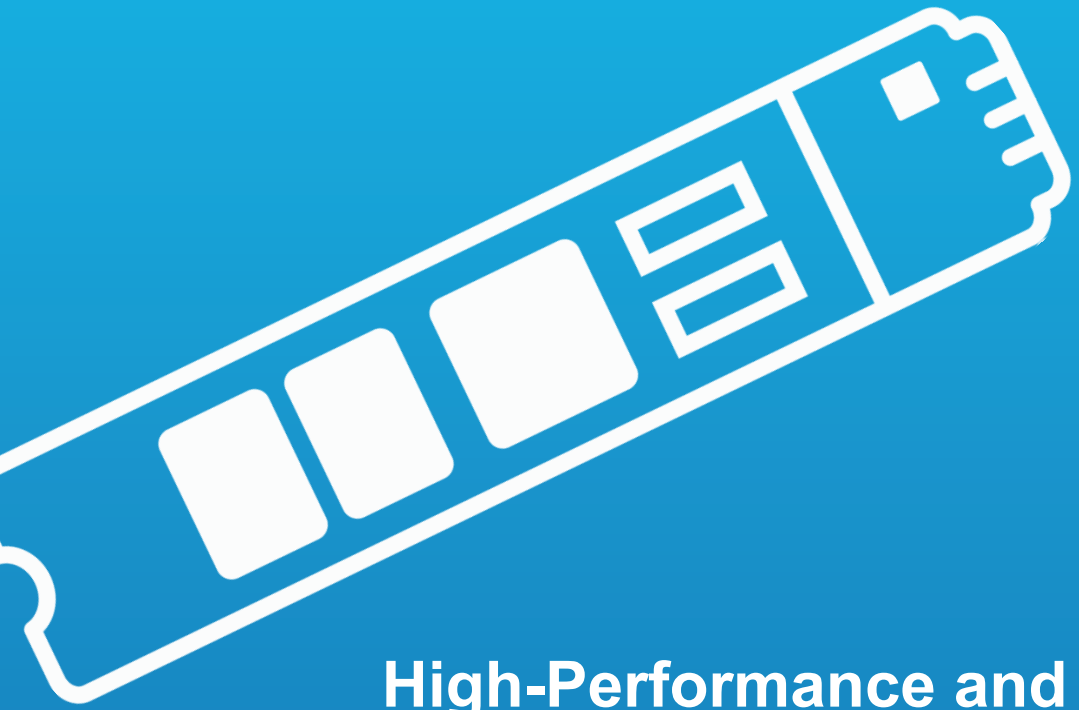


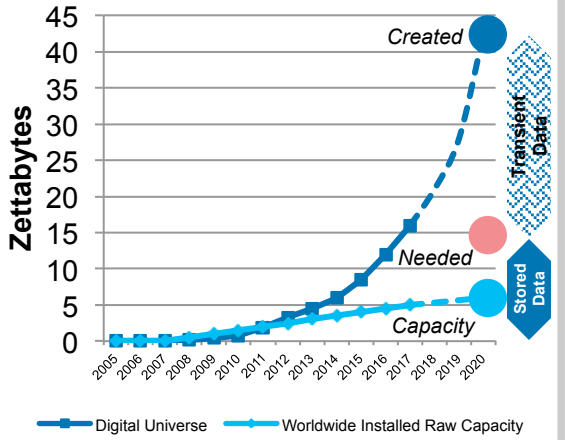
SEAGATE

High-Performance and Large-Capacity Storage: A Winning Combination for Future Data Centers

