Fujifilm’s 7th Annual Global IT Executive Summit
October 7 – 10, 2015

A peek into the future
(The future of Tape)
Dr. Mark Lantz
Principle Research Staff Member, Manager Advanced Tape Technologies
IBM Research - Zurich
Excerpts from IBM EDGE May 11-15, 2015
• Introduction: The role of tape in the era of big data

• The Future of Tape
  • Tape areal density trends and future scaling potential
  • New world record tape: low cost particulate tape areal density demo of 123 Gb/in² (IBM – FujiFilm collaboration)
  • Technologies enabling the 123 Gb/in² demo
  • Tape technology roadmap

• What About the Other Storage Technologies?

• Investing in the Future

• Conclusions
The data deluge

- HDD Areal Density Scaling

~48% CAGR


80% of all files created are inactive – no access in at least 3 months!

Source: D. Anderson, 2013 IEEE Conf. on Massive Data Storage
Tape advantages for long-term storage

- **Very energy efficient:** no power needed once data is recorded
- **Very secure:**
  - Data is inaccessible when cartridge is not mounted
  - Drive level encryption
  - Portable
- **Very long** expected media **lifetime** (30+ years)
- **Very reliable:** Typically no data loss in case of drive failure
- **Main net advantage of tape for archival storage is cost**

![Energy and Storage Systems (1PByte of Data for 1yr)](image)

*Source: R. Dee, Sun Microsystems*
Recent studies from the Clipper Group:

1) **Continuing the Search for the Right Mix of Long-Term Storage Infrastructure** – A TCO Analysis of Disk and Tape Solutions (15 July 2015) Report #TCG2015006
2) **The Impact of LTO-7 on The TCO of Long-Term Storage** (15 Sept. 2015) Report #TCG2015008

Investigate 9 year TCO of a 1PB archive that grows to 52 PB (55% CAGR)

**Major Finding:** 6.7x TCO advantage of LTO Tape of Disk
HDD Areal Density Scaling:

Areal density/capacity scaling achieved by shrinking the same basic technology to write smaller and smaller bits on disk.

Ref: http://www.storageacceleration.com/author.asp?section_id=3670&doc_id=274482
Noise and Magnetic Media Structure

Information is encoded in transition edge. Large grains $\rightarrow$ media noise
To shrink the size of a bit, we need to shrink the size of the grains

If grains become too small, magnetic state is unstable $\rightarrow$ superparamagnetic effect
Magnetic Media “Trilemma”:

- Small particles ($V$):
  
  \[ SNR \propto V \]

- Thermal Stability:
  
  \[ E_B \propto K_u \cdot V \]

- Writability:
  
  \[ H_0 \propto K_u \]

  \[ H_0 < \text{Head Field} \]

HDD has reached the limit of (known) materials to produce larger write fields.

**Technologies to go beyond the superparamagnetic limit:**

- Two dimensional magnetic recording (TDMR)
- Heat Assisted Magnetic Recording (HAMR)
- Microwave Assisted Magnetic Recording (MAMR)
- Bit Patterned Media (BPM)
Magnetic tape (r)evolution

<table>
<thead>
<tr>
<th>Product / Year</th>
<th>IBM 726 /1952</th>
<th>LTO7 / 2015</th>
<th>TS1150 /2014</th>
<th>Demo 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>2.3 MBytes</td>
<td>6 TBytes</td>
<td>10 TBytes</td>
<td>220 TBytes</td>
</tr>
<tr>
<td>Areal Density</td>
<td>1400 bit/in(^2)</td>
<td>4.28 Gbit/in(^2)</td>
<td>6.7 Gbit/in(^2)</td>
<td>123 Gbit/in(^2)</td>
</tr>
<tr>
<td>Linear Density</td>
<td>100 bit/in</td>
<td>485 kbit/in</td>
<td>510 kbit/in</td>
<td>680 kbit/in</td>
</tr>
<tr>
<td>Track Density</td>
<td>14 tracks/in</td>
<td>8.83 ktracks/in</td>
<td>13.2 ktracks/in</td>
<td>181 ktracks/in</td>
</tr>
</tbody>
</table>

