacity	1.6 TB, compressed	1.6 TB, compressed
Cartridge Capacity	1 cartridge	30 cartridges
Drives	Single or dual	Single or dual
Drive Transfer Rate	Native: 864 GB/hr*	Up to 1.7 TB/hr*
File Access Time (Avg)	62 seconds	>62 seconds
Interface	LVDS Ultrawide SCSI-2 or 4GB Fibre Channel SFP shortwave	4GB Fibre Channel SFP shortwave
Data Integrity	>1 x 10^{17} bits read	>1 x 10^{17} bits read
Tape Drive MTBF	250,000 hours @ 100% duty cycle	250,000 hours @ 100% duty cycle
Temp/Humidity	10 to 35°C / 20%-80%	10 to 35°C / 20%–80%
Power Specifications	100-240 V; 50-60Hz; 1.3-0.7A ; Auto Voltage select	100-240 V; 50-60Hz; 1.3-0.7A ; Auto Voltage select
Physical: rackmount	Standalone = 3.3"H x 5.7"W x 8.5"D; or 3U rackmount height	16.62"W x 24.34"D x 3.4"H
Weight	46 pounds (single module)	66 pounds (single module)

TS1130

Physical specifications / TS1130 E06 Tape Drive canister:

- Width, front of drive: 150 mm (5.9 in)
- Width, overall: 195 mm (7.5 in)
- Height: 95 mm (3.8 in)
- Length, front of bezel to rear of closed retention latch: 467 mm (18.4 in)
- Weight: 5.7 Kg (12 lbs 7 oz)

Operating environment

- Temperature: 16° to 32°C (60° to 90°F) in operation (media in use)
- Relative humidity: 20% to 80% non-condensing (limited by media)
- Maximum wet bulb temperature: 26°C (78.8°F)
- Individual drive (including fan):
  - Electrical power: 17 watts*, idle, no tape loaded 46 watts* — max continuous (not peak), reading and writing
  - Heat output: 157 Btu/Hour* — max continuous
  - Capacity of exhaust: 0.34 Cubic meter/min (12 CFM) per drive
  - Noise level: 4.3 Bels idle; 6.3 Bels operating

** External ac/dc power supply losses and heat output not included.*

IBM 3592 Extended Data cartridge (JB), the TS1130 Tape Drive can format a cartridge uncompressed of up to 1 TB (3 TB with 3:1 compression)

	3592 Model J1A native cartridge capacity	TS1120 Model E05 native cartridge capacity	TS1130 Model E06 native cartridge capacity
IBM 3592 Tape Cartridge (Extended)	NA	700 GB	1 TB
IBM 3592 Tape Cartridge (Standard)	300 GB	500 GB	640 GB
IBM 3592 Tape Cartridge (Economy)	60 GB	100 GB	128 GB

T10000

TABLE E-4 T10000 Tape Drive Performance Specifications

Characteristic	Specification
Capacity and Performance	
Capacity, native	500 GB (5 x 10^{11} bytes) [T10000A] 1 TB (1x10^{12} bytes) [T10000B]
Data buffer size	256 MB
Tape speeds:	
Read and write	2.0 and 4.95 m/s (T10000A or T10000B read legacy) 2.0 and 3.74 m/s (T10000B)
File search and locates	8.0 m/s to 12 m/s (varying speeds)
High speed rewind	8.0 m/s to 12 m/s (varying speeds)
Throughput	
Data rate (native, uncompressed)	120 MB/s
Burst transfer rate	200 MB/s (2Gb) or 400 MB/s (4Gb)
Interfaces	2 Gb/4 Gb Fibre Channel/FICON (T10000A) 4 Gb Fibre Channel (T10000B)

T10K --Minimum 4800 read/write passes. Uncorrected bit error rate. 1x10. -19

Media durability - *Loads/unloads 15,000. (Sun website)

Tape - *Full File Passes. 24 (T10000). 36 (T10000B).