Phil Brace | August 12, 2015

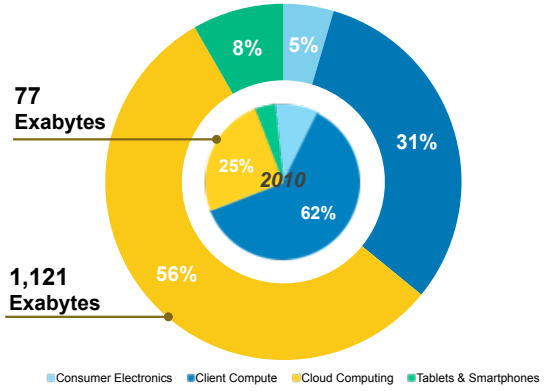
Data is Changing…

Bigger



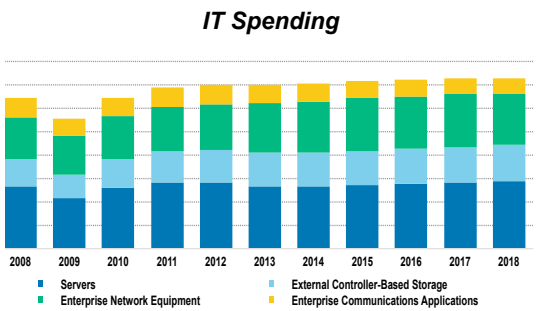
Demand GROWING at Exponential RATE

Different



Location SHIFTING dramatically to the CLOUD

$ Constrained



Stable but SLOW growth

Explosive growth in data

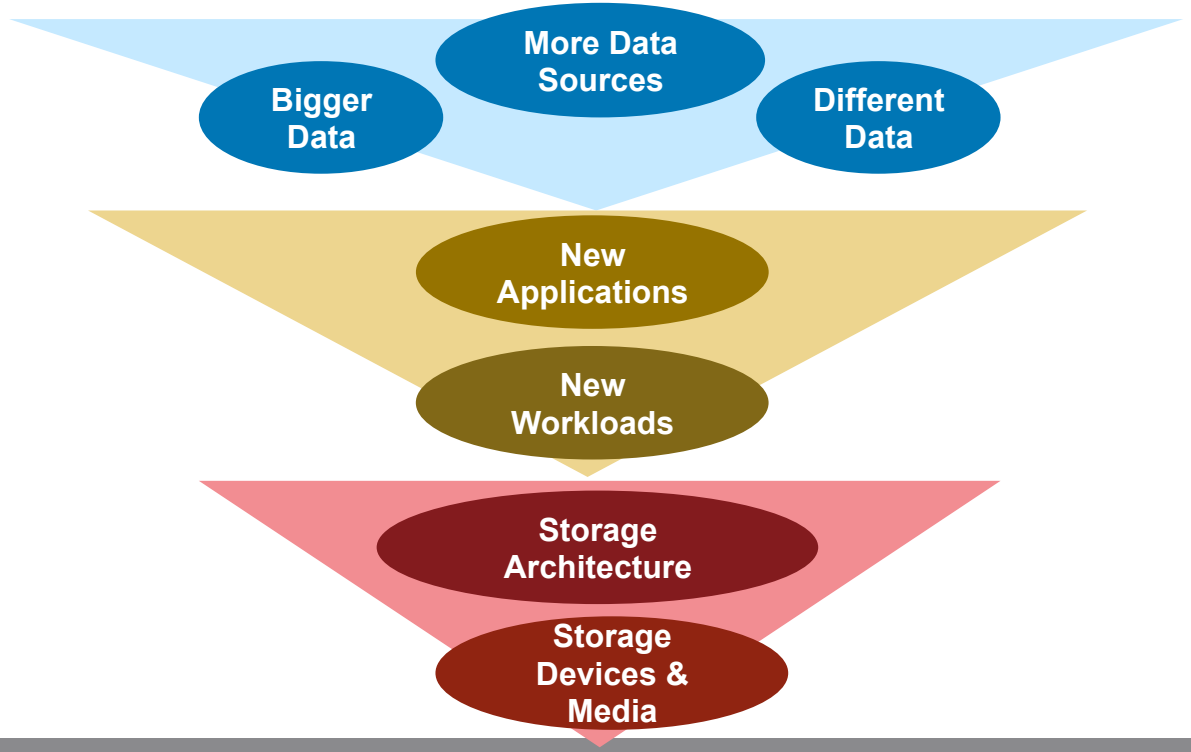
Shift in use and store model

Modest growth in IT budgets

Sources: Reinsel, David. "Where in the World Is Storage: A Look at Byte Density Across the Globe" IDC October 2013, IDC/EMC Digital Universe, April 2014 + Seagate Estimates and Marketing & Research

Exciting Time to be in the Storage Industry!