19.8 cm
IBM-FujiFilm demonstration of 123 Gb/in² on BaFe tape

Goal: Demonstrate the feasibility of tape roadmap for the next 10+ years

HDD vs. Tape Areal Density Scaling:

(Source: INSIC 2012-2022 International Magnetic Tape Storage Roadmap)
2015 Storage Bit Cells and Extendibility

- Scaled bit cells:

- Magnified 25x:

  - NAND Flash (3 bits)
    - 17.3 nm x 17.3 nm
    - 2150 Gb/in²
  - HDD
    - 47 nm x 13 nm
    - 1000 Gb/in²
  - Optical blu ray (3 layer)
    - ~114 nm x 79 nm
    - 75 Gb/in²
  - LTO6 Tape
    - 4750 nm x 65 nm
    - ~2 Gb/in²
  - Jag5 Tape
    - 2210 nm x 49 nm
    - ~6.7 Gb/in²
  - Demo
    - 140 nm x 37 nm
    - 123 Gb/in²

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

Focus on aggressive track density scaling

• Require:
  • dramatic improvement in track following → enables track width reduction
  • reduce reader width from a few microns to 90 nm

• Ultra narrow reader results in a dramatic loss in read back signal that must be compensated for with
  • improved media technology → require improved writer technology
  • improved signal processing and coding
  • improved reader technology
Servo pattern design for high areal density demo

Main design goal: nm-scale positioning fidelity
- Increased azimuth angle ⇒ increased resolution
- Increased pattern density ⇒ increased servo bandwidth and resolution

Compatible with Future 16 Data Band Tape Format
Synchronous servo channel

- Servo channel decodes the readback signal from the servo pattern and provides position information to the track follow control system
- Servo channel optimized for p-BaFe → improved resolution
- Optimized servo channel in combination with advanced BaFe media formatted with the 24° demo servo pattern provides **nanoscale position information**
New $H^\infty$ track-follow control system

- **Key features**
  - Prototype high bandwidth head actuator
  - A speed dependent model of the system delay is used for control design
  - The tape speed is used as a parameter to select the controller coefficients
  - Disturbance rejection is enhanced at the frequencies of the tape path disturbances

Track-follow control system
Prototype tape transport & hardware platform

- Precision flangeless tape path with grooved rollers & pressured air bearings to minimize disturbances
- TS1140 electronics card for reel-to-reel control and analog front end
- FPGA Board: System-on-Chip (SoC)
  -> Servo channels
  -> Microprocessor for synchronous track-follow (TF) servo controller

**FPGA Board**
Track-follow performance on BaFe tape

- Track width computation based on measured position error signal: PES (INSIC method)
- $\sigma_{\text{PES}}$ = standard deviation of position error signal: measure of track following fidelity
- Track width = $2\sqrt{2} \times 3\sigma_{\text{PES}} + \text{Reader Width}$ (Reader Width = 90nm)

\[ \sigma_{\text{PES}} \leq 5.9 \text{ nm over TS1140 speed range} \]

Reader Width = 90nm

\[ \sigma_{\text{PES}} \leq 5.9 \text{ nm} \]

Track width = 140 nm

Track density = 181 ktpi
Advanced BaFe Media Technology

Key technologies for advanced tape media

1. Fine magnetic particles with high coercivity → archival lifetime
2. Smooth surface
3. Perpendicular orientation of magnetic particles
Metal particle vs. Barium-ferrite particle

<table>
<thead>
<tr>
<th></th>
<th>Metal particle (MP)</th>
<th>Barium ferrite (BaFe)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Shape</strong></td>
<td>Acicular</td>
<td>Hexagonal platelet shaped</td>
</tr>
<tr>
<td><strong>Origin of magnetic energy</strong></td>
<td>Shape anisotropy</td>
<td>Magneto-crystalline anisotropy</td>
</tr>
<tr>
<td><strong>Material</strong></td>
<td>FeCo alloy</td>
<td>BaO(Fe$_2$O$_3$)$_6$ Oxide</td>
</tr>
<tr>
<td><strong>Passivation layer</strong></td>
<td>Needed</td>
<td>Not needed</td>
</tr>
</tbody>
</table>

- The magnetic properties of BaFe particles are NOT affected by its shape.
- BaFe particles do NOT need an oxide passivation layer because it is an oxide.
- The size of BaFe particles can be reduced while maintaining high coercivity.
Latest MP
Volume: 2850 nm$^3$
coercivity: 189 kA/m (2380 Oe)

Demo Tape BaFe
Volume: 1600 nm$^3$
coercivity: 223 kA/m (2800 Oe)

The volume of barium ferrite particle used in the demo tape is 45% smaller than the latest MP, reducing media noise and improving SNR.
Barium ferrite particles are well isolated and packed with high density.
The coercivity metal particles smaller than 3000nm³ decreases with size.

