Current and Emerging Storage Technologies
iCAS2013
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Tape Systems
Program Agenda

- Data Challenges
- Data Storage technology trends
- Disk technology trends
- Tape technology trends
The following is intended to outline our general product direction. It is intended for information purposes only, and may not be incorporated into any contract. It is not a commitment to deliver any material, code, or functionality, and should not be relied upon in making purchasing decisions. The development, release, and timing of any features or functionality described for Oracle’s products remains at the sole discretion of Oracle.
**Data Growth and Access Requirements**

The nature of storage and data management has to change

- **300x** Growth from 2005 to 2020
- **80%** of data is never used after 90 days.

Economics of Tiered Storage
Tape is the Foundation: Most of the Data Stored at the Lowest Cost

- Single Tier of Disk Storage: 100%
  - Average: ~$7.5M / PB

- Disk Multi-tiered Storage: 80%
  - Average: ~$3.5M / PB

- Modern Multi-tiered Storage: 80%
  - 5% Performance Disk: $5 - $10/GB
  - 15% Capacity Disk: $1 - $4/GB
  - Tape Storage: < $0.15/GB

Horison Information Strategies: The Era of Colossal Content Arrives Aug 2012
Archive Technology Cost Analysis

NEW Study Concludes Disk Costs 26 Times More Than Tape Solution


Study compares a 1 PB archive growing at 45% annually for 9 years on disk and tape. Assumes 1:1 compression.
Digital Archive Market Driving Tape Growth

Majority of Data is Stored on Tape

- Storage for archive and retention is a $3B Market growing to over $7B in 2017
  - Archive is distinct from primary or backup use case
  - Tape is established as primary storage tier for long-term retention

StorageTek Storage Archive Manager

Applications

Standard POSIX File System API

SAM-QFS

Primary Disk

Capacity Disk

Tape Archive

Off site
Storage Trends
Tape gets its capacity by having 1000X the recording surface area comparing a 1/2 inch cartridge to a 3 1/2 inch disk.
DNA Storage Demo

- 2.2 PB per gram
  - ~100,000 Gb/inch² equivalent areal density, see reference²
  - ~100 times more areal density than disk
- $12,400/MB
  - ~400,000,000 times more cost than tape
- “Two weeks to reconstruct their five files, although with better equipment it could be done in a day”
  - ~0.6 Bytes/sec data rate based on 739 KB stored in demo
  - ~400,000,000 times slower than tape
- Longevity could be an issue³

2. [http://uw.physics.wisc.edu/~himpsel/memory.html](http://uw.physics.wisc.edu/~himpsel/memory.html)
Tape gets its capacity by having 1000X the recording surface area comparing a 1/2 inch cartridge to a 3 1/2 inch disk.

Chart courtesy of INSIC
Tape & Disk Data Storage Price Trends

Technology Price per GB History & Predictions

- Disk
- Tape
Disk Drive Price Trends

Magnetic Recording Definitions

Tracks per inch (tpi) = (Track Pitch)$^{-1}$
Bits per inch (bpi) = (Bit Length)$^{-1}$
Areal density = (Tracks per inch) X (Bits per inch)
Bit aspect ratio (BAR) = (Track width) / (Bit length):1

Longitudinal recording

Track Pitch = Track Width + distance between neighboring tracks

Perpendicular recording

Soft magnetic under-layer

Recording Head

Media

Track Width

Bit length

N

S

N

N

S

S

N

N

S

S

N

N

S

S

N

S

N

S

N
Written Data Tracks on Tape (T10KC)

- Track width
- Direction of tape motion
- MFM image
- Data bit
Data Bit Size Comparison

- **Tape future 128 TB** Bit aspect ratio 18:1
- **T10KD 8.5 TB** Bit aspect ratio 41:1
- **T10KC 5.5 TB** Bit aspect ratio 43:1
- **Disk Patterned Media future 1Tb/inch²** Bit aspect ratio 1:1
- **Disk 500Gb/inch²** Bit aspect ratio 5:1
- **NAND 250 Gb/inch² 50nm X 50nm**

1. From INSIC roadmap 2020

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A Closer Look at the Magnetic Layer (grains or particles)
Super-Paramagnetic Effect

Neel-Arrhenius law gives: Mean time to randomly flip grain due to thermal fluctuations

\[ \tau_N = \tau_0 \exp \left( \frac{KV}{k_BT} \right) \]

V is the volume of the grain, T is the temperature and K is the grain’s magnetic anisotropy energy

\[ \frac{KV}{k_BT} > 60 \text{ for good thermal stability, 10 year data life}^{1,2} \]

\[ \frac{KV}{k_BT} > 90 \text{ for today's tape}^{3}, \text{ 30 year data life} \]

Disk Storage
Disk Magnetic Recording Tri-Lemma Review

- Smaller bits => Smaller grains for required SNR
- Smaller grains => Higher $H_c$ for thermal stability
- Higher $H_c$ => Can not write on the media

1. $H_c$ is the media Coercivity, which is the strength of the magnetic field required to flip the magnetization in the media
Technologies Likely to be Introduced

- Helium Drives (2013, WD) \(^1\)
  - 40% capacity increase 4 platters -> 6 or 7 platters
- Shingled Drives (2013, WD, Seagate) \(^1\)
  - 20-25% areal density increase
- Heat Assisted Drives (2014, Seagate) \(^1\)
  - 60% areal density increase
- Bit Patterned Media (end of the decade, WD) \(^2\)
  - 100% areal density increase

\(^1\) [http://www.theregister.co.uk/2013/02/12/seagate_hamr/
\(^2\) [http://www.hgst.com/press-room/2013/hgst-reaches-10-nanometer-patterned-bit-milestone-
anotechnology-process-will-double-todays-disk-drive-data-density]
Bit Patterned Media Concept

Single domain bits are patterned on the media, so there is one large grain and a single magnetic domain per bit.
Laser heats media reducing media $H_c$ so head magnetic field can write media

**HAMR Concept**
Wide tracks are partially overwritten to get narrower tracks.
Disk Drive Manufacturers Family Tree

IBM
Hitachi
Western Digital
Quantum
Maxtor
Seagate
Conner
Samsung
Toshiba
Fujitsu
Micropol
HP


2003
2011
1996
2000
2006
2009
1997
1996
1995
2011
Tape Storage Trends
Technology Marches Forward

10 TB Example Over 15 Years

1996
- 6000 carts
- Timberline 9490 – 1.6 GB
- 357 sq ft
- 8200 lbs

2011
- 2 carts
- T10000C – 5.0 TB
- 0.3 sq ft
- 1.2 lbs

It is good to upgrade technology
INSIC 2012 Tape Roadmap

• Generated every 3-4 years
• Roadmap Developed by Consensus
• 2012 Roadmap
  • Technical section lead by Bob Raymond
  • 16 Industry Companies
  • 8 Research Universities
  • Total of 75 participants
• Published in 2012
  • www.insic.org
The Ultimate Archive Media

StorageTek T10000 T2 Media is Formulated using Barium Ferrite magnetic particles and Aramid substrate

- BaFe has been shown to have superior life for long term applications
- 30 year accelerated tests show no change in magnetic data retention compared to current MP media¹

Hardware and Software

Oracle

Engineered to Work Together