Storage and Memory Behind the Hits:

Developments for Digital Storage in Media and Entertainment

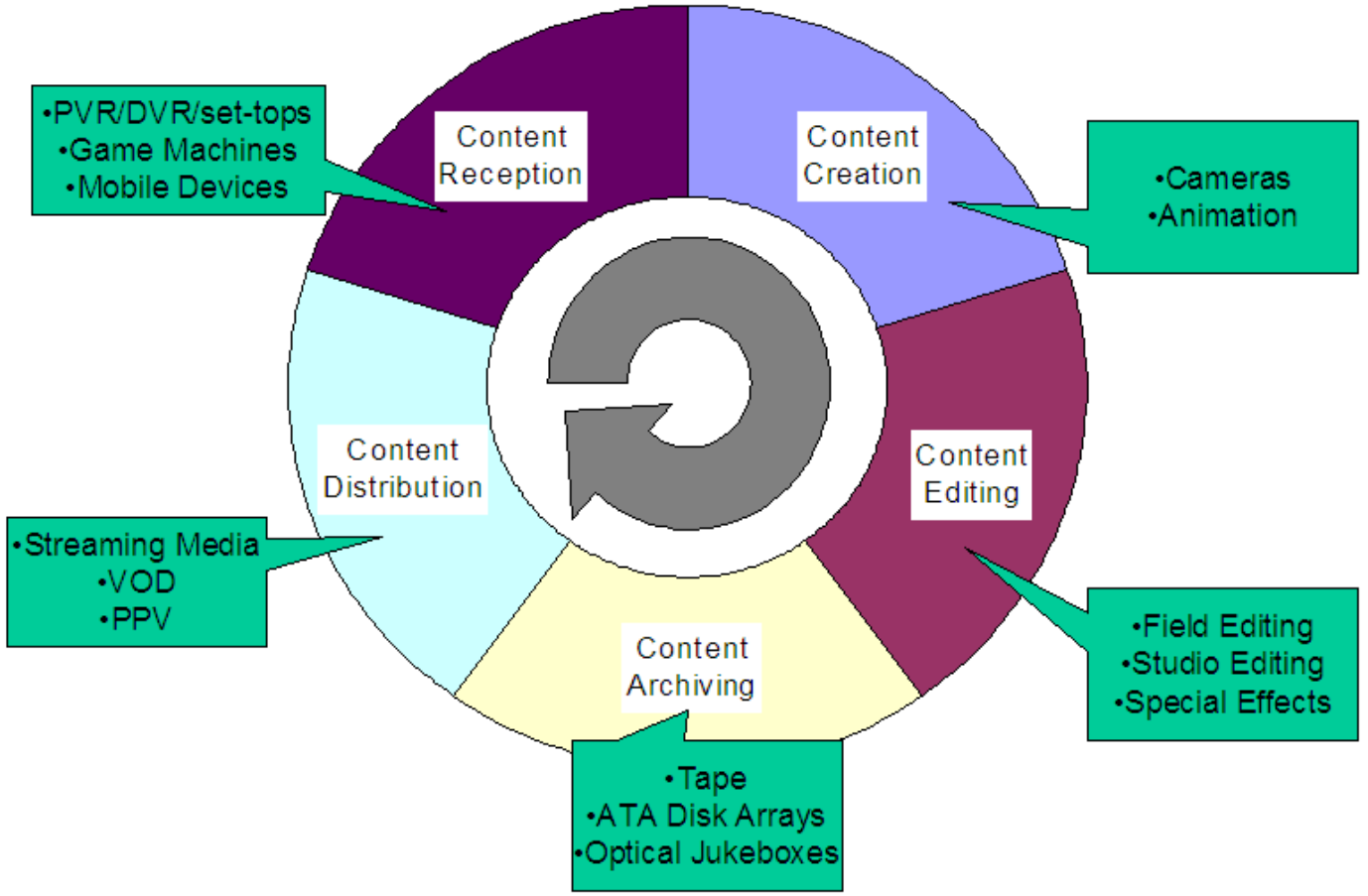
Tom Coughlin, President, Coughlin Associates, Inc.
www.tomcoughlin.com

