Quantum®

WHITE PAPER

LTO: THE NEW "ENTERPRISE TAPE DRIVE"

CONTENTS

INTRODUCTION

Over the past 30 years, there have been numerous magnetic tape formats. Nearly all have been retired, leaving three formats: Linear Tape Open (LTO), which is an open standard; and IBM 3592/ TS11xx and Oracle 9840, 9940, and T10000 proprietary formats, which are also marketed as "enterprise tape drives." In the past, differences in performance, capacity, and reliability earned the proprietary formats the term "enterprise," but today this is no longer true.

Since the initial release of LTO-1 in 2000, year after year LTO drives and media have continued to dominate the tape market due to the efforts of the LTO Consortium (Quantum, IBM, and HP). For the past several years, the LTO format accounts for over 96% of all tape drive shipments. This market dominance has made it more difficult each year for IBM and Oracle to continue to develop and deliver next-generation formats and technology for their proprietary tape drives.

With its advanced features and specifications, LTO has matched and in many cases exceeded the performance and capacity of these proprietary tape formats. LTO is an "open standard," with LTO tape drives and media developed and manufactured by the LTO Consortium. LTO has always had a price advantage—and with multiple vendors promoting the technology, the LTO Consortium has been aggressive in developing new features. Now that LTO technology is equal or superior to enterprise tape, it is clearly the best choice when customers need to expand or migrate from proprietary tape due to higher costs or end-of-life concerns.

GETTING THE COMPLETE PICTURE

When comparing data storage devices, typically a relatively small number of performance and capacity comparisons are adequate. When comparing tape devices and specific data formats, your evaluation needs to be more depth than it would be for a disk system. Adding another layer of complexity, most tape drives are installed in an automated tape library, so you also need to consider the reliability and durability of the tape library. Media quality is possibly the most important factor contributing to overall performance and reliability.

This technical brief compares LTO tape drives to the proprietary enterprise tape drives sold by IBM and Oracle. It explains how Quantum leverages its native LTO tape drive capabilities and features in its Scalar® tape libraries, and how Quantum-Certified Media plays a significant role in performance and data durability.

BASIC PERFORMANCE METRICS

Table 1 shows LTO tape drives compared to current proprietary tape drives sold by IBM and Oracle. See the table in the Capacity section for additional details about how these specifications can impact performance, reliability, and data durability in various use cases.

Table 1. *Tape Format Specifications*

Technical Feature	LTO-7	LTO-8 (Projected)•	IBM TS1150	IBM TS1155†	Oracle T10000D
Native Capacity	6 TB	Up to 12 TB*	10 TB	15 TB	8.5 TB
Compressed Capacity‡	15 TB @ 2.5:1	Up to 30 TB @ 2.5:1*	30 TB @ 3:1	45 TB @ 3:1	21.25 TB @ 2.5:1
Native Performance	300 MB/sec	Up to 360 MB/sec*	360 MB/sec	360 MB/sec	252 MB/sec
Compressed Performance‡	750 MB/sec	Up to 900 MB/sec*	900 MB/sec	900 MB/sec	800 MB/sec
Speed Matching	Yes	TBD*	Yes	Yes	Not Specified
Speed Matching Range	102–300 MB/sec	TBD*	112–360 MB/sec	112–360 MB/sec	Not Specified
Unrecoverable Bit Error Rate	1 in 1019	TBD*	1 in 1018	1 in 1018	1 in 1019
Media Coating	BaFe	TBD*	BaFe	BaFe	BaFe
Reliability (Load/Unload Cycles)	120,000	TBD*	Not Specified	Not Specified	150,000
Reliability (Head Life)	250,000 hr	TBD*	Not Specified	Not Specified	Not Specified
Load Time	22 sec	TBD*	16 sec	16 sec	13 sec
Average File Access	50 sec	TBD*	40 sec	40 sec	50 sec
Maximum Rewind	98 sec	TBD*	76 sec	76 sec	97 sec
Native Drive Encryption	Yes	Yes	Yes	Yes	Yes
Encryption Key Standard	KMIP	KMIP	Proprietary	Proprietary	Proprietary
WORM	Yes	Yes	Yes	Yes	Yes
LTFS Support	Yes	Yes	Yes	Yes	Yes
Power Consumption	30 W max, 11 W idle	30 W max, 11 W idle*	46 W max, 24 W idle	46 W max, 24 W idle	90 W max, 36 W idle
Interface Ports	8 Gb FC	8 Gb FC*	8 Gb FC, 10 GbE	8 Gb FC, 10 GbE	16 Gb FC, FICON
Warranty	3 years	3 years	1 year	1 year	1 year
Drive Price	$20,000	$20,000*	$42,000	$42,000	$40,000
Media Price	$80	$130*	$175	$175	$250

