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Current and Emerging Storage Technologies iCAS2013

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Tape Systems

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Program Agenda

- Data Challenges

- Data Storage technology trends

- Disk technology trends

- Tape technology trends

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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.

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Data Growth and Access Requirements

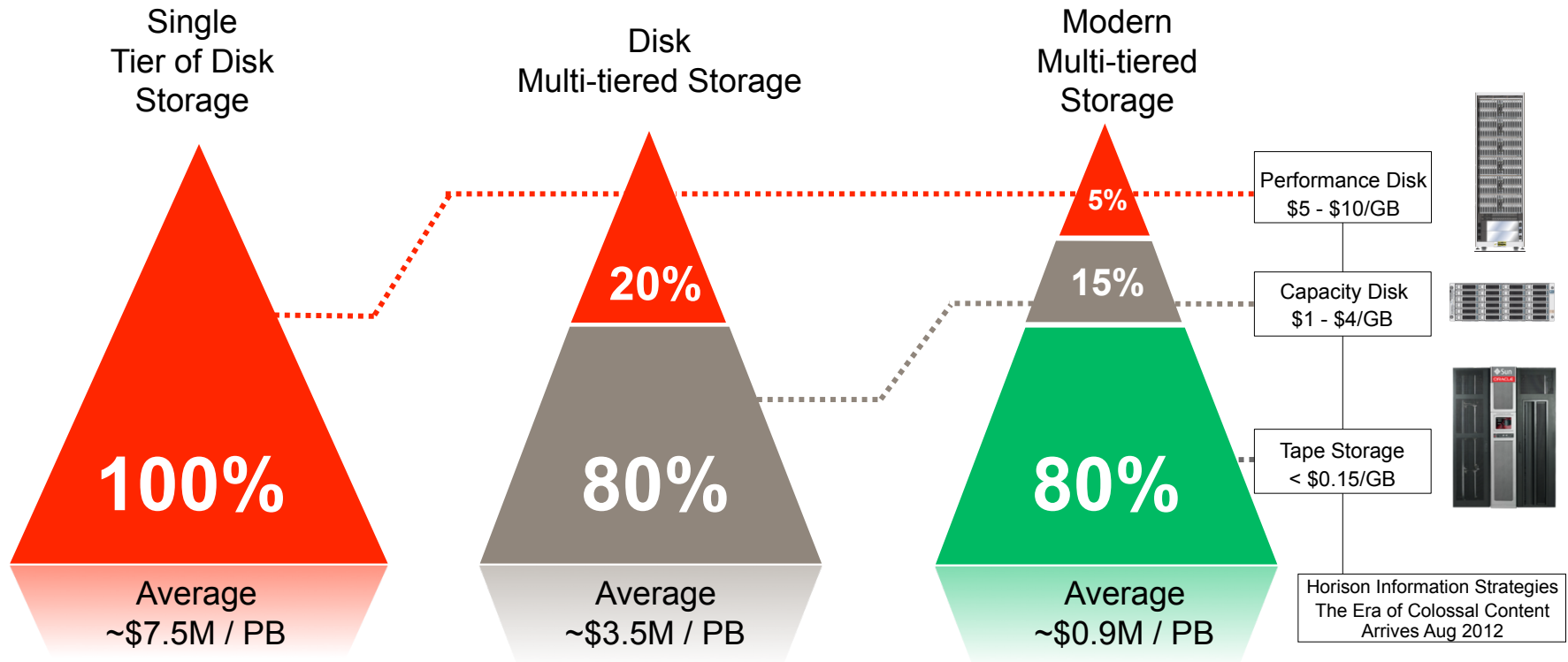## The nature of storage and data management has to change

40 Zetabytes
40,000 Exabytes

2020

- **300x** Growth from 2005 to 2020

- **80%** of data is never used after 90 days.

2005   **>130 Exabytes**

Source: IDC Document 1414_v3: THE DIGITAL UNIVERSE IN 2020: Big Data, Bigger Digital Shadows, and Biggest Growth in the Far East, 2012

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Economics of Tiered Storage

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

Single
Tier of Disk
Storage

Disk
Multi-tiered Storage

Modern
Multi-tiered
Storage

100%

20%

80%

5%

15%

80%

Average
~$7.5M / PB

Average
~$3.5M / PB

Average
~$0.9M / PB

Performance Disk
$5 - $10/GB

Capacity Disk
$1 - $4/GB

Tape Storage
< $0.15/GB

Horison Information Strategies
The Era of Colossal Content
Arrives Aug 2012

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Archive Technology Cost Analysis

NEW Study Concludes Disk Costs 26 Times More Than Tape Solution

US$ (in millions)
Equipment & Maintenance

Year 9

60

50

40

Year 6

30

20

Year 3

10

Year 3

0

Disk

Tape

The Clipper Group

New Publication TCG2013009LO — May 13, 2013

Revisiting the Search for Long-Term Storage — A TCO Analysis of Tape and Disk

Analysts: David Reine and Mike Kahn

Major Study Findings at a Glance

For long-term archiving of many petabytes of digital data growing from 1 PB to more than 28 PBs over 9 years:

(1) The TCO (including equipment, media, maintenance, energy and floor space) of the average disk-based solution costs **26** times the TCO of the average tape-based solution.
  • Tape costs about $1.5M while disk costs about $38.5M.
(2) The cost of energy alone for the average disk-based solution exceeds the entire TCO for the average tape-based solution.
  • Energy for tape costs about $47K while disk costs about $4.9M, about **105** times
(3) Disk required about **4** times the floor space of tape.

Thus, the more data preserved on tape, the lower the overall TCO.
  • With 50% on tape, the TCO is reduced by **48%**
  • With 90% on tape, the TCO is reduced by **87%**

You probably need both disk and tape, in an appropriate mix for your business. Read this report to find out.

Source: The Clipper Group, http://
www.oracle.com/us/corporate/analystreports/
industries/clipper-tco-
storage-2013-1959019.pdf

Study compares a 1 PB archive growing at 45% annually for 9 years on disk and tape.
Assumes 1:1 compression.

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Digital Archive Market Driving Tape Growth
Majority of Data is Stored on Tape

Archive Capacity Shipments (EB)