Outline

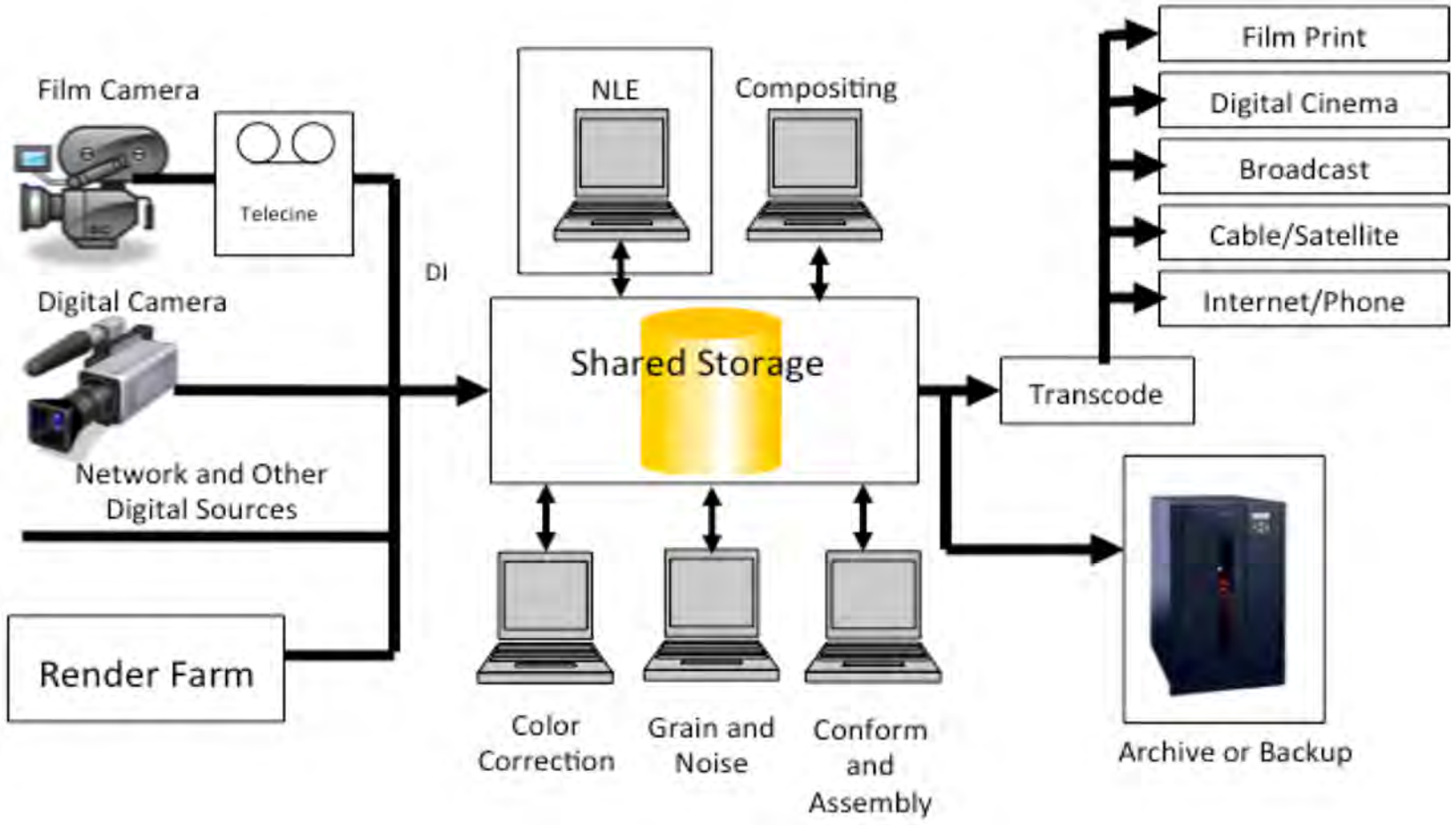
- Video is Demanding More Storage Capacity and Performance
- Storage for Content Capture
- Post Production Memory and Storage
- Storage for Content Distribution
- Archiving and Preservation
- M&E Storage and Memory Technologies
- Summary and Conclusions

Video is Demanding More Storage Capacity and Performance

Digital entertainment content value chain (an accelerating positive feedback loop)



Digital entertainment content workflow.



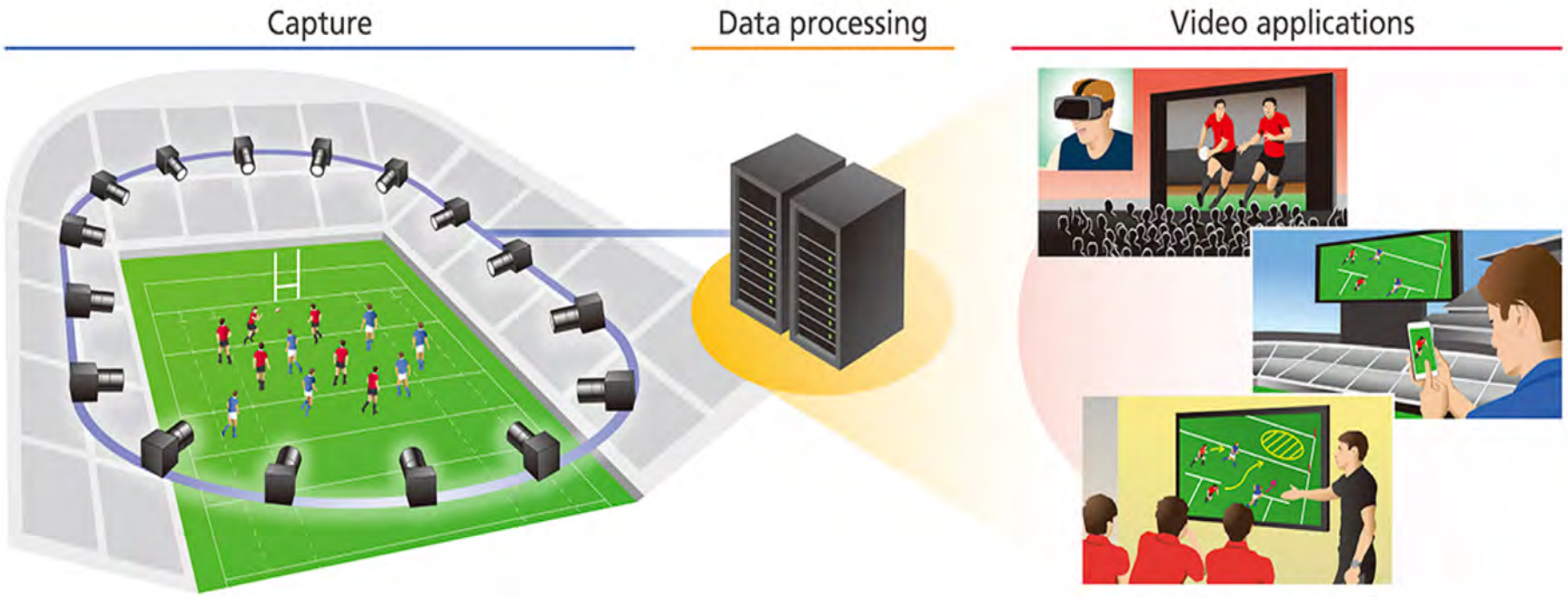
Example resolution, data rates and storage capacity requirements for professional media standards

