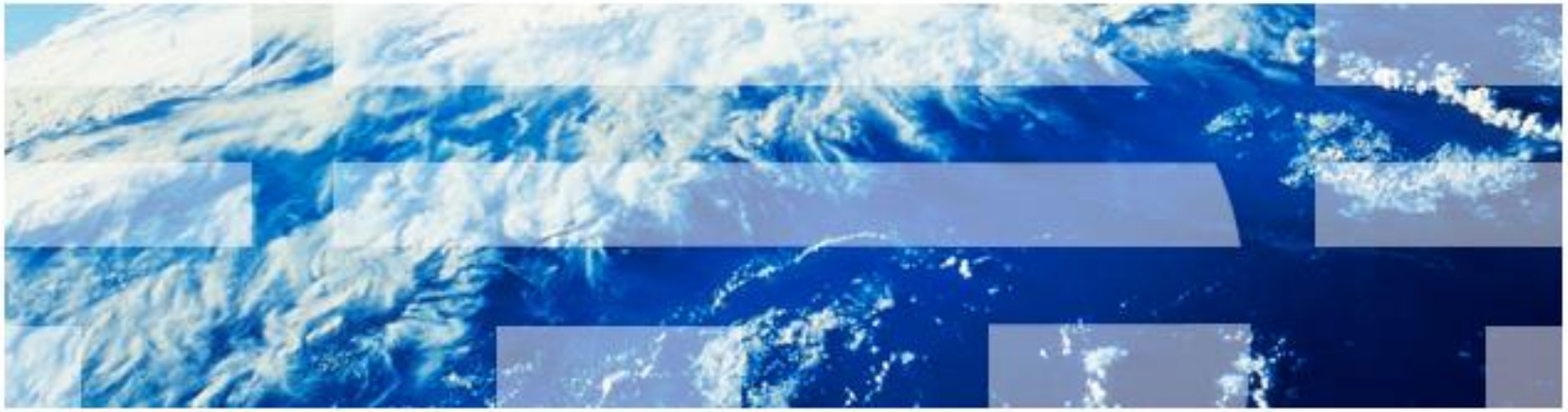
G. Decad – IBM Systems
September 20, 2016

Cloud and Archive Storage – Tape Perspectives



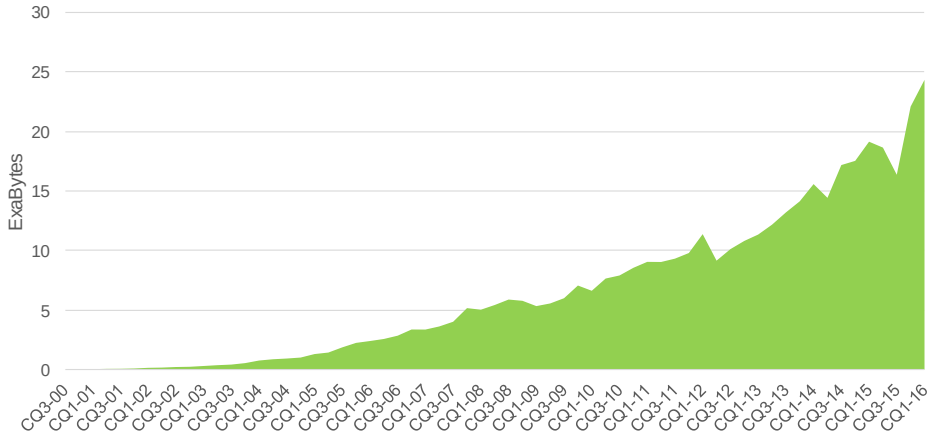
CLOUD and Archive Storage

- **TAPE TOPICS**
  - A sustainable manufacturing base, i.e drives, automation, media
  - Roadmap with at least 3 generations of cartridge capacity doubling on a 2 year to 3 year cycle through 2026
  - An integral part of the IBM storage and Cloud portfolio
  - Superior performance attributes in an archive: cost, data integrity, volumetrics