Legend:
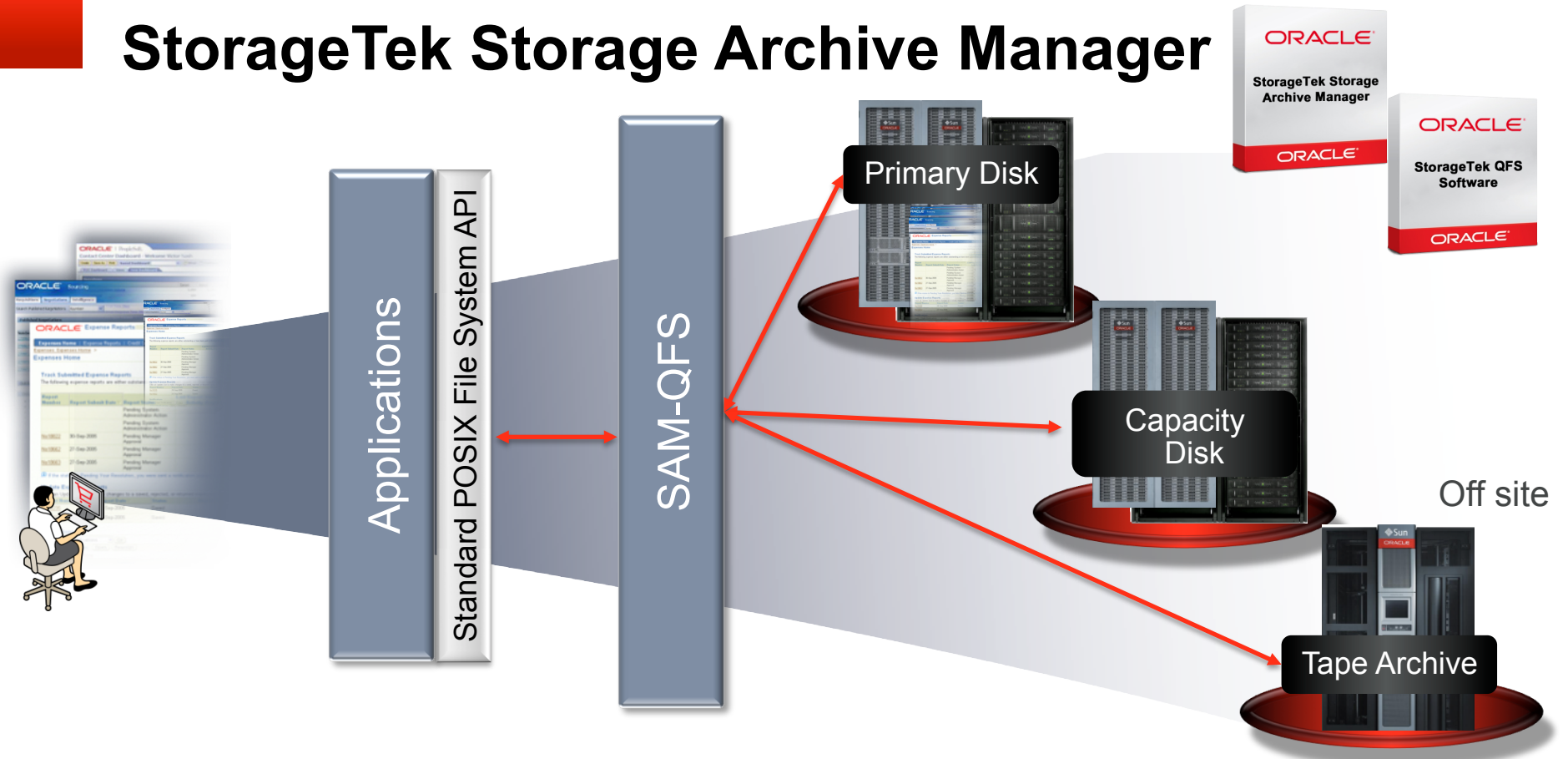- Active Disk (red)
- LT Disk (gray)
- Tape (green)
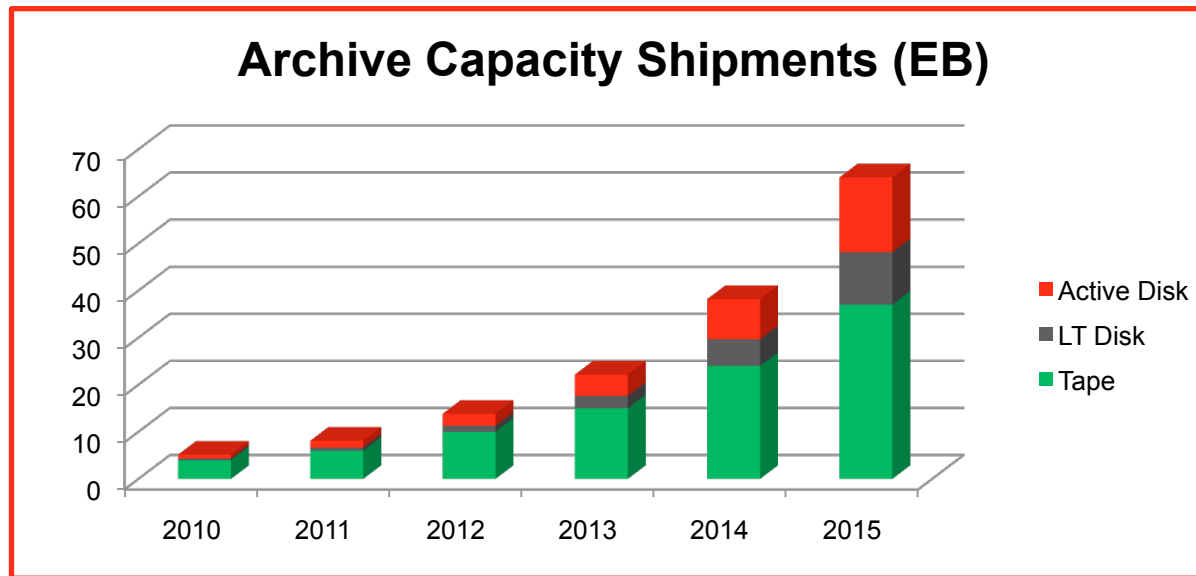
- Storage for archive and retention is a $3B Market growing to over $7B in 2017
  - Archive is distinct from primary or backup use case
  - Tape is established as primary storage tier for long-term retention

IDC Market Analysis. Worldwide Archival Storage Solutions Forecast: Archiving Needs Thrive in an Information-Thirsty World. (IDC #230762)

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StorageTek Storage Archive Manager

Applications

Standard POSIX File System API

SAM-QFS

Primary Disk

Capacity Disk

Tape Archive

Off site

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StorageTek Storage Archive Manager