* LTO-8: At this time, specifications for the LTO-8 tape drive are not final and will be updated when LTO-8 is released in late 2017.

† IBM TS1155 was recently announced and will be shipping mid-year 2017.

‡ Compressed Capacity and Performance: Specifications for compressed data are estimated based on normal data types; no vendor can guarantee these results.

In order to make educated choices about the technical comparisons, it makes sense to review the value and importance of these technical specifications in the context of common use cases. The following section provides more detail on the most critical specifications and their importance based on the tape system that will be used.

CAPACITY

It is a common belief that more capacity at a lower price is better, and the highest per cartridge capacity is the best. This is true in most tape environments, particularly when a low-cost, long-term storage system is desired. For customers who are archiving on tape to reduce cost and expense, higher capacity is clearly the best choice.

With the increased capacity delivered by the LTO-8 tape format, the proprietary drives no longer have an advantage in that area. LTO-7 has already exceeded the capacity of Oracle T10000D—and LTO-8 (available late 2017) will be nearly equal to the IBM TS1155 tape drive. Later in this technical brief, we will compare the TCO across these products. It is obvious that although the IBM TS1155 has a small capacity advantage for TCO, overall LTO has a clear and significant advantage.

DATA PERFORMANCE

As shown in table 1, sustained data performance is essentially a dead heat with LTO-8 and IBM TS1150/TS1155 drives all being able to sustain 360 MB/sec. The exception to this is the Oracle T10000 drive, which is 30% slower than LTO and the IBM tape drives.

Faster is assumed to be better, but is this always true?

Tape drive performance is measured in isolation in an engineering test lab. When measuring real-world performance, it must include the environment (servers, primary storage, and networks), which in some cases is not up to the task of sending data to a tape device at extremely high rates. When incoming data rates drop below optimum performance, the tape devices can attempt to keep writing, but eventually will need to stop and wait for more incoming data. Since the first generation of LTO tape drives, they have had the ability to do speed matching.

With speed matching, the LTO drives monitor the incoming data rates and will adjust their performance to match the rates being sent by the host system. The goal is to eliminate the stop/start activity if data does not arrive fast enough. At a certain point, if the data rates are slow enough, even the LTO tape drives will need to pause and wait for more data. The LTO design is such that the drive will stop, rewind a small amount, and when inbound data is available, ramp up to full speed and continue writing. Proprietary drive manufacturers have for years been claiming the LTO drives of doing "shoe-shining" when data rates are too low to maintain streaming data to tape. With the speed-matching capabilities of LTO drives, this actually never happens and is truly an unfounded rumor.

MECHANICAL RELIABILITY

There is no standard for measuring mechanical reliability for tape devices. The LTO Consortium openly publishes the reliability specifications for LTO tape drives in both load/unload cycles as well as tape-head life expectancy. Neither IBM nor Oracle has published specifications for their products, hoping the customer is impressed with the term "enterprise" and never asks. LTO has superior mechanical reliability compared to the proprietary formats, which is why LTO manufacturers are able to offer a three-year warranty compared to the one-year warranty on proprietary drives.