Format	Resolution (width X height)	Frame Rate (fps)	Data Rates (MB/s)	Storage Capacity GB/Hour
SDTV (NTSC, (8-bit)	720 X 480	~30	31	112
HDTV (1080p, 8-bit) RGB	1920 X 1080	24	149	537
UHD-1 4K (10-bit) RGB	3840 X 2160	60	1,866	6,718
UHD-2 8K (12–bit) RGB	7680 X 4320	120	17,916	64,497
Digital Cinema 2K (10-bit) YUV	2048 X 1080	24	199	717
Digital Cinema 4K (12-bit) YUV	4096 X 2160	48	1,910	6,880
Digital Cinema 8K (16 bit) YUV	8192 X 4320	120	25,480	91,729

8K Ultra-HD may use more than 170X capacity of HD!

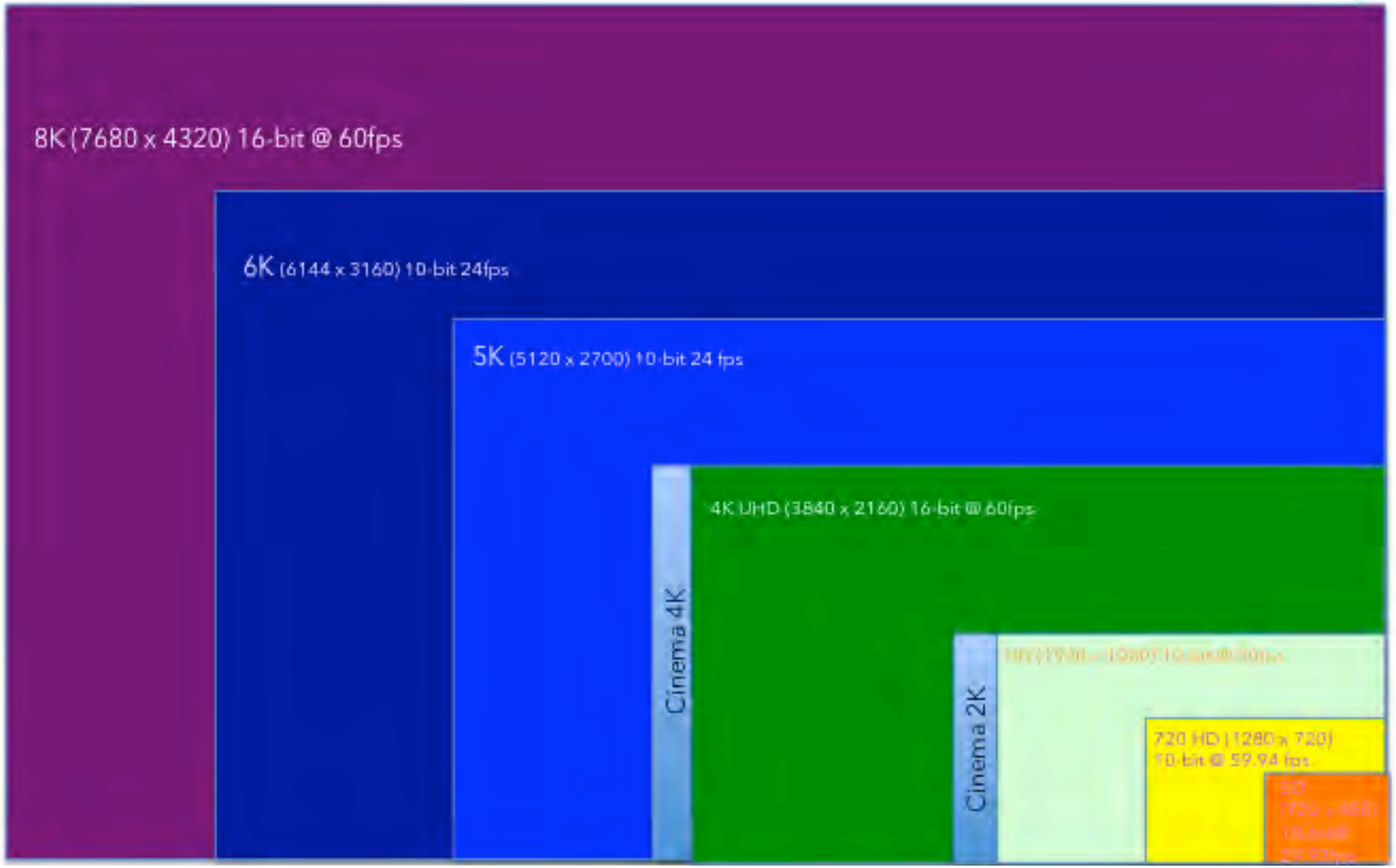
Setup and application of Canon's free viewpoint video system (Volumetric video)