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StorageTek QFS Software
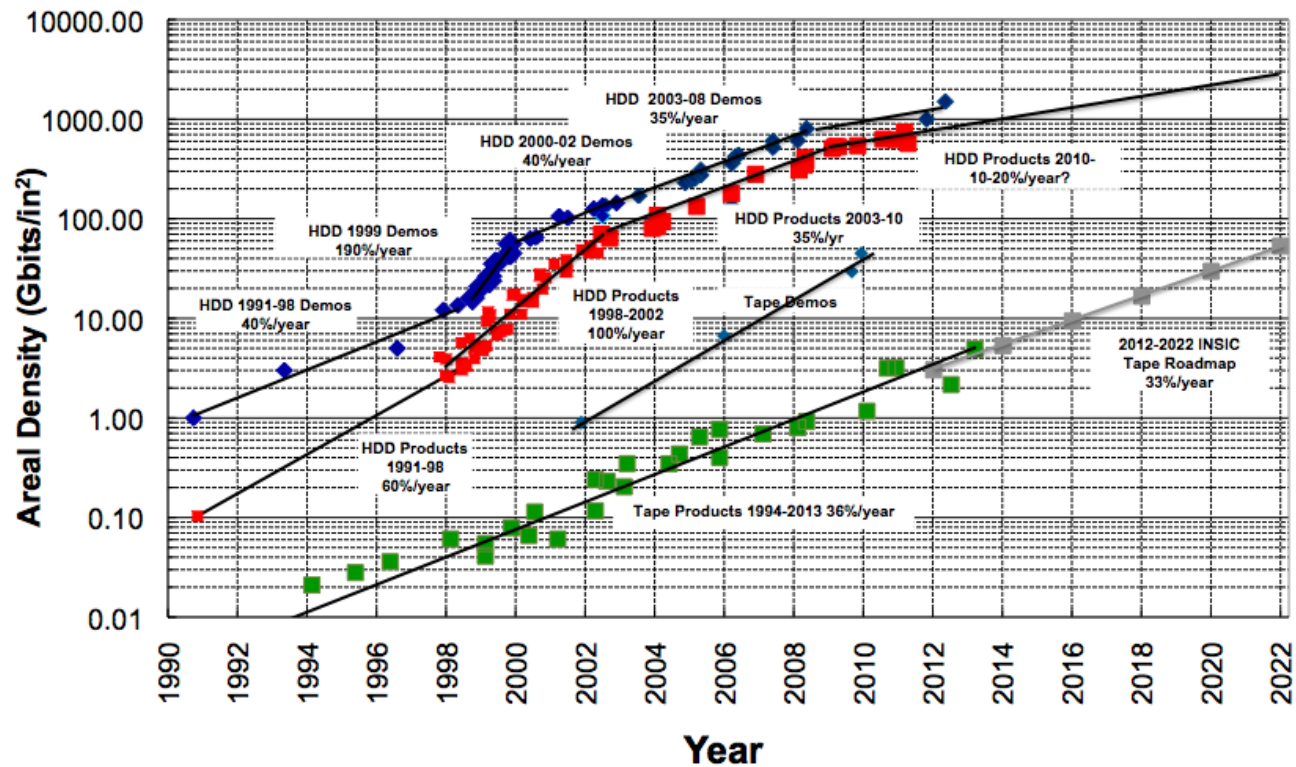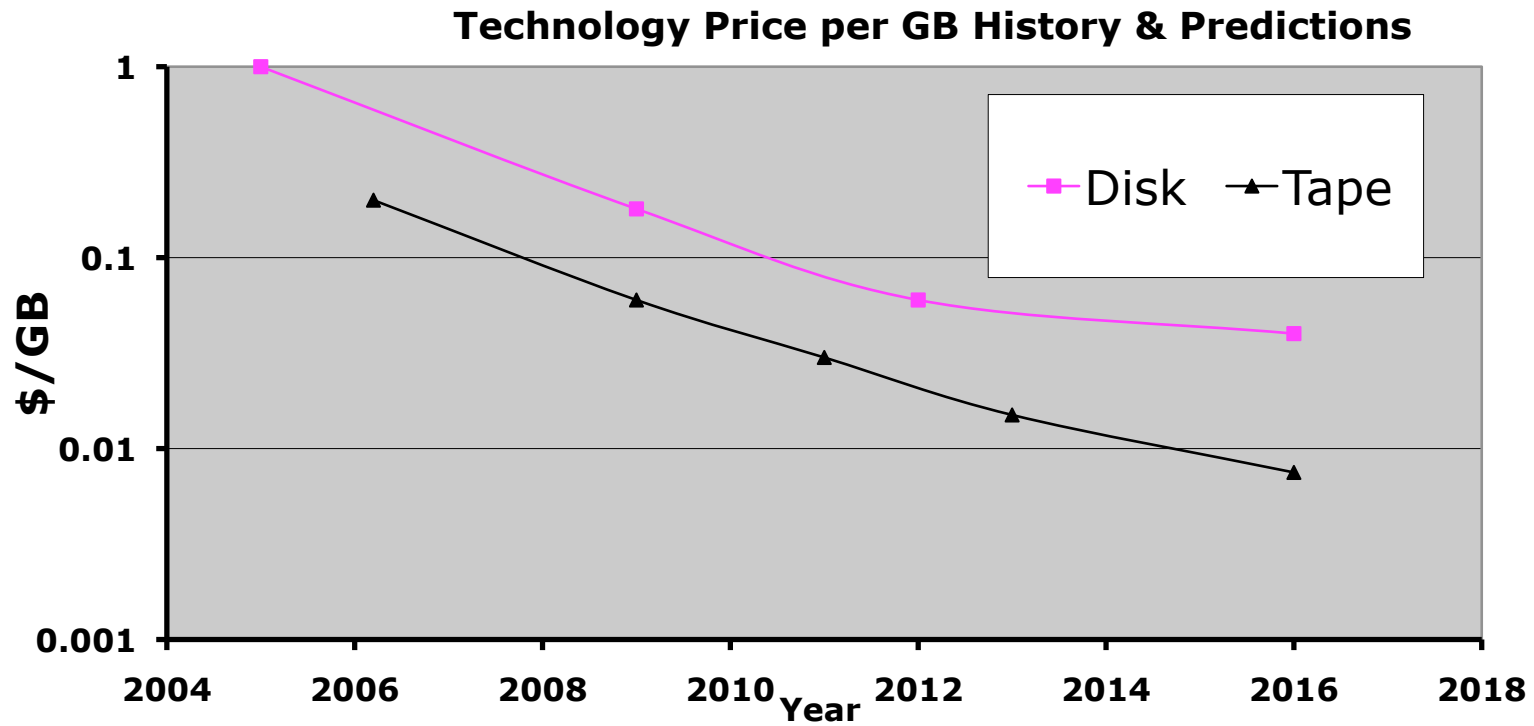
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Storage Trends

Storage Technologies Areal Density Trends
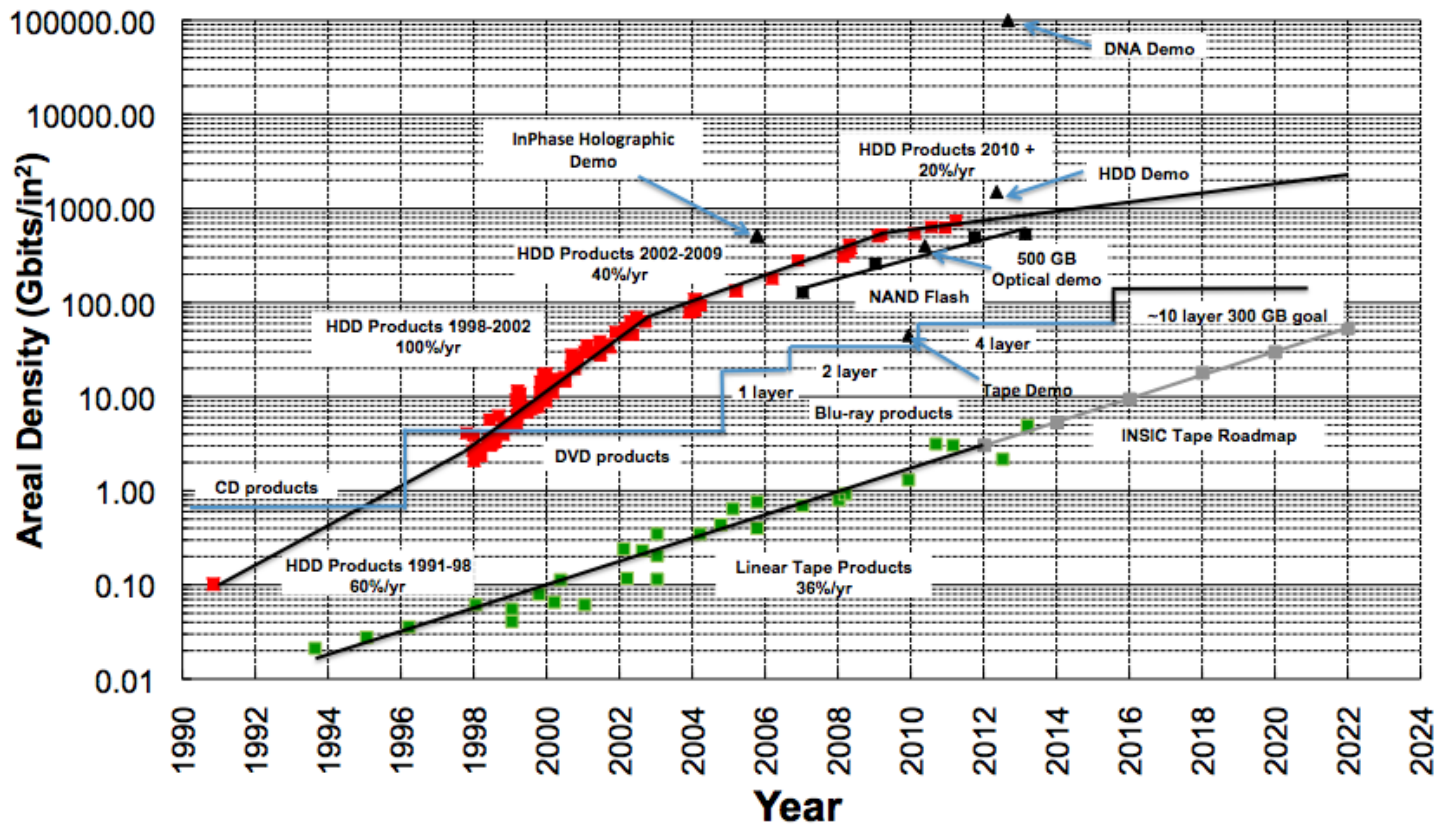
Tape gets its capacity by having 1000X the recording surface area comparing a 1/2 inch cartridge to a 3 1/2 inch disk.