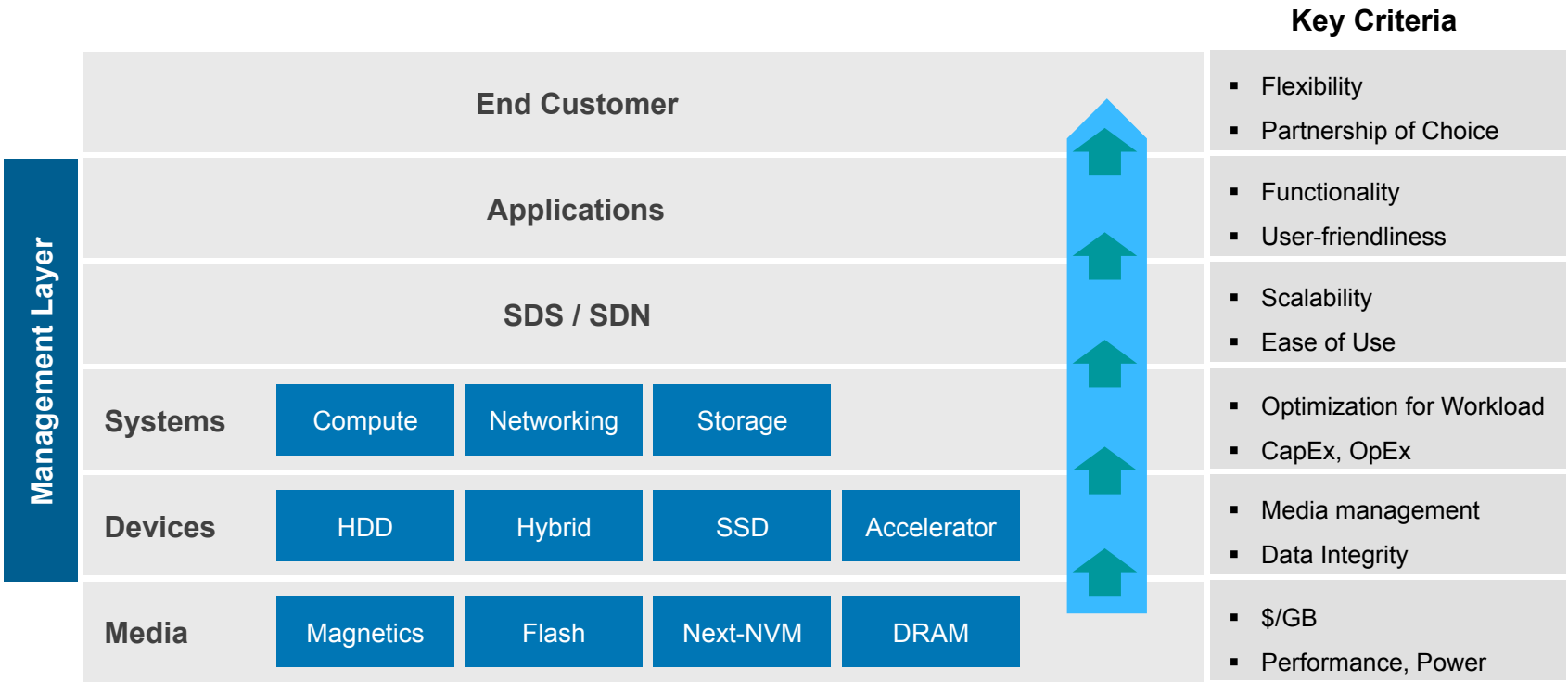
Need innovation in architecture and media within economic constraints



We have a collective opportunity

Storage Architecture

Leveraging tiers to meet workload and economic demands



Existing Media Technology

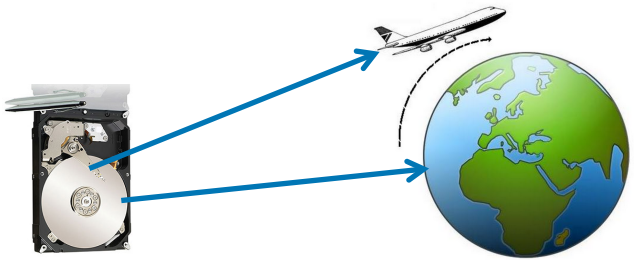
Enabled phenomenal bit-density scaling thus far

Magnetic Media	Solid-State Media

Both media have seen approx. 10,000 fold increase in areal density from 1990 until now

If the HDD HEAD was scaled to a 747, then the 747:

- Would be flying at 6 times the speed of sound
- Less than 1 centimeter off the ground
- Counting every blade of grass as it rocketed past, making an…
- Irretrievable error <10 blades of grass in lawn the size of Minnesota