The coercivity of barium ferrite particles can be tuned independently of size enabling small particle media with long archival lifetime.

BaFe particles as small as 1000nm³ have been developed indicating the further scaling potential of BaFe tape.
Surface profile

Reduced surface roughness of demo tape increases the media SNR.
Perpendicular orientation

Longitudinal orientation (MP tape)

Random orientation (TS1140 JC and TS1150 JD tape)

Highly perpendicular orientation (123Gb/in\(^2\) demo tape)

The perpendicular orientation of BaFe particle provides a strong increase in SNR
Read/write performance

The combination of small particle volume, smooth surface and perpendicular BaFe particle orientation provide a major increase in SNR.
Enhanced Write Field Head Technology

Magnetic Media “Trilemma”:

- Small particles ($V$)
  $$SNR \propto V$$

- Thermal Stability
  $$E_B \propto K_u \cdot V$$

- Writability
  $$H_0 \propto K_u$$
  $$H_0 < \text{Head Field}$$

IBM developed a **new high moment (HM) layered pole write head** that produces much larger magnetic fields enabling the use of smaller magnetic particles.

![Graph showing SNR vs Coercivity for Std Writer and HM Writer](image)

**Increasing media coercivity**

---

© Copyright IBM Corporation 2015
• A user byte-error rate of $10^{-20}$ can be achievable using two C1-C2 iterations with a byte error rate of $\approx 4 \cdot 10^{-2}$ at the output of the detector.

• With EPR4 detection $4 \cdot 10^{-2}$ byte error rate $\approx 10^{-2}$ bit error rate.

• Require $\text{SNRa} \approx 10.5 \text{ dB}$ at the input of the detector to achieve a raw bit error rate $< 10^{-2}$ at the output of the detector.
Recording performance of BaFe with High moment writer & 90 nm GMR Reader

Advanced BaFe supports a linear density of **680kbpi** with a 90nm reader and provides an operating margin of ~ 0.5dB SNR.
Summary of demo results

- Advanced Perpendicular BaFe medium
- Linear density = 680 kbpi w/ 90 nm reader (single-channel recording)
- 1-sigma PES = 5.9 nm,
- Track density = 181 ktpi (track width = 140 nm)

**Areal recording density : 123 Gb/in²**

61x LTO6 areal density

→ 220 TB cartridge capacity (*)

This demonstration shows that tape technology has the potential for significant capacity increase for years to come!

(*) 220 TB cartridge capacity, assuming LTO6 format overheads and taking into account the 48% increase in tape length enabled by the thinner Aramid tape substrate used
## INSIC 2012-2022 Tape Roadmap

![Chart showing the 2012-2022 Tape Roadmap](chart.png)