DNA Storage Demo[1]
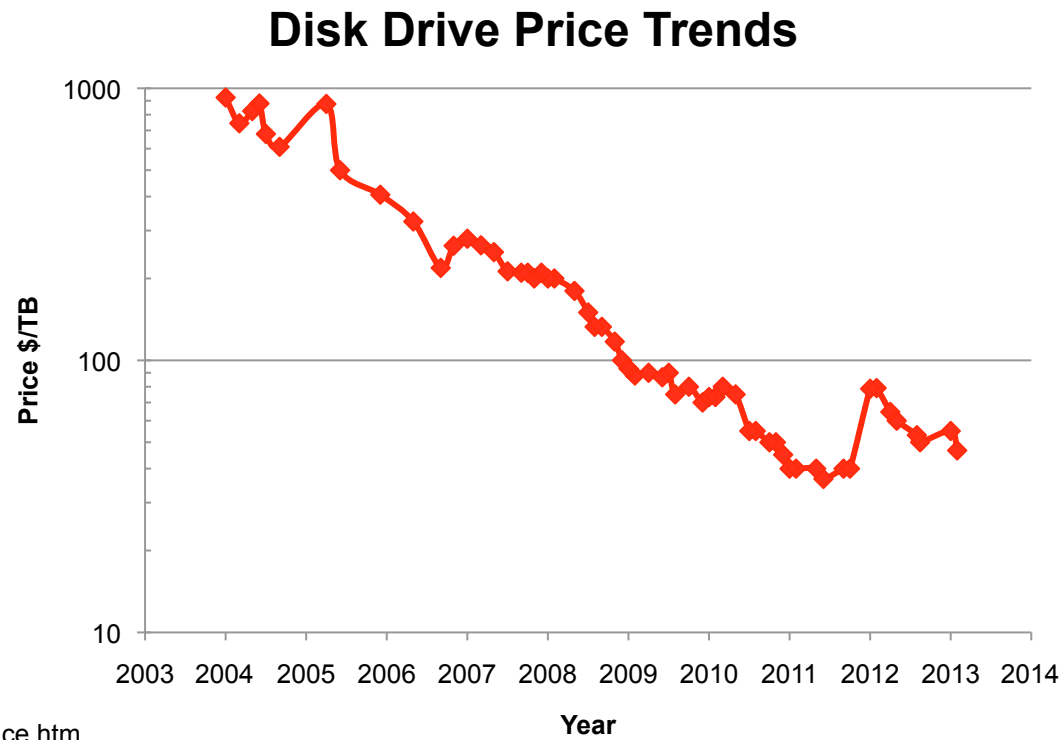
- 2.2 PB per gram
  - ~ 100,000 Gb / inch^2 equivalent areal density, see reference[2]
  - ~ 100 times more areal density than disk
- $12,400/MB
  - ~ 400,000,000 times more cost than tape
- "Two weeks to reconstruct their five files, although with better equipment it could be done in a day"
  - ~ 0.6 Bytes/sec data rate based on 739 KB stored in demo
  - ~ 400,000,000 times slower than tape
- Longevity could be an issue[3]

1 http://www.economist.com/news/science-and-technology/21570671-archives-could-last-thousands-years-when-stored-dna-instead-magnetic
2 http://uw.physics.wisc.edu/~himpsel/memory.html
3 http://www.rndsystems.com/MiniReview_MR03_DNADamageResponse.aspx

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Storage Technologies Areal Density Trends

Chart courtesy of INSIC
Tape gets its capacity by having 1000X the recording surface area comparing a 1/2 inch cartridge to a 3 1/2 inch disk.
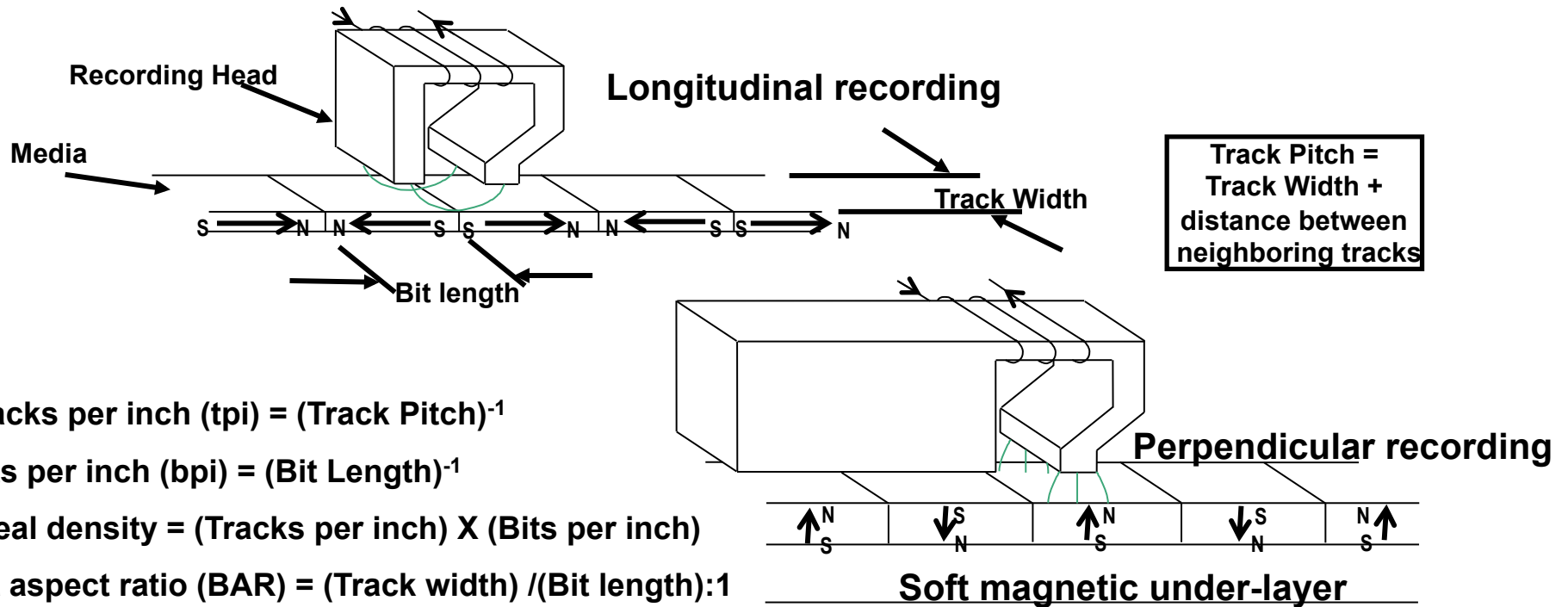
13

Tape & Disk Data Storage Price Trends

Technology Price per GB History & Predictions

Disk Drive Price Trends[1]

Disk Drive Price Trends

1. http://www.jcmit.com/diskprice.htm

Magnetic Recording Definitions

Recording Head

Media

Longitudinal recording

Track Width

Track Pitch =
Track Width +
distance between
neighboring tracks

S N N S S N N S S N

Bit length

Perpendicular recording

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

Soft magnetic under-layer

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Written Data Tracks on Tape (T10KC)