MECHANICAL PERFORMANCE

Another performance metric for tape devices is the mechanical performance—how long it takes to load a cartridge, find a specific file on tape, and rewind and unload the media after the data has been read. Historically, this is one performance metric where proprietary tape drives have had a clear advantage over LTO format. But with recent technical improvements, LTO is no longer at the back of the pack.

There are two primary ways to evaluate mechanical performance for various use cases. The first use case is typical for a data protection/archive architecture where a large amount of data is being written to tape for off-site storage and long-term retention. In this use case, the load/unload metrics are not extremely important because when a large capacity tape cartridge is written to full capacity in a single session, the tape drive and that particular cartridge will be in use for over 10 hours. With that in mind, does a few seconds of load/unload or search time really impact anything? Not really.

The majority of data that needs to be accessed quickly will be stored on some type of disk system. With the explosive growth of unstructured data, there will be several situations where tape is really where the data lives, but it can be accessed when needed. The second use case where mechanical performance can have an impact is when tape is being used as a storage tier in a managed archive environment, where tape-based data is the primary copy of the data. For this use case, file access times will be more important, and if files are scattered across multiple cartridges, load/unload performance will also be important.

Because more and more customers are using tape in this fashion, Quantum is investing, developing, and patenting technology that makes this task less dependent on standard LTO tape drive functions and adds intelligence that is applied as part of the writing process—ultimately making file access easier and faster.

MECHANICAL DESIGN—LTO AND PROPRIETARY DRIVES ARE VERY SIMILAR

Proprietary drives have been marketed as being designed to handle higher duty cycles and heavier workloads due to their mechanical superiority to LTO drives. The reality is there are actually very few design differences. In fact, there are a number of components in LTO drives that are essentially the same as those found in the TS1150/TS1155 drives from IBM.

LTO and IBM proprietary drives have nearly identical (although not interchangeable) components for handling the media as it is loaded and being written/read in the tape drives. The leader pin, tape path guides, media take-up hubs, and all of the flanges in the tape path are essentially the same. Figure 1 shows just one example of these similarities.

Figure 1. *Leader Pin—LTO vs. IBM TS1150/TS1155*

Even the mechanism that engages the cartridge to move the media in the LTO cartridge fits the IBM proprietary cartridge properly, as shown in figure 2.

Figure 2. *LTO and TS1150/TS1155 cartridge engagement designs are the same.*

LTO AND PROPRIETARY BIT ERROR RATES ARE EQUIVALENT

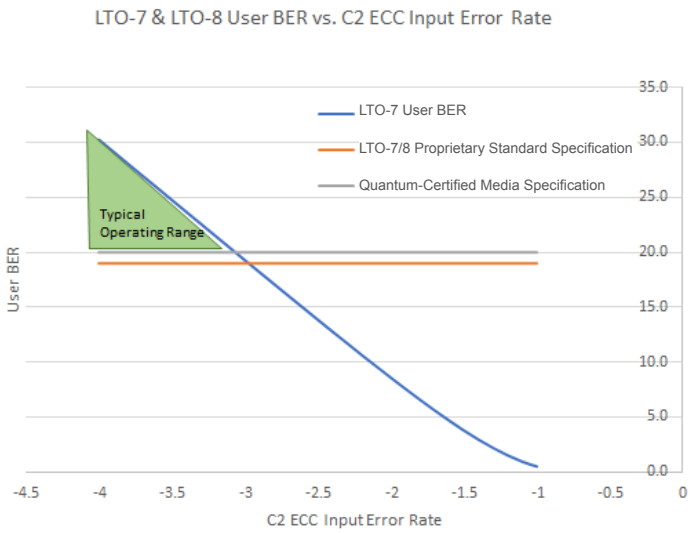
The bit error rate (BER) may be the most important specification for any storage device. Starting with LTO-7, there are several new data-integrity checking features that include error-correcting code (ECC) for headers that are a part of the format recorded on tape. It is this feature that made it possible for the BER detection specification for LTO-7 to be increased to no more than a single undetectable bit error for every 1 x 10^{19} of bits transferred. This data-integrity checking is 100 times better than LTO-6 and is considered to be enterprise-class data-integrity checking. Figure 3 compares LTO data-integrity checking to disk drives.