- 5-32 4K or higher resolution cameras surrounding an event
- Images are stitched together and allow rendering a view from anyway in the captured volume



Example setup and applications of the Free Viewpoint Video System

Video resolution comparisons



360° Video and VR Will Drive Content Growth

- VR and AR could drive 16k video (8K per eye)
- For a display as close as a pair of glasses, you can see the difference
- 8K per eye would give a more immersive experience

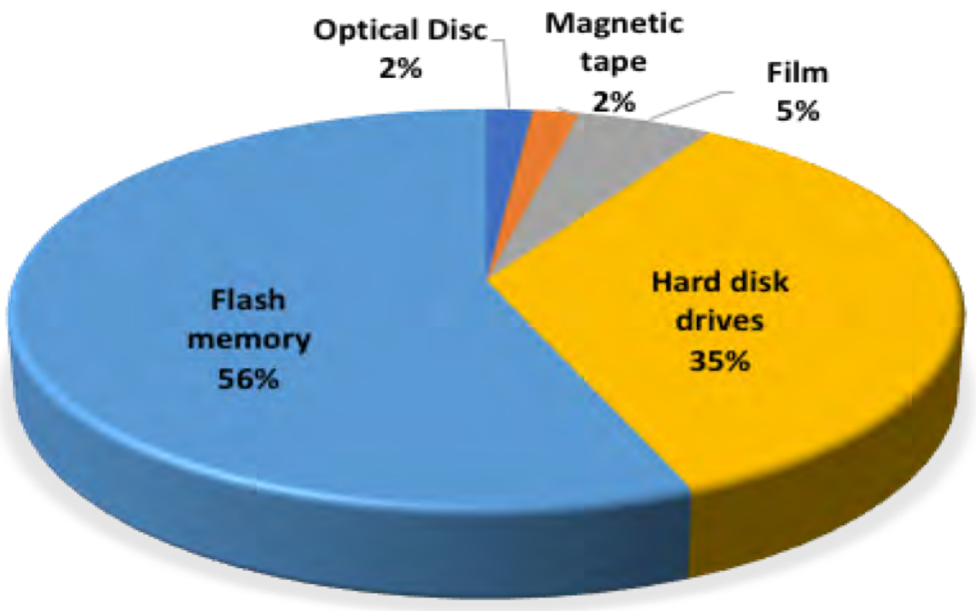
Exabyte Video Projects Coming?

- Video at 16,000 X 8,000 pixel resolution, 24 bits/pixel, 300 fps raw video content could require **115 GB/s data rates and 414 TB/hour**. If 4 cameras were used to create data for a 360 degree presentation, the raw data would be **1.66 PB for an hour of content**
- Within 10 years we could have pro-video projects generating close to an exabyte of data

Storage for Content Capture

The 2018 annual survey on digital storage in media and entertainment

- 9th survey since 2009
- Participants from all different continents and industry segments
- Covers digital storage and content creation/capture, post production, content distribution and archiving and preservation
- Covers Flash Memory, Hard Disk Drives, Optical Discs and Magnetic Tape
- White paper on top level results available
- Full survey used to help with update for the 2018 Digital Storage in Media and Entertainment Report