Track width

Data bit

Direction of tape motion

MFM image
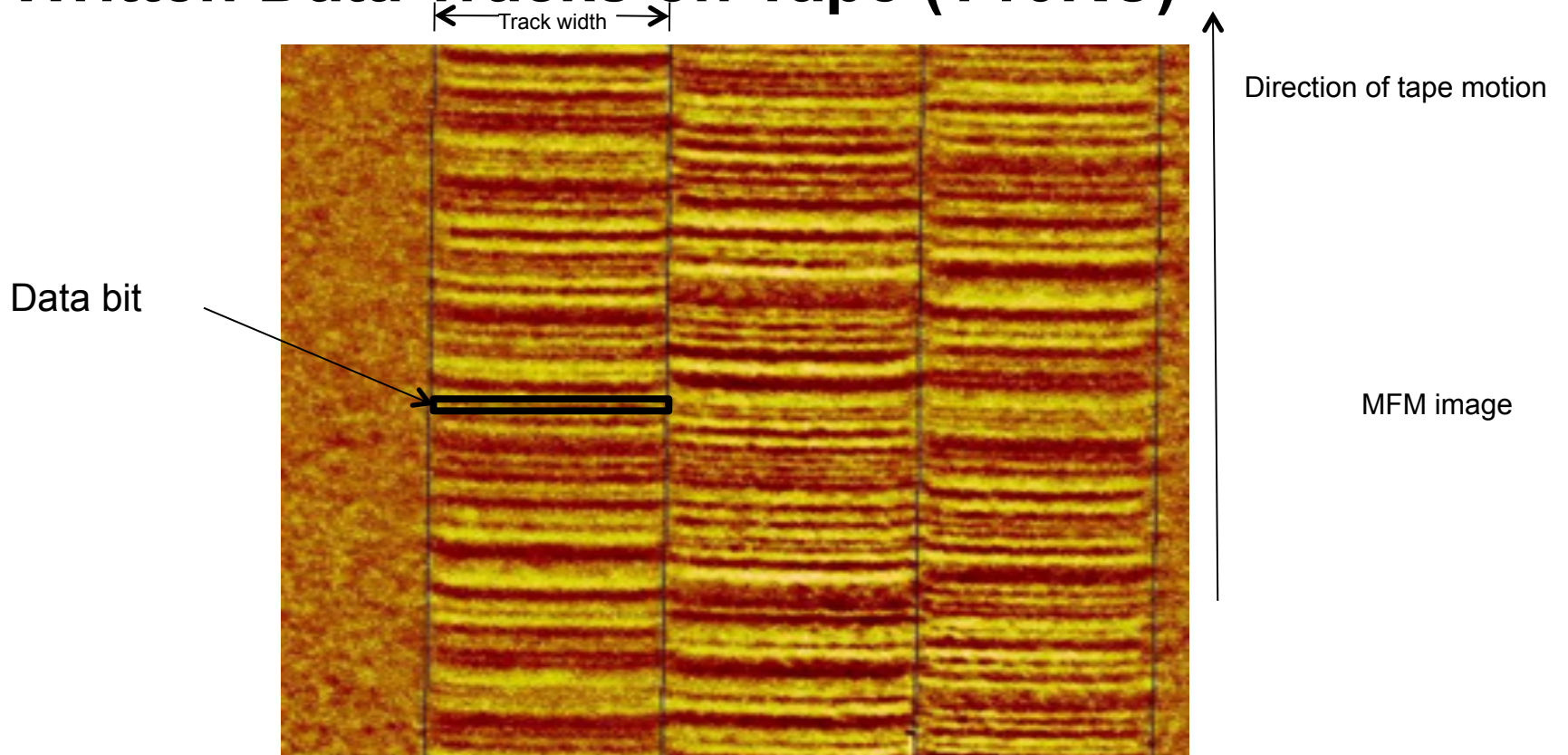
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Data Bit Size Comparison

NAND 250 Gb/inch^2 50nm X 50nm

Disk Patterned Media future 1Tb/inch^2 Bit aspect ratio 1:1

Disk 500Gb/inch^2 Bit aspect ratio 5:1

Tape future 128 TB   Bit aspect ratio 18:1[1]

T10KD 8.5 TB
Bit aspect ratio 41:1

T10KC 5.5 TB
Bit aspect ratio 43:1

Bit length direction

Track width direction

1. From INSIC roadmap 2020
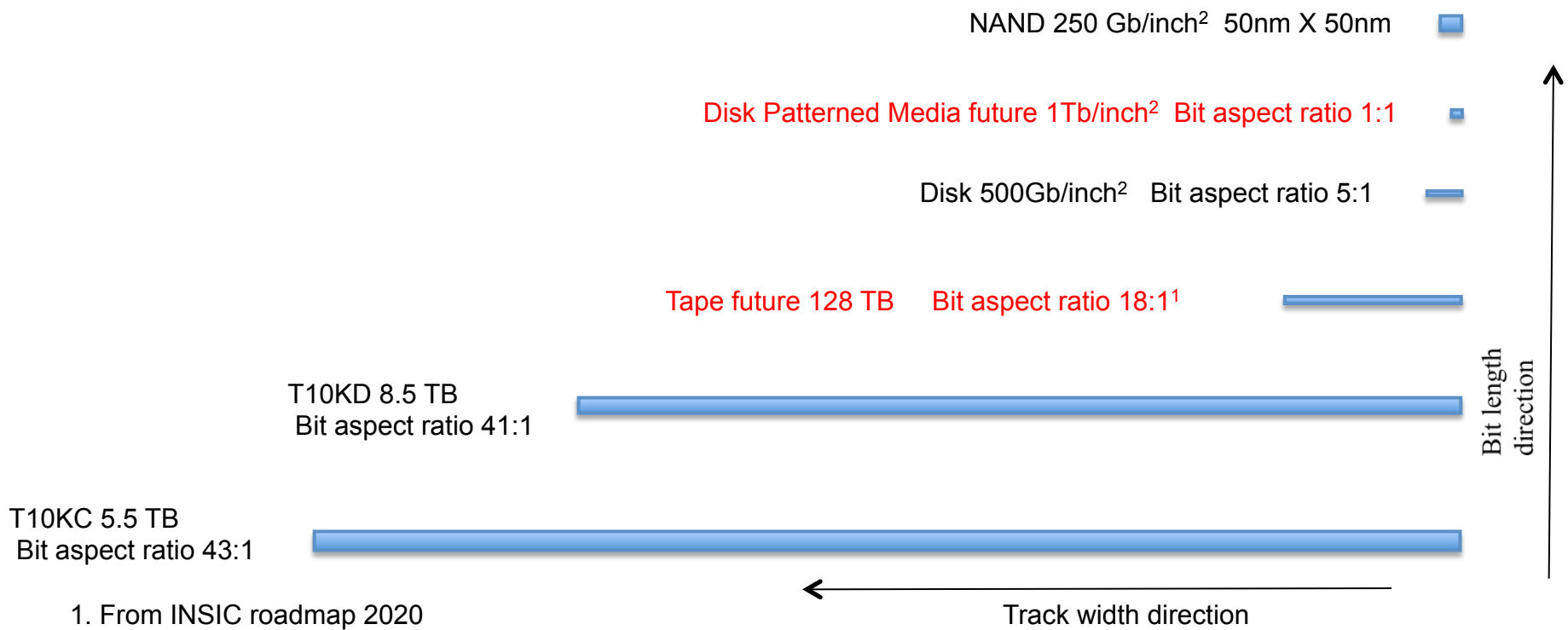
A Closer Look at the Magnetic Layer (grains or particles)

Transition region

Track width

Magnetic grain
S ⟶ N

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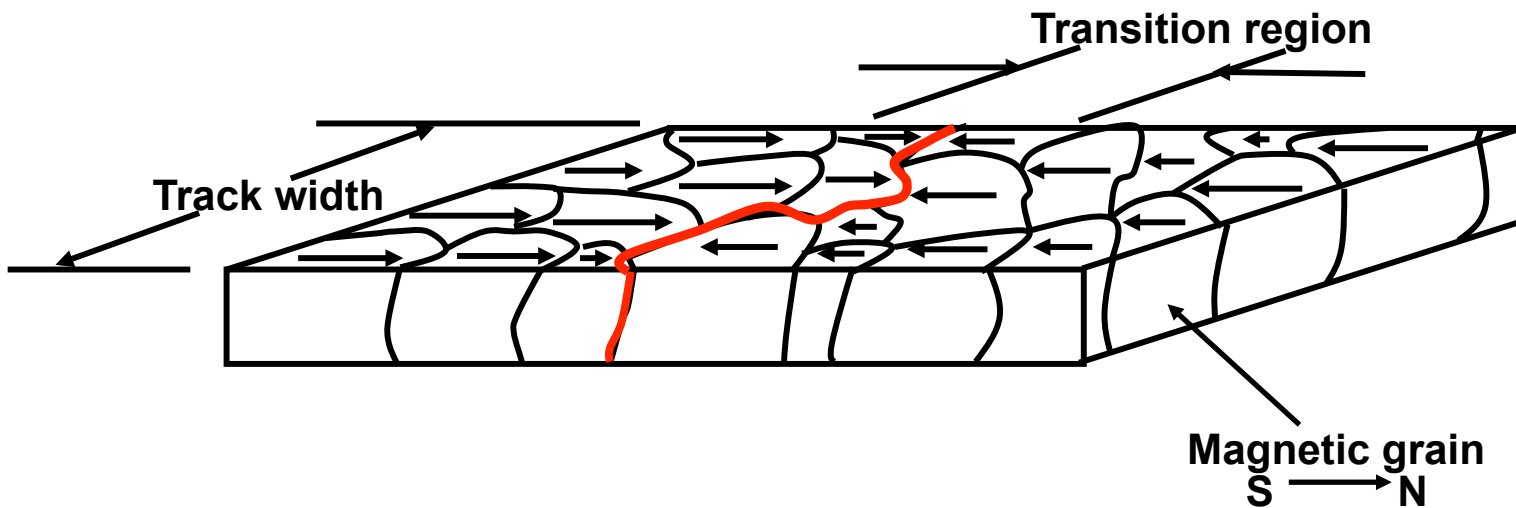
Super-Paramagnetic Effect
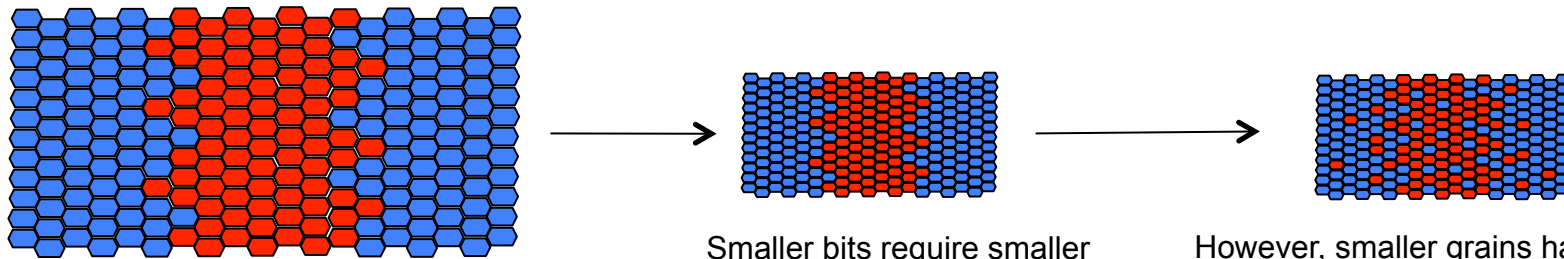
Smaller bits require smaller grains for required SNR

