Tape: New Game. New Rules

Tape Re-architects for 21st Century Data Explosion

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Abstract: Are you up to date with the latest improvements in tape technology? If not, you're not alone as much of the IT industry hasn't kept up with the significant enhancements in tape since 2000. Perceptions of tape are often quite outdated and have been generated by lingering problems from older tape technologies. This report will highlight the significant improvements that have arrived, albeit with minimal market visibility, in tape reliability, capacity, performance, media life, and accessibility.

Tape Industry Status

By 2000, the tape industry was facing the growing perception that disk had become cheaper and more reliable than tape. In response to this challenge, the tape industry had begun re-architecting itself and this process was becoming evident by 2000. Key technology improvements were borrowed from the disk industry that yielded several tape developments including much longer media life, improved drive reliability, higher duty cycles, vastly improved bit error rates and much faster data rates than any previous tape technology.

Today there are two companies offering mainframe tape drives. Mainframe tape drives are manufactured by Oracle StorageTek with the T10000 and T9840 drive families and by IBM with their TS11x0 family. The increasingly popular LTO drive family is the de-facto standard in the midrange market and represents over 80% of all tape drive shipments. LTO is now in its 5th generation with LTO-5 and another 3 generations have been defined in the LTO roadmap. LTO-5 currently offers up to 1.5 terabytes native capacity per cartridge and 3 terabytes compressed at a 2:1 ratio while improving reliability and access capability over previous models. LTO drives are produced by Hewlett-Packard, IBM, Quantum and Tandberg, and represented sales of $534.31 million, out of an overall enterprise and midrange tape industry (drives, libraries and media) that exceeded $3.1 billion in 2009. Leading tape media providers include Fujifilm, HP, IBM, Imation, Maxell, Sony and TDK. Older and low-end tape product families such as DLT, 8mm,

Travan, DAT and DDS continue to post sharp declines, though these aging devices are still used in many businesses and fuel much of the current and outdated perception of tape.

Tape markets are shifting as disk slowly encroaches on tape's traditional backup/recovery market while tape is positioning itself for the exploding tier 3 applications such as fixed content, compliance, archive and potentially cloud storage archiving. Today the primary tape market includes all mainframe environments and the midrange and SMB (Small to Medium Business) businesses.

Bottom line: As a result of this progress, tape is aggressively re-positioning itself to address the many new high growth tier 3 storage opportunities which represent over 65% of the world's digital data. Tier 3 applications are growing at nearly 60% compounded annually and it is this application tier that is becoming the primary focus for future tape architectures.

Significant Improvements in Tape Technology

Significant tape advances, particularly those related to reliability, density and performance are now being achieved at an accelerating rate. The tape industry has delivered numerous architectural enhancements in the past 10 years with major improvements in drive reliability, media life, and data rate and cartridge capacity. Cartridges were ruggedized for improved portability and tape drive Mean Time Between Failure (MTBF) soared from 80,000 hours to over 400,000 hours. The expected media life range for any new tape now ranges up to 30 years (up from 8 years). Security features were added to tape offerings including Write-Once-Read-Many (WORM), data encryption, and various write-protect capabilities to address a growing number of legal and long-term archival requirements. Tape cartridge capacities now range to 3 terabytes or more when compressed while the largest disk drive has a 3 terabyte capacity.

Tape Drive Reliability – Numerous Improvements Arrive

MTBF has been traditionally used to measure storage device reliability. Other measurements are also used to gauge reliability such as the bit error rate (BER) and the "number of nines 99.xxx - availability index" and these are also used for servers and operating system measurements. The MTBF for tape drives is calculated for a specific duty cycle based on the percentage of time the drive is actually reading, writing or verifying data. The duty cycle is important because if the actual duty cycle (drive activity level) is significantly different from the manufacturer's rated duty cycle the MTBF will vary.

For example, if the duty cycle is lower than rated, the MTBF rating will be higher. Actual duty cycles vary widely between data centers based on application activity. Duty cycles provided by manufacturers for their drive ratings can vary from 10 percent to 100 percent; however for enterprise-class tape environments a duty cycle range of 70% to 100% is commonly used. Using Fibre Channel (FC), FICON, Ultra-SCSI (Small Computer System Interface), or Serial Attached SCSI (SAS) tape drive interfaces, a highly reliable tape solution with an MTBF of 250,000 hours at a 100% duty cycle and over 400,000 hours at a 70% duty

cycle is a reality. The chart below categorizes the drive MTBF and media shelf life ratings from the first cartridge drives to the latest enterprise products.

