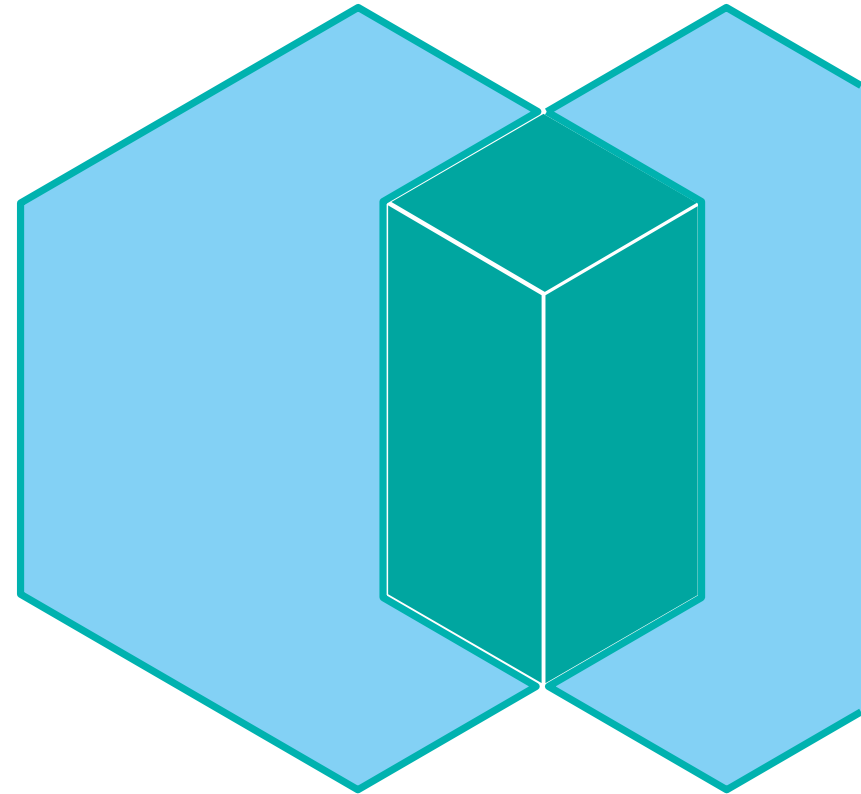




# Tape Technology Outlook

Sept 2017

**Ed Childers**  
**STSM, Manager Tape Development**



## Agenda

Why is there a problem scaling storage?

Tape Technology Outlook

IBM Tape Strategy

We all know that data is growing, demands on IT growing, but why has it become such a problem?...

## System Storage

### Increasing Data Demands on IT



## System Storage

### Data Islands to Data Continents...

#### Transactional Databases and Analysis (application data, block level, virtualization)

- I/O intensive
- Random read/write
- Large/Small files
- Modest storage growth
- Steady growth rates
- Mission Critical
- Block-level virtualization
- Structured data (mostly)



2008

8MB



16MB



20MB



60MB



36MB



4MB



20KB

#### Persistent Data Files, Data Protection and Archive Data (user data, file level, abstraction layer)

- Large files
- Very large storage
- Infrequent access
- Event driven
- Reference content
- Business vital
- Created but not modified
- Data accumulation
- Data integrity
- Long-term retention
- Explosive growth

Transactional data

DR Copy

Backup

Persistent data

DR Copy

Backup

DR Copy

Backup

DR Copy

Backup

Amount of data in the typical enterprise

Within 30 days the majority of data becomes "persistent data".

© 2013 IBM Corporation

## Changing Nature of Business and Data

Business Pressures

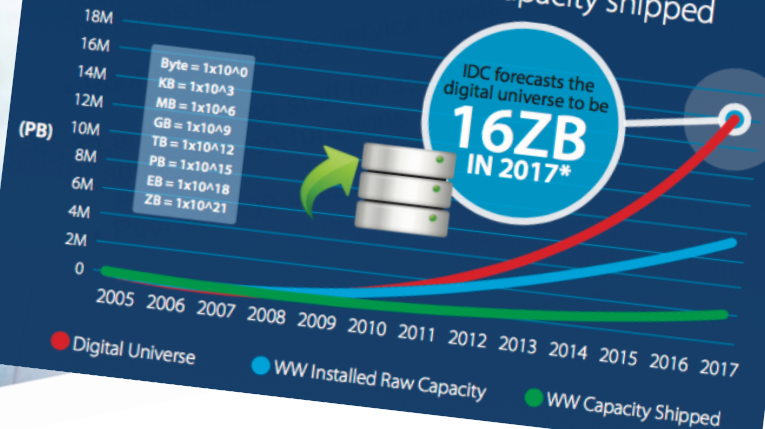
New Applications

Data

IBM System Storage SAN Volume Controller and Storwize Family  
Customer Concerns Driving Vi

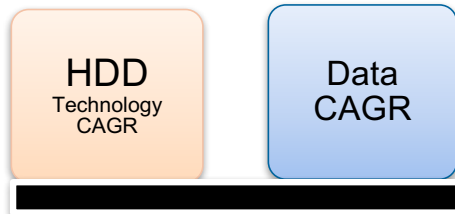
## THE GROWING IMPORTANCE OF DATA

Compare digital universe with WW installed raw capacity with WW capacity shipped

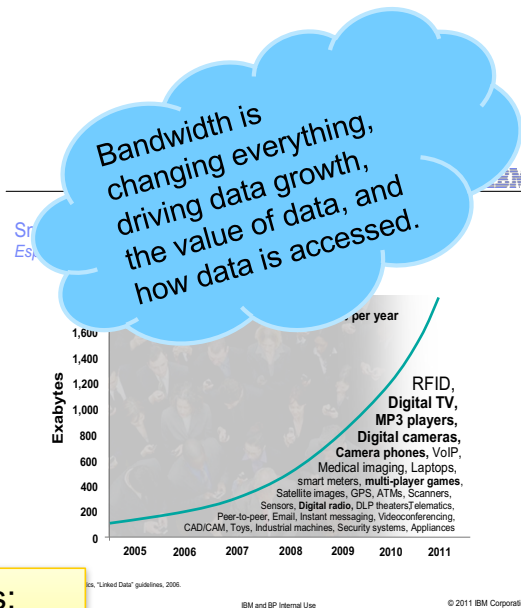


# Fundamentally – It's a Storage Scaling Problem

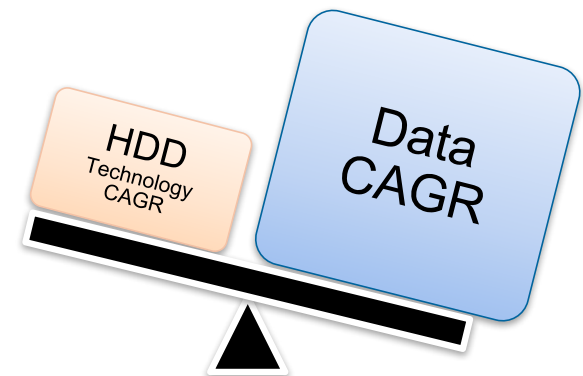
**"Before"**  
(until late 2010's)



