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2024 Technology Update Series

TAPE.
NEW GAME. NEW RULES.

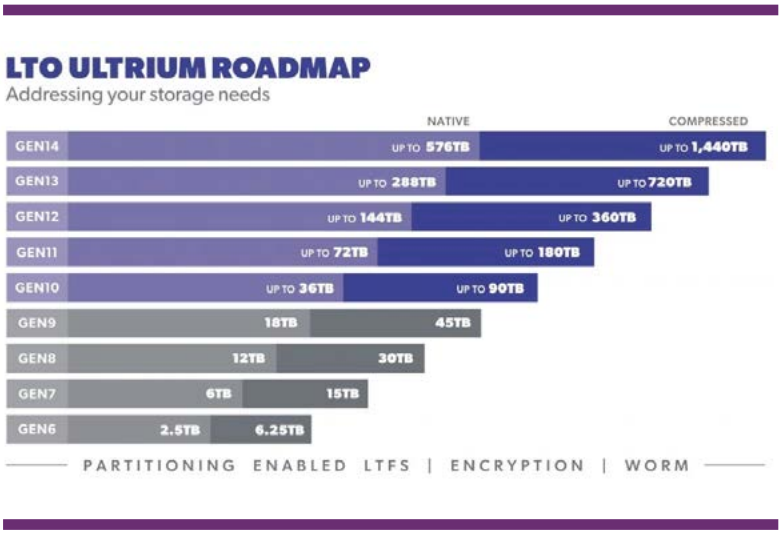
Economics, Sustainability, Cyber Security and Reliability Propelling Demand

The most recent surge of digital data growth is being driven by new compute and data intensive applications like AI/ML, surveillance, IoT, gaming, virtual reality, everything at the edge, and social media. Data retention timeframes have increased significantly over the past few years as the potential value of untapped data is highly sought after. Users want ready online-like access to that data increasing deployment of active archive solutions which can deliver near HDD-like access times to large, more active archival data reserves.

Modern tape storage has firmly established itself as *the* leading environmentally friendly and lowest-cost storage solution to manage most of this data deluge for the foreseeable future. The magnetic tape industry has continued to re-architect itself delivering compelling new technologies and functionality including increased cartridge capacity, the highest reliability of any storage device, new Barium Ferrite media now projecting a useful life of up to 50 years, and faster data transfer rates than any previous tape or HDD (Hard Disk Drive). Many of these innovations have resulted from technologies leveraged from the HDD industry and have been used in the development of both LTO (Linear Tape Open) and enterprise tape products which released an *unprecedented* 50 TB native cartridge capacity! Modern tape technology has experienced an exciting renaissance in preparation for the zettabyte era, but this is just the beginning for tape going forward. It's time to bring your understanding of modern tape up to date and take advantage of the many benefits that tape has to offer.

LTO ECOSYSTEM EXTENDS ROADMAP TO GEN 14 TO ADDRESS SECONDARY STORAGE EXPLOSION

Tape has clearly established itself as the most cost-effective secondary storage solution. In 2022, the LTO Program Technology Provider Companies (TPCs), Hewlett Packard Enterprise Company, International Business Machines Corporation, and Quantum Corporation, announced an updated LTO technology roadmap that extends the LTO Ultrium standard through 14 generations. The roadmap calls for tape capacities to double with each new generation, with LTO-14 delivering up to 1,440 TB* (1.44 PB compressed) per tape. The new LTO roadmap extension is more relevant than ever and at this point no other storage technologies have revealed a comparable multi-generational roadmap.



LTO-9 LEADS IN CAPACITY, THROUGHPUT, AND IMPROVED ACCESS TIMES

LTO-9 is the latest LTO generation bringing new functionality to tape including higher capacity, data rate, access time and reliability improvements. Containing 3,396' of BaFe magnetic media, LTO-9 increased the native cartridge capacity of LTO-8 by 50% to 18 TB (45 TB compressed) and increased drive throughput (11%) up to 400 MB/sec enabling a single LTO-9 drive to write up to 1.44 TB/hour. A new feature for the LTO family with LTO-9, oRAO (Open Recommended Access Order) reduces initial file access times to first byte of data by as much as 73%. New R/W head and servo technologies that record even narrower data tracks and further increase cartridge capacity have also been developed. A native 18 TB LTO- 9 cartridge can hold about 4,500 movies, 5,580,000 digital photos, 720 Blu-ray discs, about one day of data from an Autonomous Vehicle, 9,000 hours of movies and approximately 6,480,000 songs. Cartridge capacity increases are especially welcome for large enterprise data centers, hyperscalers, cloud service providers, and HPCs who have massive secondary storage requirements.