### Table 1: 2012 Tape Technology Roadmap Detail.

<table>
<thead>
<tr>
<th>Parameter/Year</th>
<th>2012</th>
<th>2014</th>
<th>2016</th>
<th>2018</th>
<th>2020</th>
<th>2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Capacity (TB)</td>
<td>4</td>
<td>8</td>
<td>16</td>
<td>32</td>
<td>64</td>
<td>128</td>
</tr>
<tr>
<td>2. Data rate per channel (MB/sec)</td>
<td>11.2</td>
<td>13.8</td>
<td>17.0</td>
<td>20.9</td>
<td>25.8</td>
<td>31.8</td>
</tr>
<tr>
<td>3. Total data rate (MB/sec)</td>
<td>270.0</td>
<td>405.0</td>
<td>607.4</td>
<td>911.0</td>
<td>1366.5</td>
<td>2049.6</td>
</tr>
<tr>
<td>4. FC Speed Roadmap (MB/sec)*</td>
<td>3200</td>
<td>6400</td>
<td>12800</td>
<td>25600</td>
<td>25600</td>
<td>25600</td>
</tr>
<tr>
<td>5. Number of channels</td>
<td>24</td>
<td>29</td>
<td>36</td>
<td>43</td>
<td>53</td>
<td>64</td>
</tr>
<tr>
<td>6. Tape thickness (µm)</td>
<td>6.00</td>
<td>5.53</td>
<td>5.10</td>
<td>4.70</td>
<td>4.33</td>
<td>3.99</td>
</tr>
<tr>
<td>7. Data capacity reserve</td>
<td>5.0%</td>
<td>5.0%</td>
<td>5.0%</td>
<td>5.0%</td>
<td>5.0%</td>
<td>5.0%</td>
</tr>
<tr>
<td>8. Tape length that is recordable (meters)</td>
<td>867</td>
<td>941</td>
<td>1,021</td>
<td>1,107</td>
<td>1,202</td>
<td>1,304</td>
</tr>
<tr>
<td>9. Tape length total (meters)</td>
<td>902</td>
<td>979</td>
<td>1,062</td>
<td>1,152</td>
<td>1,250</td>
<td>1,357</td>
</tr>
<tr>
<td>10. Track density (TPI)</td>
<td>6,506</td>
<td>9,773</td>
<td>14,787</td>
<td>22,496</td>
<td>34,393</td>
<td>52,791</td>
</tr>
<tr>
<td>11. Linear bit density (KFCI)**</td>
<td>467</td>
<td>545</td>
<td>635</td>
<td>741</td>
<td>864</td>
<td>1,005</td>
</tr>
<tr>
<td>12. Areal density (Gbits/inch²)</td>
<td>3.04</td>
<td>5.32</td>
<td>9.39</td>
<td>16.67</td>
<td>29.73</td>
<td>53.22</td>
</tr>
<tr>
<td>13. Tape speed (m/sec)</td>
<td>6.4</td>
<td>6.6</td>
<td>6.8</td>
<td>7.0</td>
<td>7.3</td>
<td>7.5</td>
</tr>
<tr>
<td>14. Tape width (mm)</td>
<td>12.65</td>
<td>12.65</td>
<td>12.65</td>
<td>12.65</td>
<td>12.65</td>
<td>12.65</td>
</tr>
<tr>
<td>15. ECC and formatting overhead</td>
<td>24.00%</td>
<td>21.84%</td>
<td>19.88%</td>
<td>18.09%</td>
<td>16.47%</td>
<td>14.99%</td>
</tr>
<tr>
<td>16. Servo track and layout overhead***</td>
<td>18.46%</td>
<td>16.59%</td>
<td>15.02%</td>
<td>13.67%</td>
<td>12.50%</td>
<td>11.49%</td>
</tr>
<tr>
<td>17. Number of passes to write a tape</td>
<td>110</td>
<td>138</td>
<td>175</td>
<td>222</td>
<td>283</td>
<td>361</td>
</tr>
<tr>
<td>18. Time to fill a tape (minutes)</td>
<td>247</td>
<td>329</td>
<td>439</td>
<td>585</td>
<td>781</td>
<td>1,041</td>
</tr>
<tr>
<td>19. Number of passes to end of media life</td>
<td>30,300</td>
<td>33,406</td>
<td>36,830</td>
<td>40,605</td>
<td>44,767</td>
<td>49,356</td>
</tr>
<tr>
<td>20. Number of data tracks</td>
<td>2,642</td>
<td>4,060</td>
<td>6,258</td>
<td>9,673</td>
<td>14,988</td>
<td>23,272</td>
</tr>
<tr>
<td>21. Bit Aspect Ratio (BAR)</td>
<td>88</td>
<td>67</td>
<td>51</td>
<td>38</td>
<td>29</td>
<td>22</td>
</tr>
</tbody>
</table>

*HDD 2007-2012 Demos 120% /year
**HDD Products 2007-2012 100%/year
***HDD Products 2007-2012 75%/year

Fujifilm’s 7th Annual Global IT Executive Summit
October 7 – 10, 2015

What About the Other Storage Technologies?