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

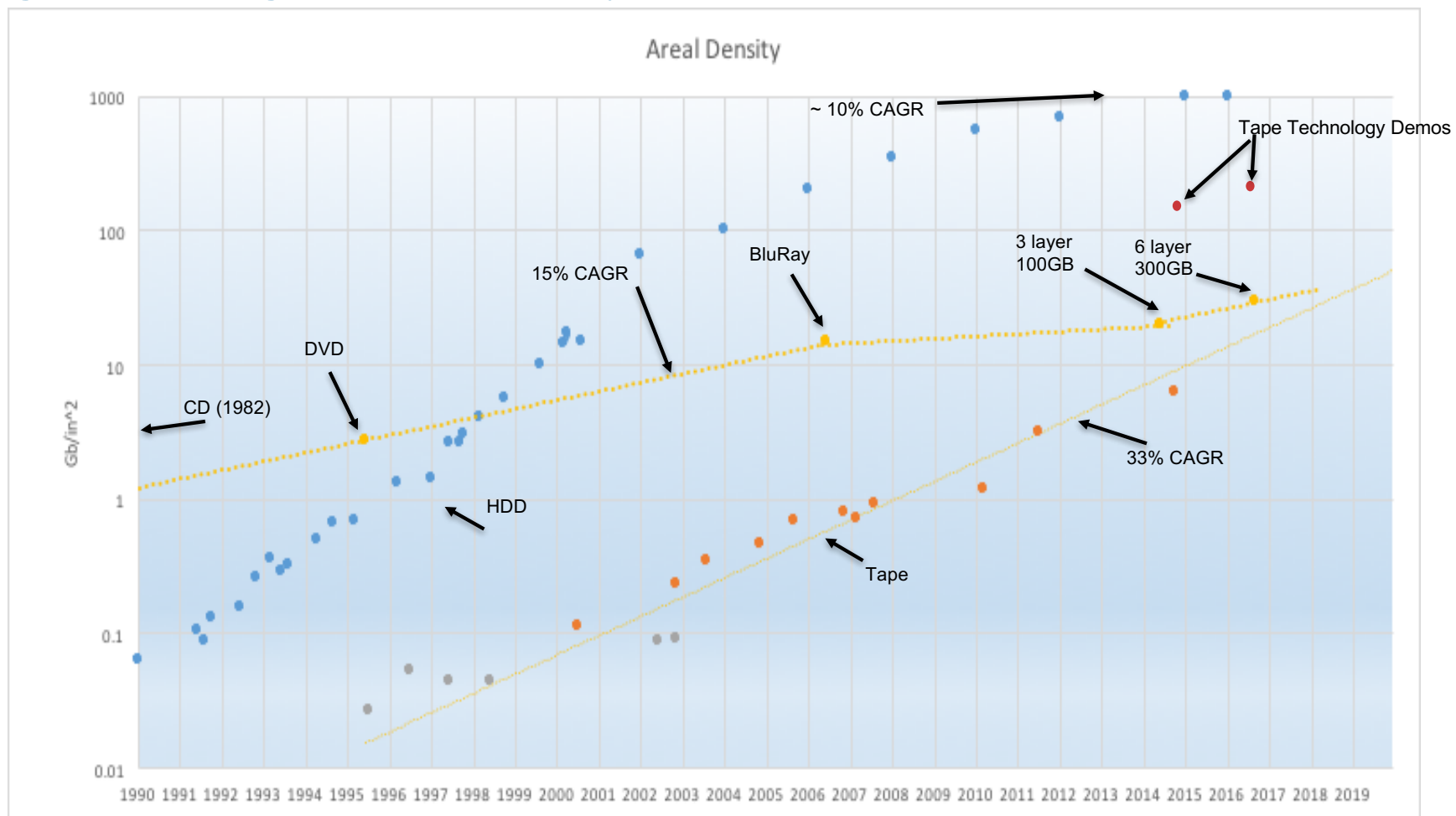


**"Now"**



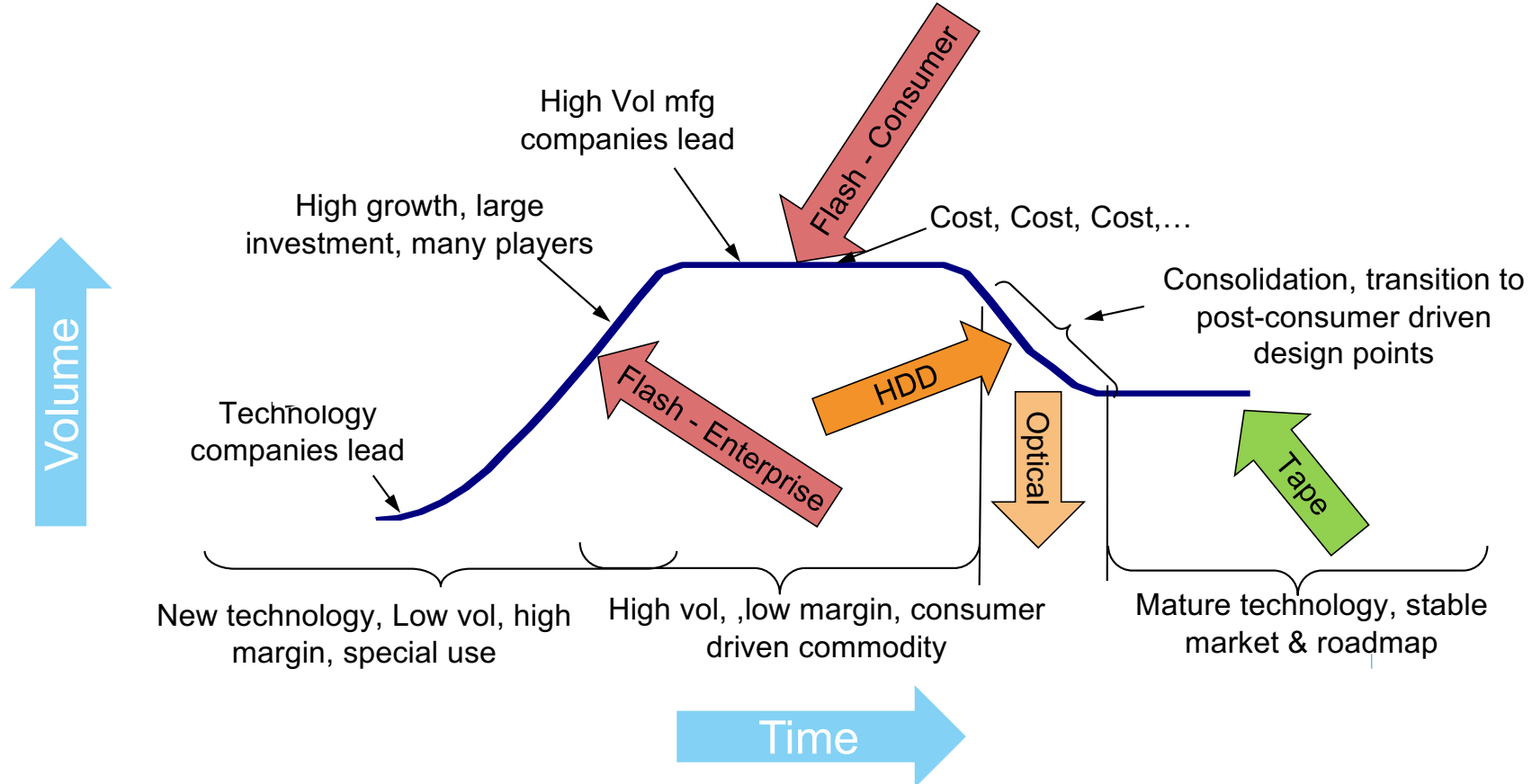
The rate of data growth is greater than:  
➤ advances in HDD technology areal density  
(No increases in IT spend to offset imbalance)

# Storage Technologies Areal Density Trends

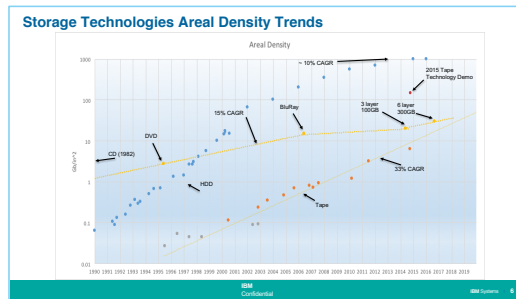


## Engineers Solve Technology Problems but...

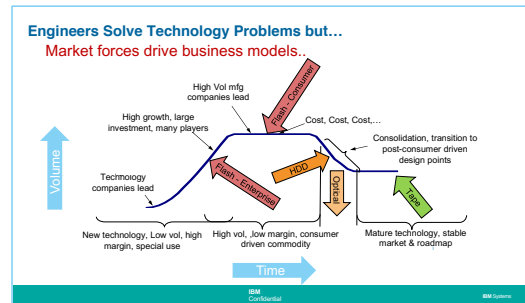
Market forces drive business models..



# Fundamental Technology Trends



# Consumer Market Trends



# Technology Outlook

## Agenda

Why is there a problem scaling storage?

### Tape Technology Outlook

- Storage Technology Trends
  - HDD, Optical, Tape Outlook & Challenges
  - Anything New Coming?
- The Storage Triple Whammy

### IBM Tape Strategy



## Storage Technologies - Refresher

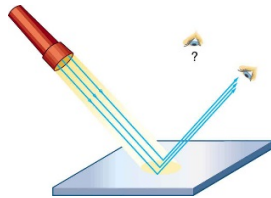
How do you store a bit?



Magnetize something



Tape & HDD



Change optical reflection



ODA, BluRay, DVD



Capture charge



Flash

## Storage Technologies - Refresher

How do you decrease \$/TB?