FUJIFILM AND IBM ANNOUNCE RECORD CAPACITY TS1170 50 TB HIGH-DENSITY TAPE STORAGE SYSTEM

In 2023, Fujifilm and IBM announced a new ultra-high-density tape drive with a native storage capacity of 50 TB in a single cartridge and capacities up to 150 TB per cartridge with 3:1 compression. The IBM TS1170 storage system represents the *world's highest cartridge capacity* ever announced and enables data intensive secondary storage applications including AI, big data, archiving, cloud computing, and analytics to significantly reduce their total cost of ownership. The improved areal recording density (the amount of data that can be recorded per square inch) and the overall recording area using a 15% longer tape media enable the higher cartridge capacity. Fine hybrid magnetic nanoparticles have been developed by combining the technologies used in the next-generation Strontium Ferrite (SrFe) magnetic particles and the Barium Ferrite (BaFe) particles that are currently used in high-capacity data storage tapes.

With a 250% increase in capacity as compared to the previous IBM TS1160 tape drive, the IBM TS1170 tape drives consist of two new models: the TS1170 Model 70F with a dual-port 16 Gb Fibre Channel interface, and the TS1170 Model 70S with a dual-port 12 Gb SAS interface. Other features include RAO (Recommended Access Order) which improves recall time and time to first byte and the IBM Storage Archive (LTFS format) for direct, intuitive, and graphical access to data. Investments in tape library automation are protected by offering compatibility with existing tape library solutions.

FURTHER IMPROVEMENT — TAPE LONGEVITY (MEDIA LIFE) REACHES 50 YEARS

In 2019, Fujifilm and JEITA (Japan Electronics and Information Technology Industries Association) officially confirmed the longevity of Barium Ferrite magnetic signal strength to be stable for at least 50 years based on studies of LTO-7 tapes. Prior to this confirmation, the number of years for LTO tape longevity had been rated up to 30 years. HDDs typically offer a five-year warranty and, in many environments, will be replaced at that time. While modern tape media can last 50 years or more, tape drives are typically replaced approximately every eight to ten years driven by the technological, economic, and operational benefits of newer drives and media. Knowing the data stored on tape can be relied upon for several decades gives confidence in the integrity of the archives. Extended media life effectively reduces the frequency of media remastering and conversions to new tape generations.

The LTO-9 18 TB tape has an areal density of 12 Gb/in^2. A 20 TB HAMR disk drive has an areal density of 1,300 Gb/in^2. LTO-9 achieves the same 18 TB capacity with 1/85th of the areal density of an 18 TB HDD. This provides significant development head room for tremendous growth in tape capacity. A 580 TB tape cartridge could store data equivalent to 120,000 DVDs which would stack .53 miles into the air. Imagine just two 580 TB tape cartridges or 1.45 PB of data easily held in the palm of your hand!

The table below provides key tape drive and media specifications for both the LTO and IBM TS11XX Enterprise tape systems.

TAPE DRIVE AND MEDIA SPECIFICATIONS (LTO AND IBM ENTERPRISE)

TAPE DRIVE MODEL	YEAR INTRODUCED	CAPACITY (NATIVE) COMPRESSION (X:Y)	DATA TRANSFER RATE (NATIVE)	CHANNELS PER HEAD	TRACKS	AREAL DENSITY
LTO-6 MP & BaFe	2012	2.5 TB (2:1)	160 MB/sec	16	2,176	2.2 Gb/in^2
LTO-7 BaFe	2015	6.0 TB (2.5:1)	300 MB/sec	32	3,584	4.3 Gb/in^2
LTO-8 BaFe	2019	12.0 TB (2.5:1)	360 MB/sec	32	6,656	8.6 Gb/in^2
LTO-9 BaFe	2020	18.0 TB (2.5:1)	400 MB/sec	32	9,288	12.0 Gb/in^2
TS1140 BaFe	2011	4.0 TB (2.5:1)	250 MB/sec	32	2,560	3.2 Gb/in^2
TS1150 BaFe	2014	10.0 TB (2.5:1)	360 MB/sec	32	5,120	6.52 Gb/in^2
TS1155 BaFe (TMR)	2017	15.0 TB (2.5:1)	360 MB/sec	32	7,680	9.78 Gb/in^2
TS1160 BaFe (TMR)	2018	20.0 TB (3:1)	400 MB/sec	32	8,704	11.7 Gb/in^2
TS1170 BaFe (TMR)	2023	50 TB (3:1)	400 MB/sec	32	18,944	15.7 Gb/in^2

