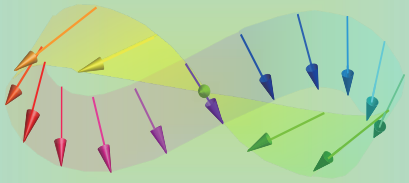
Information Storage and Spintronics 03



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Department of Electronic Engineering

THE UNIVERSITY of York

14:00 Monday, 10/October/2022 (SLB 101)

Quick Review over the Last Lecture

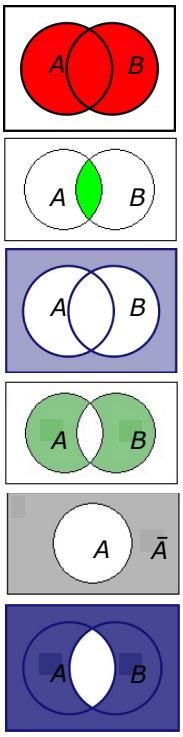
Logical conjunctions :

- AND
- OR
- NOT
- NAND
- NOR
- XOR

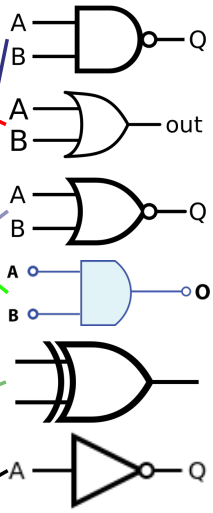
Notations :

- $\bar{A}$
- $A \downarrow B$
- $A \uparrow B$
- $A \wedge B$
- $A \oplus B$
- $A \vee B$

Venn diagrams :



Logic circuits :



You can also use the other notations :

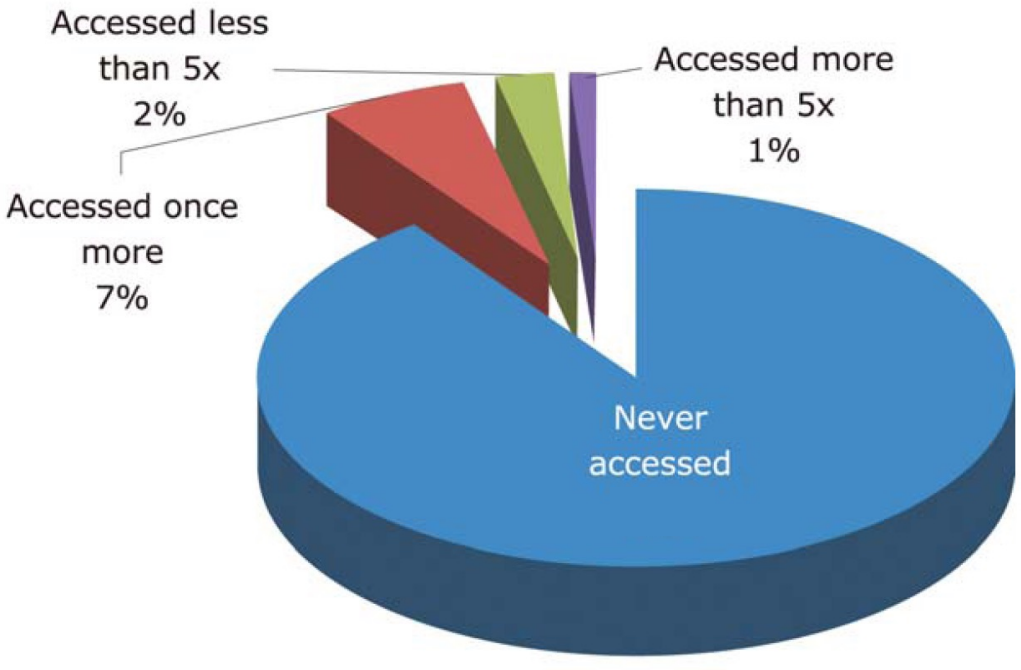
- AND : A·B, A&B
- OR : A+B, A//B

03 Magnetic Tape Storage

- Advantages
- Development
- Linear recording
- Helical recording
- 1 / 2 reel
- Linear tape open

Access Patterns to a Hard Disk Drive

Research on access patterns on network attached storages (NAS) : *

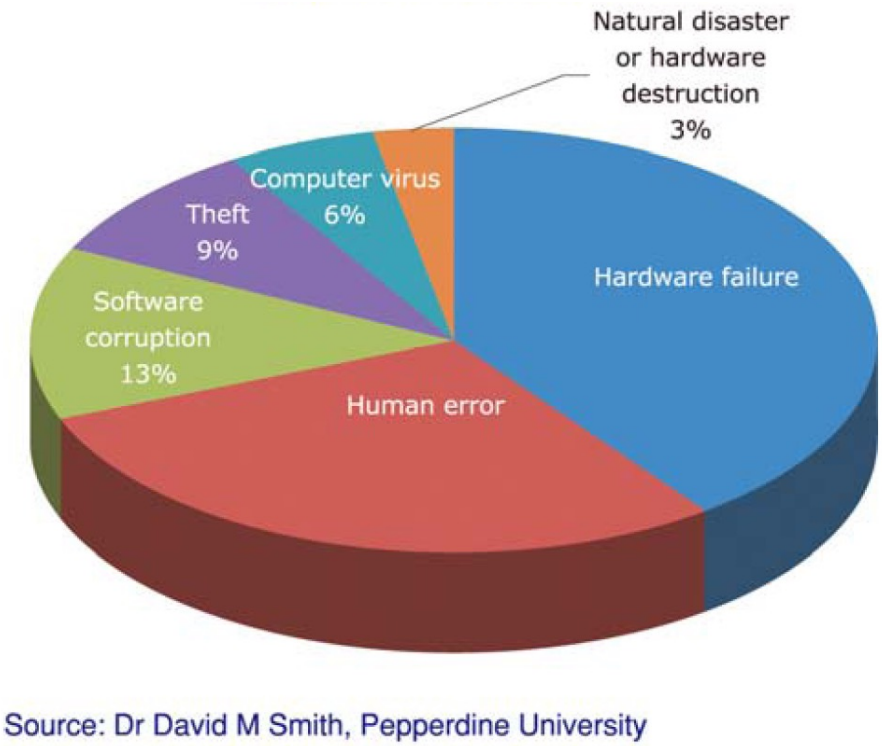


Source: University of Califomia, Santa Cruz

* http://www.oracle.com/

Origins of Data Loss

Information storage is required : *



Source: Dr David M Smith, Pepperdine University

* http://www.oracle.com/

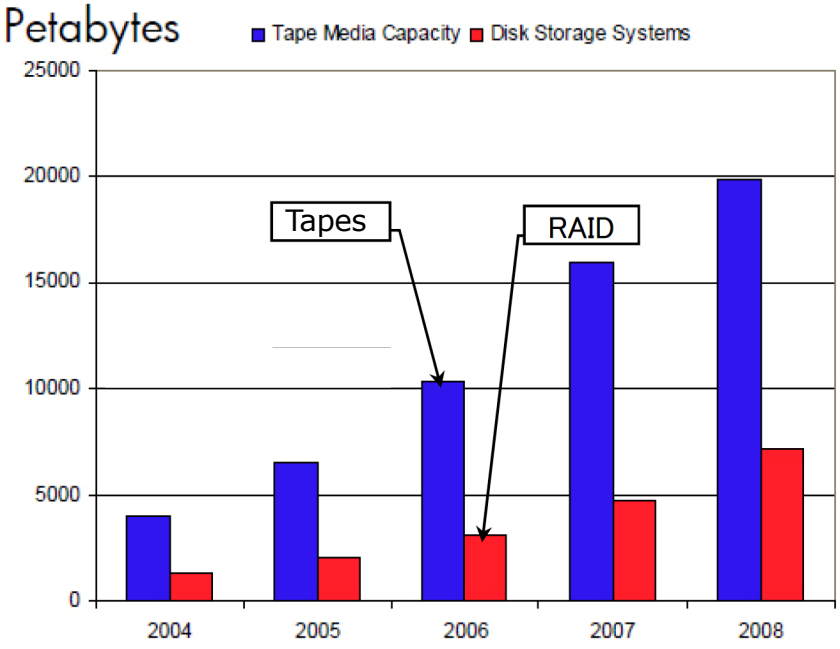
Why Tape Storage ?