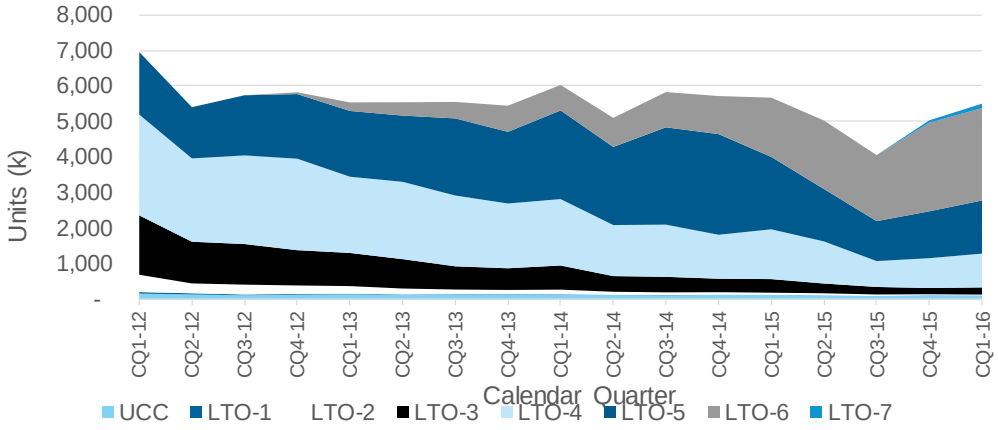
LTO Based Media shipments

- Shipped Capacity continues to Grow YTY by more than 17%
- Capacity shipped shows significant uptick in 1H2016
- Units shipped show signs of market stabilization
  - 2015 unit shipments were an anomaly
- Introduction of LTO7 is driving greater units of LTO6
  - Driven by Low cost of LTO6 media.