TMR: Tunnel Magnetoresistive | Source: Vendor's supplied specifications

THE FUTURE FOR TAPE — BEYOND THE LTO ROADMAP PETABYTE TAPE CARTRIDGES ARE ON THE HORIZON

Today's modern tape uses a Barium Ferrite (BaFe) magnetic particle layer. In 2020, IBM and Fujifilm demonstrated a record areal density of 317 Gb/in2 on linear tape yielding a native cartridge capacity of 580 TBs (1.45 PB compressed 2.5x) using a new magnetic particle called Strontium Ferrite (SrFe). SrFe has improved magnetic characteristics compared to Barium Ferrite (BaFe). For a 1 PB+ future tape cartridge, Fujifilm is developing Epsilon Ferrite (-Fe2O3), an advanced magnetic particle technology which has even smaller nanoparticles. It should be possible to continue scaling tape areal density at or beyond historical rates through the next several decades providing a sustained volumetric and native capacity advantage for tape technology. These advanced developments are increasingly critical for large enterprises, HSDCs, HPCs and CSPs whose capacity demands constantly push the limits of existing storage solutions.

TAPE CONTINUES TO LEAD STORAGE DEVICES IN RELIABILITY RATINGS

Since the introduction of LTO-1 in 2000 with a native capacity of 100 GB, the capacity of LTO cartridges has increased by 180 times and data rates have increased by 20 times. Over the same period, the specified uncorrectable Bit Error Rate (BER) of LTO cartridges has improved by a factor of 1000, three orders of magnitude improvement. LTO-9 provides an industry leading uncorrectable bit error rate of $1x10^{20}$ compared to the highest HDD BER at $1x10^{17}$. A BER of $1x10^{20}$ corresponds to one unrecoverable read error event for every 12.5 exabytes of data read. Today, both the latest LTO and enterprise tape products are more reliable than any HDD.

Tape reliability and availability concerns can be further enhanced by creating multiple copies. For all practical purposes, "two copies on tape" could be considered the equivalent of mirroring data (RAID 1) on HDDs. Specifically for tape, special prewritten servo tracks allow the tape drive heads to stay aligned with data tracks on the tape to accurately read and write tape data. To further improve tape reliability, modern tape reads a data block immediately after it is written to verify accuracy. If there is a discrepancy, the data block will be corrected and re-written to the next position on the tape.

Since 2000 enterprise and LTO drives have eliminated alignment issues by combining the pre-recorded servo tracks on the media (between the data bands). When tape is being read, it is streamed over the head at a speed of about 15km/h and with the new servo technologies, the tape head can be positioned with an accuracy about 1.5x the width of a DNA molecule. To further improve reliability, LTO drives switched to PRML from the older RLL (Run Length Limited) error checking code. PRML (Partial Response Maximum Likelihood) is *the* most effective error detection scheme and is widely used in modern disk drives by recovering data from the weak analog read-back signal enabling tape to surpass disk in reliability. Today, both LTO and enterprise tape are more reliable than any HDD. As HDDs are adding more platters and more R/W heads (more parts to fail) to increase capacity, this trend is expected to continue to favor tape.

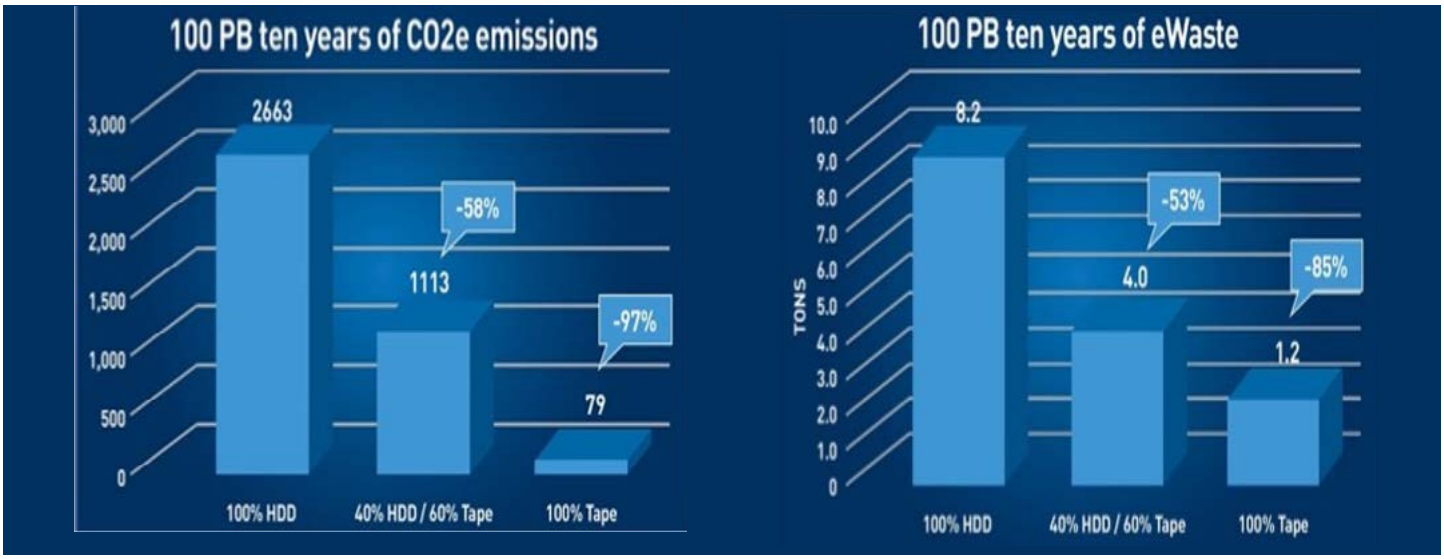
STORAGE DEVICE RELIABILITY RATINGS Source: Vendor's published BER	**BER (BIT ERROR RATE)** Bits read before permanent error
Enterprise Tape TS1160, TS1170	$1 \times 10E^{20}$ bits
LTO (LTO-7, 8, 9)	$1 \times 10E^{20}$ bits
Enterprise SSD (NAND Flash)	$1 \times 10E^{18}$ bits
LTO 5-6	$1 \times 10E^{17}$ bits
Enterprise HDD (FC/SAS)	$1 \times 10E^{16}$ bits
Enterprise HDD (SATA)	$1 \times 10E^{15}$ bits
Desktop/consumer HDD (SATA)	$1 \times 10E^{14}$ bits