Magnetic tape media : *

-times-more data are stored as compared with a hard disk drives (HDD).

Almost EB data are stored in tape media

→ Almost tapes !



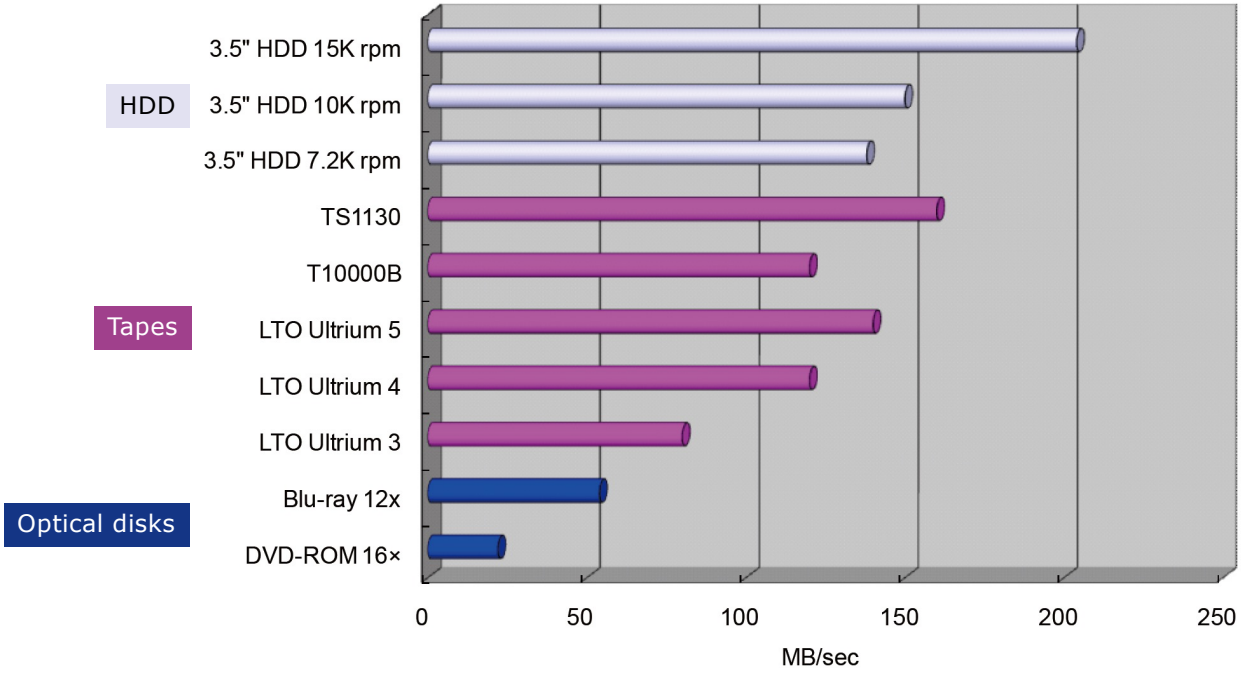
* http://home.jeita.or.jp/

Data Transfer Speed

Magnetic tape media : *

Without compression, MB / sec. (GB / h).

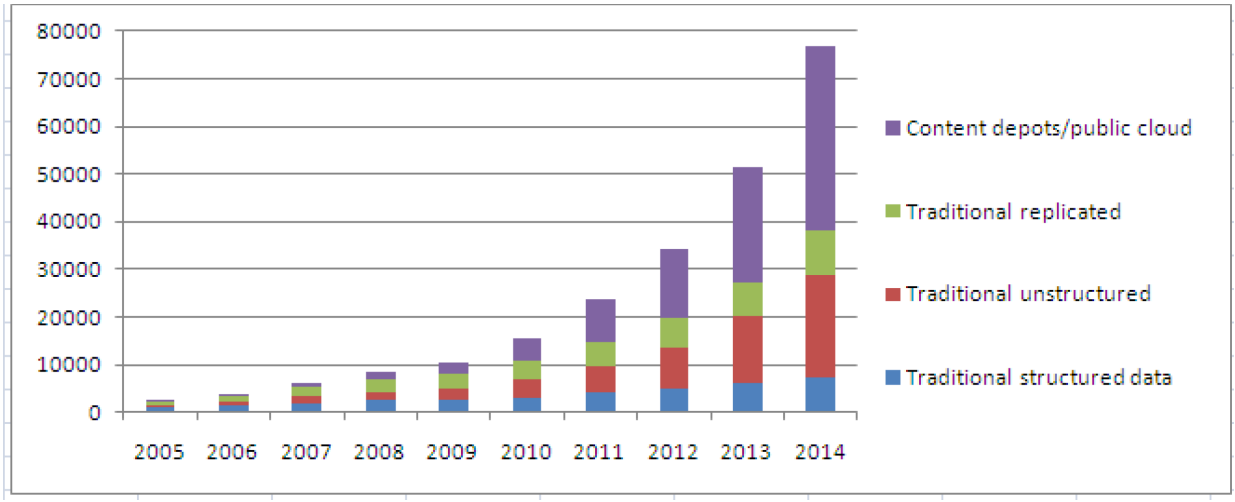
Almost comparable with a HDD



* http://home.jeita.or.jp/

Where are Magnetic Storages Used ?

World-wide enterprise disk storage consumption : *



* http://home.jeita.or.jp/

Energy Consumption

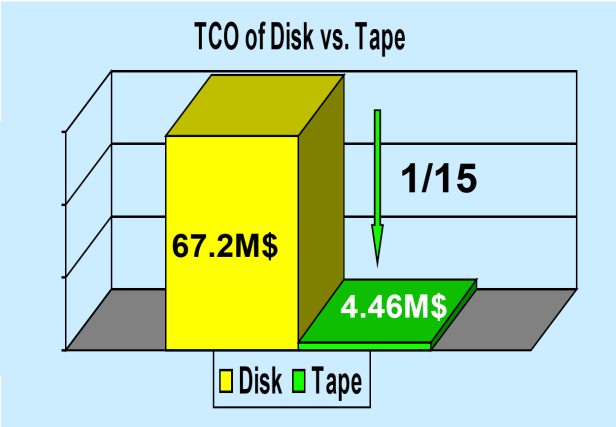
Energy costs : *

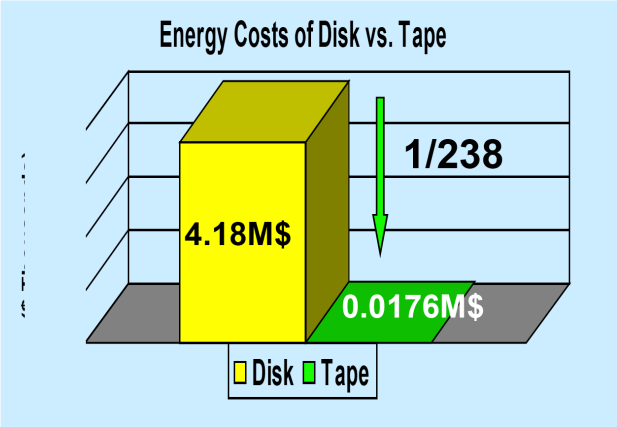
Tape media : LTO-5 without compression

Initial 3 PB data + 45 % annual increase for 12 years

→ Total cost of ownership (TCO) : 1/ of HDD

→ Energy cost : 1/ of HDD





* http://home.jeita.or.jp/

First Magnetic Tape Drive

In 1951, Remington Rand introduced the first tape drive for a computer : *

UNIVAC (Universal automatic computer) I uses a tape drive, UNISERVO.