T9940

Table A-8. T9940 Tape Drive Performance Specifications

Characteristic	Value	
	T9940A	T9940B
Capacity and Performance		
Capacity, native	60 GB	200 GB[1]
Data buffer size	16 MB	64 MB
Tape speed, read/write	2 m/sec	3.4 m/se
Performance, native (head-to-tape)		
(uncompressed)	10 MB/sec	30 MB/sec[1]
(compressed, maximum)	35 MB/sec	70 MB/sec
Burst (FC / FICON)	100 MB/sec	200 MB/sec
Burst (ESCON)	19 MB/sec	19 MB/sec
Interface data		
Fibre Channel	1 Gb	2 Gb
Ultra-SCSI HVD	40 MB/sec	N/A
ESCON	20 MB/sec	20 MB/sec
FICON	NA	2 Gb
Access times		
Tape load and thread to ready	18 sec	18 sec
File access, first (average)	59 sec	59 sec
Rewind (maximum/average)	90/45 sec	90/45 sec
Unload	18 sec	18 sec
Reliability		
Mean time between failure (MBTF)		
Power on @ 100% duty cycle	290,000 hr	290,000 hr
Tape load @ 10/day (100K loads)	240,000 hr	240,000 hr
Tape path motion (TPM) @ 70% duty cycle	196,000 hr	196,000 hr
Head life @ 70% TPM duty cycle	8.5 yr.	8.5 yr.
Uncorrected bit error rate	1 x 10^{-18} 1 x 10^{-33}	1 x 10^{-18}
Undetected bit error rate		1 x 10^{-33}

1. VR² is a trademark of Overland Storage.
VR² technology is used to achieve T9940B capacity and performance.

T9840D

TABLE A-8 T9840 Tape Drive Performance Specifications

Characteristic	Value			
	T9840A	T9840B	T9840C	T9840D
Capacity and Performance				
Capacity, native	20 GB	20 GB	40 GB[1]	75 GB[1]
Data buffer size	8 MB	32 MB	64 MB	64 MB
tape speed, read/write	2 m/s	4 m/s	3.295 m/s	3.4 m/s
Performance, native (head-to-tape				
uncompressed	10 MB/s	19 MB/s	30 MB/s	30 MB/s
compressed (maximum)	35 MB/s	60 MB/s	60 MB/s	60 MB/s[2]
Burst (FC & FICON)	100 MB/s	200 MB/s	200 MB/s	200 MB/s
Burst (ESCON)	17 MB/s	17 MB/s	17 MB/s	17 MB/s
Interface data				
Fibre Channel	1 Gb	2 Gb	2 Gb	2 Gb
Ultra SCSI (HVD)	40 MB/s	40 MB/s	N/A	N/A
ESCON	17 MB/s	17 MB/s	17 MB/s	17 MB/s
FICON	N/A	2 Gb	2 Gb	2 Gb
Access times				
Tape load and thread to ready	7 sec	7 sec	6.5 sec	8.5 sec
File access, first (average)	8 sec	8 sec	8 sec	8 sec
Rewind (maximum/average)	16/8 sec	16/8 sec	16/8 sec	16/8 sec
Unload	8 sec	8 sec	11.5 sec	12.5 sec
Reliability				
Mean time between failure (MTBF)				
Power on @ 100% duty cycle	290,000 hr	290,000 hr	290,000 hr	290,000 hr
Tape load @ 10/day (100k loads)	240,000 hr	240,000 hr	240,000 hr	240,000 hr
Tape path motion (TPM) @ 70% duty cycle	216,000 hr	216,000 hr	216,000 hr	216,000 hr
Head life @ 70% TPM duty cycle	5 years	5 years	5 years	5 years
Uncorrected bit error rate	1×10^{-18}	1×10^{-18}	1×10^{-18}	1×10^{-18}
Undetected bit error rate	1×10^{-33}	1×10^{-33}	1×10^{-33}	1×10^{-33}

TABLE A-9 T9840 Data Cartridge Physical and Performance Specifications

Characteristic	Value
Cartridge physical data	
Drive compatibility	T9840A, T9840B, T9840C, T9840D
Form factor	1/2 in. cartridge, 3490/3490E
Width	10.9 cm (4.29 in.)
Length	12.5 cm (4.92 in.)
Height	2.54 cm (1.0 in.)
Weight	262 g (9.17 oz)
Drop strength	1.0 m (39.4 in.)
Tape media data	
Capacity, native (uncompressed)	20 GB (T9840A, T9840B) 40 GB[1] (T9840C)) 75 GB[1] (T9840D)
Tracks	288 (T9840A, T9840B, T9840C) 576 (T9840D)
Track following servo	Factory pre-recorded
Formulation	Advanced metal particle (AMP)
Physical thickness	9 microns
Physical length	271 m (889 ft)
Recordable length (including MIR)	251 m (823 ft)
Reliability	
Archival life	15-30 years
Short-length durability	80,000 write/read passes minimum
Long-life durability	6,500 write/read passes minimum
Load/unloads	10,000 minimum
Uncorrected bit error rate	1×10^{-18}
Permanent errors	Zero

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