Tape Drive and Media Reliability Improvements Summary

Drive type	Era	MTBF hours 70% duty cycle*	MTBF hours 100% duty cycle	Shelf Life Archival
3480/4480 (1st cartridge drive)	1984	35,000	24,500	<10 years
DLT 2000	1993	80,000	56,000	~10 years
SDLT 160/320/600	2002	250,000	175,000	Up to 30 years
LTO family	2000 →	357,000	250,000	Up to 30 years
T9840B-D	2000 →	414,000	290,000	Up to 30 years
T10000, TS11x0	2006 →	414,000	290,000	Up to 30 years

* MTBF ratings are provided by tape drive manufacturers at a specified duty cycle meeting environmental specifications.

Bottom line: By 2002, tape drive reliability had dramatically increased with MTBF ratings improving over 5 times for drives and 3.75 times for media shelf life. The result is that the useful life of tape storage is now considerably longer than a typical 3-5 year life for disk drives reducing the frequency of costly technology conversions.

Tape Media Improvements Push Reliability and Media Life Higher

Customers have indicated for years that their most frequent perceived cause of tape failure was due to media and handling errors and this perception has persisted even as new tape media has made significant strides. Special prewritten data tracks on the tape called servo tracks keep the tape heads on the correct track while reading and writing. With the older linear tape products, the edges of the tape media served as servo tracks (a track that allows the tape drive head to stay aligned with the tape.) Since 2000 enterprise and LTO drives have basically eliminated this issue by combining the pre-recorded servo tracks on the media (away from the edge) along with ruggedized cartridge shells that are relatively impervious to handling damage.

Tape media advances are closely linked with the ongoing progress of tape drive development. The most popular enterprise class tape cartridge formats use a half-inch wide media and use high performance advanced metal particle (MP), metal evaporated (ME), or Barium Ferrite tape materials. Along with magnetic material advances, tape media have increased substrate dimensional stability with reduced thickness, much smoother surfaces, lower defect densities, and increased edge slitting precision. With these advancements, shelf life for all new enterprise media and LTO media is rated up to 30 years. Many new enterprise class media enhancements have appeared since 2000 and are highlighted in the following chart.

Tape Media Reliability Improvements

Cartridge design	Significantly more rugged cartridge design protects data during physical transportation and handling
Tape path reliability	Fully enclosed tape path provides for higher reliability
Contamination protection	Spring-loaded doors protect the cartridge leader from damage and contamination
Media tension control	Hub-lock technology implemented to maintain the correct tension on the media inside the cartridge preventing media rotation, reducing read errors and preventing the hub from hitting the inside of the cartridge during handling
Smart cartridges	Use of a radio frequency identification (RFID) non-volatile memory chip mounted inside the tape cartridge shell that can be accessed via an RFID interface providing a direct connection to the tape drive's on-board processors. These can speed access to tape files, hold the cartridge's log, and store manufacturer identification and date, cartridge type, and tape reliability statistics for media health monitoring

Bottom line: Tape media management has historically been viewed as one of the biggest operational challenges for tape administrators. Since 2000, tape media has steadily improved in reliability, ruggedness, and media life compared to its predecessors, making many commonly held perceptions of tape media reliability outdated. Tape's much longer useful life enables customers with long-term retention requirements to have less frequent labor-intensive migrations to the next technology.

Tape Library Architecture Improvements

The introduction of Nearline® automated tape libraries by StorageTek in 1987 led a tape revival as robotics effectively eliminated many of the historical labor intensive tape handling activities and associated problems. Over twenty years later, tape automation has become a de-facto standard for enterprise class tiered storage implementations and represents the most cost effective architectural solution for many mass storage applications of the future. Tape libraries have proven to be the ultimate long-life storage repository as the useful life of a robotic library outlasts that of the attached tape drives and media. Reliability measurements for tape libraries have always been relatively high. Automated tape library reliability has benefited from several other architectural enhancements and serviceability features that have been introduced since 2000.

Tape Library Reliability Improvements

Hot-swap components	Control-path and data-path automatic fail-over, hot-swappable and fully redundant components including multiple robots which are designed to provide higher availability levels for the library system
Non-disruptive micro-code loads	Microcode, robotics and library electronics can be replaced on the fly while the library is operating for non-disruptive serviceability for higher uptime
Non-disruptive capacity upgrades	Capability to add additional slots and tape drives easily without scheduling downtime
Virtual library partitioning	Software controls that can configure a physical library into multiple virtual libraries (partitions)
Power protection	Redundant power supplies and AC power feeds

Note: Not all features are offered by all vendors.