- ½-inch wide tape
- Nickel-plated phosphor bronze (Vicalloy)
- 1,200 feet long
- 8 channels (for data, for parity and for timing)
- inch / sec. (= characters / sec.)

* http://www.wikipedia.org/

Fabrication of Magnetic Tape

* https://www.youtube.com/watch?v=FeKxC8pLTbI

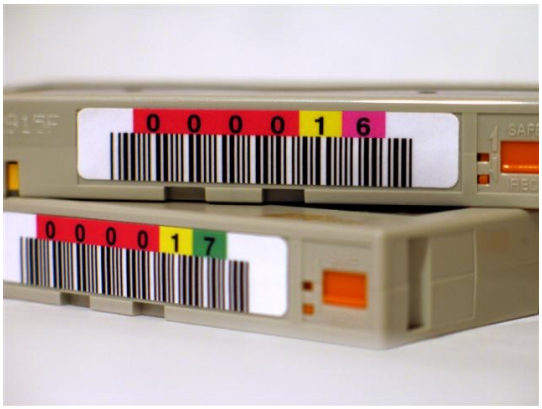
Advanced Intelligent Tape

In 1996, Sony introduced Advanced Intelligent Tape (AIT) : *

- 8-mm wide tape
- 25 ~ 800 GB (without compression)
- MB / sec. (without compression)
- Memory in cassette (MIC) : 64-kbit
  Electrically erasable programmable read-only memory (EEPROM) stores usage history and data address.

  → Fast operation
- Adaptive lossless data compression (ALDC) :
  Data compression ~ 1/2.6.

  → High recording density



* http://www.wikipedia.org/

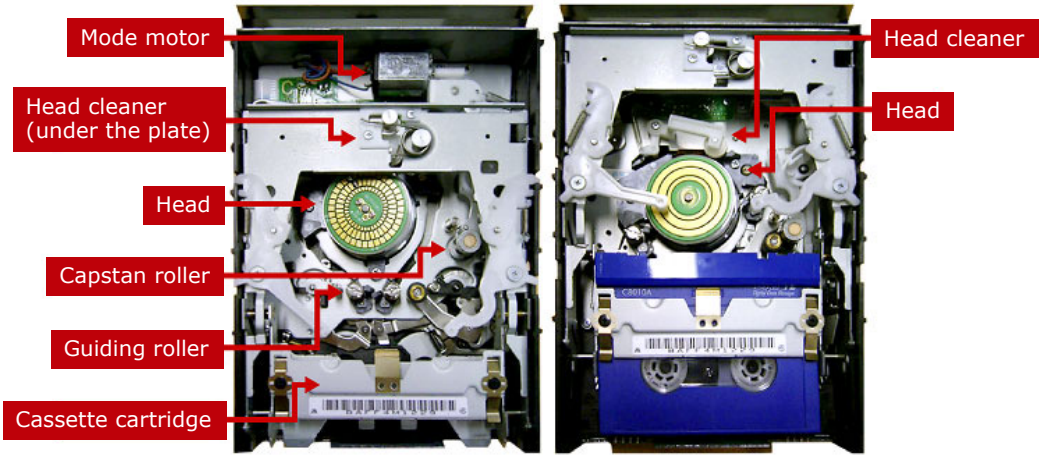
Digital Data Storage

In 1987, Sony introduced Digital Audio Tape (DAT) : *

Digital Data Storage (DDS) was then developed in 1989.

- 0.15-inch (3.81-mm) or 8-mm wide tape
- 60 ~ 170 m long
- 2 write heads at 6° angle with 9,000 rpm
- ~ mm / sec. (MB / sec.)

- > 17M units shipped
- ~ 50 % in magnetic tape storage

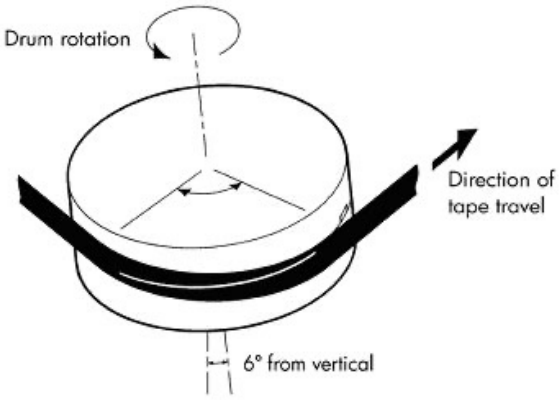


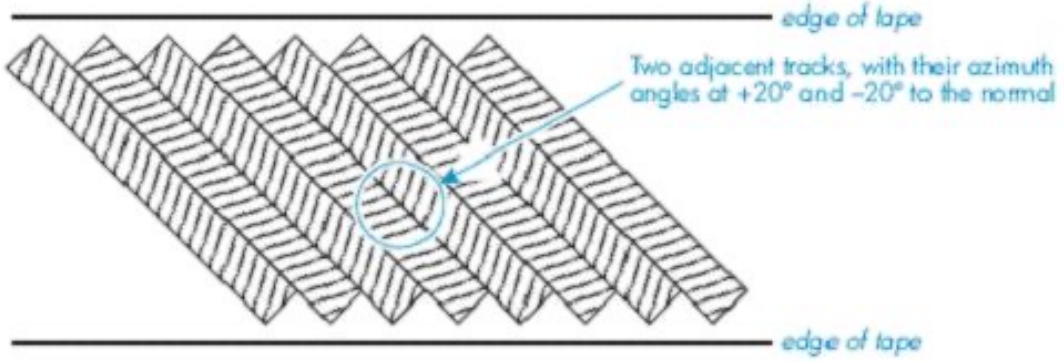
* http://www.itmedia.co.jp/enterprise/articles/0607/13/news034.html