Increase # of bits



Constant cost



Lower \$/GB

“Areal Density”  
=  
Number of bits  
per sq inch

Increase areal density without increasing cost of media or device is key

Increase capacity



Higher cost



Lower \$/GB

# HDD Storage Basics

Write with electro-magnet

Read with “MR” sensor

(“magneto-restrictive” sensor changes resistance in a magnetic field)

1

Better areal density & higher capacity achieved by shrinking the same basic technology to write smaller and smaller bits on disk  
Smaller magnetized bits make smaller data bits  
Smaller write heads to magnetize smaller pieces  
Better “MR” sensors to read smaller bits

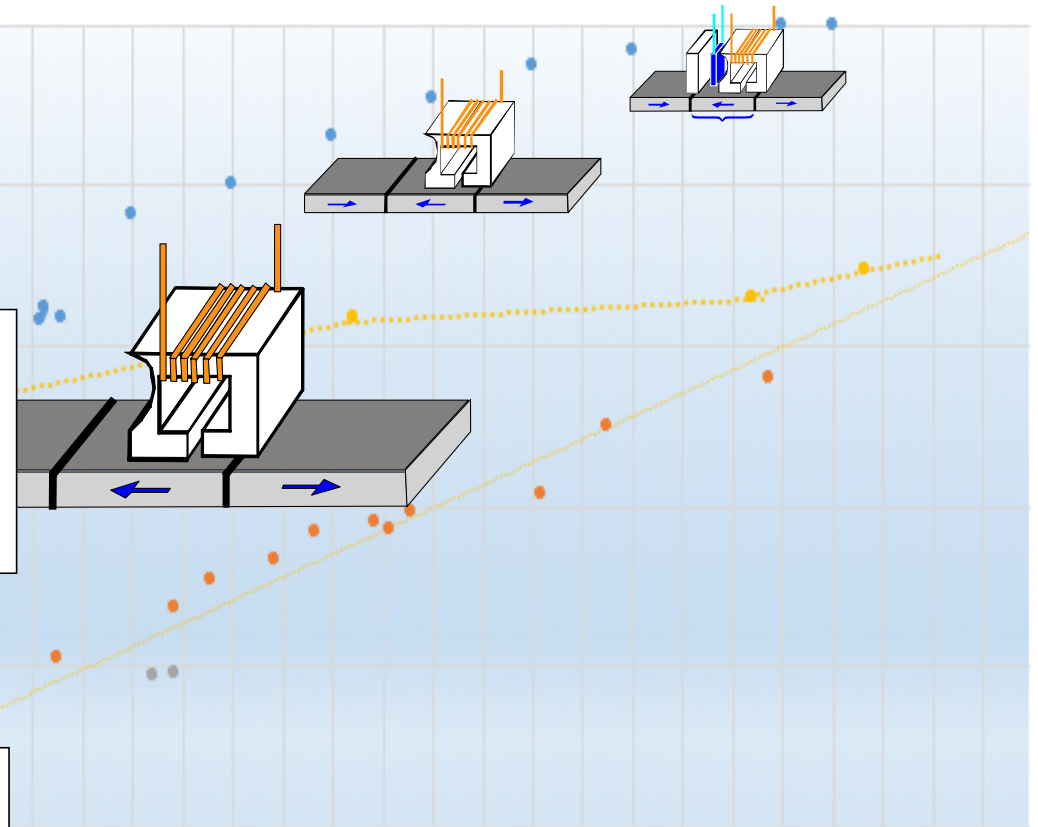
2

The smaller the magnetized bit, the less stable.  
When a bit gets so small it's unstable @ room temperature = “superparamagnetic limit”

3

HDD has reached the “superparamagnetic limit”.  
Means to get around limit are difficult & expensive.

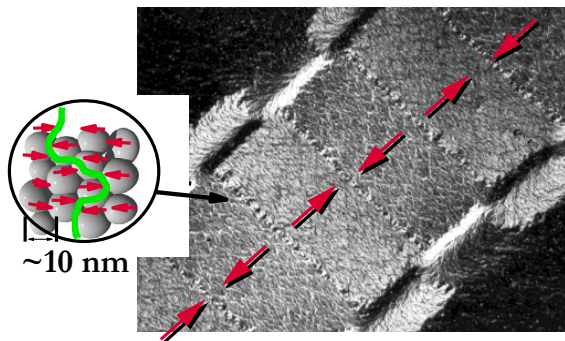
Areal Density



1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019

# HDD Challenges

Technology Scaling Limits +



If grains become too small,  
magnetic state is unstable  
→ superparamagnetic effect

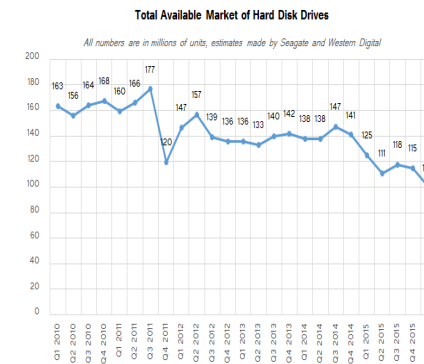
\$/TB Impacted  
By Increased  
Cost Of Brick