Compressed Capacity Shipments by Quarter

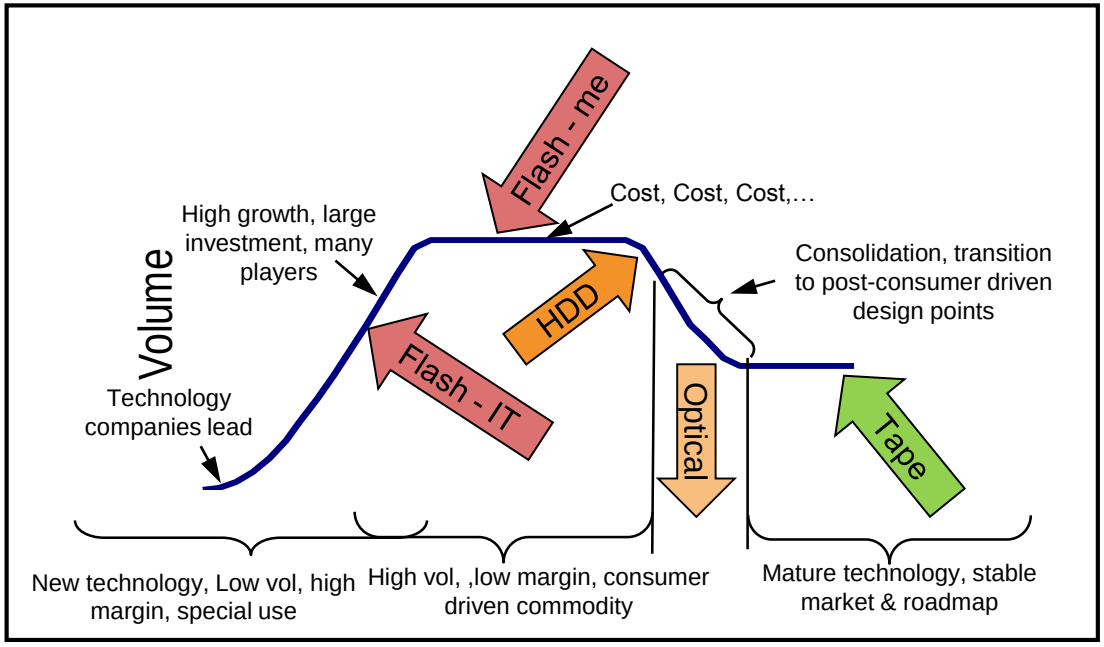


Unit Shipments: per quarter Running 4 year

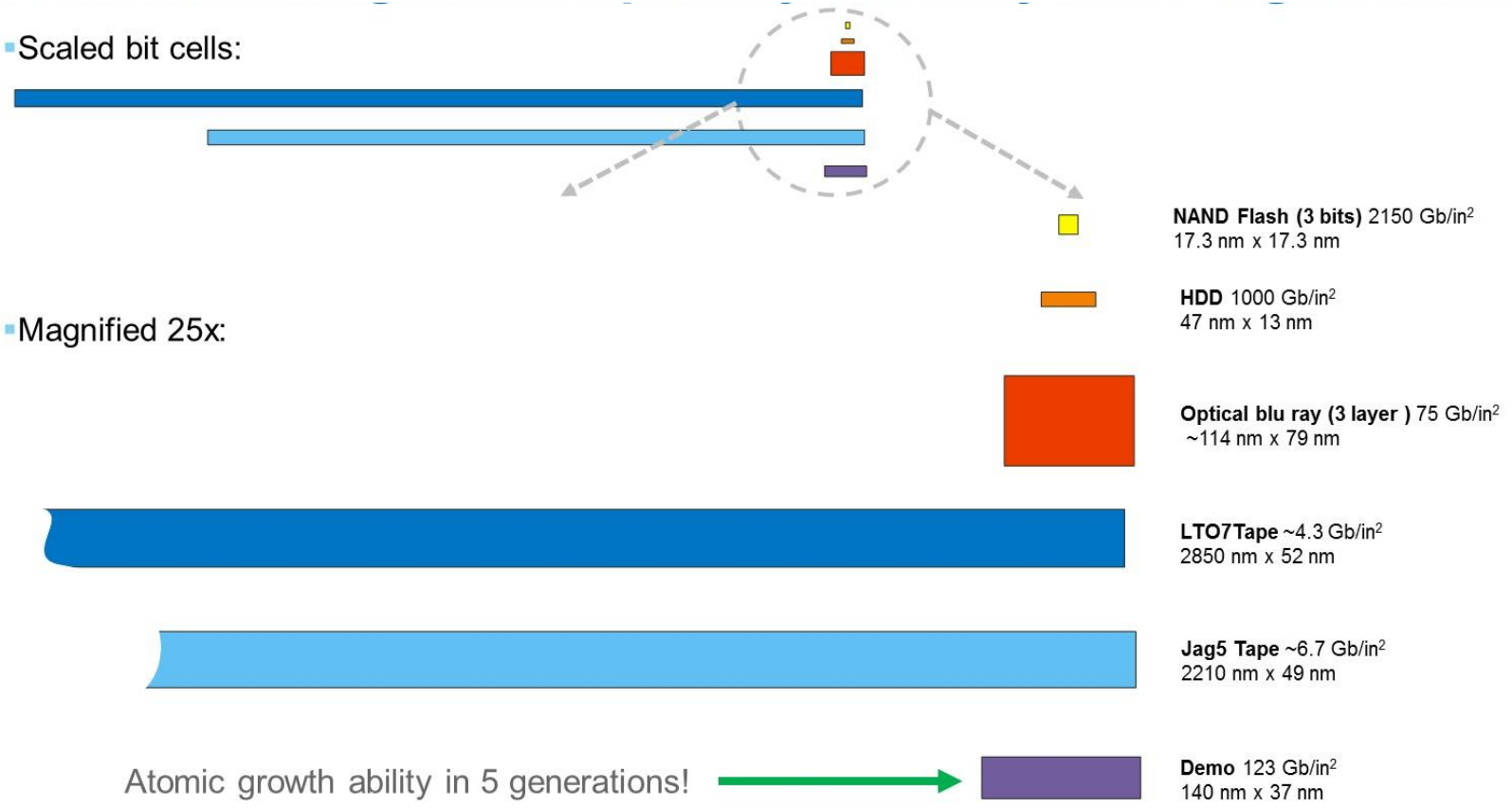


Storage Technology Transitions

- **HDD** starting transition to post-consumer driven marketplace
  - Consolidation
  - Less aggressive cost take-downs
- **Optical**
  - will not transition from consumer phase
  - not able to scale technology to future storage stack
- **Flash**
  - Front end of consumer commoditization will drive low cost flash requirements
  - Enterprise flash solutions to differentiate on performance and reliability
- **Tape**
  - post consumer, stable marketplace & technology roadmap through 2026