Minimisation of Bit Errors

2 read / write heads : *

Two adjacent tracks with their azimuth angle at ± 20°

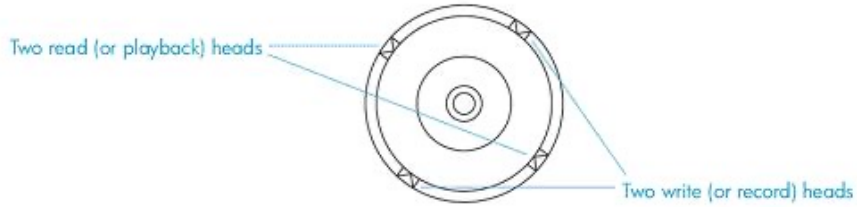


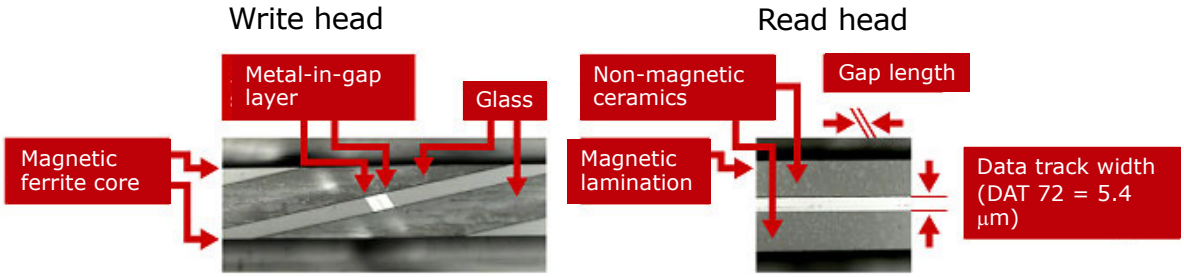


* http://www.itmedia.co.jp/enterprise/articles/0607/13/news034.html

Head Configuration

2 pairs of read / write heads : *



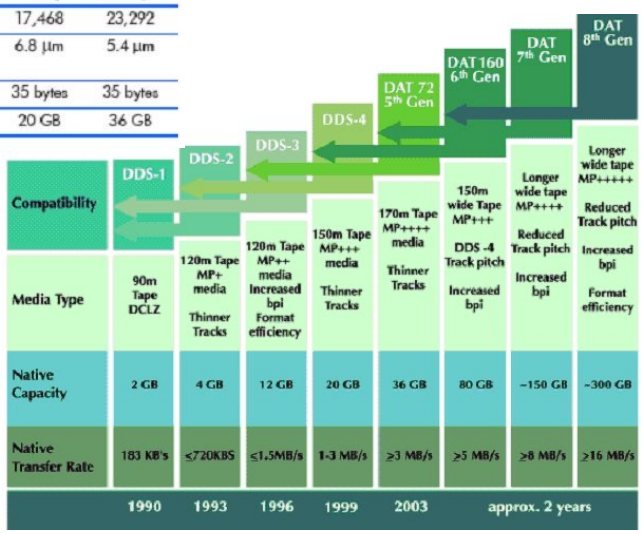


* http://www.itmedia.co.jp/enterprise/articles/0607/13/news034.html

Development of a DDS

Capacity doubles every 3 year : *

	DDS-1 (60m)	DDS-1 (90m)	DDS-2	DDS-3	DDS-4	DAT 72
Tape Width	3.81 mm	3.81 mm	3.81 mm	3.81 mm	3.81 mm	3.81 mm
Tape Length	60m	90m	120m	125m	150m	170m
Tape Thickness	14 µm	9 µm	6.5 µm	6.5 µm	5.6 µm	5.5 µm max.
Coating	MP	MP	MP+	MP++	MP+++	MP4+
Recording Density *(flux transitions per mm)*	3000 ft/mm	3000 ft/mm	3000 ft/mm	6000 ft/mm	6000 ft/mm	8000 ft/mm
Linear Density	2.4 Kb/mm	2.4 Kb/mm	2.4 Kb/mm	4.8 Kb/mm	4.8 Kb/mm	6.4 Kb/mm
Bit Length *(nominal)*	0.3333 µm	0.3333 µm	0.3333 µm	0.1666 µm	0.1666 µm	0.125 µm
Data Bytes per frame	5,756	5,756	5,756	17,468	17,468	23,292
Track Width or Pitch *(measured)*	13.6 µm	13.6 µm	9.1 µm	9.1 µm	6.8 µm	5.4 µm
Group Information Table size	32 bytes	32 bytes	32 bytes	35 bytes	35 bytes	35 bytes
Tape Capacity *(native)*	1.3 GB	2 GB	4 GB	12 GB	20 GB	36 GB



* http://www.itmedia.co.jp/enterprise/articles/0607/13/news034.html

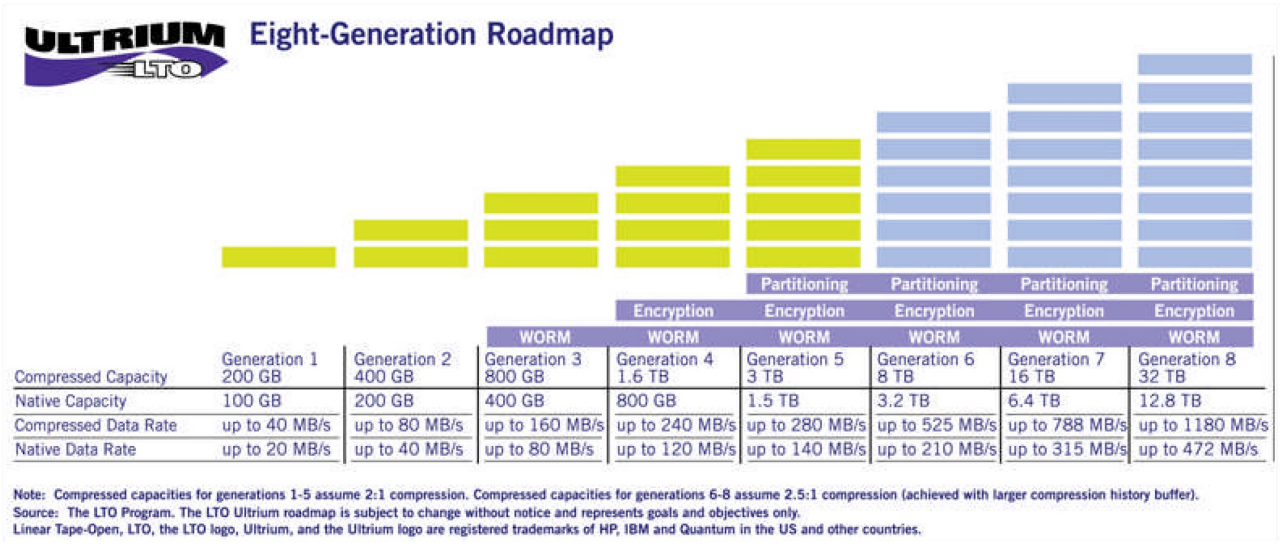
Linear Tape Open

In 2000, IBM, HP and Seagate introduced Linear Tape Open (LTO) : *

- Based on research at IBM Tucson Laboratory
- DLT and AIT have dominated the market.
- Accelis :
  - 8-mm wide tape
  - 2 reels
  - High access speed
  - Resembles Sony AIT
- Ultrium :
  - ½-inch wide tape
  - 1 reels and linear scan
  - Large storage capacity
  - Resembles Quantum DLT
  - 100 GB capacity (without compression)
  - MB / sec.