Bottom line: Tape libraries have been steadily re-architected delivering higher performance, non-disruptive upgrades, and higher availability through redundancy and fault-tolerance designs minimizing scheduled maintenance activity.

Comparing Tape Drive to Disk Drive Reliability

Disks store the vast majority of the world's mission critical and high performance data. Disks are typically more costly to acquire and operate than tape. One way to improve disk reliability is to reduce the drive spin rates as data becomes less active. This concept, sometimes called green mode, makes sense in theory, however it is difficult to achieve with RAID array disks using striping that evenly spreads and balances I/O activity across multiple drives. Disk drive rebuild times are becoming increasingly elongated as drive capacities steadily increase. In the early 1990's it took about one minute to rebuild a disk drive. Today a 2TB drive can take nearly 8 hours or more to rebuild. Within the next several years expect to see 30TB disk drives which, if nothing changes, will take nearly a month or more to rebuild. The disk industry will have to address this mounting problem in the near future.

Bit Error Rate Favors Tape Reliability over Disk

For storage devices, Bit Error Rate (BER) is quickly becoming a more popular means of measuring reliability. For data, network, and telecommunication transmission, the BER is the percentage of bits that have errors relative to the total number of bits received in a data transfer, usually expressed as 10 to a negative power. For example a data transmission might have a BER of $10E^{-8}$ to, meaning that, out of 100,000,000 bits transmitted, one bit was in error. The BER is also an indication of how often a data or other packet has to be retransmitted because of an error. Several retries are typically performed by the drive read/write logic until a soft error threshold is exceeded; then it is logged as a permanent I/O error. BER is becoming critical when using data reduction features as the loss of a single bit for any data that is encrypted, compressed, or has been de-duplicated will make reconstruction of the data virtually impossible yielding unusable data.

Published values for BER:

- Disk (FC, SAS, SATA)
  - Enterprise FC/SAS Hard Read Errors per Bits Read 1 sector per 1 x $10E^{16}$ bits
  - Enterprise SATA Hard Read Errors per Bits Read 1 sector per 1 x $10E^{15}$ bits
  - Desktop SATA Hard Read Errors per Bits Read 1 sector per 1 x $10E^{14}$ bits

- Tape (Mainframe and midrange)
  - LTO-5 Hard Error Rate 1 x $10E^{17}$ bits
  - T10000B Hard Error Rate 1 x $10E^{19}$ bits
  - TS1120/1130 Hard Error Rate 1 x $10E^{19}$ bits

Comparisons between disk and tape reliability are often debated and much of the debate is the result of past experiences with aging tape technologies, however things have changed. New tape technology has a higher (better) BER than disk and thus can transfer more data than disk before encountering a permanent error. In addition, today's tape drives have a useful life at least twice as long as disk drives, with the help of backward read-compatibility, while tape media can last 4-5 times or longer compared to disk drives. Current tape drives typically read data from a cartridge in its own generation and at least the two prior generations. When a tape library is combined with disk buffers to provide tape caching in an Integrated VTL, typically 70% or more of the I/O operations that would normally go to tape are satisfied by the disk buffer lowering the duty cycle and extending tape drive and media life. Of increasing importance, tape's better BER also makes it safer to encrypt and compress data on tape than disk as loss of a single bit renders data unrecoverable. Also, if de-duplicated disk data has a bit in error, the reconstruction process will likely fail.

Bottom line: Tape drives and tape media now have a higher BER and longer useful life than disk products making them better suited for the long-term data retention requirements demanded by fixed content, compliance and archive applications. For a specific amount of data transmitted, tape now has a marked reliability advantage over disk – a surprise for many.

Data Security Solutions Expand Tape's Role for Regulatory and Compliance Requirements

The enterprise class tape solution providers are positioning tape for its emerging role as the long-term archive and compliance solution of choice by providing encryption and Write-Once-Read-Many (WORM) capabilities. Designed to further enhance the integrity of tape data, WORM provides a non-erasable, non-rewritable, tape-based storage solution. After information is written to tape, information can be read or added as often as needed, but never changed, moved, or deleted.

Accessing encrypted data is meaningless unless it can be successfully decrypted. Decryption requires access to unique keys and key management is the key to a successful encryption strategy. Expect encryption for digital data to become a standard feature for nearly all tape drives and eventually for selected disk drives and mobile personal appliances.

Bottom line: Today's tape products offer encryption and WORM to ensure that compliance data, e-mails, health care records, sensitive data and financial transactions cannot be tampered with or read by unauthorized sources for the duration of their life-cycle. Tape's higher tape BER favors it over disk for applications requiring data encryption.