Technologies to go  
beyond the  
superparamagnetic  
limit = \$\$

- HAMR
- MAMR
- BPM
- BPM+HAMR

+

Declining Consumer Demand



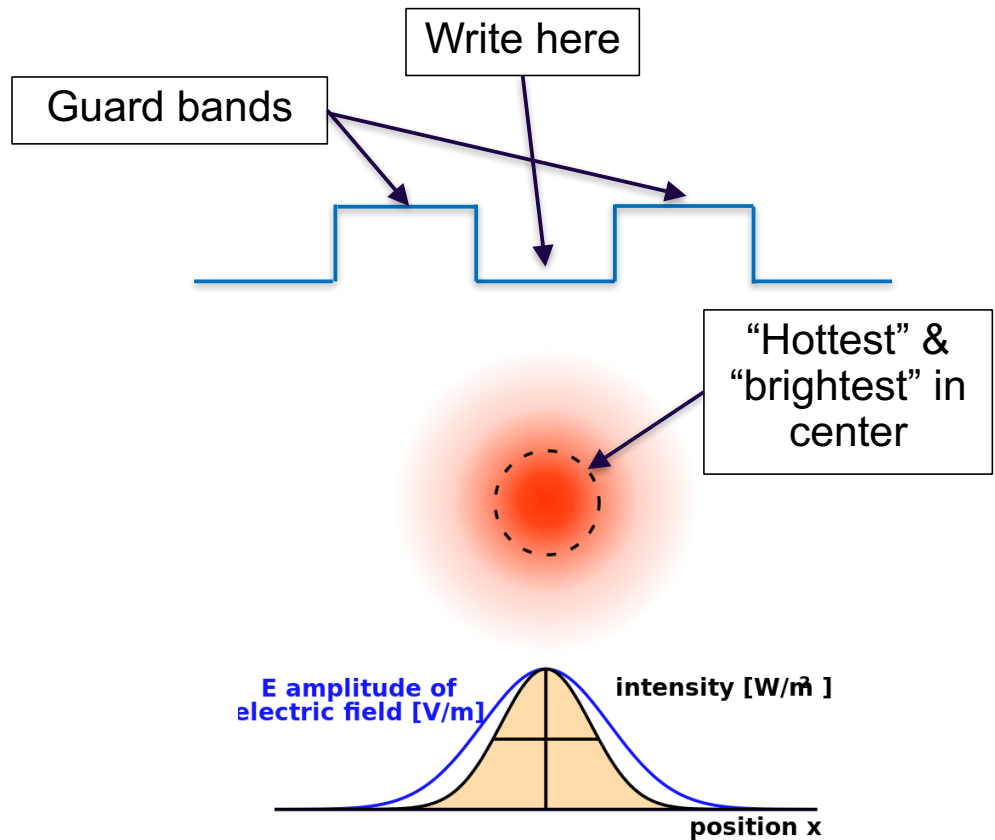
+

High Perf & High Margin  
Market Taken Away By Flash

## Optical Storage Basics

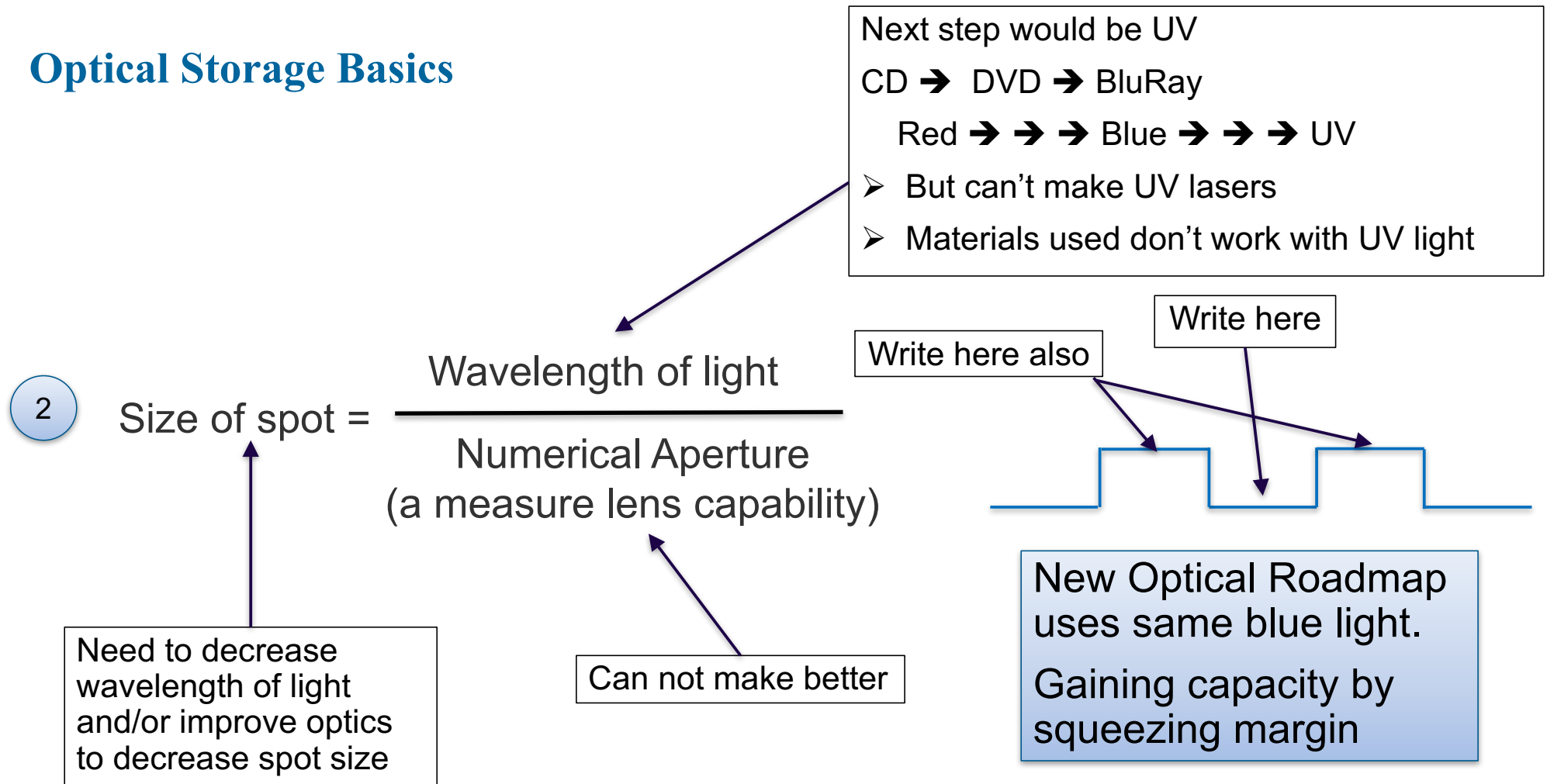
Write with heat  
Read with reflection

- 1 Better areal density / higher capacity achieved by heating smaller spot on disc  
➤ Spots are put on embossed tracks in disc
- 2 Size of spot =  $\frac{\text{Wavelength of light}}{\text{Numerical Aperture}}$   
(a measure lens capability)
- 3 The “spot” is fuzzy



By FDominec - Own work, CC BY-SA 3.0,  
<https://commons.wikimedia.org/w/index.php?curid=3017519>

## Optical Storage Basics



# Optical Challenges

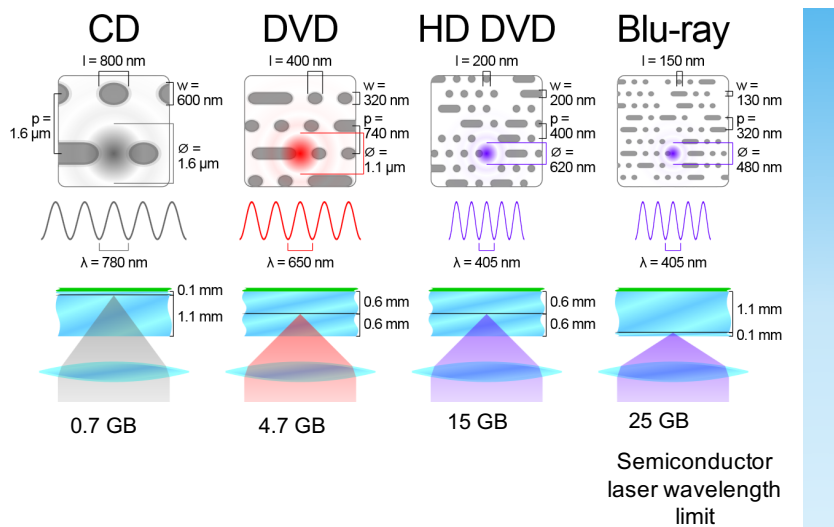
Technology Scaling Limits



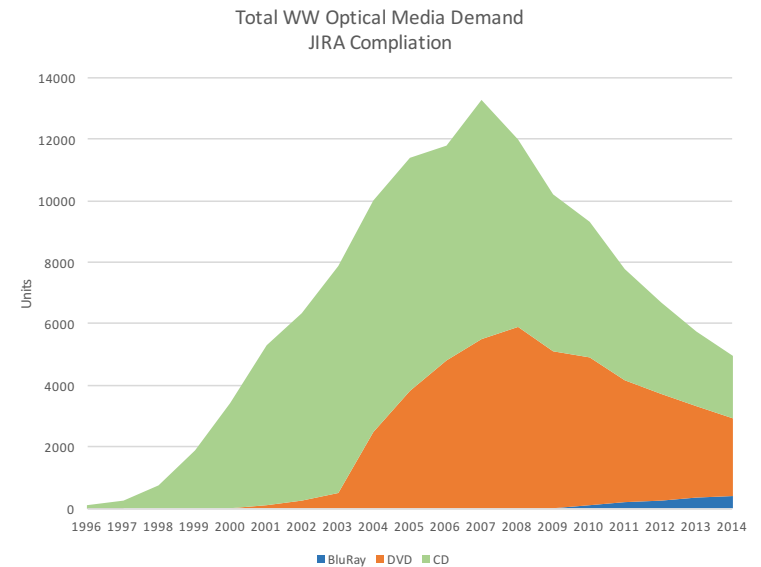
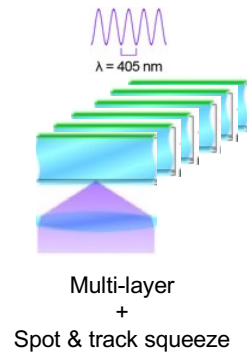
\$/TB not reduced  
with multi-layer



Declining Mfg Media Demand



ODA



"Comparison CD DVD HDDVD BD" by Cmglee - Own work. Licensed under CC BY-SA 3.0 via Wikimedia Commons - [http://commons.wikimedia.org/wiki/File:Comparison\\_CD\\_DVD\\_HDDVD\\_BD.svg#/media/File:Comparison\\_CD\\_DVD\\_HDDVD\\_BD.svg](http://commons.wikimedia.org/wiki/File:Comparison_CD_DVD_HDDVD_BD.svg#/media/File:Comparison_CD_DVD_HDDVD_BD.svg)

# Tape Areal Density Scaling

Write with electro-magnet

Read with “MR” sensor

(“magneto-restrictive” sensor changes resistance in a magnetic field)

So why doesn't tape have the same problems as HDD?

1

Better areal density / higher capacity achieved by shrinking the same basic technology to write smaller and smaller bits on disk

- Smaller magnetic pieces to make smaller bits
- Smaller write heads to magnetize smaller pieces
- Better “MR” sensors to read smaller bits

2

The smaller the magnetic piece, the less stable. When a bit gets so small it's unstable @ room temperature = “superparamagnetic limit”

3

Much, much bigger magnetic pieces & much, much larger surface to store data

0.01

1990 1991 1992 1993 1994 1995 1996 1997

2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019

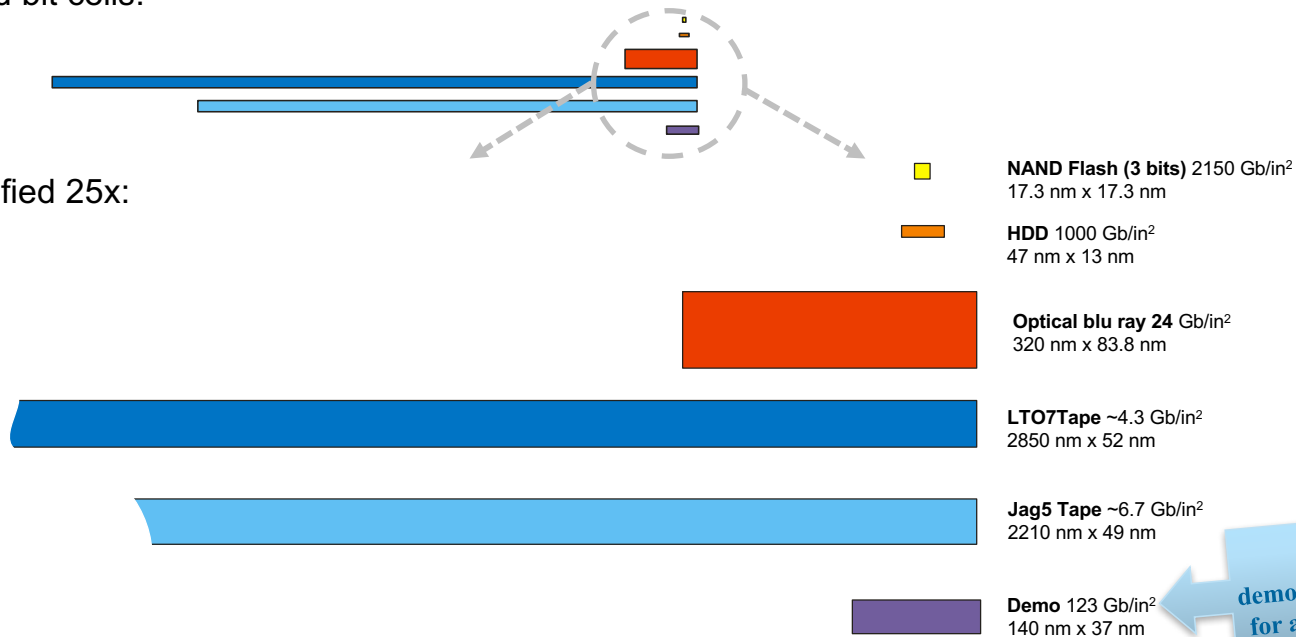


## Relative Size of Bit Cells in Storage

Tape has more bit cell growth potential than any other archive storage

■ Scaled bit cells:

■ Magnified 25x:



IBM Zurich  
demonstrates technology  
for a 220TB Cartridge

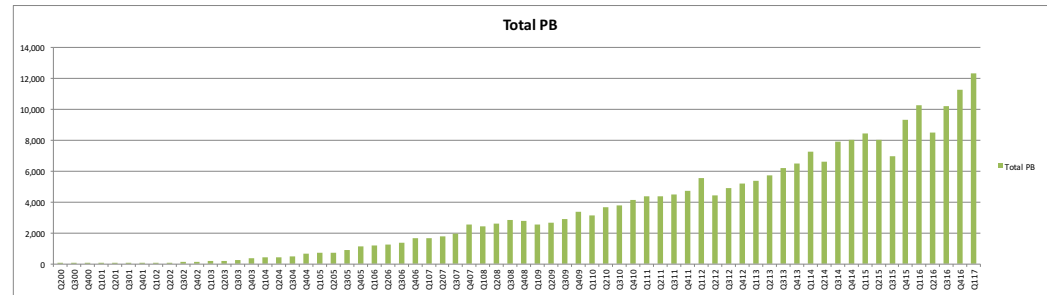
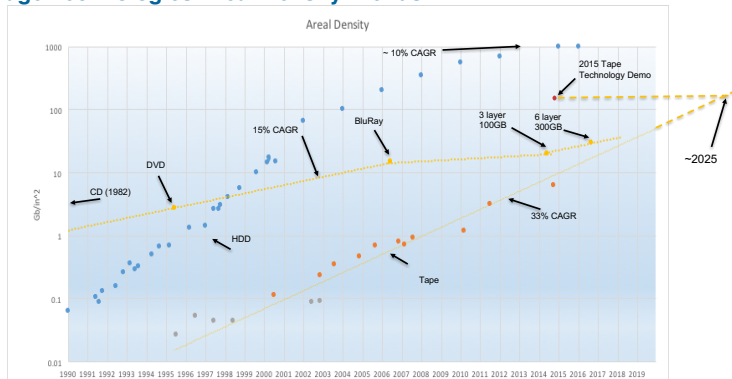
IBM Zurich  
demonstrates  
technology for a  
330TB Cartridge

# Tape Outlook

No Technology Scaling Limits +

Increasing Demand

Storage Technologies Areal Density Trends



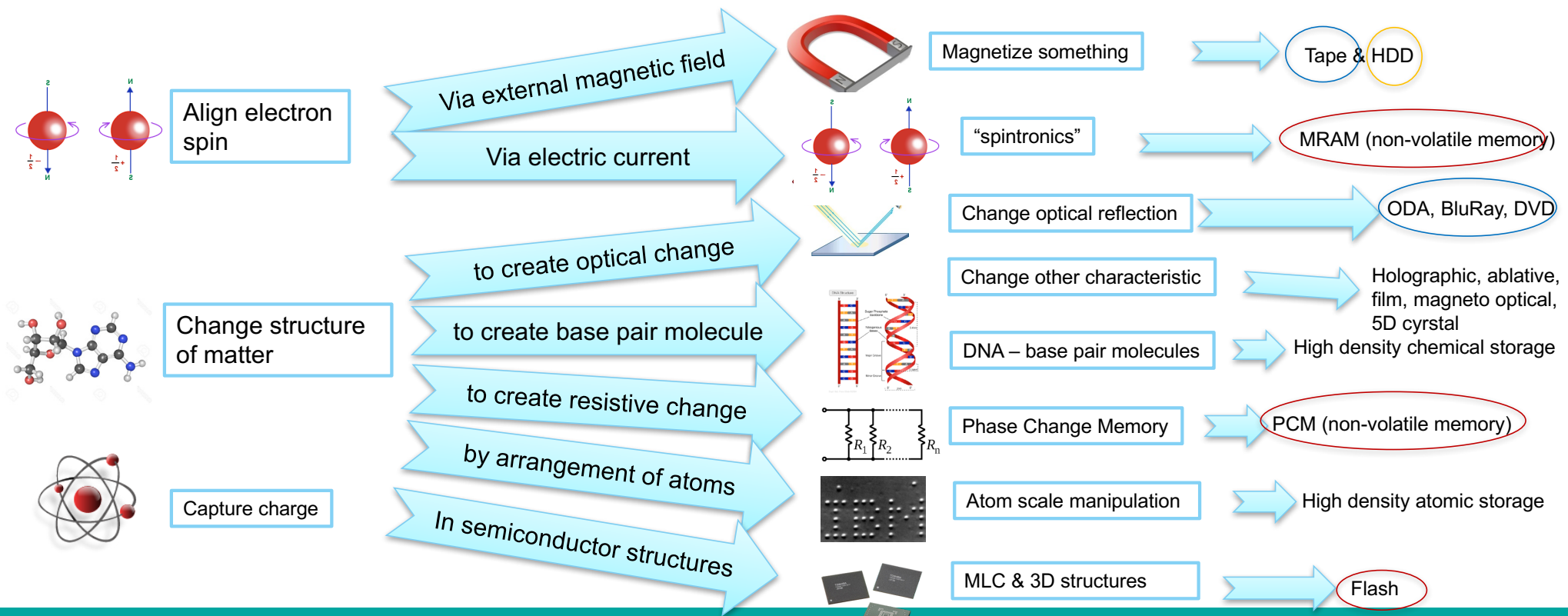
Tape Challenge → Software stack transition from backup to archive

# Storage Technologies

## How do you store a bit? (looking forward)

Low Latency/high perf

Low cost, archive



## Possible Disruptors

### Non-Volatile Memory - Phase Change Memory & Spintronics

- Improved R/W latency over flash + low power + non-volatile
- Enables archive on memory, offline memory archives
- Challenges -Reduction to scale (cost) + entry to crowded market

### Macromolecule Base Pair / DNA

- Incredible densities possible - EB/in<sup>3</sup>
- Extreme long life + low power
- Challenges -Reader and Writer speed

### Atomic Storage

- 500x areal density over magnetic possible – 500 Tb/in<sup>2</sup>
- Challenges -Read and Write speed, current operating temp very, very, very low

### 5D Crystal

- Mult-state optical WORM
- Potential for permanent records, high density – media & laser challenges

### Electron quantum holography

- Stanford demonstrated in 2009. The method stores bits as waveforms caused by the ever-moving electrons of a copper chip. potential of achieving 3 EB/in<sup>2</sup>