* http://www.wikipedia.org/

LTO Ultrium Roadmap



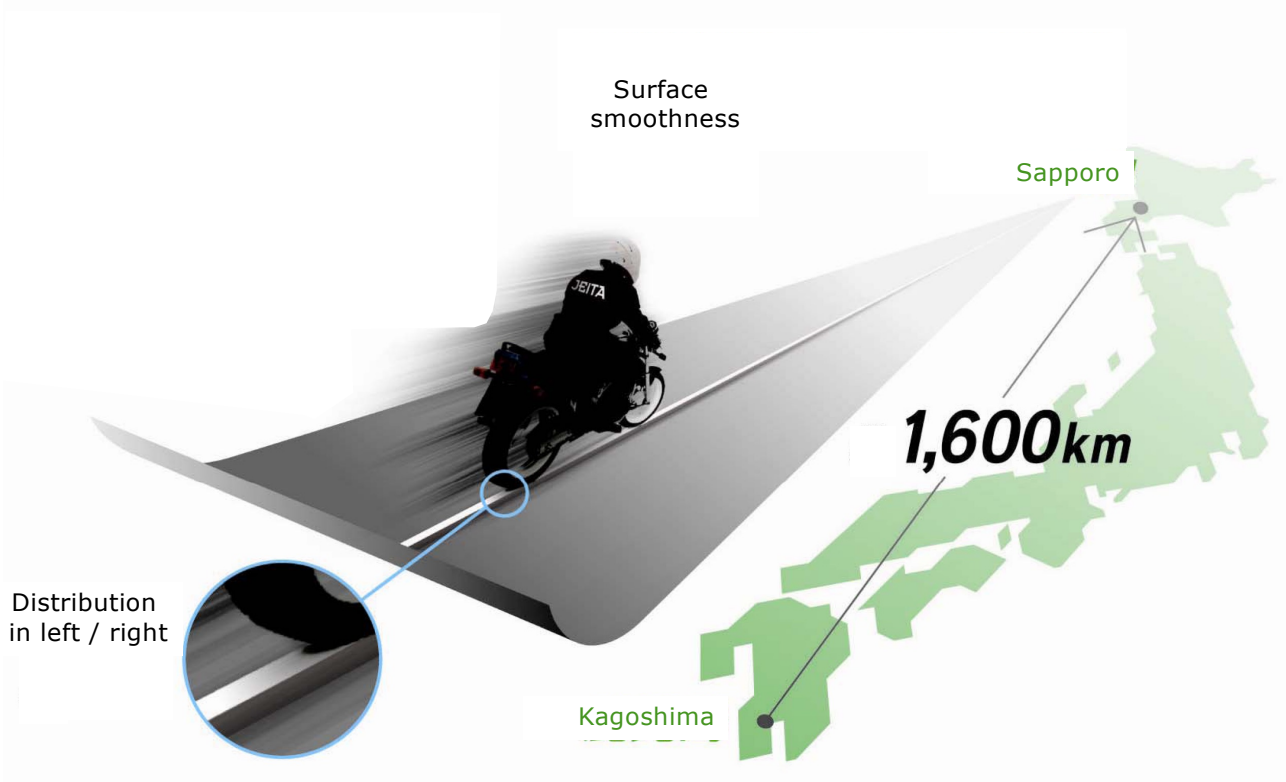
Compressed Capacity	Generation 1 200 GB	Generation 2 400 GB	Generation 3 800 GB	Generation 4 1.6 TB	Generation 5 3 TB	Generation 6 8 TB	Generation 7 16 TB	Generation 8 32 TB
Native Capacity	100 GB	200 GB	400 GB	800 GB	1.5 TB	3.2 TB	6.4 TB	12.8 TB
Compressed Data Rate	up to 40 MB/s	up to 80 MB/s	up to 160 MB/s	up to 240 MB/s	up to 280 MB/s	up to 525 MB/s	up to 788 MB/s	up to 1180 MB/s
Native Data Rate	up to 20 MB/s	up to 40 MB/s	up to 80 MB/s	up to 120 MB/s	up to 140 MB/s	up to 210 MB/s	up to 315 MB/s	up to 472 MB/s

Note: Compressed capacities for generations 1-5 assume 2:1 compression. Compressed capacities for generations 6-8 assume 2.5:1 compression (achieved with larger compression history buffer).
Source: The LTO Program. The LTO Ultrium roadmap is subject to change without notice and represents goals and objectives only.

* http://www.ultrium.com/

Precise Positioning

Data subsets are repeatedly stored in various tracks : *

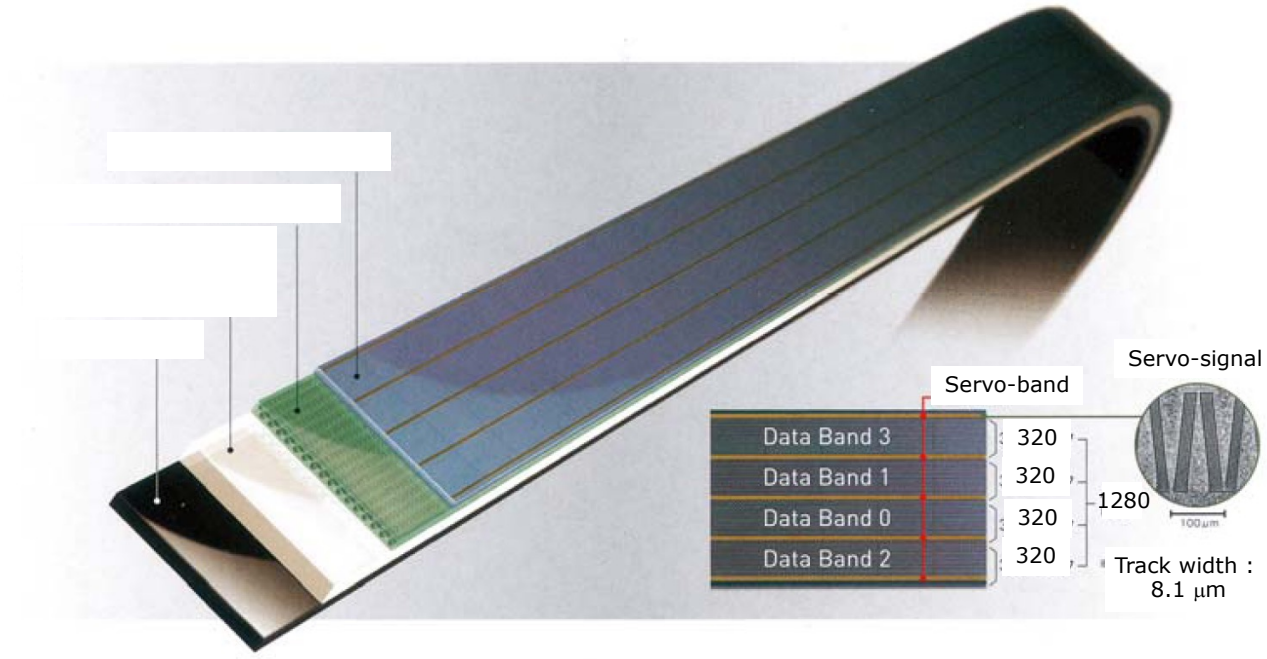


* http://home.jeita.or.jp/

LTO Tape Media

Track width of LTO tape media : *

- 12.65 mm wide tape / tracks
- Track width : μm



* http://home.jeita.or.jp/

Recent Development

In order to store 10 TB data : *

It is good to upgrade technology!

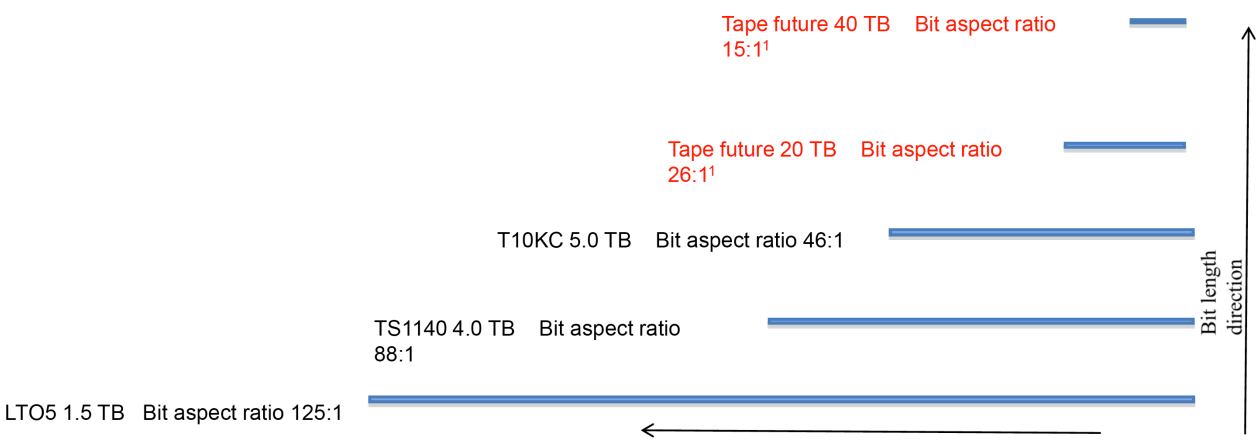
1996
- 6000 carts
- Timberline 9490 – 1.6 GB
- 357 sq ft
- 8200 lbs