Capacity and Performance Increases for Tape

By 2000, magnetic tape technology began experiencing the most significant technological improvement curve in its history. Tape data transfer rates have increased 7 times since 2002, markedly improving performance for many throughput intensive and data streaming applications. Non volatile caching at the tape drive level was developed to reduce the performance impact of back-hitching caused by checkpoint and small block transfers. When the capacity of magnetic tape cartridge surpassed the capacity of the largest disk drive for the first time ever in 2002, the rules of the game for magnetic tape had changed regarding acquisition cost, operating cost, and volumetric storage density.

The LTO-5 drive specification was announced on April 12, 2010 and raised the bar for tape as a viable backup solution and archival solution by offering native data rates of 140MB/sec. and a native capacity of 1.5 TB or 3 TB compressed capacity. LTO-5 tape has taken significant new steps toward addressing the archive, disaster recovery and business continuity markets with the announcement of LTFS (Linear Tape File System). LTFS is a true file system for tape allowing tape to be used in a fashion more like disk by including directory tree structures.

With LTFS, LTO-5 media can be partitioned into two segments. LTFS uses the first partition to store a self-contained hierarchical file system index (metadata) for the contents of the tape on the second partition. LTFS becomes valuable in environments requiring faster search times for retrieving large amounts of unstructured data and tier 3 applications. The potential for LTFS in a wide variety of archival applications awaits those companies that have the vision to exploit it. Finally LTFS makes the sequential nature of tape access more random-like.

Disk and Tape Capacity Comparison

Year	Disk Actuator Capacity	Tape Cartridge Capacity and Data Rate
1980	630 MB	180 MB " "
1985	1.26 GB	200 MB (cartridge) 3.0 MB/sec
1990	1.89 GB	800 MB native to 1.6 GB 6.0 MB/sec (now with 2x compression*)
1998	47 GB	20-40 GB 10-30 MB/sec
2001-2002	72 GB	100-200 GB (LTO) 20-40 MB/sec
2003	300 GB	200-400 GB (LTO) 40-80 MB/sec
2004	500 GB	400-800 GB 80-160 MB/sec
2007	1.0 TB	750 GB-1.5 TB 120-240 MB/sec
2008	1.5 TB	1-2 TB 120-240 MB/sec
2009	2.0 TB	1-2 TB 120-240 MB/sec
2010	3.0 TB	1.5 – 3.0 TB 140-280 MB/sec
2015 (est.)	20 TB	10 – 20 TB 300-500 MB/sec
2019 (est.)	50 TB	64 - 128 TB 800-1,600 MB/sec

* Tape data compression first arrived on the IBM 3490 drive in 1986. Note: a 2x compression factor is the norm for open environments. IBM uses 3x for their mainframe data and Oracle/STK uses 4x for its mainframe data. A conservative 2x compression factor is used for tape cartridge capacity calculations in this report. Capacity estimates from a variety of sources.

Bottom line: By 2002, and for the first time ever, the native capacity of a tape cartridge surpassed the capacity of the biggest disk drive signaling a fundamental change in the $/GB pricing model of tape libraries compared to disk subsystems. Native capacities are predicted to exceed 60 terabytes (compared to 50 terabytes for magnetic disk) over the next ten years yielding over a 120 TB compressed capacity per cartridge and serves as a strong indicator that the continued price per gigabyte/petabyte advantage of automated tape over disk will continue. LTFS adds a new and important dimension to improving access times for tape retrieval in the future.

Tape Pricing and Average Selling Prices (ASP) for the Storage Hierarchy

Since its inception, the storage industry has used the price per megabyte and today the price per gigabyte as the primary measure of capital expense (Capex) for disk and tape storage. The Capex figures shown below are raw hardware ASPs (Average Selling Prices). List prices are higher than ASPs and $/GB/month rates are lower than ASPs. The $/GB prices would need to be divided by the number of months (12, 24, 36...) to determine a monthly $/GB rate.

The ASPs below are for working subsystems only and do not include storage management software, personnel, facility costs, energy or maintenance costs as these items are typically used in TCO comparisons and vary widely. Working disk subsystems ASPs include cache, controller and drives. For tape ASPs, a disk buffer (if an integrated VTL), robotic libraries, drives and media with a 2-to-1 compression ratio are used to determine total price and capacity for tape libraries. Deals and discounting levels vary by size of the deal, vendor, customer account level, preferential status, and potential future sales opportunity. Automated tape remains the lowest-price storage for midrange and enterprise systems based on Capex, and technology roadmaps indicate that this is expected to remain so for the foreseeable future.