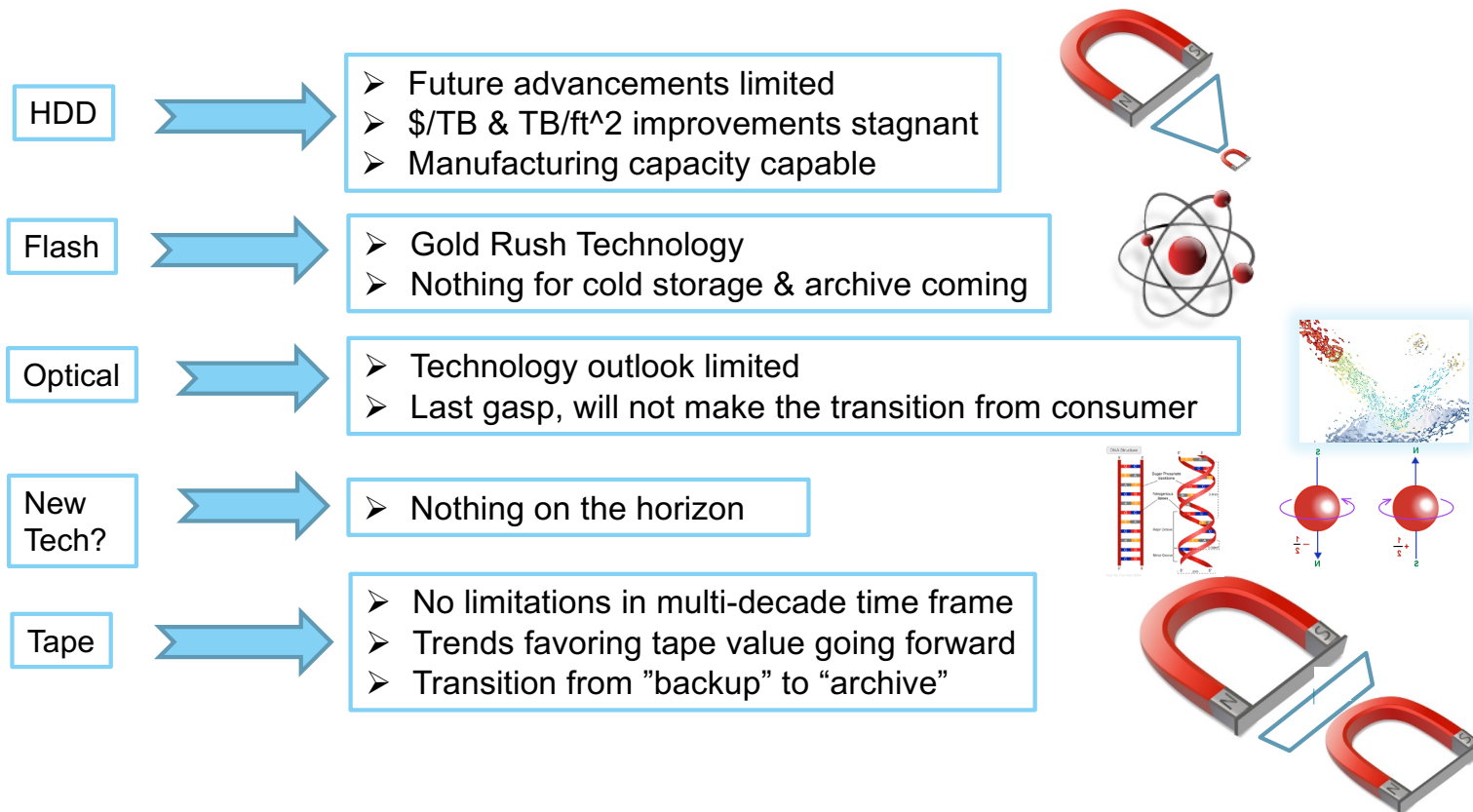
Flash memory will improve going forward, cost for cold archive will not materialize short term

Never or, at best, not any time soon

another "future" optical / holographic like promise – not near term

Cool but no clue on outlook

## Looking Forward - Cold Storage Technologies



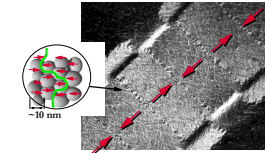
# The Archive Storage Triple Whammy

1) HDD technology scaling breaking down

2) Data is growing faster than previously

3) Consumer market demand shifting focus

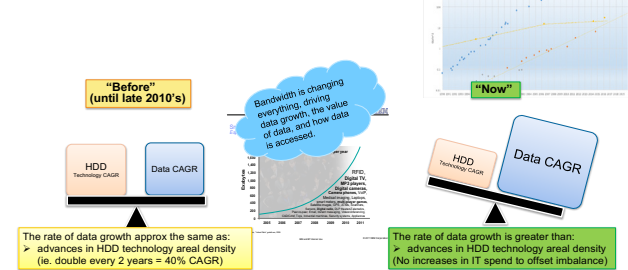
## HDD Superparamagnetic Limit



If grains become too small, magnetic state is unstable  
→ superparamagnetic effect

IBM Confidential IBM Systems 13

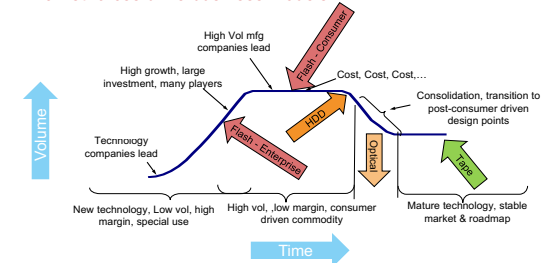
## Fundamentally – It's a Storage Scaling Problem



IBM Confidential IBM Systems 14

## Engineers Solve Technology Problems but...

Market forces drive business models...



IBM Confidential IBM Systems 15

## What are the options for cold archive?

- 1) Increase the budget, build out more floorspace, spend more \$ on disk
  - HDD mfg capacity OK, but \$/TB & TB/ft<sup>2</sup> not keeping pace with data

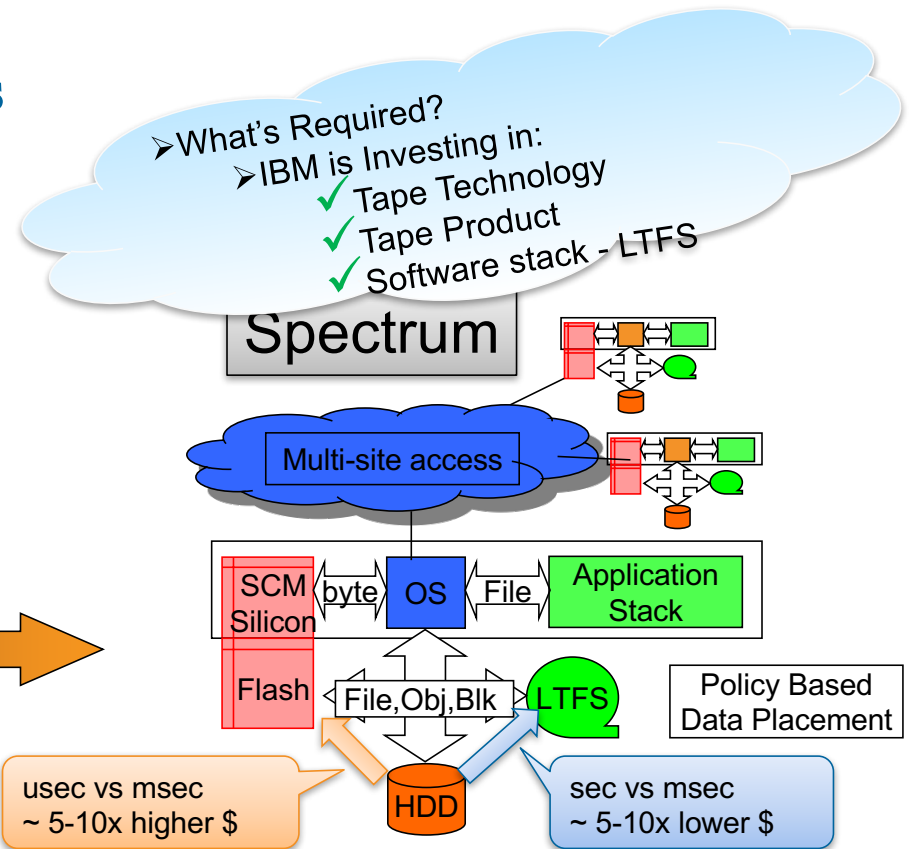
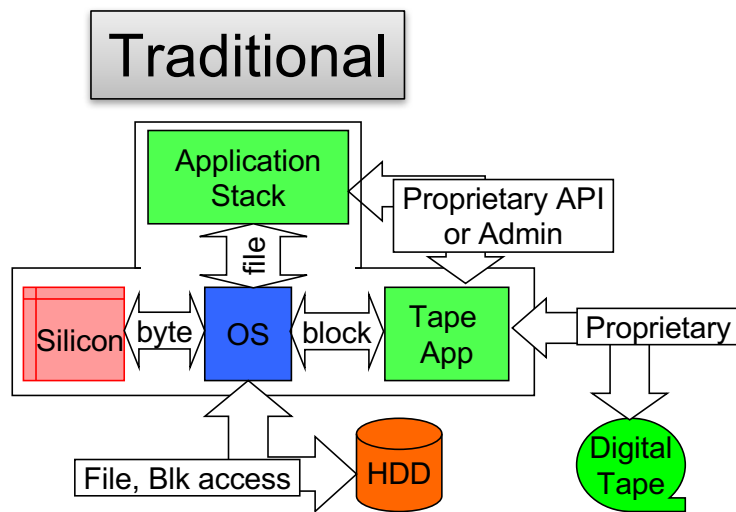
- 2) Pay someone else to deal with it – aka cloud services
  - Cloud storage, including connectivity bandwidth/\$

- 3) Hope for a storage technology breakthrough
  - There is nothing on the horizon

- 4) Breakdown traditional storage islands
  - Tiered storage solution including flash, HDD, tape
  - Spectrum Archive as part of the Spectrum Storage family

**IBM Focus  
Tape Enables**

## The Answer - Break Down Storage Islands





## Agenda

Why is there a problem scaling storage?

