Cloud and Archive Storage – Tape Perspectives
• **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.
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

- Scaled bit cells:

- Magnified 25x:
  - NAND Flash (3 bits) 2150 Gb/in²
    - 17.3 nm x 17.3 nm
  - HDD 1000 Gb/in²
    - 47 nm x 13 nm
  - Optical blu ray (3 layer) 75 Gb/in²
    - ~114 nm x 79 nm
  - LTO7 Tape ~4.3 Gb/in²
    - 2850 nm x 52 nm
  - Jag5 Tape ~6.7 Gb/in²
    - 2210 nm x 49 nm
  - Demo 123 Gb/in²
    - 140 nm x 37 nm

→ 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

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

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

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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

- 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.
What is the likelihood of data retrieval

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

Why is technology refreshed

<table>
<thead>
<tr>
<th>Technology</th>
<th>Introduction</th>
<th>Capacity (GB)</th>
<th>$ Cost/GB (introduction)</th>
<th>GB Capacity per ft³</th>
</tr>
</thead>
<tbody>
<tr>
<td>3590 Tape</td>
<td>1994</td>
<td>10</td>
<td>5</td>
<td>960</td>
</tr>
<tr>
<td>LTO1 Tape</td>
<td>2000</td>
<td>100</td>
<td>0.8</td>
<td>5000</td>
</tr>
<tr>
<td>3592 JA</td>
<td>2003</td>
<td>300</td>
<td>0.42</td>
<td>25200</td>
</tr>
<tr>
<td>LTO5 Tape</td>
<td>2010</td>
<td>1500</td>
<td>0.06</td>
<td>75000</td>
</tr>
<tr>
<td>3592 GEN4/TS1140</td>
<td>2011</td>
<td>4000</td>
<td>0.06</td>
<td>336000</td>
</tr>
<tr>
<td>LTO6</td>
<td>2012</td>
<td>2500</td>
<td>0.04</td>
<td>125000</td>
</tr>
<tr>
<td>3502 GEN5/TS1150</td>
<td>2014</td>
<td>10000</td>
<td>0.05</td>
<td>840000</td>
</tr>
</tbody>
</table>

- 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
- 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