Average Storage Selling Prices

Subsystem Category	ASP Range ($/GB)	Notes
Solid State Disk (DRAM) FC, SCSI	$300-500 (avg. $400/GB)	ASP range based on capacity and high-availability features.
(Flash) SSD/HDD	$50-100 (avg. $75/GB)	ASP based on single Flash SSD.
Enterprise disk SCSI, FC	$7-20 (avg. $13.50/GB)	Includes controller, cache & drives. Add-on storage modules with no controller and cache are lower.
Midrange disk SCSI, FC, SAS	$1-8 (avg. $4.50/GB)	Includes controller, cache & drives. Add-on storage modules are lower.
Optical disc library (Blu-laser) SCSI/WORM	$5-20	Includes drives, media and library (No longer a data center technology).
Economy disk SATA, JBOD	<$1-5	Price range varies widely based on capacity and array configuration.

Tape library (mainframe) Integrated Virtual Tape Library with disk cache buffer	<$.25 (varies by disk buffer size and number of tape drives)	Includes disk buffer, tape drives, media and library and uses 2:1 compression to determine library capacity.
Tape library (non mainframe)	<$ .15	Includes tape drives, media and library and uses 2:1 compression to determine library capacity.

Source: Horison Information Strategies (Sept. 2010) Average Selling Prices are used; prices vary by configuration and vendor. These are not list prices or $/GB/month figures.

Bottom line: The price per gigabyte for all types of storage continues to fall annually, helping businesses reduce storage acquisition expenses while keeping pressure on storage suppliers to continually improve their technologies at lower costs. In all cases the acquisition costs for tape subsystems is lower than for disk subsystems.

Emerging Applications are Driving Future Tape Growth

While some backup applications are moving to disk in non-mainframe systems, long-term storage applications like digital archives, fixed content, multi-media and compliance are economically better suited for tape storage. A growing list of government and legal regulations worldwide now describe the way data must be managed and stored throughout its lifetime. For many applications and data files, the duration of storage preservation requirements has become infinite as they will never be deleted. Much of the fixed content, compliance and archive data that makes up tier 3 is unstructured data in the form of file storage and industry estimates indicate that over 60% of all digital data is unstructured. The social networking wave has quickly become a major generator of low-activity unstructured digital data that is kept (archived) indefinitely and these applications are most cost-effective on tape. Primary drivers of tier 3 storage requirements are listed in the chart below.

Data Rich, High Capacity Applications Accelerate Tier 3 Storage Demand

Digital Assets
E-mail archives, ~80% of total e-mail capacity is stored in attachments
Archival Data - Compliance & Litigation with long-term storage requirements
Medical Patient Data, Files/Fixed Images
Insurance Claims, Stock Market Transactions, Banking Records
Web Content, Static Images, Digital Photos
Social Networking Explosion, Wikis
Documents Printed Materials, Books, Contracts

Rich Media (3D, Multi-dimensional)
Digital Audio & Video (iPods, MP3, Digital Surveillance/Security, YouTube)
Games, Music, Movies, Shopping, Super- imposed Motion Imaging
Medical Images (3D MRIs, CAT Scans, Facial Recognition, Forensics)
Geophysical, Geospatial, GIS, Seismic, Google Earth etc.
Fixed Content and Archival Futures…
XAM, a New Fixed Content Data Management Interface Standard Using Metadata
Automated Tiered Storage for Tape and Disk (HSM-like policy-based software)
Linear Tape File System (LTFS) for enhanced and faster tape archive access
Cloud archiving services using tape for lower cost, highly secure archiving solutions

Source: Horison Information Strategies

Digital entertainment content, which is one component of tier 3 storage, is rapidly becoming a major driver for new tape technology. Highlights from The sixth annual report from Coughlin Associates on digital storage in media and entertainment, titled 2010 Digital Storage for Media and Entertainment, reports the growth for select tier 3 applications as follows:

• About 93% of the total storage capacity will be used for archiving and data preservation in 2009

• In 2009 about 86% of the total storage media shipped for all the digital entertainment content segments was tape with about 10% HDD, 4% optical and 0.3% flash memory (mostly in digital cameras and some media distribution servers)

• By 2015 tape units will decline slightly to 83%, HDDs increase to about 14%, optical declines to 2% and flash doubling in percentage to 0.6%

• Digital storage requirements are exploding due to use of higher resolution and stereoscopic content in the media and entertainment industry

Tape Means Dark Green Storage

As the cost of power continues to increase, the favorable impact of optimally using tape storage on the IT budget will only grow. Average data-center energy costs are growing at 10-20% per year or more. Unlike storage providers, energy providers have shown little interest in lowering their rates! Compounding this dynamic is the fact that power density is going up for most IT equipment at a rate of 20% to 30% per year. This has the following domino effects; 1) more power needs to be supplied to each square foot of a data center 2) more power is required to cool hotter equipment and 3) more heat extraction equipment is needed to support each square foot of a data center.