Tape Technology Outlook

IBM Tape Strategy

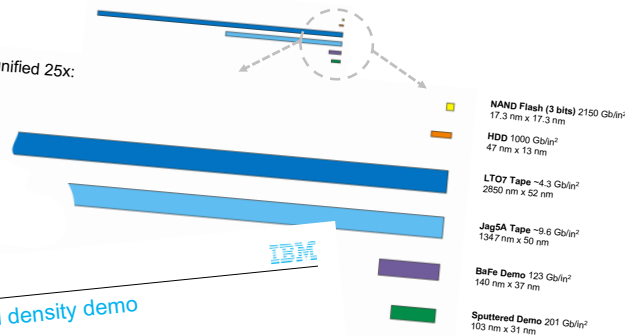
- Investment in Tape Technology
- Investment in Enterprise Tape and Commitment to LTO Roadmap
- Investment in the Tape Software Stack – LTFS, OpenLTFS & SwiftHLM
- Investment in Tape Automation

# Investment in Tape Research

## 2017 Storage Bit Cells and Extensibility

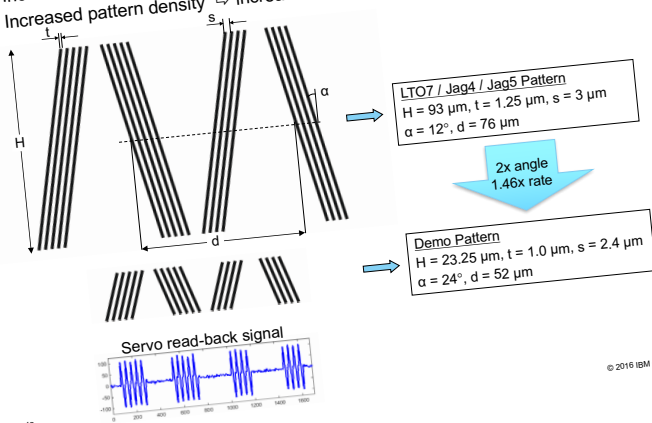
• Scaled bit cells:

• Magnified 25x:



## Servo pattern design for high areal density demo

- Increased azimuth angle  $\Rightarrow$  increased resolution
- Increased pattern density  $\Rightarrow$  increased servo bandwidth and resolution



• Increased track density  
• Improved control  
• Increased data channel

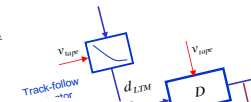
© 2016 IBM Corporation

## New $H_\infty$ track-follow control system

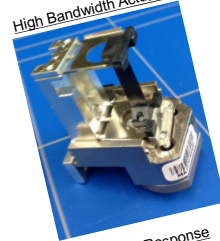
### Key features

- 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

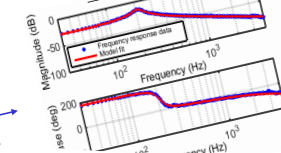
Track-follow control system



## High Bandwidth Actuator

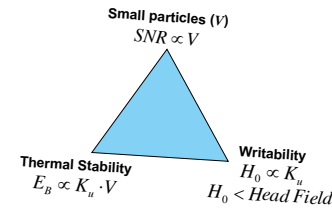


### Actuator Response

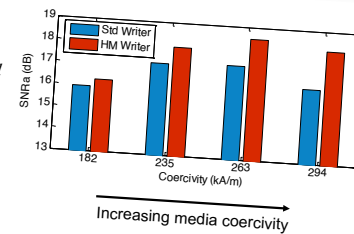
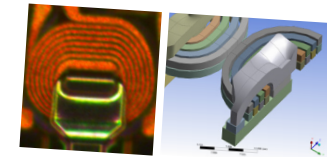


## Enhanced Write Field Head Technology

Magnetic Media "Trilemma":

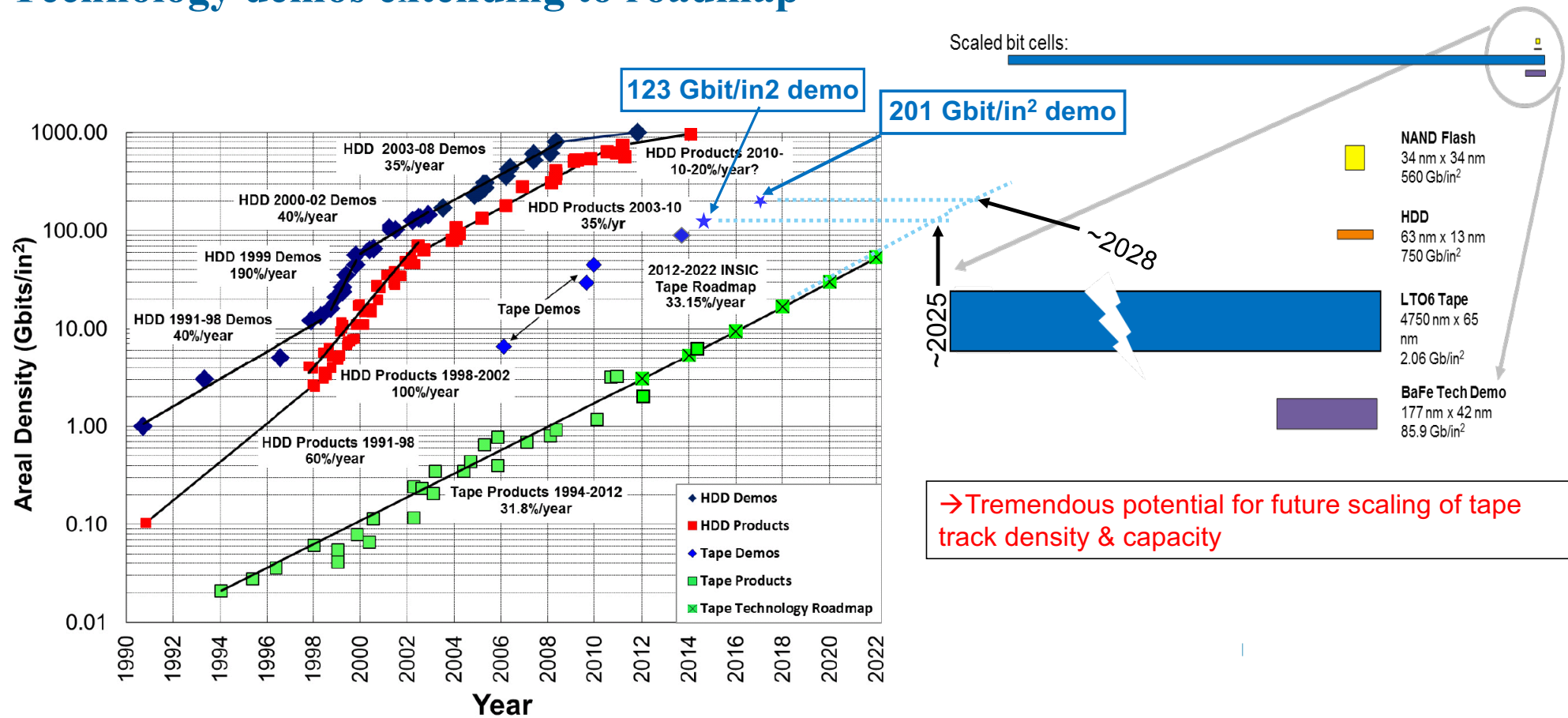


IBM developed a new high moment (HM) layered pole write head that produces much larger magnetic fields enabling the use of smaller magnetic particles