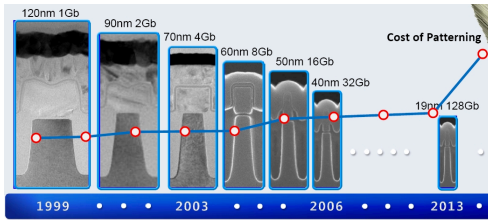


Physical scaling has moved from 120nm to 15nm

- Use of advanced manufacturing

Logical scaling has moved from SLC to MLC to TLC

- Program / Erase Cycles have gone from 100K to <1K
- Error correction has risen from nearly 4 bits/KB to ~60 bits/KB



Source: Future Technology Challenges For NAND Flash And HDD Products, E. Grochowski, R. Fontana, Flash Memory Summit, 2012 + Seagate Internal, http://itersnews.com/?p=68244

New Media Technology Driving Density Further

Innovations are almost defying Physics – rapidly increasing noise to signal

Magnetic Media

Shingled Magnetic Recording (SMR)

- Focus on reducing track pitch
- Areal Density ~1.2 Tb/in^2
- 20% Areal Density Increase

Two Dimensional Magnetic Recording (TDMR)

- Focus on reducing track pitch
- Improved Signal - to - Noise Ratio
- 15% Areal Density Increase

Heat Assisted Magnetic Recording (HAMR)

- Focus on reducing grain size
- Areal Density ~1.2 - 5.0 Tb/in^2

Solid-State Media

2D scaling attempting to go to 12/10nm

- Storing charge with handful of electrons
- Manufacturing complexity due to geometry

3D-NAND

- Exploits the Z-dimension to increase density
- Projected to go to 64-layers and above
- Complex deposition and etch – new tools

Re-RAM, PCM, 3D-XPoint and STT-RAM are future contenders

Media Management Innovations

Enable reliable signal extraction in increasingly high noise environments

Magnetic Media

Algorithms for SMR, MSMR, HAMR
Fly-Height Control
Hybrid Tiering IP
Significant Analog/Mixed-Signal IP
Large Block/Track Codes
Drive Mechanics

Solid-State Media

Recycling/Garbage-Collection
Flash Translation Layer
Compression
Mostly Digital IP
Page/Block/Chip Failure Tolerance

Signal Processing
Interface Technology (PCIe, SAS, SATA)
Virtualization of LBA Space
Wear-Leveling

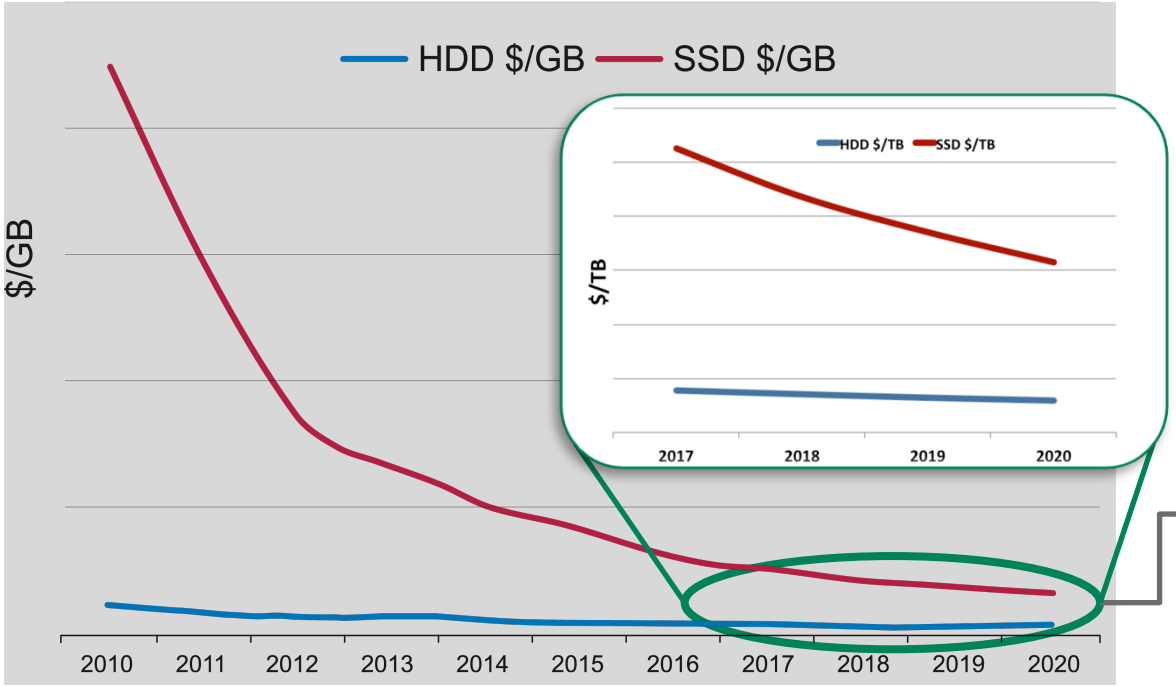
Security
Error Correction (LDPC)
Calibration
Defect Management