The maximum heat density that can be air-cooled in a data center is approximately 10,000 watts/sq ft, yet most data centers have been designed for power densities of less than 1,000W/sq ft. The limits of power distribution in many data centers is being approached, which is forcing organizations to begin exploring new cooling techniques such as water-cooled racks, outdoor cooling or in some cases, building another data center. Building another data center is normally a last resort and is extremely expensive mandating that energy consumption be properly managed. Average IT electrical consumption rates are summarized in the chart below.

Average Electrical Power Usage for Data Centers

Chillers, cooling, pumps, air-conditioning	24%
Uninterruptible power supply	8%
Air movement, circulation, fans etc.	10%
Misc. lighting, security, perimeter surveillance	3%
Total support infrastructure – external consumption	**45%**
Servers	30%
Disk drives, control units	12%
Tape drives, robotic libraries	3%
Network gear, SAN switches and other devices…	10%
Total IT gear – internal consumption	**55%**

Source: Horison, Inc. and estimates/averages from various industry sources.

Average electrical consumption within a data center (not including external HVAC) indicates that tape is the greenest storage technology and tape typically uses about one-fourth of the electricity that disk does. In addition, heat is the enemy of all IT technology regarding reliability and maintaining recommended environmental requirements is a critical factor. Utility companies in certain areas are restricting the amount of power some businesses can use. Focusing on disk storage can decrease its average 12% electrical consumption figure considerably by shifting less-active and archival data to tape storage supporting green initiatives in the data center.

Perceptions and Reality for Tape and Disk

Perceptions	**Reality**
Tape is slower than disk for backup and recovery.	True in some cases except for an Integrated VTL which uses a disk front-end to cache data for several days. For large sequential data streaming applications like video and large unstructured files, effective data rates are also faster for tape.
Tape can only perform sequential access.	True – however this is now changing as faster access to specified tape regions becomes reality with the new LTFS tape partitioning capability for LTO-5 drives.
Green initiatives and energy consumption favor tape. ***CIO Imperative**: Ultimately, data that isn't being accessed shouldn't consume energy*.	True - tape storage is the greenest of storage solutions; tape vendors will more aggressively market these advantages and facilitate customers to easily move inactive data to-and-from disk to more eco-friendly tape.