The following figures and table show how Quantum verifies and tests LTO drives and media to meet or exceed published LTO specifications. As you will see, proprietary tape formats do not have any advantages for data integrity and reliability.

The LTO-7 BER specification is based on a calculation of uncorrectable C2 ECC events, assuming all errors are random and uncorrelated. This is a theoretical analysis since experimentation-based estimates will require approximately 130 years at a 300 MB/sec data rate to encounter an error event. These theoretical calculations are based on the LTO-7 format's 32-channel, multi-dimensional, deep interleaving format architecture, and a new ECC format with advanced Barium Ferrite (BaFe) media, assuming all byte errors are random and uncorrelated. This assumption has

been experimentally verified. More complex reliability models, which are based on the theory of renewal processes, can account for correlated errors and defective header and synchronization fields. Therefore, the theoretical analysis of the error correction scheme implemented in LTO-7 leads to an uncorrectable error rate over the lifetime of the drive of one error per 1 x 1019 bits read.

Figure 3. *Comparison of Standard BER to Quantum-Certified Media BER*



Based on the error rate plot, as long as the input to the C2 ECC engine (in the reading drive), as shown in the x-axis, is below 10^{-3} error rate, the user's BER, the y-axis, will always be less than 10^{-20}, which is equal to the enterprise media specification. LTO-8 has the same technology that was introduced with LTO-7. When combined with Quantum-Certified LTO Media, this number is increased to provide higher levels of data integrity—which is equal any technology available in proprietary tape drives.

For more details on the error correction technology used in LTO tape drives and media, read this IEEE publication authored by the members of Quantum's Advanced Technology Engineering team.

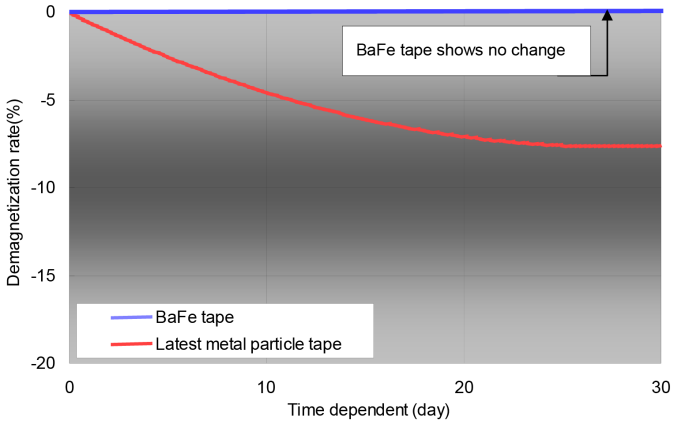
OTHER FACTORS

In addition to the primary specifications which are typically used to make choices for tape formats, there are a number of other advantages LTO has over proprietary tape formats. Lower power and cooling costs, and encryption key standards are just a few details that may not typically influence how a tape drive works in a given use case, but can actually make a significant difference in operating costs for large library environments.