TAPE REDUCES CARBON EMISSIONS, EWASTE AND TCO

The carbon footprint of data centers has become a major concern. As more and more data center operations are managed in the cloud, the energy required to process and perform those operations is generated mostly by fossil fuels. Studies show that over 2,700 colocation centers across the U.S. consume enormous amounts of electricity and water while requiring few human jobs to operate.

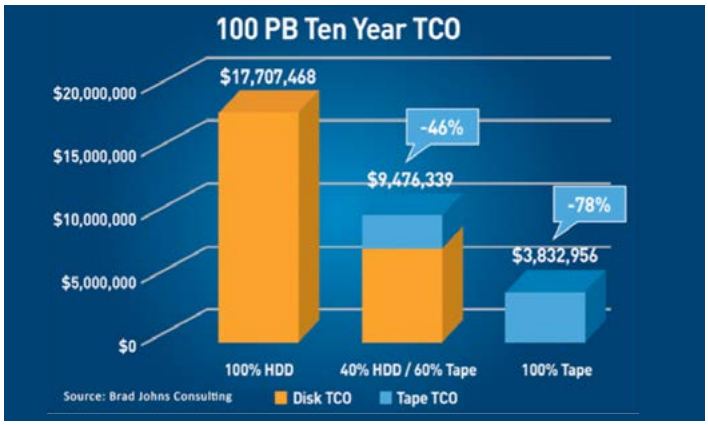
The need for storage optimization arises from the ever-increasing volumes of data that organizations generate and retain, sometimes indefinitely. Analysts widely agree that 60% to 80% of data quickly becomes cold with little or no access frequency after 90 to 120 days. Yet a disproportionate amount of data remains on energy intensive HDDs due to historical inertia and a lack of strategic data management. This will significantly change in 2024 as the energy efficiency, cost and reliability of automated tape systems becomes a strategic imperative.

Improving Information Technology Sustainability with Modern Tape Storage, a research paper issued by Brad John's Consulting, compared an all data on HDD solution to an all-tape solution and to an active archive that moved 60% of the HDD resident (low activity) data to tape. Moving 60% of HDD data to tape for 10 years reduced carbon emissions by 58% and electronic waste was reduced by 53%. For eWaste (electronic waste), storing all 100 PBs on HDDs and refreshing them after 5 years generates 8.2 tons of eWaste, while storing 60% of the data on tape created 4 tons of eWaste, a 51% reduction.