Ed Childers
STSM, Manager Tape and LTFS
IBM Storage Development, Tucson, AZ

Excerpts from IBM EDGE  May 11-15, 2015
How do you store a bit?

- Magnetize something → Tape & HDD
- Change optical reflection → BluRay, DVD
- Capture charge → Flash
What’s limiting ability to increase areal density?

**Tape**
- No limitations in multi-decade time frame
  - Size of elements >100x than HDD
  - No lithographic challenges
  - Magnetic domain stability not an issue
  - No fundamentals of physics issues

**HDD**
- Size of magnetic domains
  - Stability of magnetic domains @ room temp
  - Long awaited superparametric limit is here
- Lithographic capability to make heads smaller
  - Approaching limits / reaching chip requirements

**Flash**
- Captured charge / # of electrons in level
- Longer term – aspect ratio’s of structures
- Longer term – 3D eventually

**Optical**
- Reducing wavelength of light in semiconductor laser, there is no viable path
  - ie. nothing after Blu – no roadmap
HDD Areal Density Scaling:

Areal density/capacity scaling achieved by shrinking the same basic technology to write smaller and smaller bits on disk.

HAMR or patterned media required to advance. Both difficult technology transitions → HDD scaling will continue to be slow until at least mid 2018.

From Mark Lantz – Future of Tape presentation

Ref: http://www.storageacceleration.com/author.asp?section_id=3670&doc_id=274482
### Optical Roadmap – A Squeeze Play

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ECMA</td>
<td>ECMA-130</td>
<td>ECMA-267</td>
<td>ECMA-364</td>
<td>BD-ROM</td>
<td>BD-R</td>
<td>BD-R</td>
</tr>
<tr>
<td>GB</td>
<td>0.682</td>
<td>4.70</td>
<td>8.55</td>
<td>25</td>
<td>100</td>
<td>300</td>
</tr>
<tr>
<td>Layers</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Capacity / Layer</td>
<td>0.682</td>
<td>4.70</td>
<td>4.27</td>
<td>25.00</td>
<td>33.33</td>
<td>50.00</td>
</tr>
<tr>
<td>Areal Density (User)</td>
<td>Gb/in^2 0.41</td>
<td>2.77</td>
<td>2.52</td>
<td>14.73</td>
<td>19.64</td>
<td>29.46</td>
</tr>
<tr>
<td>Areal Density (Raw)</td>
<td>Gb/in^2 1.44</td>
<td>6.54</td>
<td>5.95</td>
<td>26.72</td>
<td>25.23</td>
<td>37.85</td>
</tr>
</tbody>
</table>

#### Red
- Optical factor: 6.89
- Track Squeeze factor: 2.35
- Bit Squeeze factor: 1.37
- Channel Eff factor: 1.00
- Format Eff factor: 1.37
- Disk Area Eff factor: 1.02
- Total factor: 6.89

#### Blue
- PRML channel & modulation, 6% loss in LD due to layers

#### Green
- Smaller Wavelength Laser
- Multi-state Recording
- Improved Channel?

#### Orange
- Spot squeeze (ie. areal density increase not due to smaller spot size or improved format efficiency
- Less channel overhead
- Elimination of guard band on write, 19% of spot overwriting adjacent track, cancellation technology

#### Blue
- Optical factor: 0.91
- Track Squeeze factor: 1.00
- Bit Squeeze factor: 0.91
- Channel Eff factor: 1.00
- Format Eff factor: 1.00
- Disk Area Eff factor: 1.00
- Total factor: 0.91

#### Orange
- PRML channel & modulation, 6% loss in LD due to layers

#### Green
- Can not be scaled continually

#### Blue
- Optical factor: 5.32
- Track Squeeze factor: 5.17
- Bit Squeeze factor: 0.78
- Channel Eff factor: 1.33
- Format Eff factor: 0.98
- Disk Area Eff factor: 1.02
- Total factor: 5.36

#### Orange
- PRML channel & modulation, 6% loss in LD due to layers

#### Green
- Can not be scaled continually

#### Blue
- Optical factor: 1.33
- Track Squeeze factor: 1.02
- Bit Squeeze factor: 0.94
- Channel Eff factor: 1.41
- Format Eff factor: 1.00
- Disk Area Eff factor: 1.00
- Total factor: 1.50