LTO MEDIA COMPOSITION

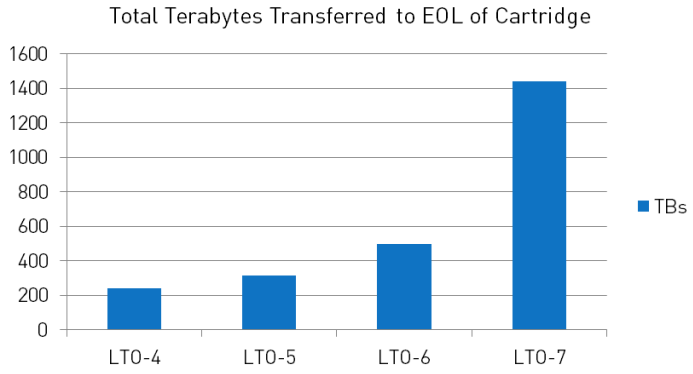
Beginning with LTO-7, all LTO-certified media must use a BaFe magnetic coating, which is the key to the capacity and performance of the LTO format. Another important benefit of the BaFe media is its ability to reliably store data for much longer periods of time than the previous metal particle (MP) coatings. Figure 4 compares the older MP media used in LTO-1 through LTO-6, and BaFe LTO-7 media, which can retain data for up to 30 years with proper storage and handling. All future LTO generations will be required to use BaFe media.

Figure 4. *BaFe vs. MP Long-Term Signal Retention.*[1]



Another way to understand the benefits of BaFe media is to examine the number of "uses" a cartridge will be able to support over its life span. Figure 5 shows how much data a single cartridge will be able to reliably store over its planned life expectancy. It is easy to see how all of these technology advancements combine to provide nearly three times the cartridge life expectancy compared to previous LTO generations.

Figure 5. *LTO Improved Long-Term Durability*



QUANTUM-CERTIFIED MEDIA

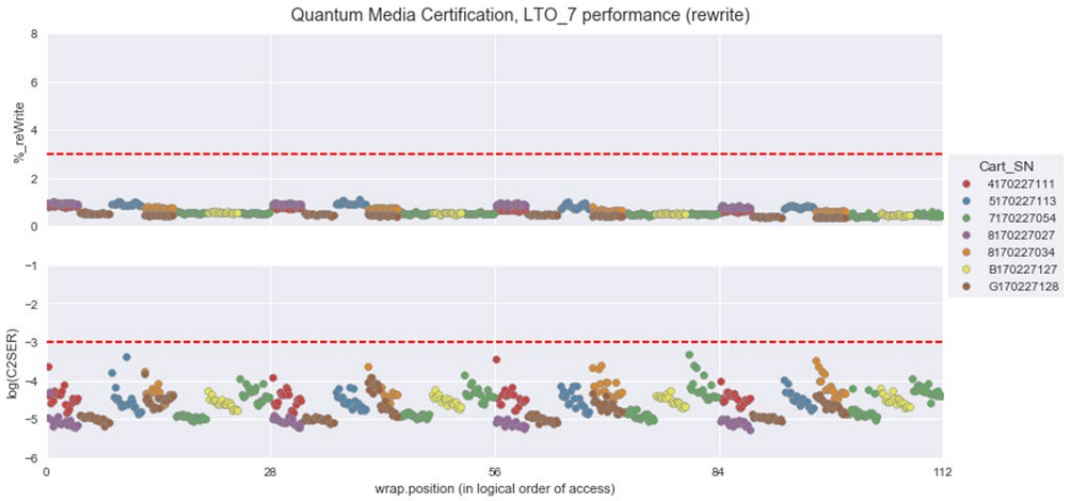
To maintain LTO Ultrium trademark compliance, LTO media suppliers are required to pass rigorous compliance tests. The testing process ensures the media adheres to the LTO Ultrium format specification, including interchange testing, which validates that all media and LTO drives from different manufacturers are interoperable. This well-defined and strict compliance testing is managed by the LTO Consortium with the media supplier's full cooperation. For more details about LTO, visit www.lto.org, the website maintained by the LTO Consortium.

To complement and extend the certification and testing done by the media manufacturers, Quantum has implemented an additional certification process at our expense. Quantum LTO certification is a value-added process focusing on five key user metrics: capacity, transfer rate, servo, and green media characteristics, with specific emphasis on testing the durability of the written data.