The report estimates that moving 60% of the world's (low activity, inactive) data from HDDs to tape could avoid 79 million tons of C02e, not to mention an immediate release of HDD space. With insatiable secondary storage demand, expect tape to play a pivotal role in data center sustainability initiatives as moving low activity data from HDDs to tape pays enormous dividends. *Storing low activity and archival data on spinning HDDs is a strategy, just an extremely expensive one.*

TCO (Total Cost of Ownership) is an assessment of all the costs your organization incurs while procuring, installing, running, and maintaining your IT infrastructure. Effectively addressing the storage optimization challenge of "getting the right data, in the right place, at the right time and at the right cost" presents an enormous TCO savings for storage managers. As most data ages, access frequency drops off rapidly and data typically reaches archival status between 90 to 120 days eventually becoming cold data. Much archival data continues to live on HDDs long after it reaches archival status, an expensive residence for cold data. The TCO (Total Cost of Ownership) for an HDD solution is compared to a tape solution using LTO-9 tape media and drives in the adjacent chart. The estimated ten- year TCO for keeping all 100 PB on HDDs



is $17,707,468. With the tiered storage approach, moving 60% of HDD data to tape, the ten-year TCO drops to $9,476,339, a 46% savings. Moving all data to tape results in a 78% cost reduction. The greatest economic benefits of tiered storage are realized when the tape tier is used. Intelligent data management software that moves data between tiers is a key component for an optimized storage infrastructure. Look for AI to play a significant role in data placement and management decisions going forward. *Adding tape is strategic - adding disk is tactical AND very expensive!*

TAPE AIR GAP: A STANDARD FOR CYBERCRIME PROTECTION

The countless ransomware cyber-criminals have made it a priority to destroy or render your backups and other select files useless. They want to take away your last line of defense. Cybercrime includes everything from theft or embezzlement to data hacking and destruction. The reality is that attackers today have a >90% success rate. The tape air gap, inherent with tape technology, has ignited significant interest in storing data on air-gapped tape. The "tape air gap" means that there is no electronic connection to the data stored on a removeable tape cartridge therefore preventing a malware attack on stored data. HDD and SSD systems remaining online 7x24x365 are always vulnerable to a cybercrime attack. U.S. ransomware attacks increased over 37% in 2023 while the average ransom demand was ~$5.3 million. Air gapping should be an integral part of any archive, backup and recovery plan. It's not a matter of "if" but "when" hackers will breach your network. There has never been a greater requirement to build cybersecurity data protection than at this moment in time.

DATA PROTECTION STRATEGIES FOR BACKUP AND ARCHIVE DATA

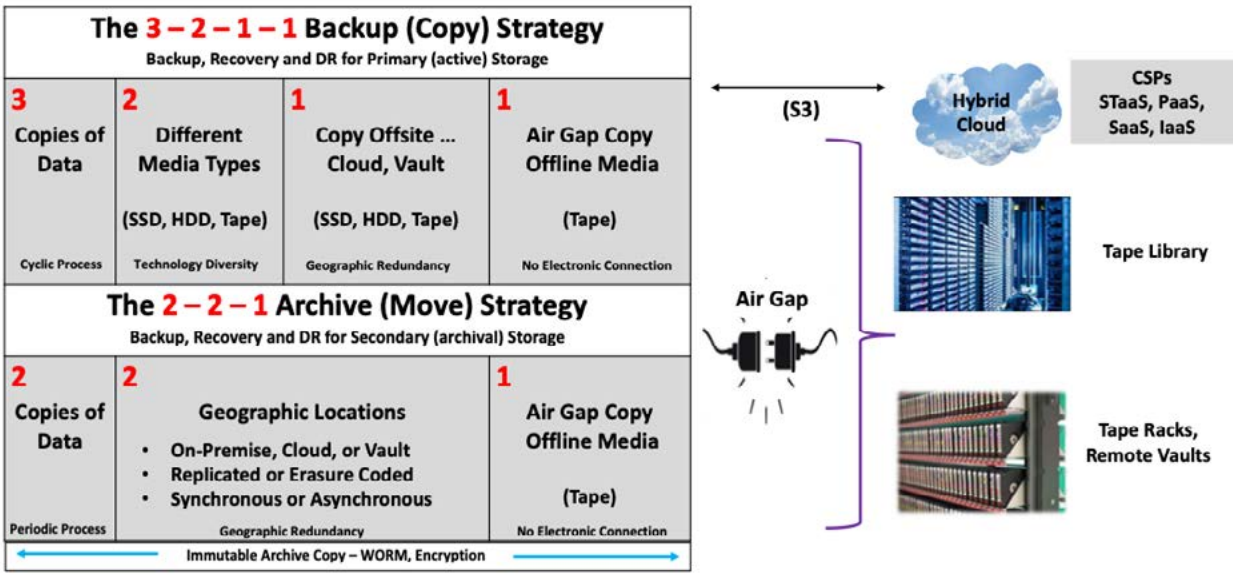
Using tape to backup HDDs was the original data protection strategy, but having one backup copy is no longer sufficient. The widely accepted and genetically diverse **3-2-1-1 Backup Strategy** states that enterprises should have three copies of backup data on two different media types, one copy offsite and one air gap copy. Combining the tape air gap copy with available tape drive encryption and available WORM (Write Once Read Many) tape strengthens any data center cyber resiliency strategy. Recovery (access) time to backup data on tape has been significantly improved with features such as oRAO with LTO-9 which can reduce the time needed for file access to recover backup files and archive data from tape by as much as 73%. Remember the time-tested rule - *Backup is important but recovery is everything.*