2011

* http://www.oracle.com/

Bit Size Roadmap

Data subsets are repeatedly stored in various tracks : *



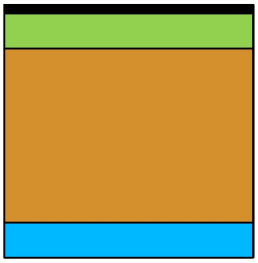
1. Extrapolated from INSIC roadmap

* http://www.oracle.com/

New Media

Smaller grain sizes required for better signal-to-noise ratios (SNR) : *

- Barium ferrites ($BaFe_{12}O_{19}$)
  - Hexagonal platelet
  - Naturally stable oxide (no corrosion)

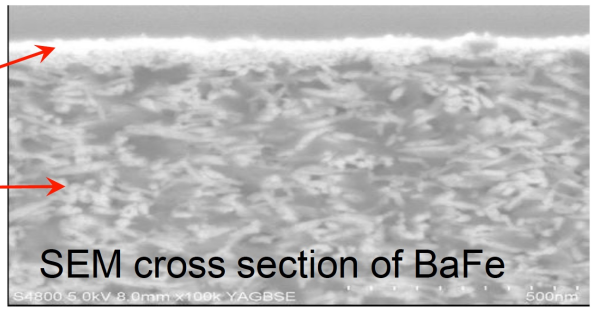


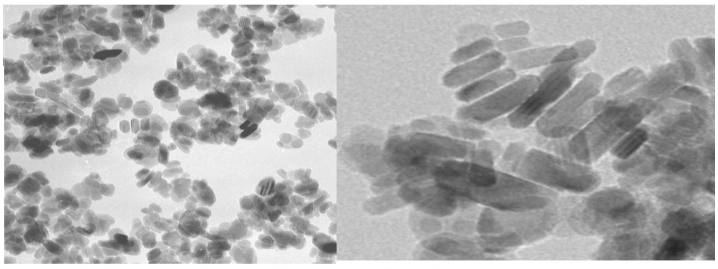
Magnetic layer (MP or BaFe)

Underlayer (non-magnetic)

Basefilm/Substrate (PEN, PET, or Aramid)

Backcoat

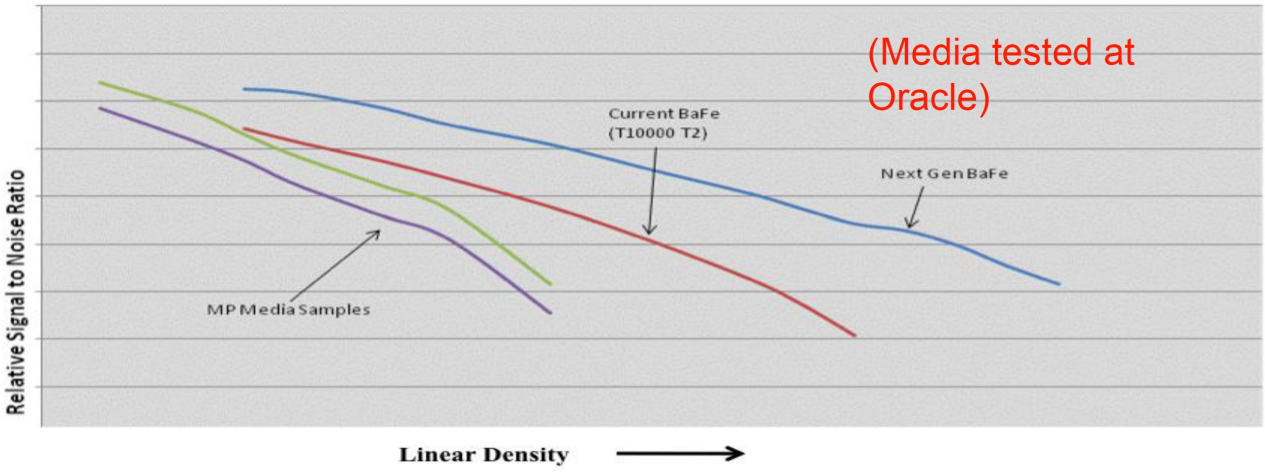




* http://www.oracle.com/

New $BaFe_{12}O_{19}$

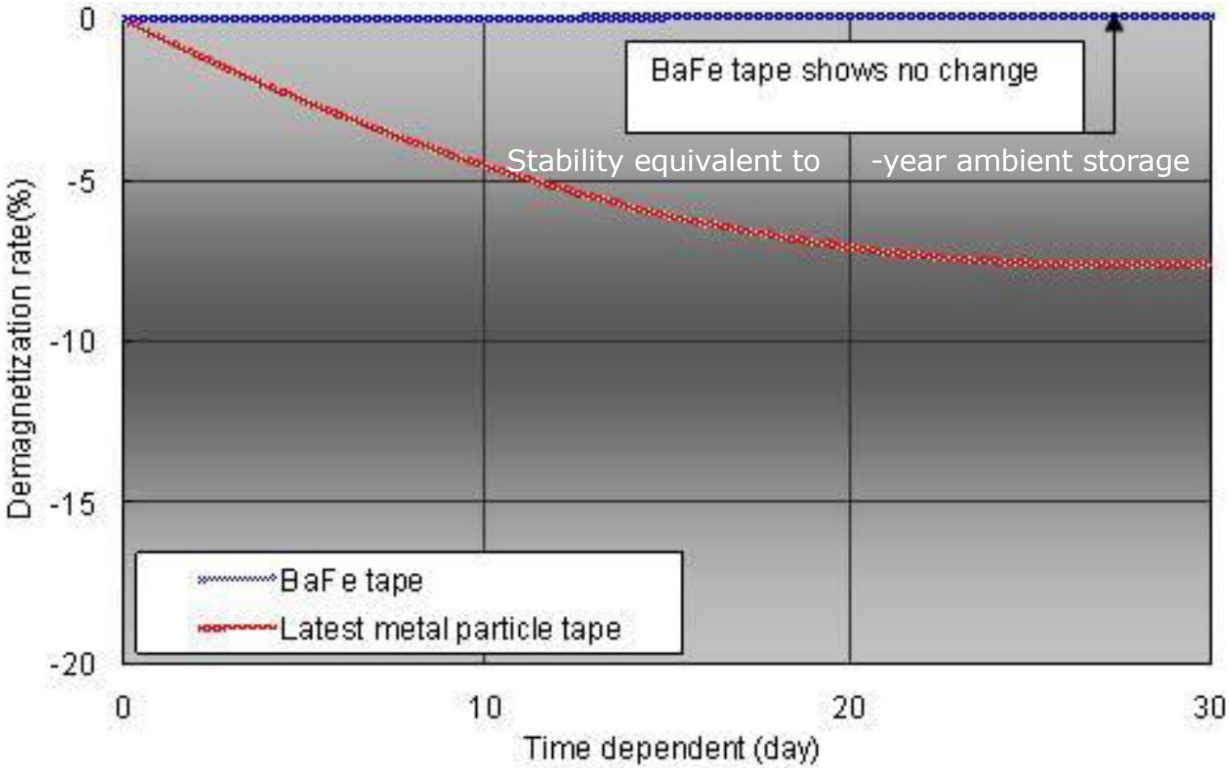
New tape media is under development : *



* http://www.oracle.com/

Magnetic Degradation

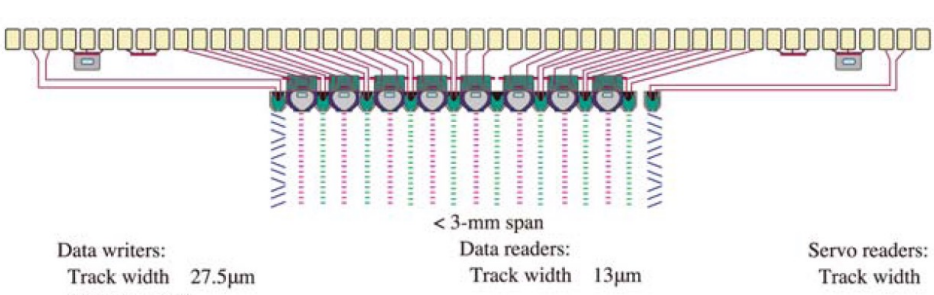
Measuring changes in demagnetisation : *