[1] Fujifilm, "Long Term Archivability and Stability of Fujifilm Magnetic Tape Using Barium-Ferrite (BaFe) Particle," p. 2.

During testing, sampled cartridges are tested using a special tape drive read-and-write process that enables the captured data samples to be analyzed. The read-and-write process includes controlled underruns to ensure that testing includes back-hitch motions rather than benign full-streaming modes. Special calibrated reference cartridges are used to support the analysis. Figure 6 shows how Quantum-Certified Media exceeds the LTO Consortium specifications by a significant margin. Media that is certified to a higher standard is one factor that ensures customers using Quantum LTO tape drives and certified LTO media (which has a three-year warranty) will have the highest level of performance and reliability. Inferior media significantly impacts tape drive and media performance and reliability.

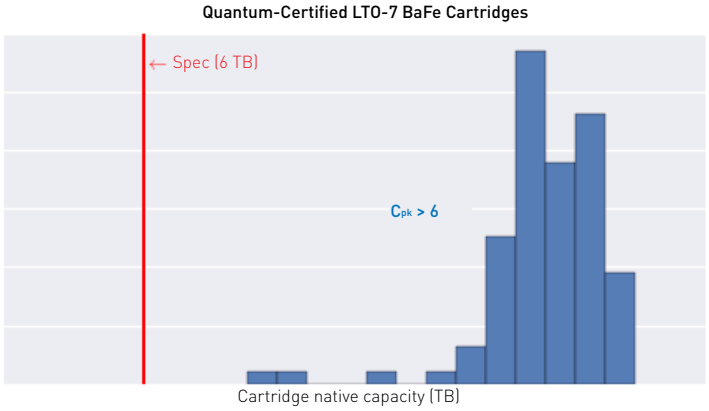
Figure 6. *Quantum Certified Media Test Results*



LTO media is designed to have a 3% allowance for error correction/recovery and still deliver the full native capacity the customer is expecting. Figure 6 shows actual test results that were collected during the Quantum-Certified Media test process. The upper portion of the chart shows the test data for a sample set of cartridges and verifies that all of the media tested is actually performing better than the LTO standard specification. The lower plot shows how well the Quantum media performs when errors are purposely injected into the test process to verify that the media is able to deliver the highest levels of data integrity.

For our customers, this means that Quantum LTO drives and Quantum-Certified Media technology is equal to or better than proprietary tape formats.

Figure 7. *Quantum Certified Media Exceeds LTO Specifications*



For more details about the test environment, test procedures, and results of the Quantum media certification process, read the Quantum white paper, Cloud-Ready Quantum Certified LTO Media.

QUANTUM SCALAR LIBRARIES

Quantum has been the market-leading tape automation provider for many years. In addition to delivering reliable robotics, Quantum has been an innovator in developing library-based technology that proactively monitors and warns about any degrading media or tape drive performance. Scalar libraries also provide options for provide non-disruptive, policy-based data integrity testing, allowing customers to verify that media being stored for long periods of time is still readable. With tape taking on an increasing role for long-term, cost-effective storage, it is more important than ever to be able to ensure written data will be intact when needed. The following are key features of the Quantum Scalar library portfolio.