#### Orange
- PRML channel & modulation, 6% loss in LD due to layers

#### Green
- Can not be scaled continually

#### Blue
- Optical factor: 1.67
- Track Squeeze factor: 1.42
- Bit Squeeze factor: 1.05
- Channel Eff factor: 1.67
- Format Eff factor: 1.67
- Disk Area Eff factor: 1.67
- Total factor: 1.67

#### Orange
- PRML channel & modulation, 6% loss in LD due to layers

#### Green
- Can not be scaled continually

#### Blue
- Optical factor: 2.00
- Track Squeeze factor: 1.00
- Bit Squeeze factor: 1.00
- Channel Eff factor: 1.00
- Format Eff factor: 1.00
- Disk Area Eff factor: 1.00
- Total factor: 2.00

#### Orange
- PRML channel & modulation, 6% loss in LD due to layers

#### Green
- Can not be scaled continually
Storage Technologies Areal Density Trends

Areal Density

- CD (1982)
- DVD
- HDD
- BluRay
- BluRay 3 layer 100GB
- Tape
- < 10% CAGR
- 33% CAGR

Proposed New Roadmap

2015 Tape Technology Demo

© Copyright IBM Corporation 2015
Market forces drive business models

- **High Vol mfg companies lead**
  - High growth, large investment, many players
  - Cost, Cost, Cost,…
  - Consolidation, transition to post-consumer driven design points

- **Technology companies lead**
  - New technology, Low vol, high margin, special use
  - Flash - IT

- **Volume**
  - High vol, low margin, consumer driven commodity
  - HDD
  - Optical
  - Tape

- **Mature technology, stable market & roadmap**
 Investing in the Future

Ed Childers
STSM, Manager Tape and LTFS
IBM Storage Development, Tucson, AZ

Excerpts from IBM EDGE  May 11-15, 2015
How do we capitalize on the technology?

• The Problem
  • (ie. where to aim)

• What’s Required?
  • (in what do we need invest?)

• What’s the return?
  • (it’s about $)
Session objectives

• The Problem
  ➢ Data use shift
    ➢ Data is an asset
      ➢ It needs to be accessible to have value
  ➢ Storage Market Transition / Disruption
    ➢ Traditional Scaling breaking down
      ➢ Consumer Volume Shifts

• What’s Required?

• The Bottom Line
Data was traditionally a tool of the business

Data = 🗬️

Utilize
Age Hold
Data Life Cycle
Create
Retire
Delete

Now, Data *is* the business

Data = 💸

Aggregate
Create Value
Data (re)Use Cycle
Ingest
Sell/Use
Reuse (Archive)
The Marketing Glossy Problem Statement

Demands on IT, Storage, and Shift to Cloud
Underneath, more to the point

Fundamentally – It’s a Storage Scaling Problem

The rate of data growth approx the same as:
- advances in HDD technology areal density
  (ie. double every 2 years = 40% CAGR)

The rate of data growth is greater than:
- advances in HDD technology areal density
  (No increases in IT spend to offset imbalance)
Session objectives

• The Problem

➤ What’s Required?
➤ Investments in:
  ✓ Tape Technology
  ✓ Tape Product Delivery
➤ Software Stack
➤ LTFS

• The Bottom Line
IBM Tape Investment Strategy

- **Tape Technology Pipeline - IBM Development & IBM Research**
  - Large research investment Zurich and Almaden laboratories
  - Technology demonstrations – 220 TB in 2015
    - Substantiates roadmap thru 2025
  - Drive technology value into Enterprise, leverage into LTO when industry is capable
- **TS1150 Enterprise Tape product line**
  - Reliability, Performance and Function differentiation
  - Enterprise media cartridge **with reuse**
  - Enterprise Automation compatible
- **LTO Midrange product line**
  - Open Tape Streaming product family
  - Full Automation Product support – 1U to HD Frames
  - TPC Consortium driven development/function
- **Software - LTFS**
  - IBM invented, open source, open standard
  - Provides file system support, integration of tape into Spectrum Scale