However, smaller grains have a higher probability of reversing over time

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

$$\tau_N = \tau_0 \exp\left(\frac{KV}{k_B T}\right)$$

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

$\frac{KV}{k_B T}$ > 60 for good thermal stability, 10 year data life [1,2]

$\frac{KV}{k_B T}$ > 90 for today's tape [3] , 30 year data life

Magnetic energy

$\Delta E = K V$

0°   90°   180°
Angle from easy axis of grain magnetization
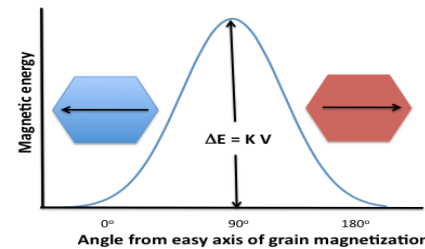
1. Dobisz et al. Patterned Media: Nanofabrication Challenges of Future Disk Drives, Proceedings of the IEEE, Vol. 96, No. 11, November 2008
2. Weller et al. Thermal Effect Limits in Ultrahigh-Density Magnetic Recording, IEEE Transactions on Magnetics, VOL. 35, NO. 6,November1999
3. Watson et al. Investigation of Thermal Demagnetization Effects in Data Recorded on Advanced Barium Ferrite Recording Media, IEEE Transactions on Magnetics, Vol. 44, No. 11, November. 2008

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Disk Storage

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Disk Magnetic Recording Tri-Lemma Review

- Smaller bits => Smaller grains for required SNR

- Smaller grains => Higher Hc[1] for thermal stability

- Higher Hc => Can not write on the media

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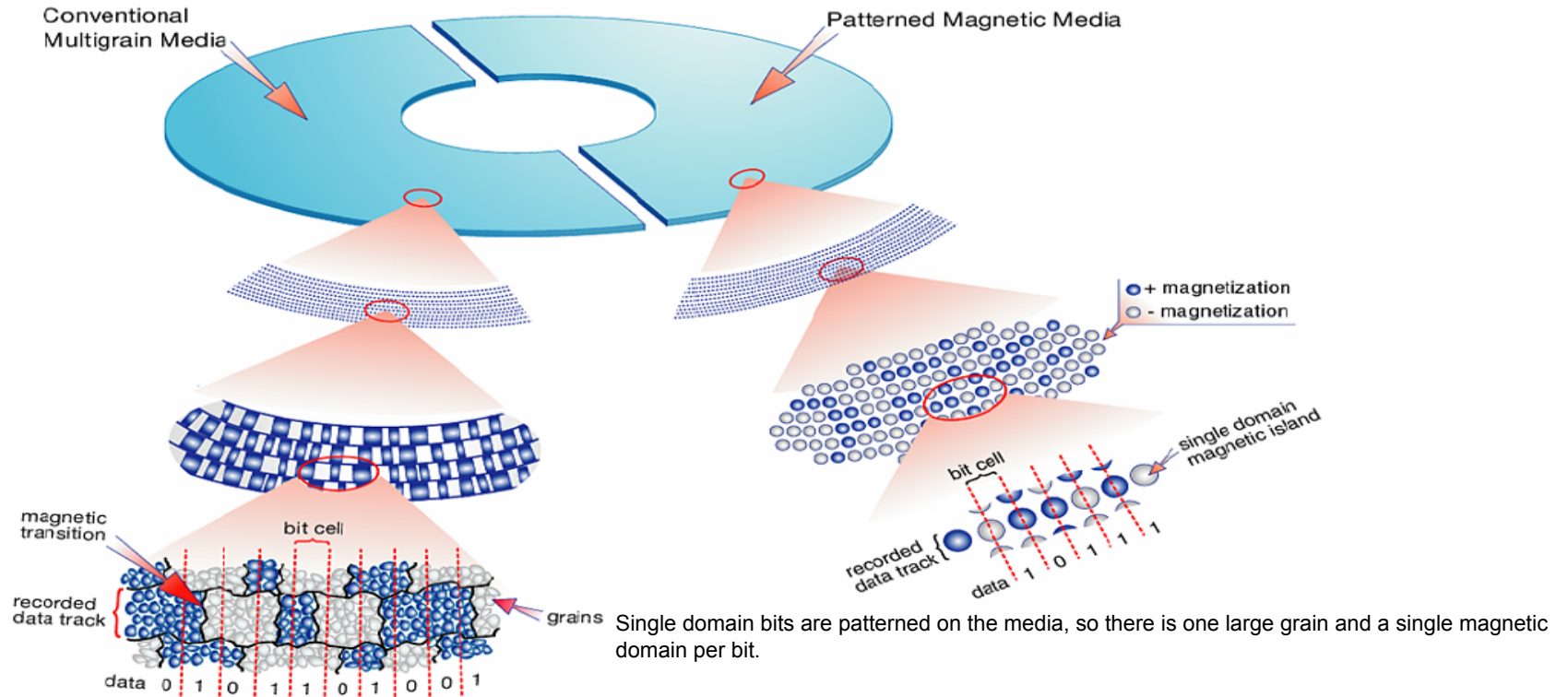
Technologies Likely to be Introduced