Digital Tape has more bit growth capability than any other digital media

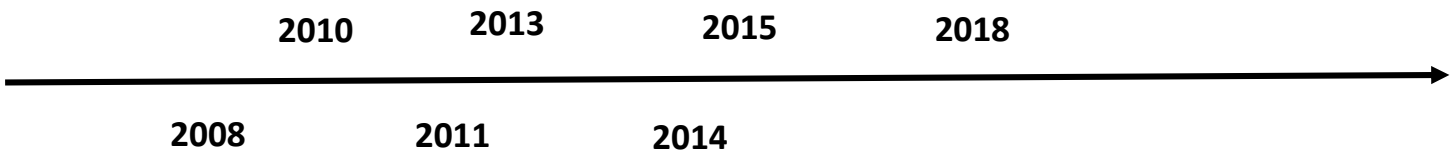


→Tremendous potential for future scaling of tape track density
→Key technologies: improved track follow servo control improved media, reader, data channel

Tape Drive History and Roadmap

- Planned strategy for continuing cartridge capacity doubling in a 2 yr to 3 yr cycle

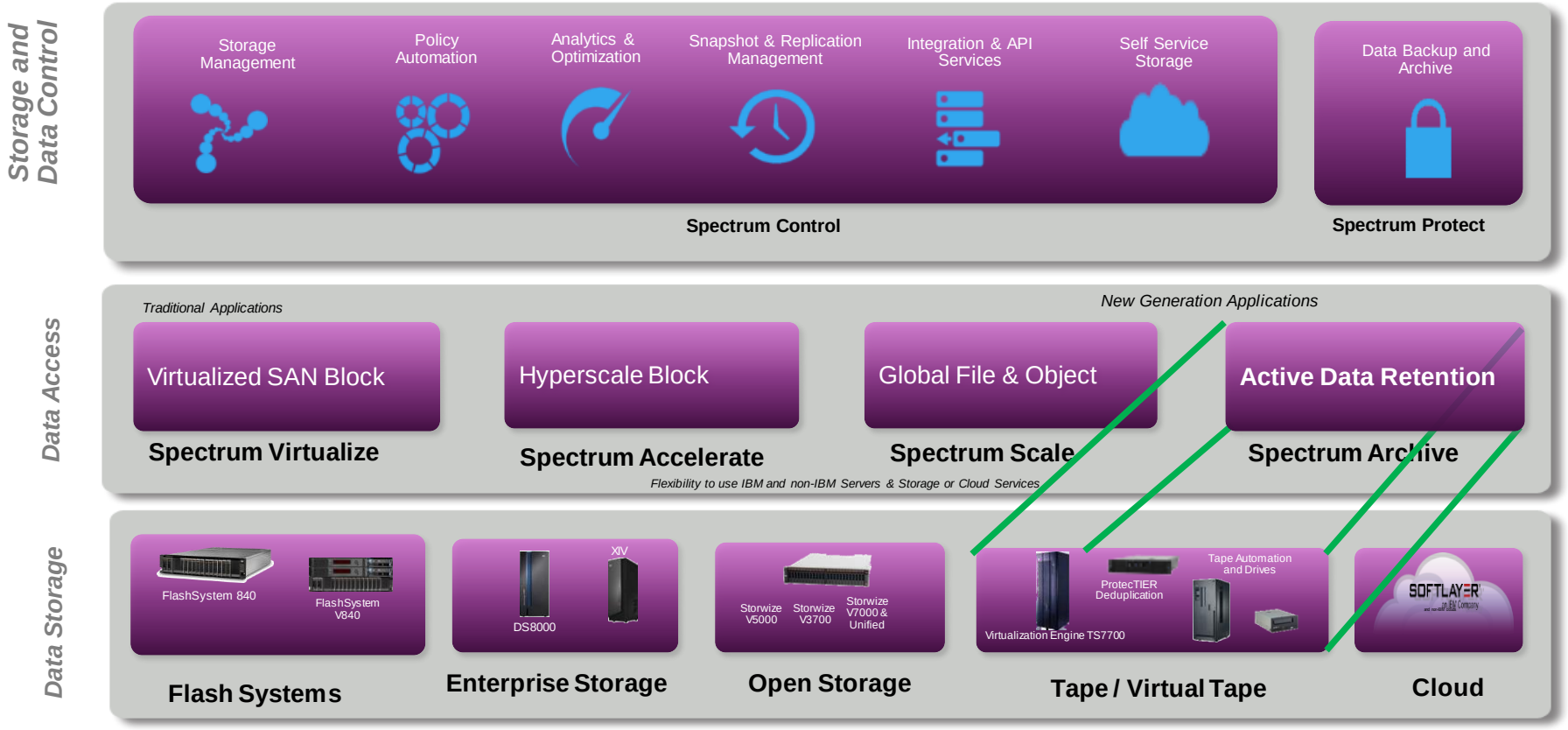
LTO Generations	LTO-5	LTO-6	LTO-7	LTO-8	LTO-9	LTO-10
New Format Capacity (Native)	1.5 TB	2.5TB	6.4 TB	Up to 12.0 TB	Up to 25 TB	Up to 50 TB
Compressed Capacity	3.0 TB	6.25 TB	15 TB	Up to 30 TB	Up to 60 TB	Up to 125 TB
Native Data Rate	140 MB/s	160 MB/s	315 MB/s	472 MB/s	708 MB/s	1100 MB/s