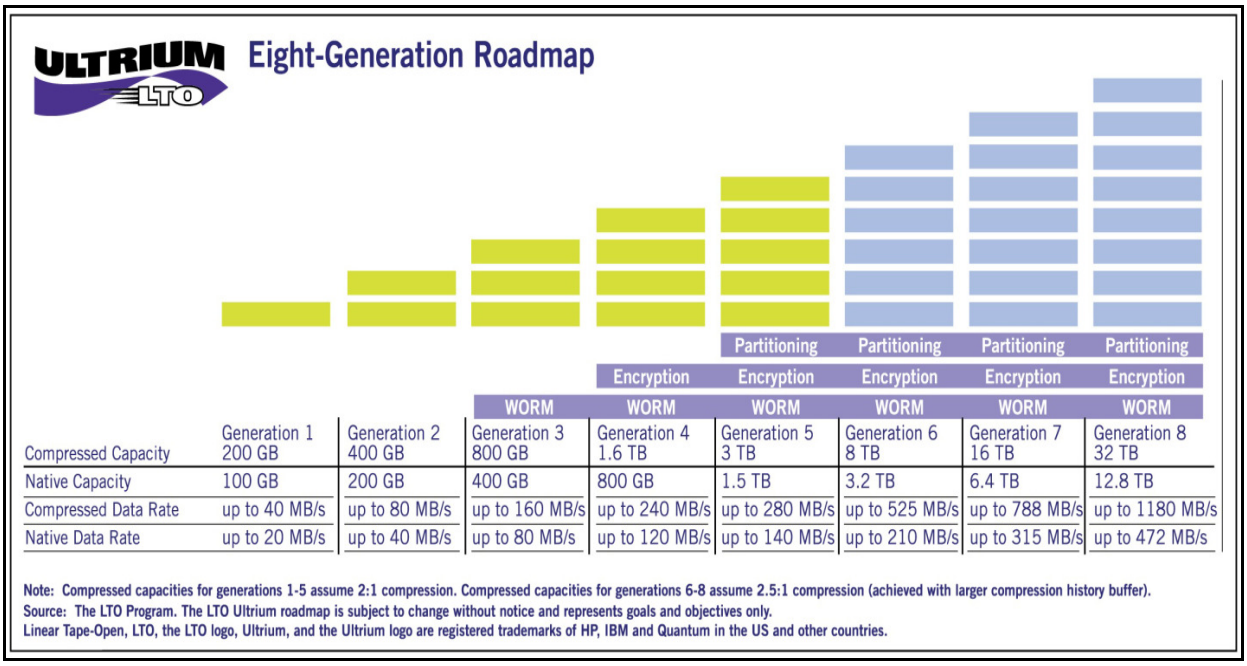
Tape has media life and drive reliability problems.	Those are outdated customer perceptions of tape and left over from the 1990s. New tape products have 8-10x improved MTBF, duty cycle and media life capability compared to tape 15 years ago. The bit error rates for today's tape are markedly better than disk. Disk drives fail too and the impact is usually much greater.
Old tape media won't work on new tape drives.	Not exactly true – enterprise and LTO drives to can **read** data from a cartridge in its own generation and at least the two prior generations and can **write** data to a cartridge in its own generation and to a cartridge from the immediate prior generation and in the prior generation format.
Removable media has disadvantages and isn't needed anymore.	Not true - removable media has advantages. The amount of data that needs to be backed up continues to exceed the growth rate of affordable bandwidth – and is expected to for the foreseeable future. In some cases it is less expensive to move large amounts of data physically than electronically.
Electrical outages and natural disasters often favor tape for portability.	True - tapes can be moved during electrical outages while disk drives almost always require electricity to move data. Fires, floods, hurricanes other and natural disasters increase likelihood of unscheduled electrical outage.
Heat causes tape media to degrade.	True – but heat causes reliability problems for all technologies – tape, disk, servers, and switches when environmental specifications are not adhered to. Tape media life is now up to 30 years for current products and 3-5 years for disk drives when environmental specifications are met.
Tape Requires More Frequent Device and Media Conversions Than Disk.	Not true - tape drives have a longer useful life than disk drives as current tape media is rated up to 30 years, reducing the need to move data to new media as frequently.
Disk Has a higher CAPEX and OPEX than Tape.	True - the CAPEX ($/GB) is lower for automated tape than disk, the ongoing costs are lower as ultra-high capacity cartridges, simpler backup processes, and lower energy costs keep down operating expenses.

Tape Roadmaps Show Continued Progress

The tape industry has delivered numerous enhancements in the past 15 years with significant improvements in drive reliability, media life, and data rate and cartridge capacity. You can expect more breakthroughs to follow. In Jan. 2010, IBM Zurich recorded data onto an advanced prototype tape developed by Fujifilm Corp. The prototype recorded data at 29.5

billion bits per square inch potentially producing a tape cartridge up to 35 terabytes native capacity, 23.3 times larger than an LTO-5 cartridge.

Fujifilm has advanced the development of BaFe particles. This advanced development aims to provide higher coercivity (using micro fine particles), lower noise, higher frequency characteristics and superior storage performance in comparison to other metal particles. In parallel, Fujifilm also announced it was able to demonstrate the long term archive capability of Barium-Ferrite (BaFe) magnetic tape particles proving its reliability can exceed a 30 year time period.



Compressed Capacity	Generation 1 200 GB	Generation 2 400 GB	Generation 3 800 GB	Generation 4 1.6 TB	Generation 5 3 TB	Generation 6 8 TB	Generation 7 16 TB	Generation 8 32 TB
Native Capacity	100 GB	200 GB	400 GB	800 GB	1.5 TB	3.2 TB	6.4 TB	12.8 TB
Compressed Data Rate	up to 40 MB/s	up to 80 MB/s	up to 160 MB/s	up to 240 MB/s	up to 280 MB/s	up to 525 MB/s	up to 788 MB/s	up to 1180 MB/s
Native Data Rate	up to 20 MB/s	up to 40 MB/s	up to 80 MB/s	up to 120 MB/s	up to 140 MB/s	up to 210 MB/s	up to 315 MB/s	up to 472 MB/s

Note: Compressed capacities for generations 1-5 assume 2:1 compression. Compressed capacities for generations 6-8 assume 2.5:1 compression (achieved with larger compression history buffer).
Source: The LTO Program. The LTO Ultrium roadmap is subject to change without notice and represents goals and objectives only.
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The LTO Consortium publishes a well defined roadmap with each successive LTO generation arriving in approximately two year intervals. The LTO roadmap identifies that future LTO tape drive models will improve the acquisition price, capacity and performance, and will reduce cost of ownership over previous models. LTO's stated direction is that "an LTO Ultrium drive is expected to **read** data from a cartridge in its own generation and at least the two prior generations. An Ultrium drive is expected to **write** data to a cartridge in its own generation and to a cartridge from the immediate prior generation in the prior generation format." This eases customer conversion efforts by extending the life of the older media while newer LTO tape drives replace prior versions.