- 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]
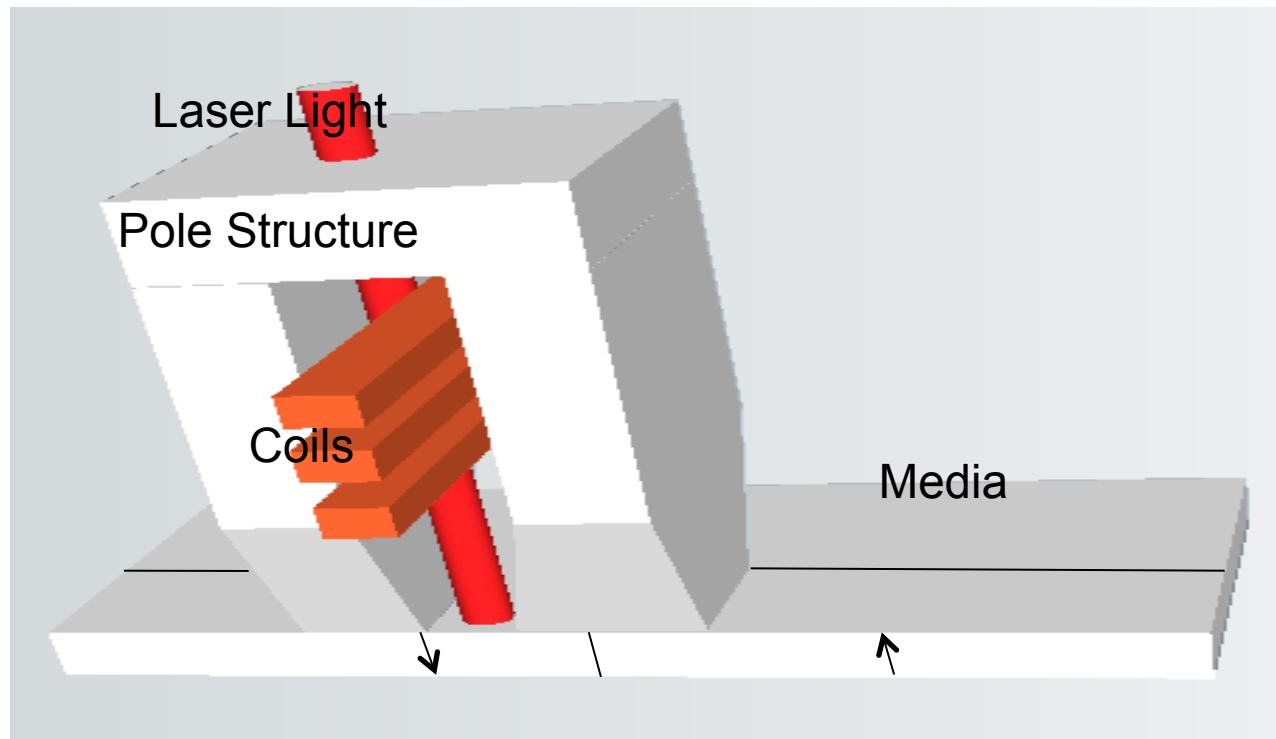   - 100% areal density increase

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-nanotechnology-process-will-double-todays-disk-drive-data-density

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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.

HAMR Concept

Laser Light

Pole Structure

Coils

Media

Laser heats media reducing media Hc so head magnetic field can write media

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Shingled Recording Concept

Final overwritten Track Width

Written Track Width

Head

Media

Direction of media velocity
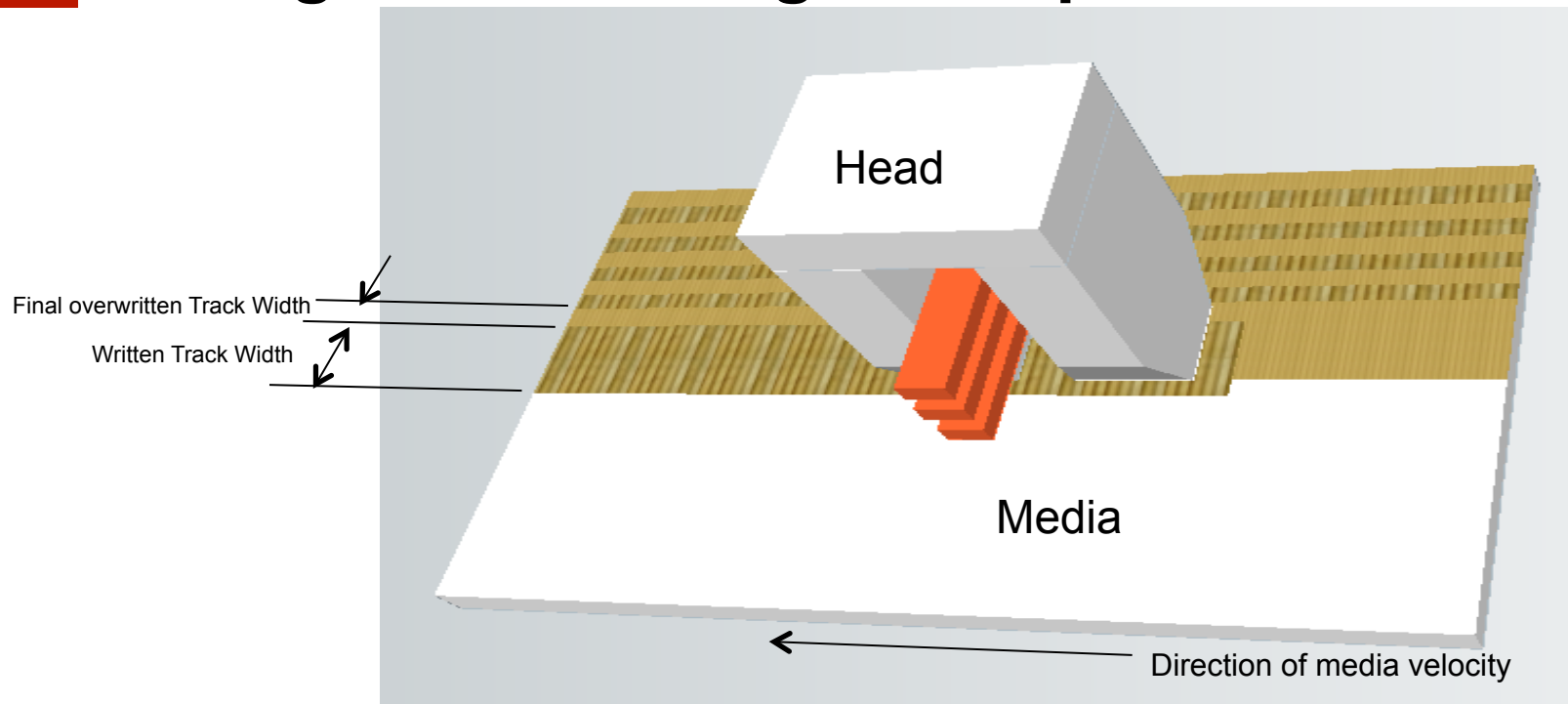
Wide tracks are partially overwritten to get narrower tracks

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Disk Drive Manufacturers Family Tree