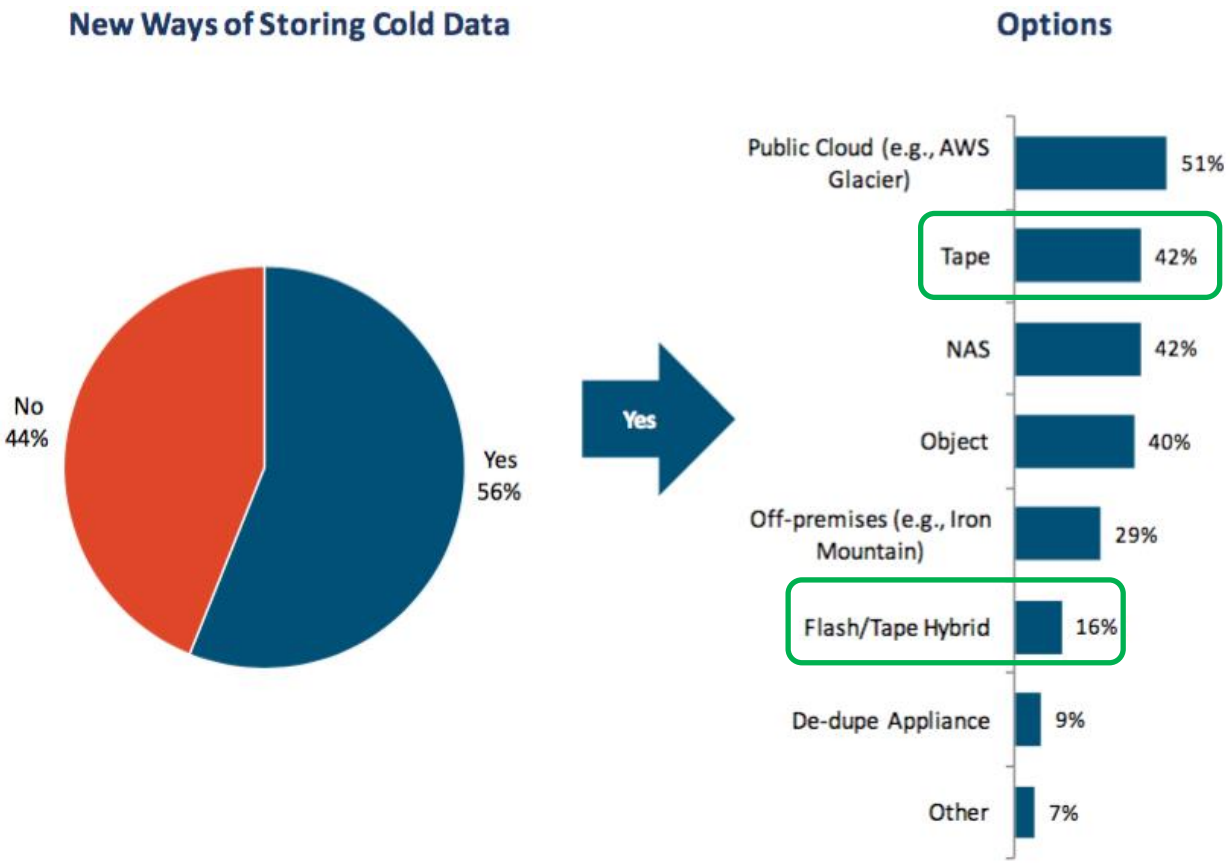
TS1100 Generations	TS1130	TS1140	TS1150	TS1155 (TBD) (TS1150 variant)	TBD	TBD
New Format Capacity (Native)	1.0 TB (JB) 0.6 TB (JA)	4.0 TB (JC) 1.6 TB (JB)	10.0 TB (JD) 7.0 TB (JC)	14-16 TB (JD) 10-12 TB (JC)		
Native Data Rate	160 MB/s	250 MB/s	360 MB/s			