**Announcing Availability of LTO Gen 7**
Oct 6 2015
• **Timing-Based Servo and Surface control guiding**
  • TBS revolutionized tape track following with 10X precision of analog patterns
  • Surface control guiding reduces frequency of tape guiding transients for robust track following

• **Compact tape path with flat head geometry contour and flangeless rollers**
  • Flat head design reduces friction – head/media wear improved
  • Flangeless tape path eliminated edge contact with the tape – improved media life
  • This enables short tape path – reduced complexity, friction, and improved access

• **GMR head technology with protective overcoat**
  • 3X signal amplitude enabling track density and longer head life
  • TMR on way in future

• **Multi-level ECC with NPML(LTO) and DD-NPML(TS1140) channels**
  • Multi-level Reed-Solomon Error Correction codes with End-to-End CRC
  • Tape format interleaves data both vertically and longitudinally on the media
  • Advanced self-optimizing channel technology for maximum readback reliability
  • Full on-the-fly decryption/decompression

• **Barium Ferrite Tape Media Collaboration**
  • Collaboration with Fujifilm on media technology advancements
Breaking Down Storage Islands

Spectrum Storage – Unlocking Data, Enabling Lower Costs
Basic LTFS

![Image of LTFS interface]

<table>
<thead>
<tr>
<th>Name</th>
<th>Date modified</th>
<th>Type</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>3_8_inch_chip</td>
<td>11/9/2010 2:09 PM</td>
<td>JPEG image</td>
<td>34 KB</td>
</tr>
<tr>
<td>DM_IBM_S360</td>
<td>11/9/2010 2:09 PM</td>
<td>JPEG image</td>
<td>3,154 KB</td>
</tr>
<tr>
<td>IBM_29_Punch</td>
<td>11/9/2010 2:09 PM</td>
<td>JPEG image</td>
<td>45 KB</td>
</tr>
<tr>
<td>IBM_1800</td>
<td>11/9/2010 2:09 PM</td>
<td>JPEG image</td>
<td>32 KB</td>
</tr>
<tr>
<td>IBM_PC_5150</td>
<td>11/9/2010 2:09 PM</td>
<td>JPEG image</td>
<td>315 KB</td>
</tr>
<tr>
<td>IBM_Series_1</td>
<td>11/9/2010 2:09 PM</td>
<td>JPEG image</td>
<td>32 KB</td>
</tr>
<tr>
<td>IBM_System3</td>
<td>11/9/2010 2:09 PM</td>
<td>JPEG image</td>
<td>3,336 KB</td>
</tr>
<tr>
<td>IBM360-65-1.corestore</td>
<td>11/9/2010 2:09 PM</td>
<td>JPEG image</td>
<td>942 KB</td>
</tr>
<tr>
<td>SAGE</td>
<td>11/9/2010 2:09 PM</td>
<td>JPEG image</td>
<td>35 KB</td>
</tr>
<tr>
<td>StretchConsole</td>
<td>11/9/2010 2:09 PM</td>
<td>JPEG image</td>
<td>47 KB</td>
</tr>
<tr>
<td>System_360</td>
<td>11/9/2010 2:09 PM</td>
<td>JPEG image</td>
<td>28 KB</td>
</tr>
</tbody>
</table>
Spectrum Archive Tiered Operational Storage

File Storage Tiers

- LTFS Pool 1
  - One.txt
  - Memo.txt
  - Video1.mpg
  - Inv02.txt
  - Memo.txt

- LTFS Pool 2
  - Repair.mp
  - Video1.mpg
  - Movie1.mpg

File Namespace

- C:/user defined namespace
  - Move files older than X
  - Move files named *.mpg
  - Never move files named *.db2
  - Move files opened for modification

- G:/
  - Subdir 1
    - One.txt
    - Video1.mpg
    - Database.db2
  - Dept0A
    - Memo.txt
    - Movie1.mpg
    - Manuf
    - Inv02.txt
    - Repair.mp
    - Sales.db2
Session objectives

➤ The Problem

➤ Why Spectrum Archive?
➤ Breaking Down Storage Islands

➤ The Bottom Line
➤ Lower costs for cold data while maintaining access
Tape & HDD side by side
Setting up the comparison