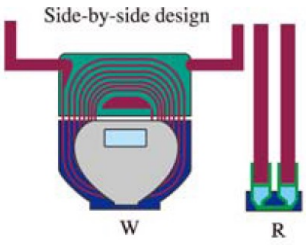


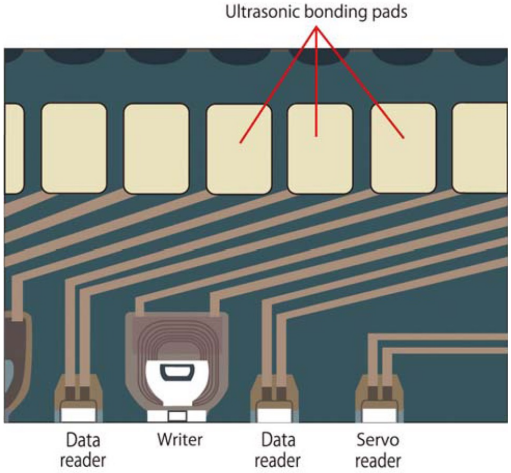
* http://www.fujifilm.com/news/n100910.html

Head Design

Miniaturisation of the head components : *



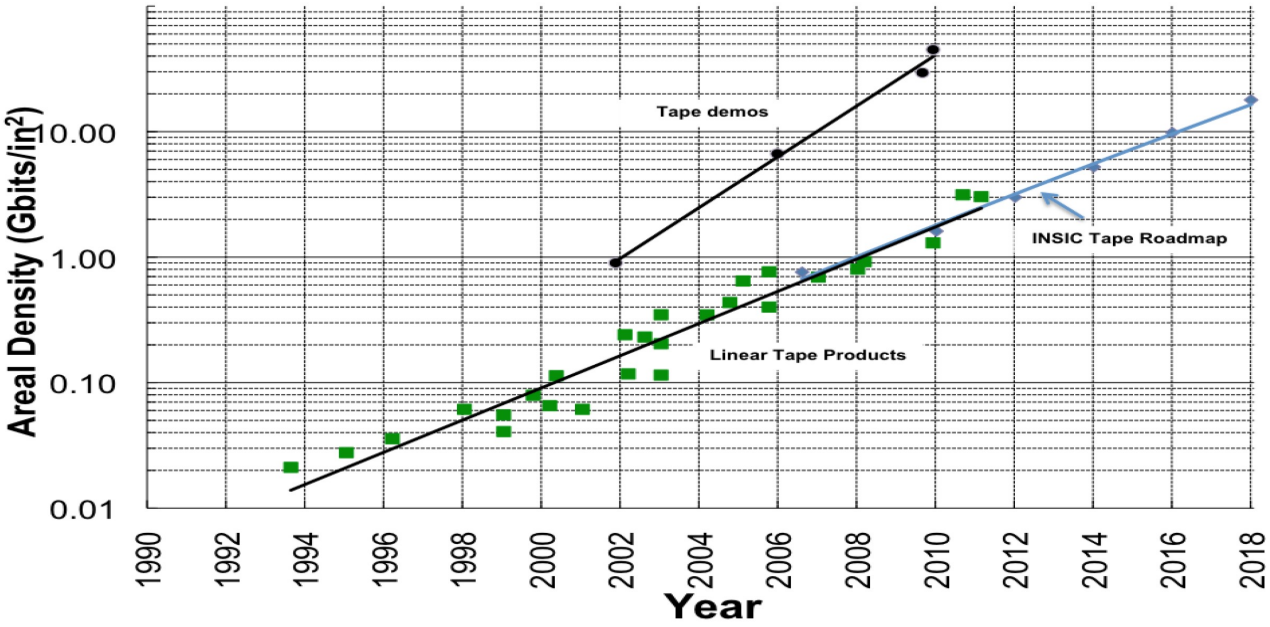




* http://home.jeita.or.jp/

Areal Density Roadmap

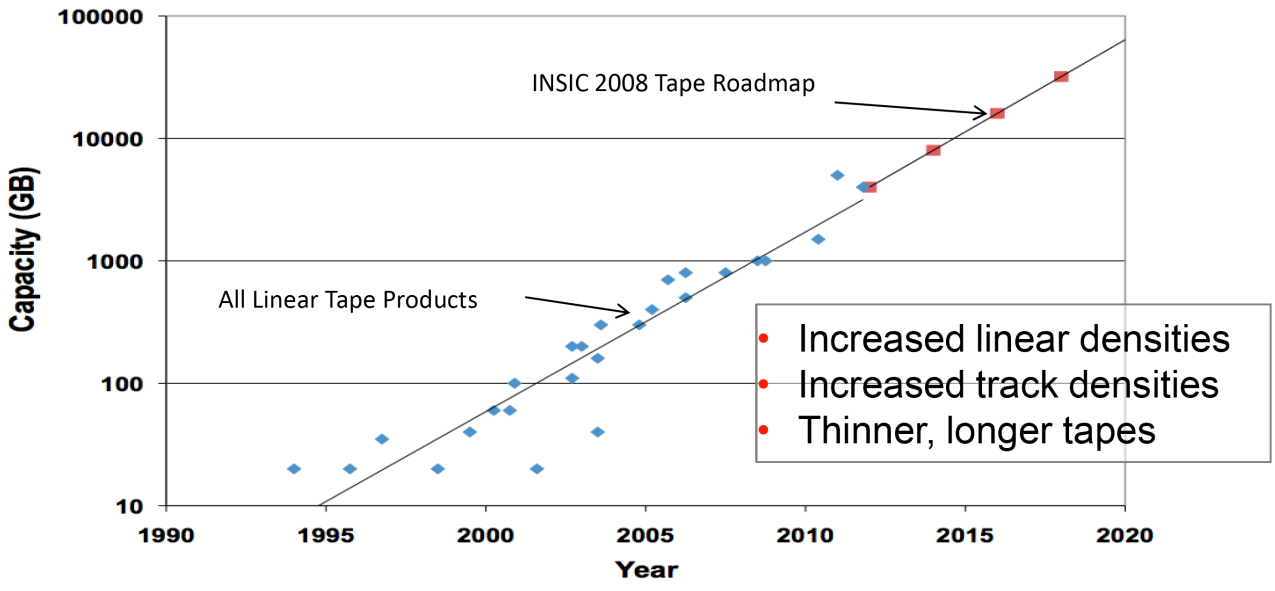
Consistent increase in areal density is anticipated : *