- **Quantum iLayer™ intelligent software:** Automates administrative tasks, reducing administrative time up to 75% compared to other tape library products.
- **Extended Data Life Management (EDLM):** Quantum's exclusive policy-based media, health-check feature that ensures availability of data placed in long-term storage/archive for disaster recovery (DR). EDLM integrates with StorNext® Storage Manager, providing self-healing data protection for archived data.
- **Active Vault:** Archives tapes inside the library to minimize costs and cartridge handling while improving security and access to vaulted content.
- **Advanced reporting:** Media, drive, and security reports improve understanding of library utilization and performance. Automated report scheduling and distribution save time.
- **Path failover:** Control path and data path failover features ensure the library system stays operational and accessible even with a SAN fabric failure.
- **Smart bulk cartridge imports/exports:** The largest import/export capability in the industry, coupled with exclusive auto-import and export-redirect features, significantly reduces cartridge load/unload time.
- **Modular architecture:** Continuous robotics provides flexible scalability in a standard 19-inch rack form factor without sacrificing reliability.
- **Capacity-on-demand growth:** Simplifies storage growth by scaling quickly and easily—without disruption.
- **Quantum Vision® management software support:** Reduces management time in multiple-device environments and integrates easily with Quantum disk backup solutions.
- **Scalar Key Manager support:** FIPS-validated solution makes it easy to manage keys, mitigating risk of lost data.

Quantum Scalar libraries provide all of these features in systems that scale from 25 to 12,000 slots. For more information, visit www.quantum.com.

TOTAL COST OF OWNERSHIP

Tape is clearly maintaining its lead position for providing the most capacity at the lowest cost when compared to other storage products and technologies. When comparing the various tape formats, it is easy to see that LTO has a significant advantage over the proprietary formats when comparing costs. As shown in table 2, LTO tape drives have a list price of $22,000, where proprietary drives are typically over $40,000 per device. This higher price also extends to media purchases. An LTO cartridge is typically available for $80 to $130, and the proprietary media can range up to $250 per cartridge.

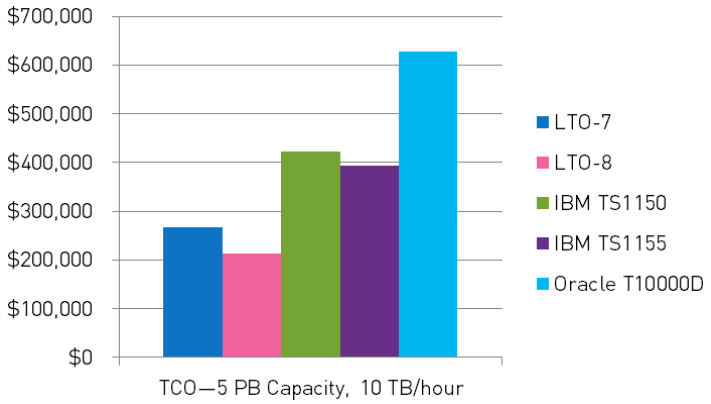
To show how this price impacts overall TCO, table 2 compares how many cartridges are needed to store 5 PB and how many tape drives are required to store 10 TB/hr. These examples show that LTO has a clear and significant advantage when comparing TCO for media and drives compared to the proprietary formats.

Table 2. *LTO vs. Proprietary – Total Cost of Ownership*

Capacity	LTO-7	LTO-8	IBM TS1150	IBM TS1155	Oracle T10000D
Native Capacity	6 TB	12 TB	10 TB	15 TB	8.5 TB
Number of Cartridges = 5 PB	833	417	500	334	589
Price per Cartridge	$80	$130	$175	$175	$250
Cost for 5 PB Capacity	**$66,640**	**$54,210**	**$87,500**	**$58,450**	**$147,250**
Data Performance					
Native Performance	300 MB/sec	360 MB/sec	360 MB/sec	360 MB/sec	252 MB/sec
Number of Drives = 10 TB/hr	10	8	8	8	12
Price per Drive	$20,000	$20,000	$42,000	$42,000	$40,000
Cost for 10 TB/hr Performance	**$200,000**	**$160,000**	**$336,000**	**$336,000**	**$480,000**
TCO					
5 PB Capacity, 10 TB/hr	**$266,640**	**$214,210**	**$423,500**	**$394,540**	**$627,250**

To summarize the data included in the chart above, the following graph shows LTO is clearly the price-performance leader when examining TCO for a tape environment.