For many data centers, the archive copy is typically the only copy of archival data exposing it in case of any data loss event. Given that the business value of untapped archival data is rapidly increasing with the advent of AI, creating a second, secure air-gapped copy in a different geographic location will become a strategic data protection strategy. To this end, archive data can be protected by implementing a **2-2-1 Archive Strategy** creating a second copy of select archival data at a different physical location.

Several tape library vendors are adding additional air gap protection capabilities by offering libraries with managed partitions consisting of dedicated slots which are invisible to external applications. These isolated partitions contain no drives creating a secure air-gapped storage location within the library providing an additional barrier to access. The partitions are solely configured by the tape library administrator who can create, modify, delete, or reconfigure partitions to meet any size required. Since partitioned tapes remain in the library, physical media handling is avoided. Modern tape provides immutable air gapping at a favorable price point at scale for backup and archive data and should be an integral part of any data protection strategy whether on-premises, in the cloud, or a hybrid cloud.

Data Protection Strategies Evolve for Backup and Archive

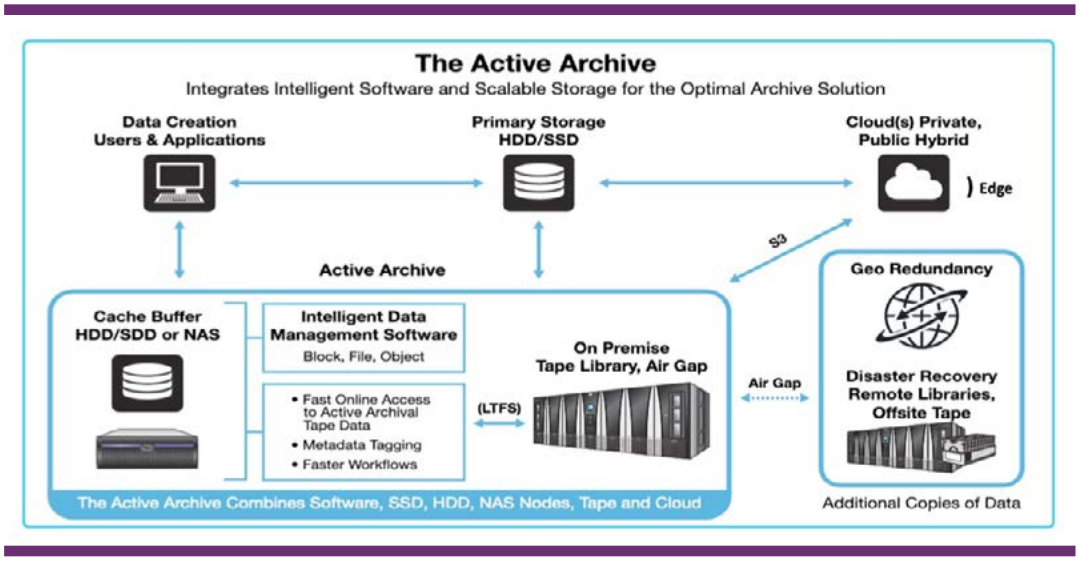
Tape Air Gap Plays Key Role in the Data Security Ecosystem