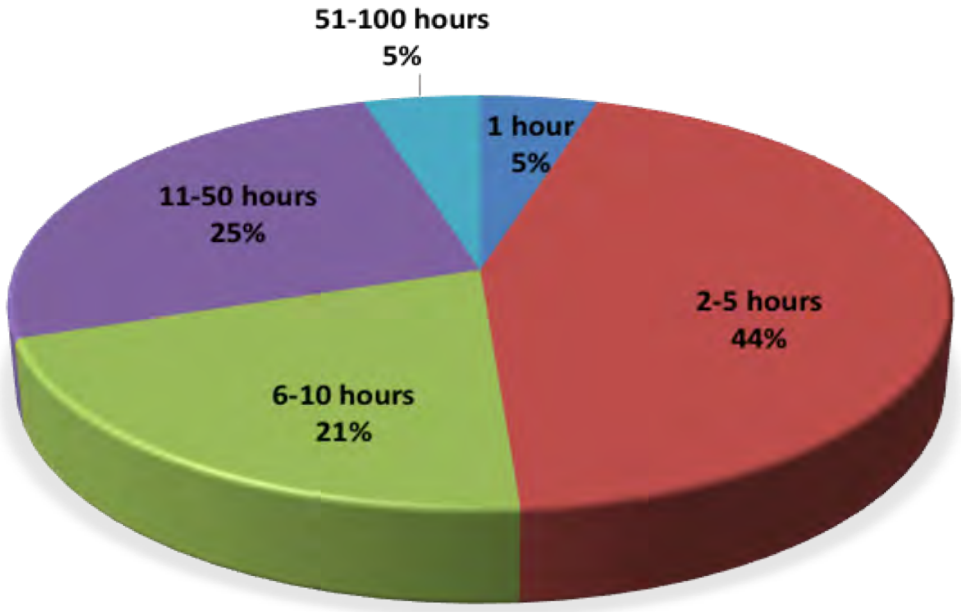


2018

Percentage of various recording media in professional video cameras

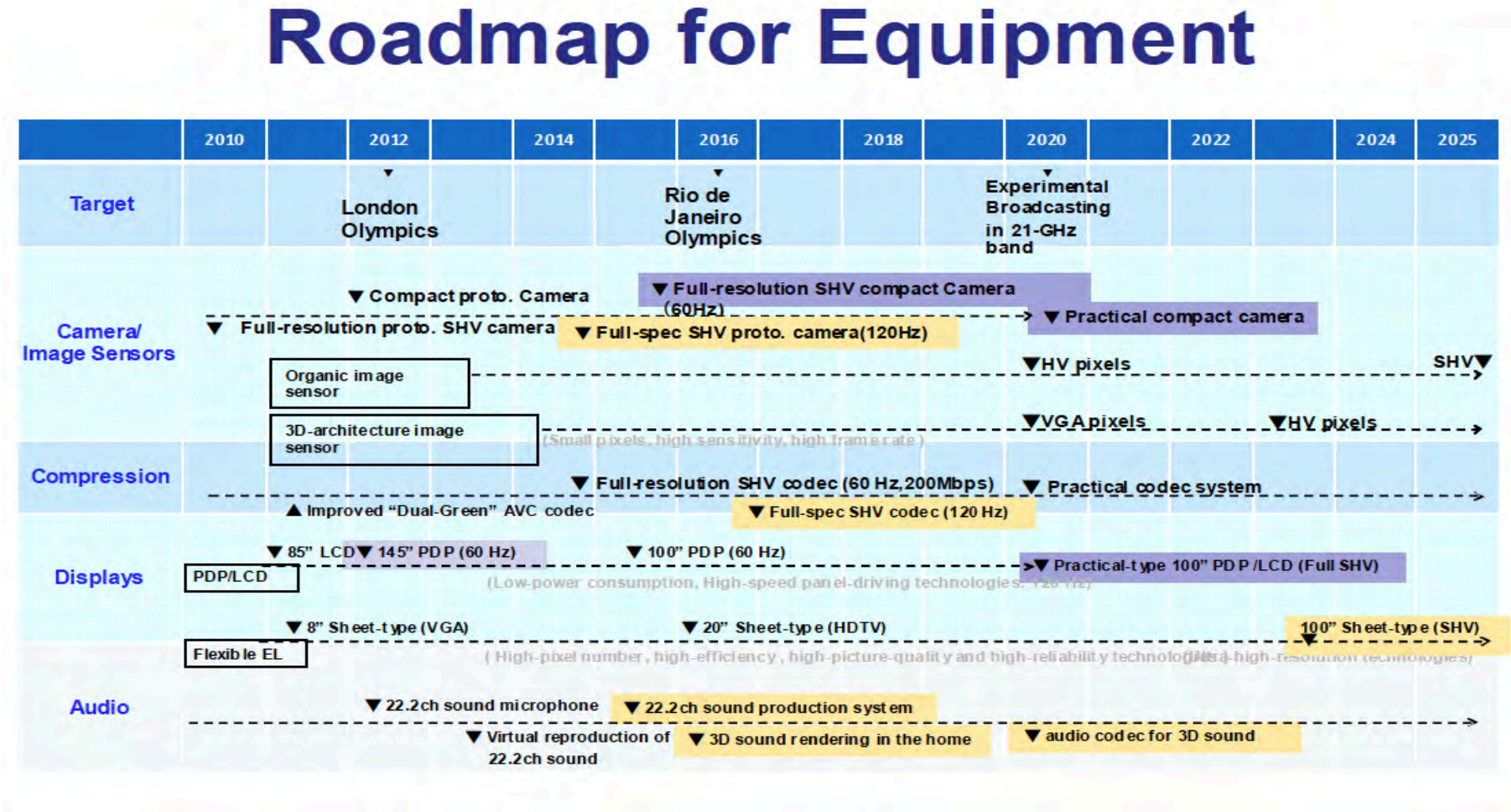
Year	Magnetic Tape	HDD	Optical	Flash Memory	Film
2009	34%	23%	9%	19%	15%
2010	25%	22%	17%	28%	8%
2012	20%	22%	12%	44%	2%
2013	15%	18%	7%	59%	1%
2014	7%	24%	10%	57%	2%
2015	4%	21%	8%	66%	1%
2016	2%	34%	8%	54%	2%
2017	5%	33%	3%	59%	0.16%
2018	2%	35%	2%	56%	5%