Significant commonality in Magnetic and Solid-State Media-Management

SMR = Shingled Magnetic Recording; MSMR = Multi-Sensor Magnetic Recording, HAMR = Heat Assisted Magnetic Recording

Requirement for Both Flash and Magnetics

$/GB differential projected to continue into 2020



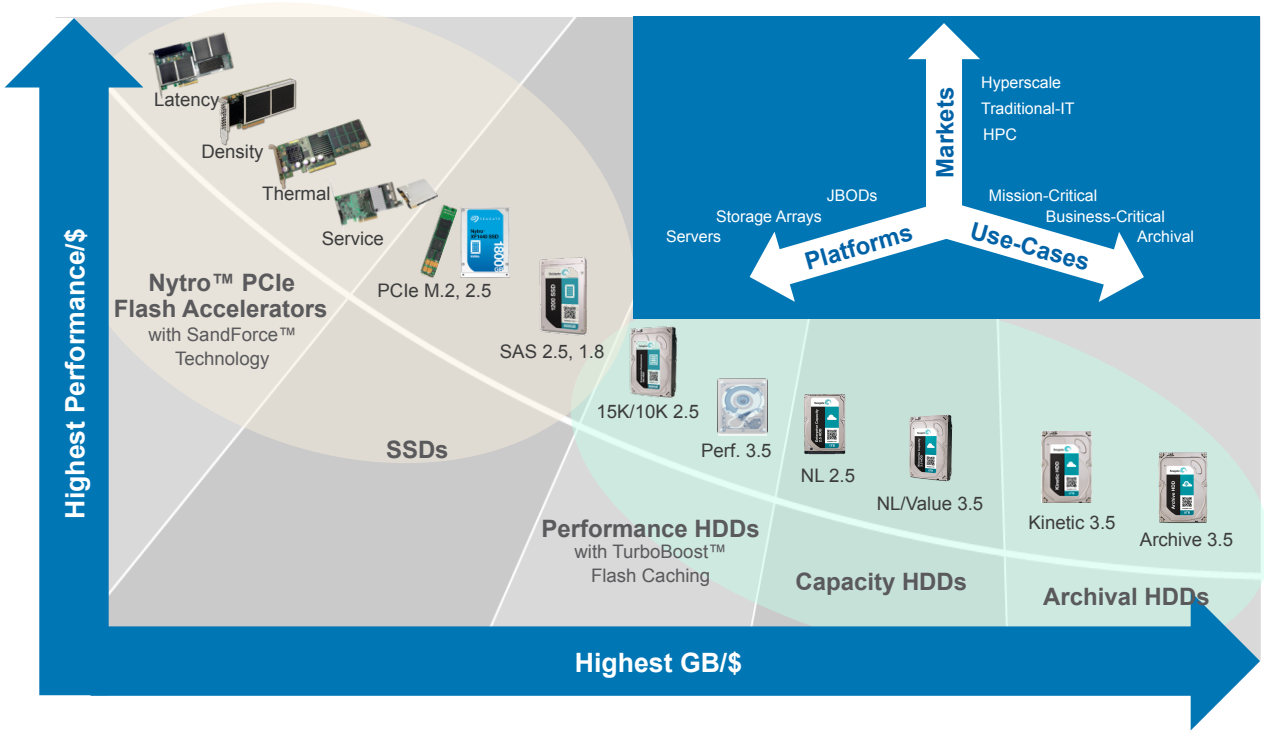
Data Demand, Workload Variation and $/GB differential will require HDD and SSD

5x – 10x
Differential
based on Application

Source: Seagate Strategic Marketing and Research 2014

Seagate – Spanning Performance and Capacity

Servicing diverse workloads in integrated manner



Summary

- **Data is changing – bigger, different and $ constrained**
- **New applications driving different workloads/economics – need tiered solutions**
- **Innovations in storage architecture and media required – access and density**
- **MIPS commoditized, storage needs to be tailored – seek integrated solutions**
- **Exciting time to in the Storage industry – we have a collective opportunity!**

Thank You