* http://www.oracle.com/

Tape Cartridge Capacity Roadmap

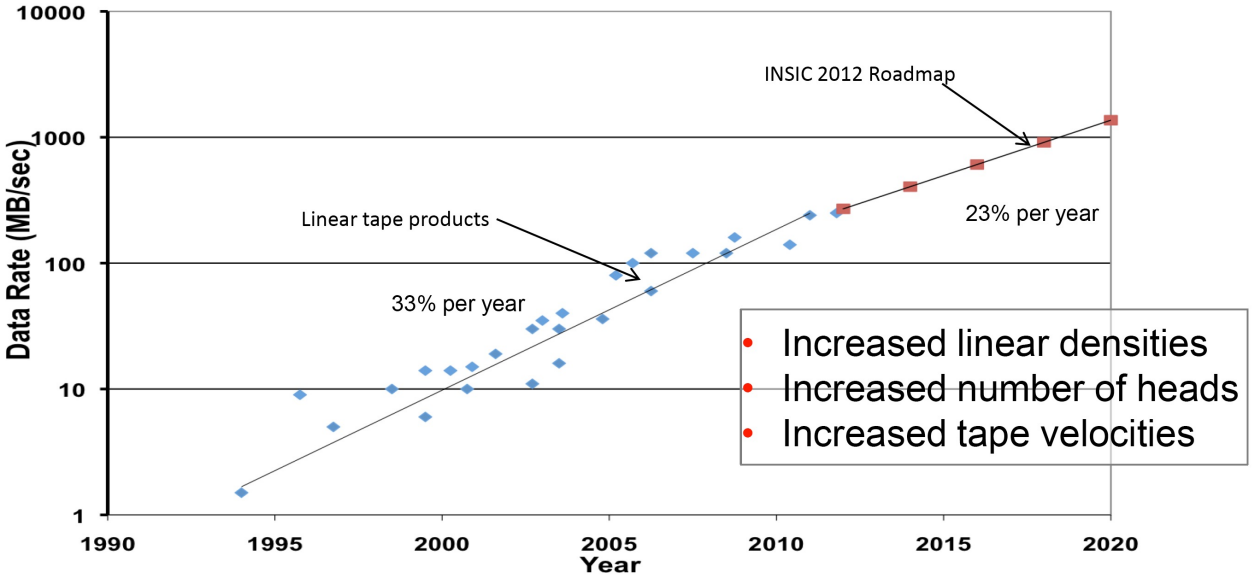
Consistent increase in cartridge capacity is anticipated : *



* http://www.oracle.com/

Data Transfer Rate Roadmap

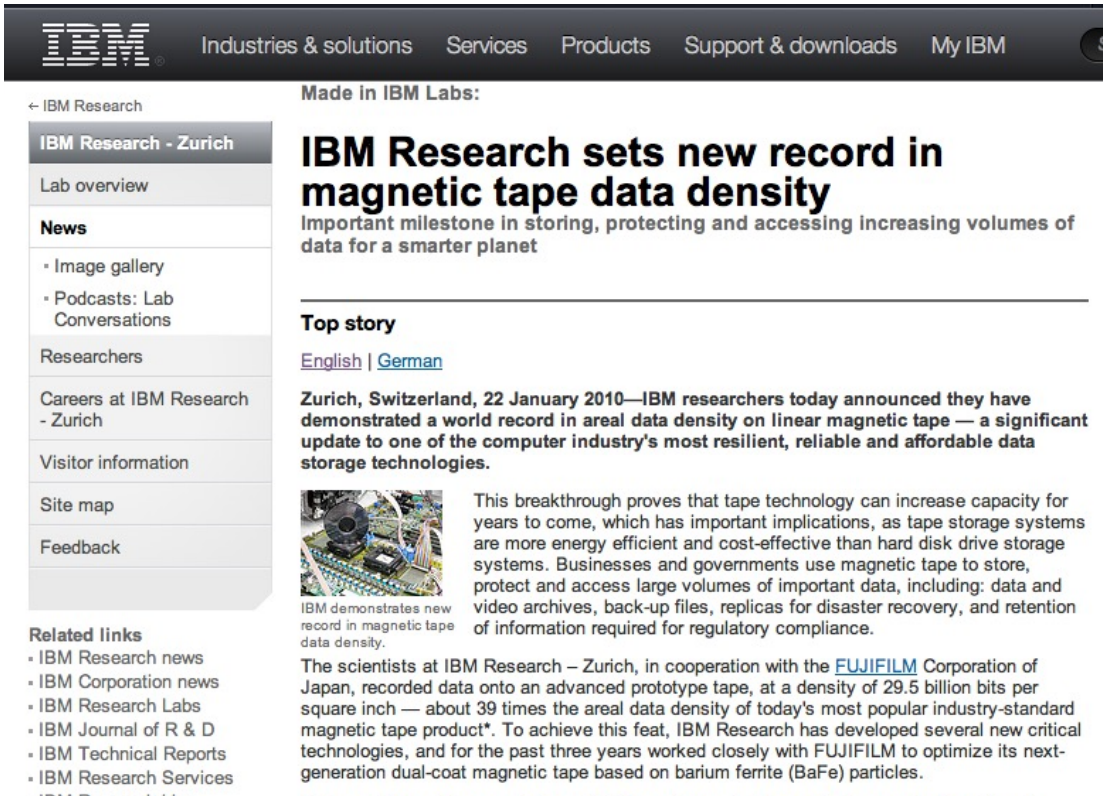
Consistent increase in data transfer rate is anticipated : *



* http://www.oracle.com/

35 TB Storage Demonstration

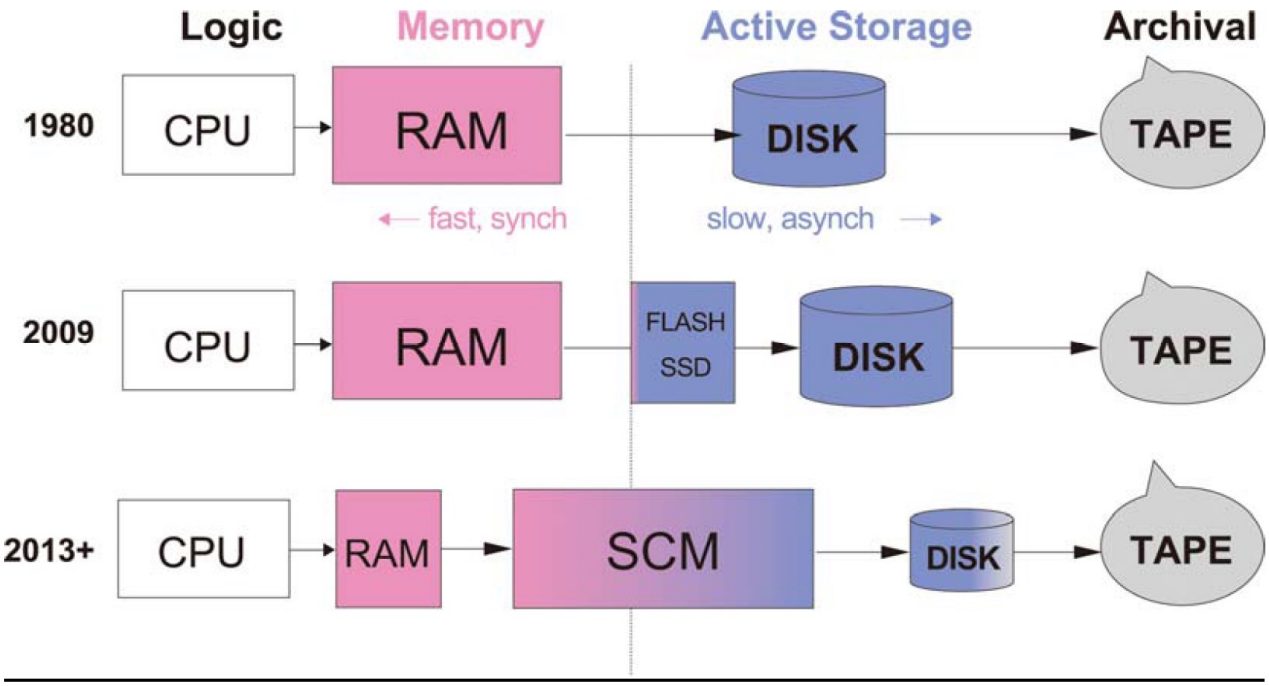
In 2010, IBM and Fuji Film announced a record : *



* http://www.zurich.ibm.com/news/10/storage.html

Tape Storage Can Survive

In order to fill the memory / storage access speed gap : *



* http://home.jeita.or.jp/