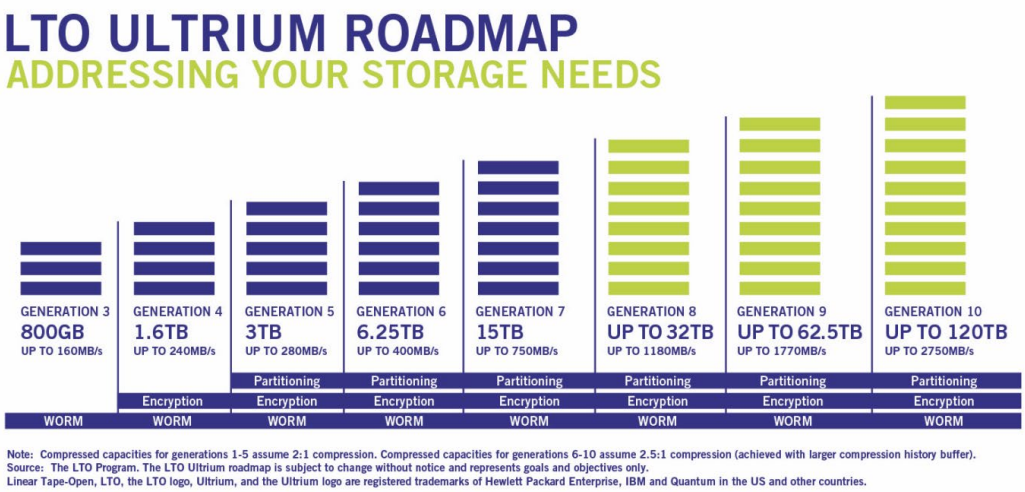
Figure 8. *The Real TCO*



THE FUTURE OF TAPE

The LTO Consortium has presented a roadmap that continues through LTO-10. LTO-10 is projected to have 48 TB per cartridge native capacity and up to 1,100 MB/sec data rates (see figure 9). While LTO-10 is planned to be available in 2022, the engineering that needs to be done to ensure aerial bit density, servo/indexing, and overall reliability through error detection/correction has already been proven in lab environments. As a key technology partner in the LTO Consortium, Quantum has gone beyond this published roadmap to prove the technical feasibilities well beyond LTO-10 for future generations of this technology. Quantum is also researching, testing, and has patented a variety of other technologies that are based on using standard LTO drives and media to support massive cloud archives with extremely long-term data integrity.

Figure 9. *LTO Roadmap Provided by the LTO Consortium*



SUMMARY

After reviewing all of the comparisons, it is easy to see that LTO is clearly the best tape format for portability and long-term retention.

- **Capacity:** LTO offers equivalent capacity at a much lower price per cartridge.
- **Performance:** LTO equals the performance of any of the enterprise drives.
- **Data durability:** LTO has demonstrated in accelerated media testing that data can safely be stored and accessed for 30 years assuming proper care and handling.
- **Reliability:** LTO drives are the only tape drives that offer a three-year warranty, a testament to the mechanical reliability of the tape drives.
- **Roadmap and future generations:** LTO being promoted by multiple vendors, offering the strongest commitment to future generations of tape technology.
- **Cost:** LTO delivers the lowest TCO, and based on capacity projections for cloud storage, tape is in many cases the only technology that can meet these needs.
- **Automation:** It is not just the tape drives and media that are important to reliability, the tape library plays a key role to ensure data is recorded and able to be read for many years.

ABOUT QUANTUM

Quantum is a leading expert in scale-out tiered storage, archive, and data protection, providing solutions for capturing, sharing, and preserving digital assets over the entire data lifecycle. From small businesses to major enterprises, more than 100,000 customers have trusted Quantum to address their most demanding data workflow challenges. Quantum's end-to-end, tiered storage foundation enables customers to maximize the value of their data by making it accessible whenever and wherever needed, retaining it indefinitely and reducing total cost and complexity. See how at **www.quantum.com/customerstories**.

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