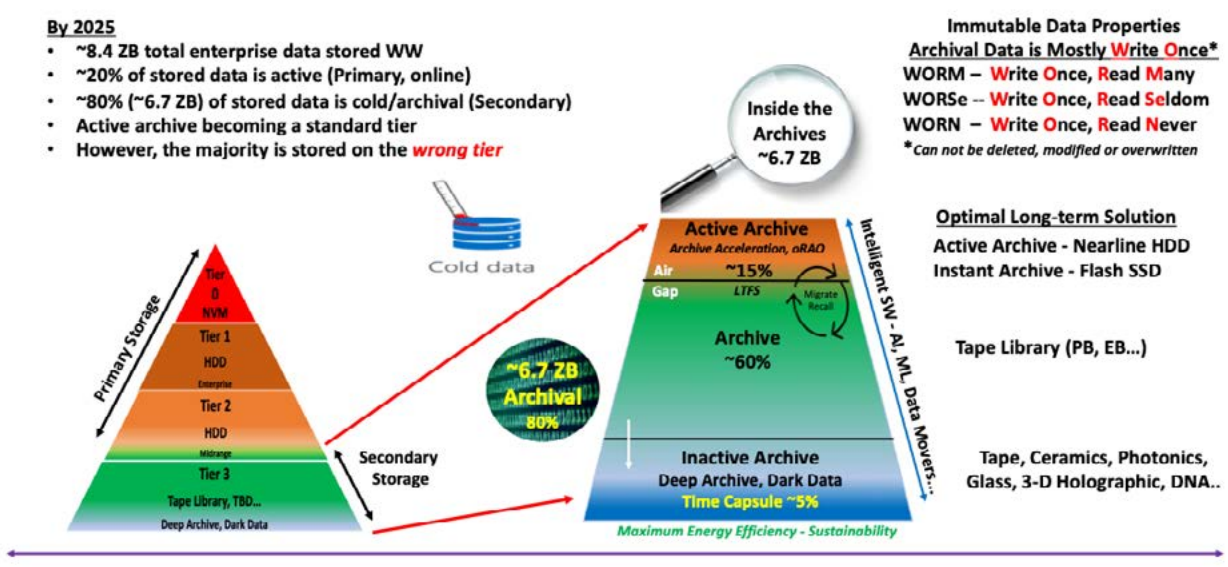
Source: Horison Information Strategies, LLC

AI, SURVEILLANCE, SOCIAL MEDIA PROPEL ACTIVE ARCHIVE DEMAND

AI, surveillance, and social media have generated demand for faster access to archival data. An active archive integrates two or more storage technologies (SSD, HDD, tape, and cloud storage) behind a file system providing a seamless means to manage archive and lower activity data in a single virtualized storage pool. SSDs or HDDs serve as a cache buffer for archival data stored on secondary storage (tape) providing faster access to first byte of data, higher IOPs, and random access for more interactive archival data. Many data management products now support tape as an object storage target using S3 services. Combining the open tape file system LTFS with tape partitioning, data mover software (HSM, etc.), an HDD array or NAS in front of a tape library creates an active archive. Using an SSD for the cache further in creates an instant archive. LTFS currently has 34 implementers, and it is expected that an increasing number of ISVs (Independent Software Vendors) will exploit LTFS in the future. The active archive is supported by the Active Archive Alliance. See the Active Archive conceptual view below.



The data storage hierarchy has long been depicted by a pyramid with the fastest and most expensive technologies at the top and higher capacity, lower cost technologies at the bottom. Approximately 20% of the world's data is active and served best by primary storage SSDs and HDDs, and 80% is low activity or cold data best served by secondary solutions like tape and nearline HDDs in some cases. As the amount of secondary storage data soars, new technology tiers are emerging in secondary storage in including the Active Archive, Traditional Archive and Deep Archive to address many new use cases. About 15% of archive data can be active at any point in time to support analysis of archival data that requires fast access time for a few hours or a few days. When the analysis is completed, the data is either deleted from the Active Archive if it hasn't been modified or the modified copy is re-written to traditional archive storage. The Active Archive uses either nearline HDDs or SSDs to add a performance buffer to the traditional tape archive. With a media life rated up to 50 years, tape is also the leading Deep Archive technology. Developmental technologies such as Ceramics (Cerabyte), DNA (several), Photonics (Folio) and Glass (Microsoft) remain in various stages of laboratory development. For the foreseeable future, tape will be the optimal secondary storage solution.



Source: Horison Information Strategies

TAPE PERFORMANCE IMPROVES ACCESS TIMES AND THROUGHPUT

HDDs and SSDs have much faster access times than tape to the first byte of data. For large files, tape systems have faster access times to the last byte of data. Previously available for IBM enterprise tape drives, oRAO (Open Recommended Access Order) was made available with LTO-9 full-high tape drives. oRAO reduces initial file access time serving as a data retrieval accelerator enabling applications to retrieve non-consecutive (random) files from tape by optimizing physical seek times between files. oRAO can improve random access time to data segments on tape by as much as 73%, when compared with retrievals of the same data segments linearly while significantly reducing physical tape movement and drive wear by creating an optimally ordered list of files on a cartridge.

In addition, LTO-9 increases drive data rate to 400 MB/sec. making it ideal for data streaming and large file transfers. RAIT serves as a data rate multiplier enabling parallel data transfer from an array of tape drives. Faster access time and throughput capabilities position LTO-9 for Big Data, AI and ML applications that are increasing access to archival and Big Data for countless purposes.