Content shot for an hour of completed work

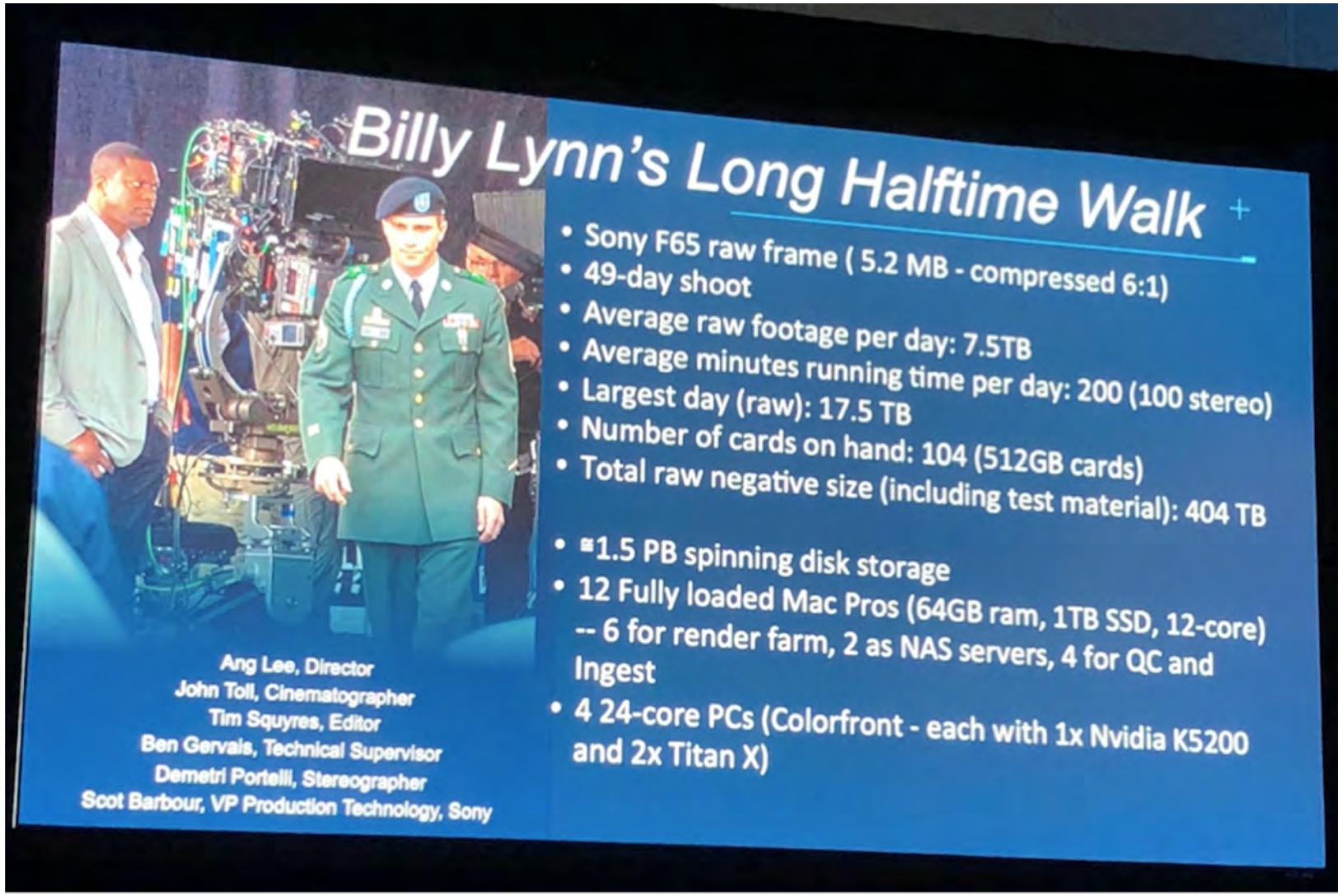


2018

NHK Super High Vision (8K) equipment roadmap



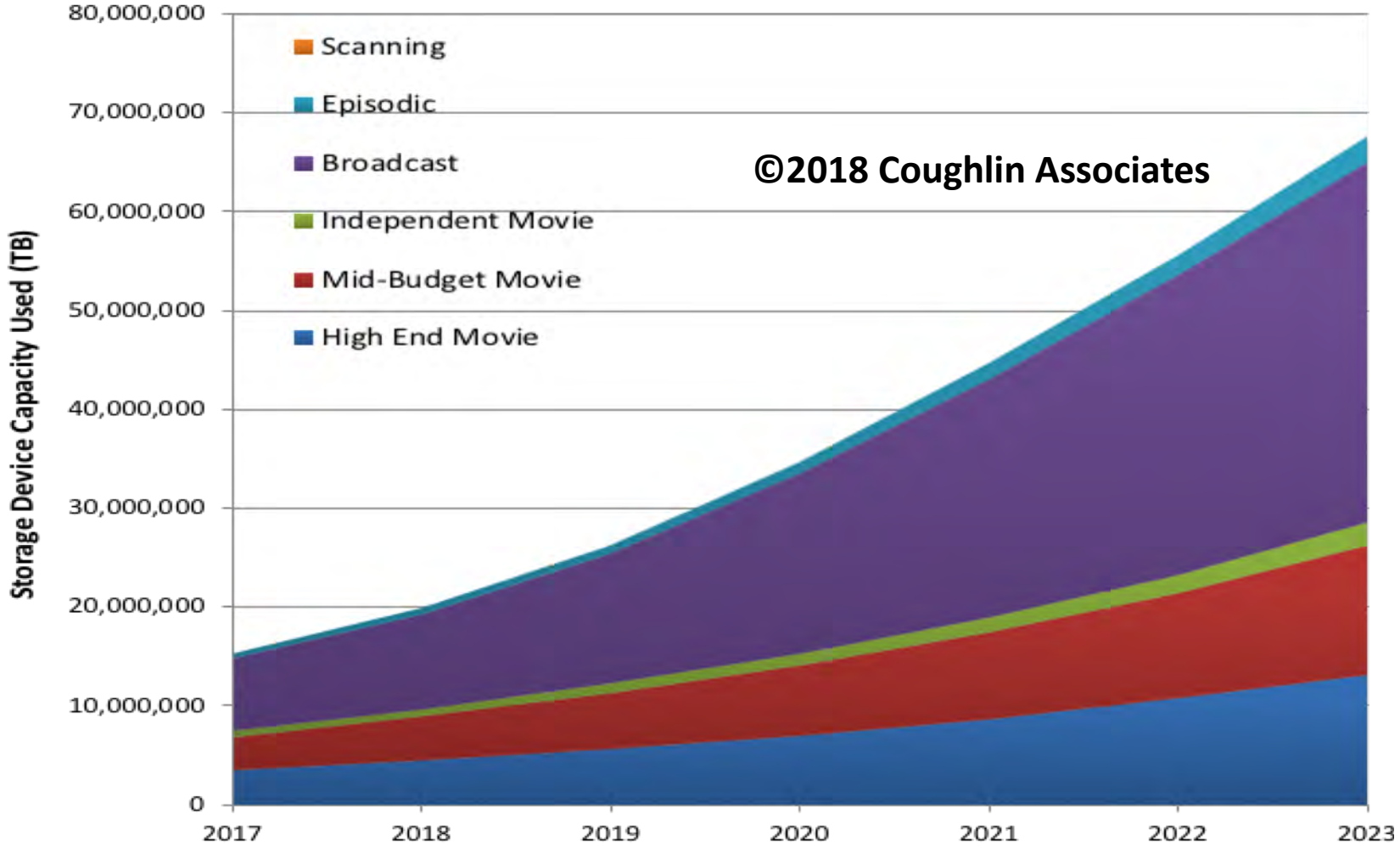
Statistics for Ang Lee's Billy Lynn's Long Halftime Walk