IBM

Hitachi

2003

Western Digital ———————————————————————————————→ **Western Digital**

2011

Quantum

Maxtor

2000

1996

Seagate ———————————————————————————————→ **Seagate**

Conner

2006

2011

Samsung

2009

Toshiba ———————————————————————————————→ **Toshiba**

Fujitsu

Micropolis ——→X
1997

HP ——→X
1996

1995

2011

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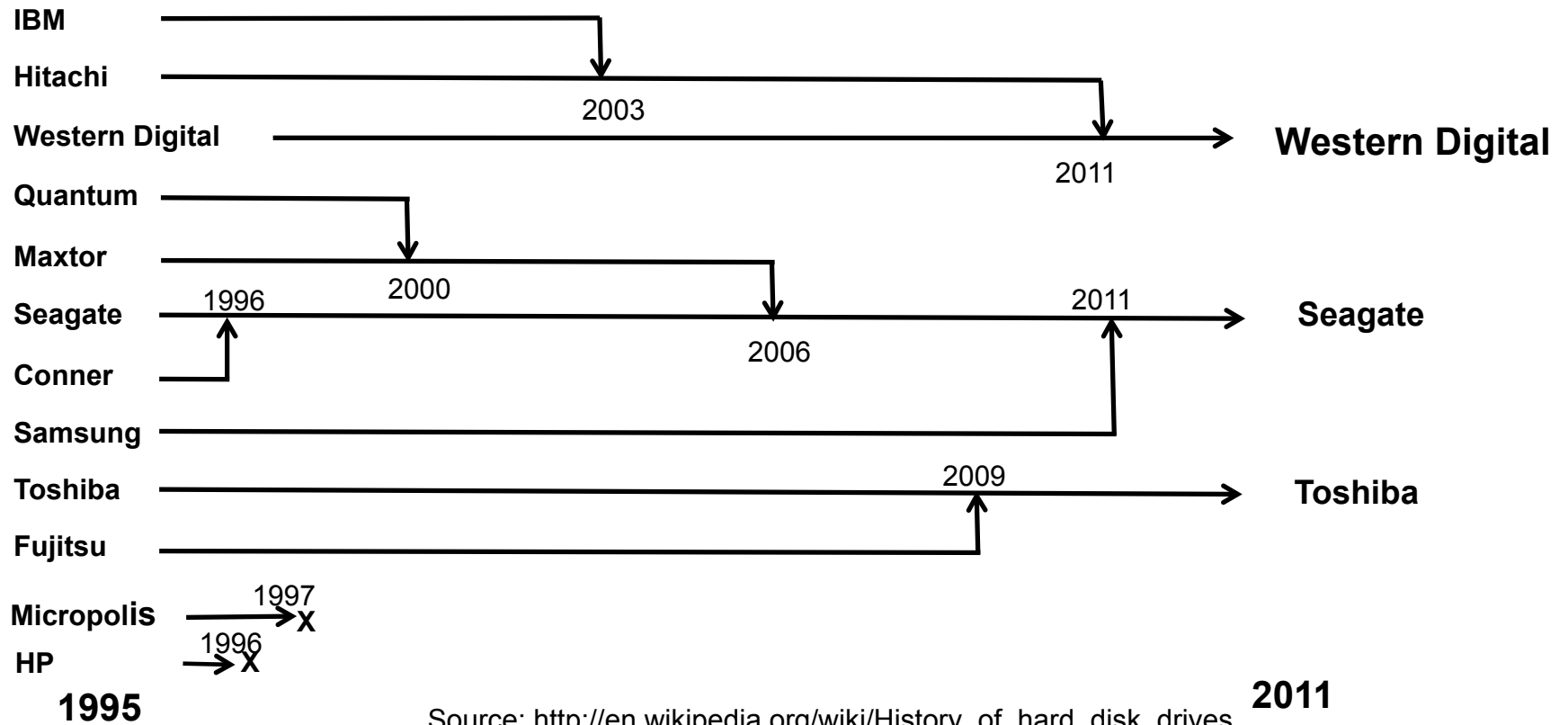
Tape Storage Trends

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Technology Marches Forward

10 TB Example Over 15 Years

It is good to upgrade technology

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

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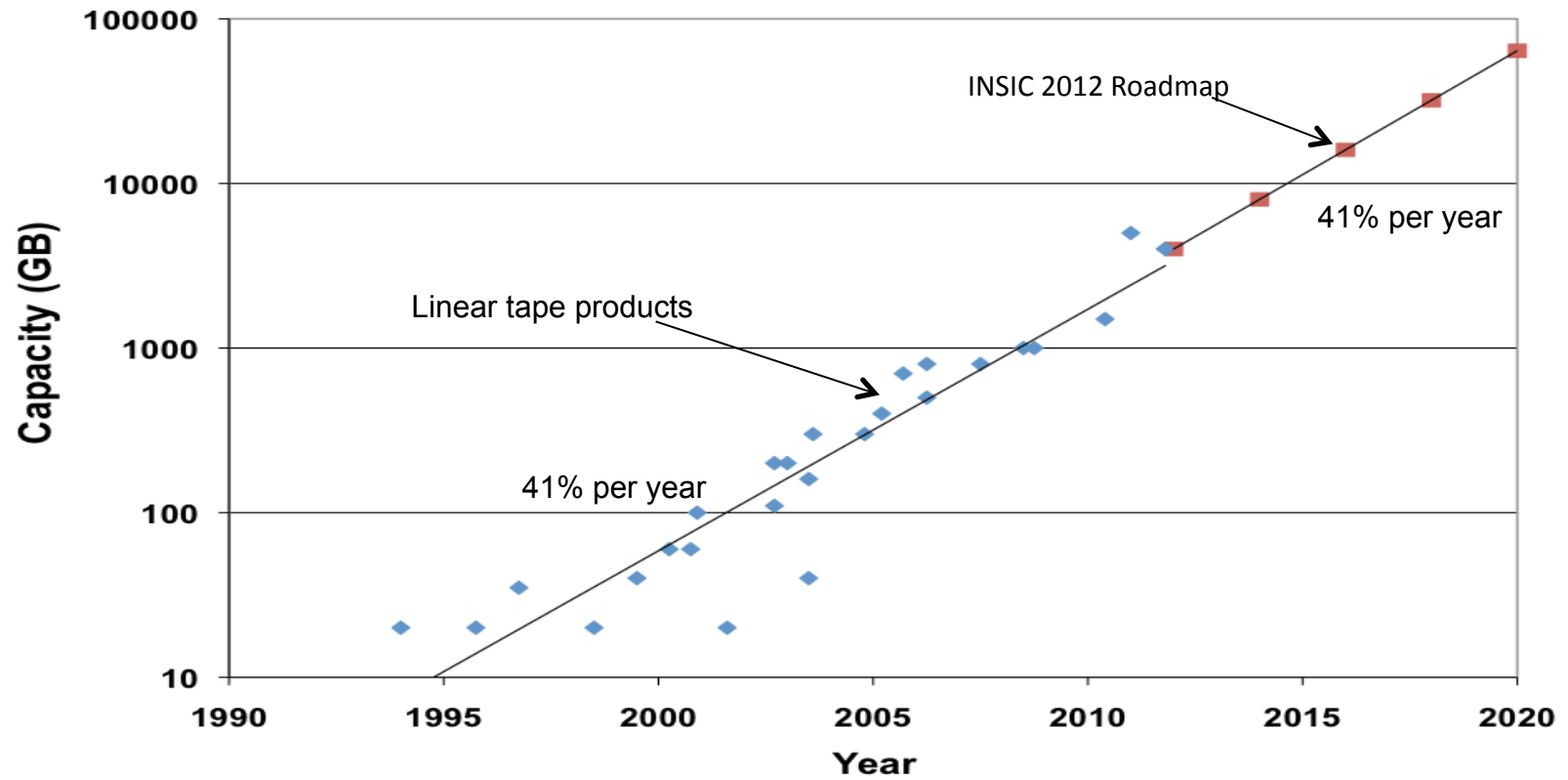- 1.2 lbs

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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

Tape Cartridge Capacity Trend

INSIC 2012 Roadmap

41% per year

Linear tape products

41% per year

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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 media[1]

[1]http://www.fujifilm.com/news/n100910.html
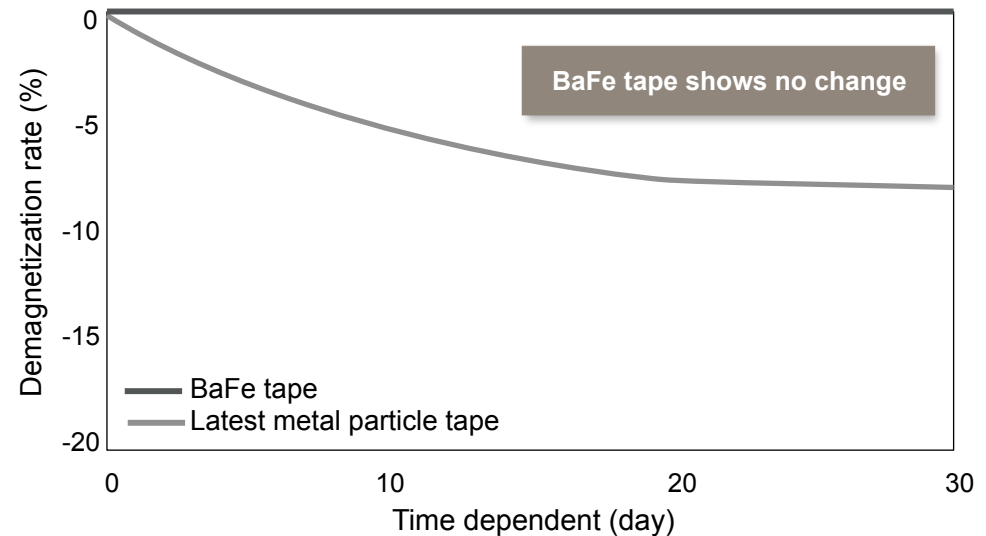
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Hardware and Software

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