TAPE ACCESS TIME IMPROVEMENTS (TIME TO 1st BYTE)	
Active Archive	Active archive greatly improves access time to file and object tape data by using high-capacity HDDs or SSDs as a cache buffer in conjunction with a tape library.
oRAO	oRAO Open Recommended Access Order) arrived with LTO-9 and produces an optimized list called "best access order" enabling applications to retrieve non-consecutive files from tape by minimizing physical seek times between files.
LTFS	LTFS provides access to files directly without the application that wrote the data.
Faster and Smarter Library Robotics	Faster, intelligent robotics optimize robotic movements reducing cartridge mount and access times while improving reliability. Ransomware free partitions boost security.

TAPE THROUGHPUT IMPROVEMENTS (DATA TRANSFER RATE)	
Fastest Data Rates	The LTO-9 and TS1160/70 enterprise drives each have a data transfer rate of 400 MB/sec. This compares to the 7,200 RPM HDDs ranging between 160 – 260 MB/sec.
RAIT	RAIT (Redundant Arrays of Independent Tape) stripes data across multiple tape drives in parallel significantly increasing throughput and provides parity for data reconstruction like RAID does for HDDs.
RAIL	RAIL (Redundant Arrays of Independent Libraries) stripes data across tape cartridges but in different libraries which may be in different geographic locations.

TAPE DELIVERS A COMPELLING VALUE PROPOSITION

The current state of the tape industry is highlighted with continued development and investment in smart libraries, new drives, advanced media, and intelligent management software. The tape value proposition below is compelling and effectively addresses the relentless demand for higher reliability, higher capacity, much better power efficiency, ease of use and the lowest $/TB and TCO of any available storage solution.

TAPE FUNCTION	BENEFITS SUMMARY
Price/TCO	Tape Has the Lowest Acquisition Price $/TB and Lowest TCO.
Energy, CO2 Sustainability	Tape Uses Much Less Energy and Has Much Lower Carbon Footprint Than HDDs (~97% Lower).
Performance (Access time)	Much Improved Access Times - Active Archive, Fastest Data Rates, Smarter and Faster Robotics, RAIT, RAIL, New Time to 1st Byte Features (oRAO), Re-writable.
Capacity	LTO-9 Cartridge Capacity @18 TB (45 TB compressed) with 400 MB/sec Data Rate. Smart Zone, Robotic Libraries Surpass One Exabyte Capacity levels, Lab Demos Reach 580 TBs per Cartridge.
Scalability	Tape Easily Scales Capacity (PBs to EBs) by Adding Media/Racks Without Adding Energy Consumption, HDDs Scale Capacity by Adding Drives and Adding More Energy Consumption.
Portability	Tape Media is Easily Portable in Case of Disaster, HDDs More Difficult to Physically Move to a Different Location.
Cybersecurity	Air Gap, WORM and Encryption Options Protect Against Malware Attacks, Providing Immutability.
Durability/Media	LTO Reliability BER ($1x10^{20}$) Surpassed HDDs ($1x10^{16}$), Media Life >50 Years for Modern Tape.
Recording Limits	HDDs Have Reached Areal Density and Performance (IOPs) Limits. Tape Has a Well-Defined Roadmap extending through LTO-14.
Open Standards	LTO and LTFS Provide Open Standard File Interface, APIs. SW (S3 API) Support for Tape Object Storage and Cloud Access.
Tape and Cloud Ecosystem	Tape Interfaces Seamlessly with Clouds Using Industry Standard API's. Native Cloud Applications Can Write to and Read from Tape.

CONCLUSION

As data creation continues to grow at 25% or more per year, at least 80% of the world's digital data is optimally suited to reside on secondary storage and this amount could reach nearly 7 ZBs by 2025. In response to this secondary storage challenge, the tape ecosystem has significantly expanded its capabilities in recent years. Tape has also become the leading pure storage solution to defend against cybercrime by seamlessly integrating air gap, encryption and WORM capabilities. Roadmaps signal that the trend of steady tape innovation will continue well into the future. Tape is the greenest storage technology and can significantly reduce carbon emissions and eWaste from data center operations. More large-scale tier 2 data centers are determined to contain their infrastructure costs and improve their sustainability metrics. They will be motivated to rethink existing data storage practices and take advantage of advanced magnetic tape as they approach exabyte scale. Combined with improved access times, faster data rates, a 50-year media life, lowest TCO and the highest device reliability, modern tape has the greatest potential to address the massive capacity demands of the zettabyte era.

It's no coincidence that the rise of these tape advancements coincides with the explosion in data storage demands. After carefully considering the alternatives for the foreseeable future - tape has clearly become the primary choice for secondary storage.

Horison Information Strategies is a data storage industry analyst and consulting firm specializing in executive briefings, market strategy development, whitepapers and research reports encompassing current and future storage technologies. Horison identifies disruptive and emerging data storage trends and growth opportunities for end-users, storage industry providers, and startup ventures.