- Shot at 120 frames per second (fps) in 3D at 4K resolution
- Used 1.5 PB of HDD storage
- Could this be the future of video projects?

Ang Lee’s data center (in his apartment)

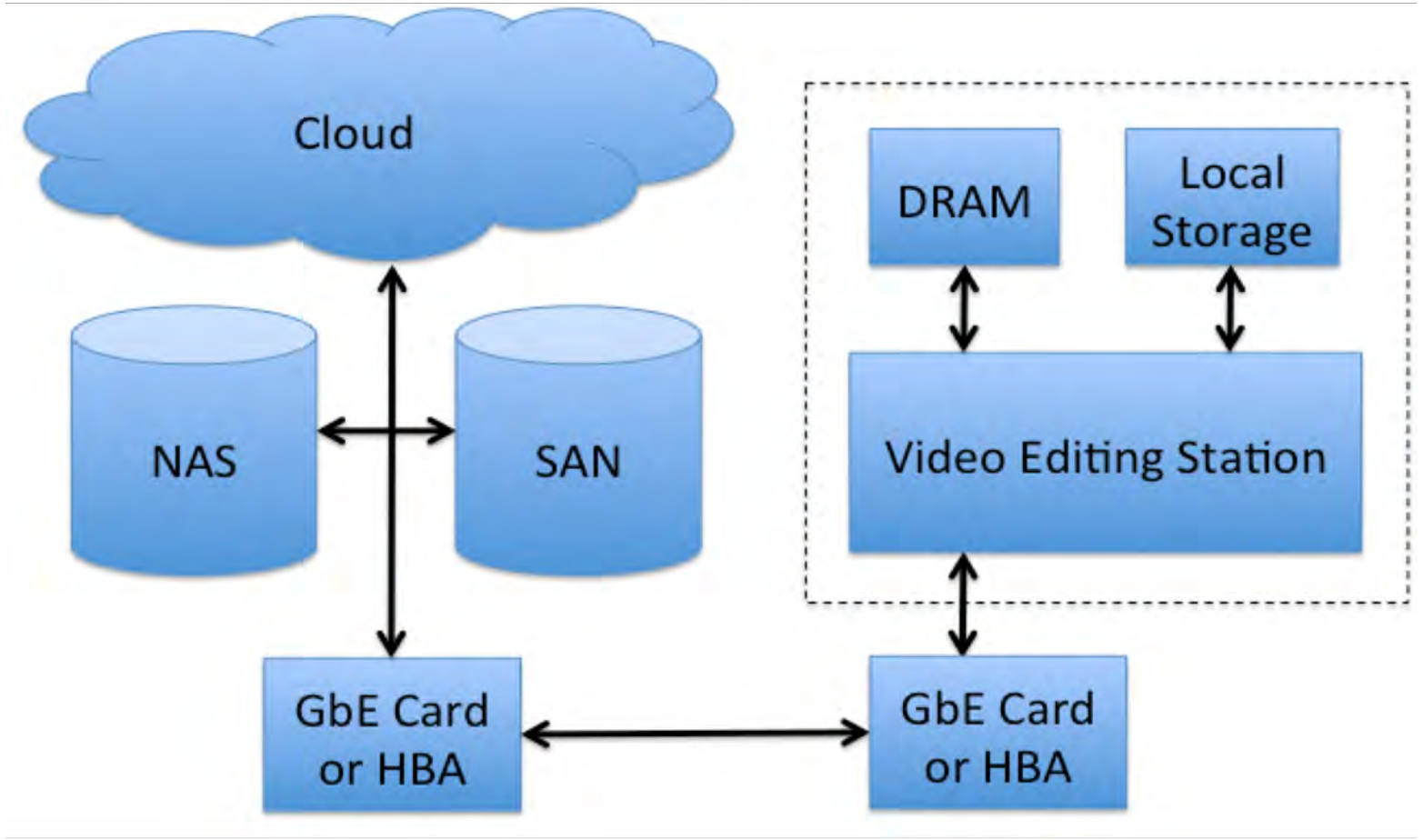
Annual storage system capacity growth for digital content acquisition