© 2016 IBM Corporation

# Technology demos extending to roadmap



Source: Mark Lantz, IBM Zurich

# IBM Tape 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

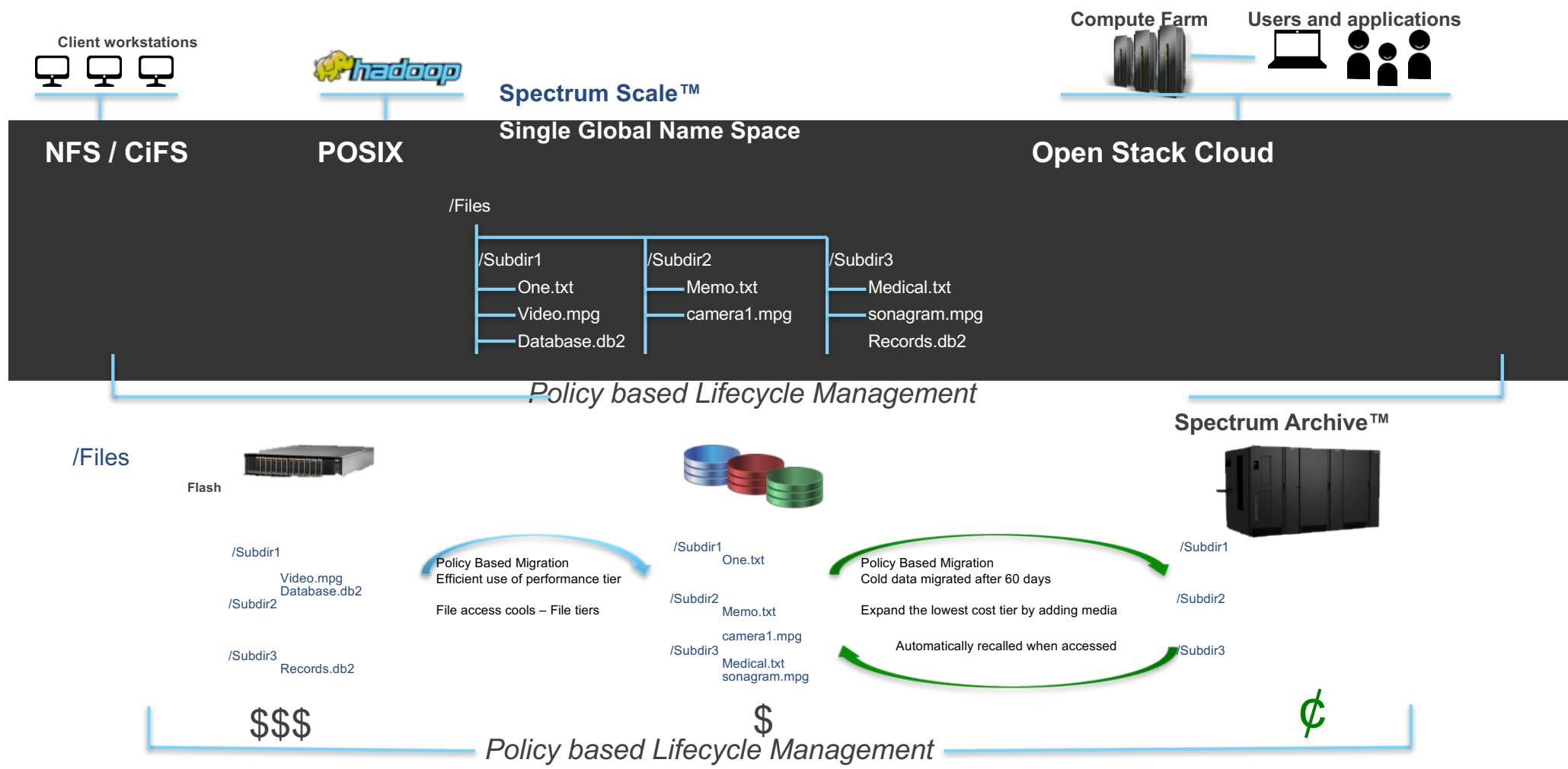
## Software - LTFS

- IBM invented, open source, open standard
- Provides file system support, integration of tape into Spectrum Scale

Jag5A – 15TB availability June 2017

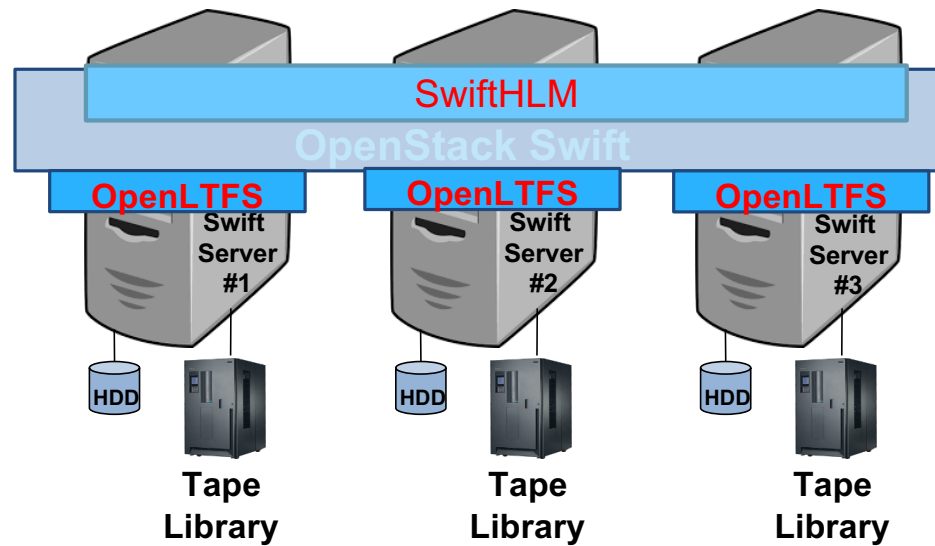


# Spectrum Archive – How it works



# IBM Research Initiatives

## OpenStack SwiftHLM & OpenLTFS – Object support for Tape



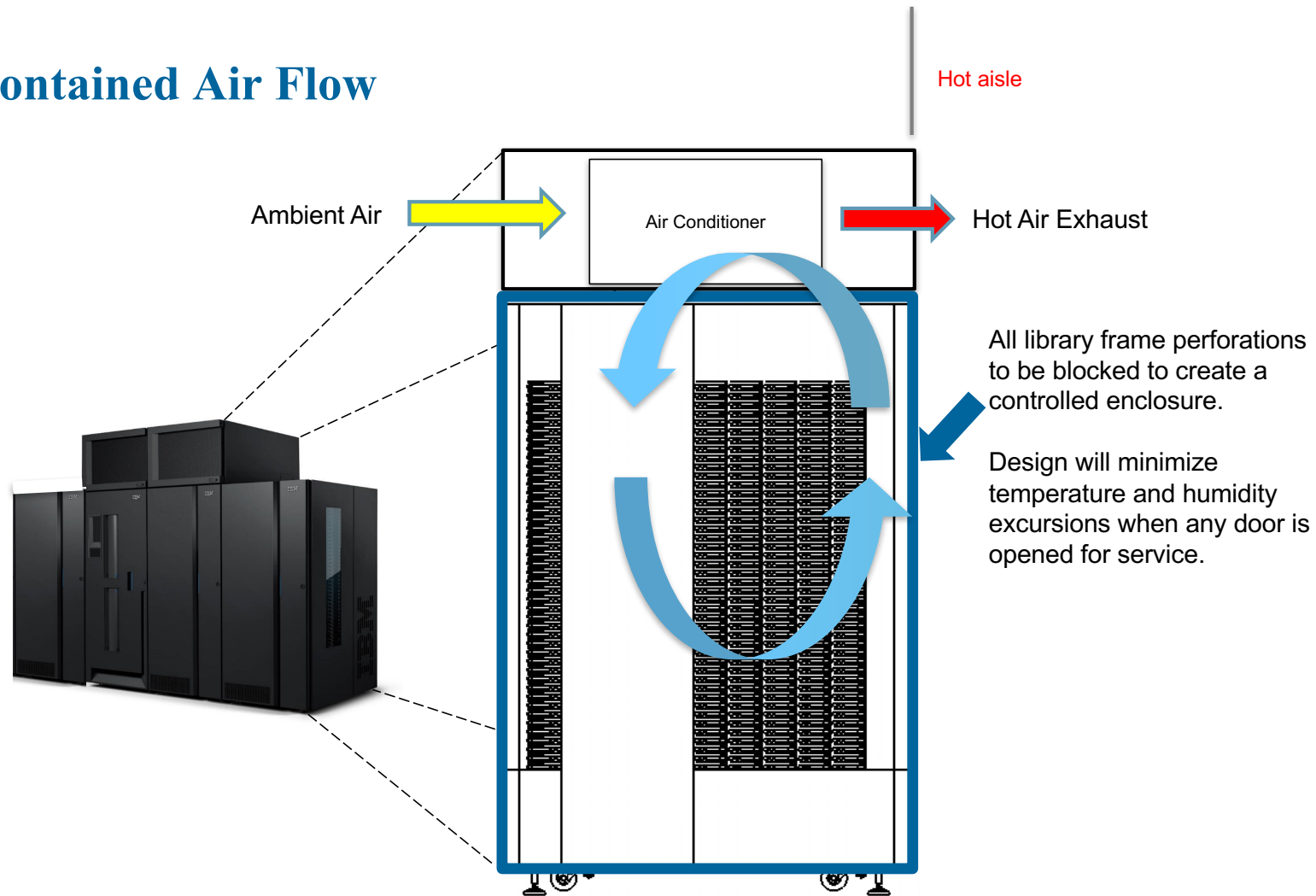
- OpenLTFS** – LTFS with disk cache, tape backend, and data&resource mgmt.
- SwiftHLM** – Swift High Latency Media middleware (open source)
- Swiftbrowser** – Django Swiftbrowser with SwiftHLM API support

## TS4500 Tape Library

- Scales to over 175 PB native
- Supports up to 128 tape drives
- Next-generation storage density
  - 5.5 PB native in a single frame tape library
  - Scales at up to 1 PB per square foot
- Simplified management
  - Magazine I/O
  - Integrated management
  - Improved ease-of-use
  - Extensible platform



## Self-contained Air Flow





## Advice and Predictions for Data Storage Experts

Tape will be around for a long, long time ...



No matter how sophisticated your infrastructure, don't put all your eggs in one basket..



You will always have someone like this in your food chain, get used to it..



**Thank you!**