Bottom line: Future tape development roadmaps will describe more than just capacity and data rate increases signaling that smarter tape systems will be developed to meet a broader set of requirements. The much longer tape lifecycles of the past have provided a solid evolutionary technology base on which to build future products. Major breakthroughs with media development will continue to address the tier 3 data explosion.

Tape in the Cloud

Cloud Computing dominated IT headlines in 2010 and is expected to do the same in 2011 as it is evolving from early adopter deployments into more of a mainstream initiative. To be sure, the cloud is not a viable destination for mission critical, database, or OLTP (Online Transaction Processing) applications at the present time. View the cloud - for now - as outsourcing certain IT storage and compute services. The cloud business model presents the illusion of having lower cost infinite computing resources available on demand with the ability to pay for the use of those resources on a short-term basis and release them as needed.

The most common applications for the cloud so far have been backup and some archiving - all done with disk as tape storage has yet to appear in the cloud. Few existing cloud vendors have considered tape for cloud archival storage and they frequently use getting rid of tape as part of their marketing message. This unfortunately highlights their out of date perception of the current world of tape. Expect this to change as savvy cloud providers open the cloud to significantly less costly archiving services using enterprise class and LTO-5 tape solutions with intelligent front-end disk buffering capabilities to address the growing tier 3 storage and archive requirements.

Key Customer and Cloud Provider Benefits of Using Tape in the Cloud Include:

- Significantly lower $/GB/month rates than disk-only cloud alternatives
- The most cost-effective solution for long-term archival storage
- Provide secure and reliable file storage capability with 256-bit AES encryption and WORM capability as selectable options for compliance, fixed content and archive data
- Easily supplement or upgrade existing tape environment by storing off-site data copies in the cloud
- Rapid scaling and improved access times for fast growing tier 3 applications with LTO-5 technology
- Less frequent drive and media conversions for tape than for disk with longer-life technology
- Implement an affordable disaster recovery plan as data copies stored in the cloud are, by definition, off-site and protected in the event of a local disaster
- Shift storage costs from a capital expenditure to an operational expenditure, freeing capital to support other parts of the business

Bottom line: Expect the cloud model to expand its market and include significantly less costly archiving services with secure storage with acceptable access times using LTO-5 tape solutions coupled with intelligent front-end disk buffering capabilities.

Conclusion – Tape Redefines Its Role for the 21st Century

Despite the prevailing market perception, tape has improved its position as a viable complement to disk for the foreseeable future due to its lower price per gigabyte, improved reliability, lower operating expenses and/ lower energy costs. The growth opportunity that lies ahead for tape storage solutions is increasing and is being fueled by the following advancements in tape technology:

- Cartridge tape capacities will continue on an unprecedented growth pace and are expected to approach or exceed 60 terabytes by 2019.
- The average price per gigabyte for automated tape library storage is expected to remain below that of magnetic disk storage for at least the foreseeable future.
- The operating expense (opex) for automated tape systems should remain significantly below that of online disk storage as people, facilities and energy costs rise. The average tape library administrator manages from 40TB to more than 1PB (varies based on capacity of a single library) of data. Today's storage administrator currently manages an average nearly 30 TB for non-mainframe disk and over 100 TB for mainframe disk.
- Bit error rates are considerably better for tape than disk favoring tape for applications requiring encryption and compression as the loss of a single bit renders data unrecoverable.
- Tape media has a much longer storage life than disk, eliminating the need to migrate data to new media as frequently and reducing labor intensive conversion costs.
- Archiving data in the cloud using the latest tape technology represents a new, untapped, and lower cost storage opportunity than todays "only use disk in the cloud" approaches.

The general perception of tape is often quite different than today's reality as the magnetic tape industry has progressed significantly in the past 10 years. The latest technology developments in the tape industry indicate that while disk may address a growing portion of the backup and recovery market, tape will be more cost-effectively suited for the tier 3 archival opportunities, whether on-site or in the cloud. An updated understanding of today's tape solutions can yield significant operational efficiencies. Tape is not going away, and we can now see its role is expanding from primarily a backup solution to that of a premier long-term archival storage technology. For tape it's now "a new game with new rules".