<table>
<thead>
<tr>
<th>Component</th>
<th>$/TB (raw)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardware</td>
<td>$/TB (raw)</td>
</tr>
<tr>
<td>System</td>
<td>$/TB/mo (raw)</td>
</tr>
<tr>
<td>Solution</td>
<td>$/TB/mo (user)</td>
</tr>
</tbody>
</table>

LTFS

© Copyright IBM Corporation 2015
## 20PB Static Archive

### Component Hardware (raw)

<table>
<thead>
<tr>
<th>Component</th>
<th>LTFS</th>
<th>HDD</th>
</tr>
</thead>
<tbody>
<tr>
<td>$/TB</td>
<td>14.00</td>
<td>39.17</td>
</tr>
<tr>
<td>$/TB</td>
<td>21.26</td>
<td>63.95</td>
</tr>
</tbody>
</table>

### System Hardware (raw)

- 7 frame TS4500
- 24 drive, 8K carts

- LTFS HDD
  - 3 years $/TB/mo: 0.71
  - 5 years $/TB/mo: 0.48
  - 8 years $/TB/mo: 0.35

- LTFS
  - 3 years $/TB/mo: 14.00
  - 5 years $/TB/mo: 21.26

- LTFS $/TB: 284 TB/sq ft

### Solution Hardware (user)

- LTFS
  - 3 years $/TB/mo: 1.79
  - 5 years $/TB/mo: 1.23
  - 8 years $/TB/mo: 0.91

- Glacier
  - 3 years $/TB/mo: 10.00
  - 5 years $/TB/mo: 10.00
  - 8 years $/TB/mo: 10.00

- HDD
  - 3 years $/TB/mo: 8.29
  - 5 years $/TB/mo: 6.13
  - 8 years $/TB/mo: NA

- LTFS + $2600/mo admin/maint

### Summary

- 2.5TB LTO 6 @ $35
- 6TB HDD @ $235

- LTFS Glacier HDD
  - 3 years $/TB/mo 1.79 10.00 8.29
  - 5 years $/TB/mo 1.23 10.00 6.13
  - 8 years $/TB/mo 0.91 10.00 NA

- Backblaze like pods

- Storage Only – no R/W
- No connectivity $
### 20PB Static Archive – Looking Forward

<table>
<thead>
<tr>
<th>Component</th>
<th>LTFS 5.83</th>
<th>HDD 19.58</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardware (raw)</td>
<td>LTFS 10.11</td>
<td>HDD 32.00</td>
</tr>
<tr>
<td></td>
<td>4 frame TS4500 24 drive, 8K carts</td>
<td>37 45 12TB Backblaze like pods</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>System (raw)</th>
<th>LTFS 0.34</th>
<th>HDD 1.38</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LTFS 0.22</td>
<td>HDD 1.01</td>
</tr>
<tr>
<td></td>
<td>LTFS 0.16</td>
<td>HDD NA</td>
</tr>
<tr>
<td></td>
<td>660 TB/sq ft</td>
<td>221TB/sq ft</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Solution (user)</th>
<th>LTFS 0.92</th>
<th>Glacier 10.00</th>
<th>HDD 4.13</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LTFS 0.63</td>
<td>Glacier 10.00</td>
<td>HDD 3.03</td>
</tr>
<tr>
<td></td>
<td>LTFS 0.47</td>
<td>Glacier 10.00</td>
<td>HDD NA</td>
</tr>
</tbody>
</table>

- LTFS $/TB @ 2x redundancy
- Glacier $/TB @ 3x redundancy
- $2600/mo admin/maint

**Additional Costs:**
- $0.14/KWH
- $200/sq ft/yr
- SWIFT $/TB $0.14 @ 2x redundancy

Storage Only – no R/W
No connectivity $
Summary:

- The era of big data is creating demand for cost effective storage solutions

- Tape remains the most cost-efficient and greenest technology for archival storage and active archive applications

- Tape has a sustainable roadmap for at least another decade
  - 123 Gbit/in² areal density demo shows feasibility of multiple future tape generations
  - Potential exists for the continued of scaling of tape beyond 123 Gbit/in²

- The cost advantage of tape over HDD and optical disk will continue to grow