IBM Cloud and Storage Architecture - Tape Positioning

- Tape is an integral part of the larger IBM storage portfolio.
- Tape presence through IBM Spectrum Scale, and IBM Spectrum Archive.
- Tape is the lowest cost target in all tiered models supported by IBM.



Customers are looking for new ways to Retain Cold Data



Reference: 2015 451 Research Market Analysis

- 56% of customers are looking for lower cost cold data storage
- Tape is ranked amongst the top choices for that data
- Tape is also included in NAS and Flash/Tape Hybrid solutions
- Above ~ 300TB capacity range, tape is a lowest TCO leader on a 10 year span, power being the largest contributor

Cold storage is the focus to control storage budgets

- **Commodity Flash:** fast random access (Touch Rate), relatively expensive, Low reliability over time (cannot hold a charge)
- **HDD with erasure coding:** fast response, relatively expensive, highest TCO with power
- **Archive HDD (Algorithmically powered):** Decreased access time due to power up times, lower TCO than HDD in active system, relatively rapid replacement
- **Optical:** lower access time than HDD, relatively slow performance, Better random access time than tape. Relatively low capacity. Perceived long life of media based on 2 point or 3 point Arrhenius plots, ½ acquisition cost of disk
- **Tape:** Linear access device, High capacity, High streaming I/O, long media life, extremely low bit error rate, if not the best BER .

Data Integrity

What is the likelihood of data retrieval

Device	Hard Error Rates in bits	Equivalent in Bytes	PB Equivalent
Optical	10E13	1.25E+12	0.001
SATA Consumer	10E14	1.25E+13	0.01
SATA Enterprise	10E15	1.25E+14	0.11
SAS/FC Enterprise	10E16	1.25E+15	1.11
Enterprise SAS SSD	10E17	1.25E+16	11.1
LTO7	10E19	1.25E+18	111
Enterprise tape	10E20	1.25E+19	1120

- The lower the Bit Error Rate (BER) the more likely to be able to retrieve the data
- Optical Technology has the worst BER in the digital storage market, 1E7 worse than tape
- Tape offers the best Bit Error Rate

Why is technology refreshed

Technology	Introduction	Capacity (GB)	$ Cost/GB (introduction)	GB Capacity per ft^3
3590 Tape	1994	10	5	960
LTO1 Tape	2000	100	0.8	5000
3592 JA	2003	300	0.42	25200
LTO5 Tape	2010	1500	0.06	75000
3592 GEN4/TS1140	2011	4000	0.06	336000
LTO6	2012	2500	0.04	125000
3502 GEN5/TS1150	2014	10000	0.05	840000

- Every 9-10 years density of storage improves by 2 orders of magnitude
- Advances in density are required to minimize expansion of storage footprint
- Technology refreshes cost less than not migrating data

Conclusions

- Archive digital tape cartridge capacity is extendable by at least a factor of 4, i.e. > 40 TB by 2020
- Cost, data integrity, and volumetric advantages favorable to cold storage applications of digital tape
- Roadmaps (LTO and Enterprise) are credible representations of future technology that will sustain cost and volumetric advantages

What about the Future

- Data Retention and Archive Clients will continually require more manufactured PB of storage for their applications
- **Question:** What will be the 10 year future environment for storage when NAND, HDD, and even TAPE reach fundamental limits?
- **Answer:** Propose a symposium of industry and academic experts to discuss present and future technology trends in storage
- **Sponsorship:** Library of Congress and National Institute of Standards and Technology
- Topics
  - Traditional Storage and what it would be in 2026: NAND, TAPE, HDD
  - The next solid state memory – what is it
  - What are the projected PB requirements in 2026
  - What about Cloud in 2026
  - What roles will TAPE, HDD, and NAND have in 2026
  - What are the new technologies and can they be manufactured at appropriate $/GB