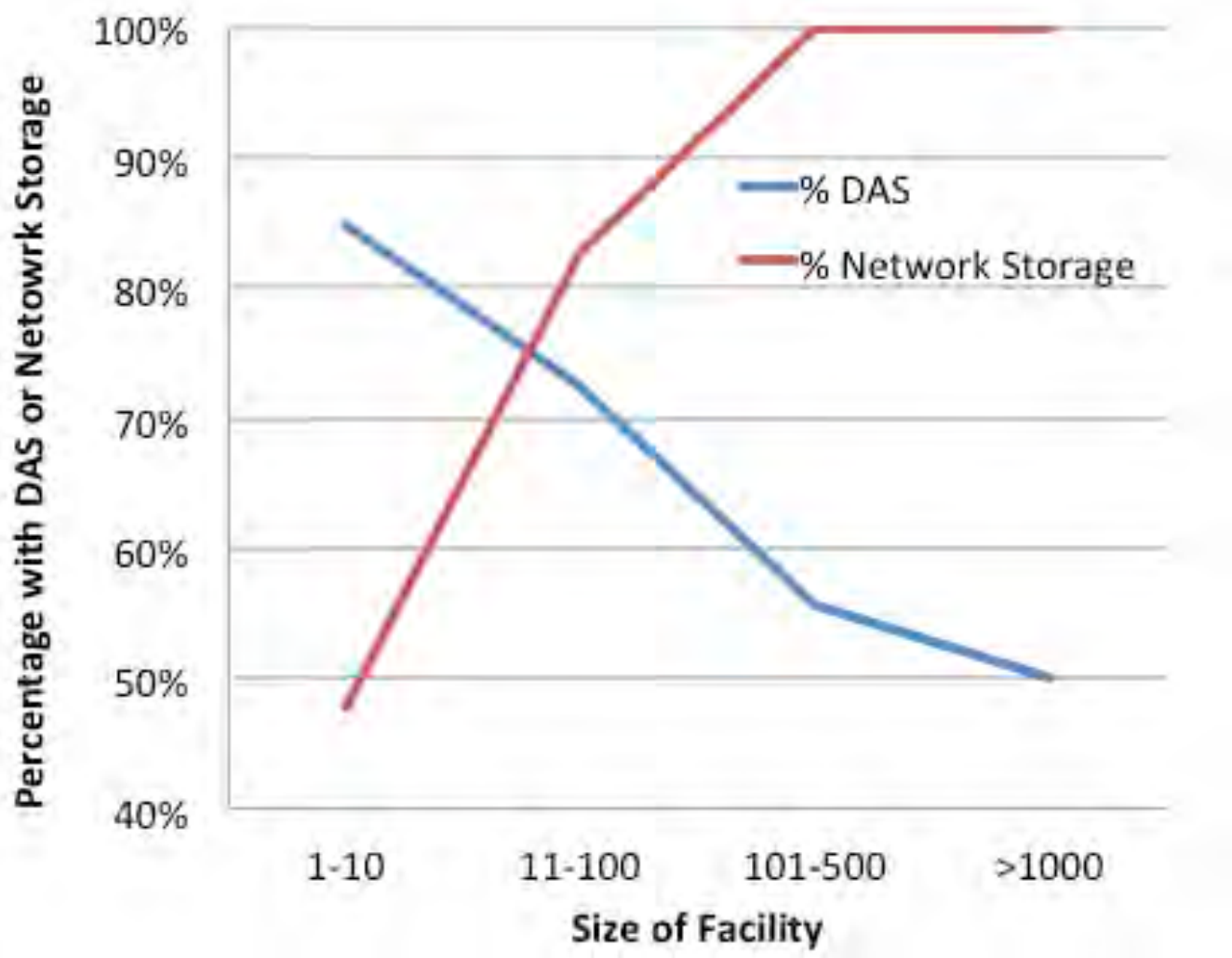
From the 2018 Digital Storage in Media and Entertainment Report, Coughlin Associates, http://www.tomcoughlin.com/techpapers.htm

Post Production Memory and Storage

Professional non-linear editing model System

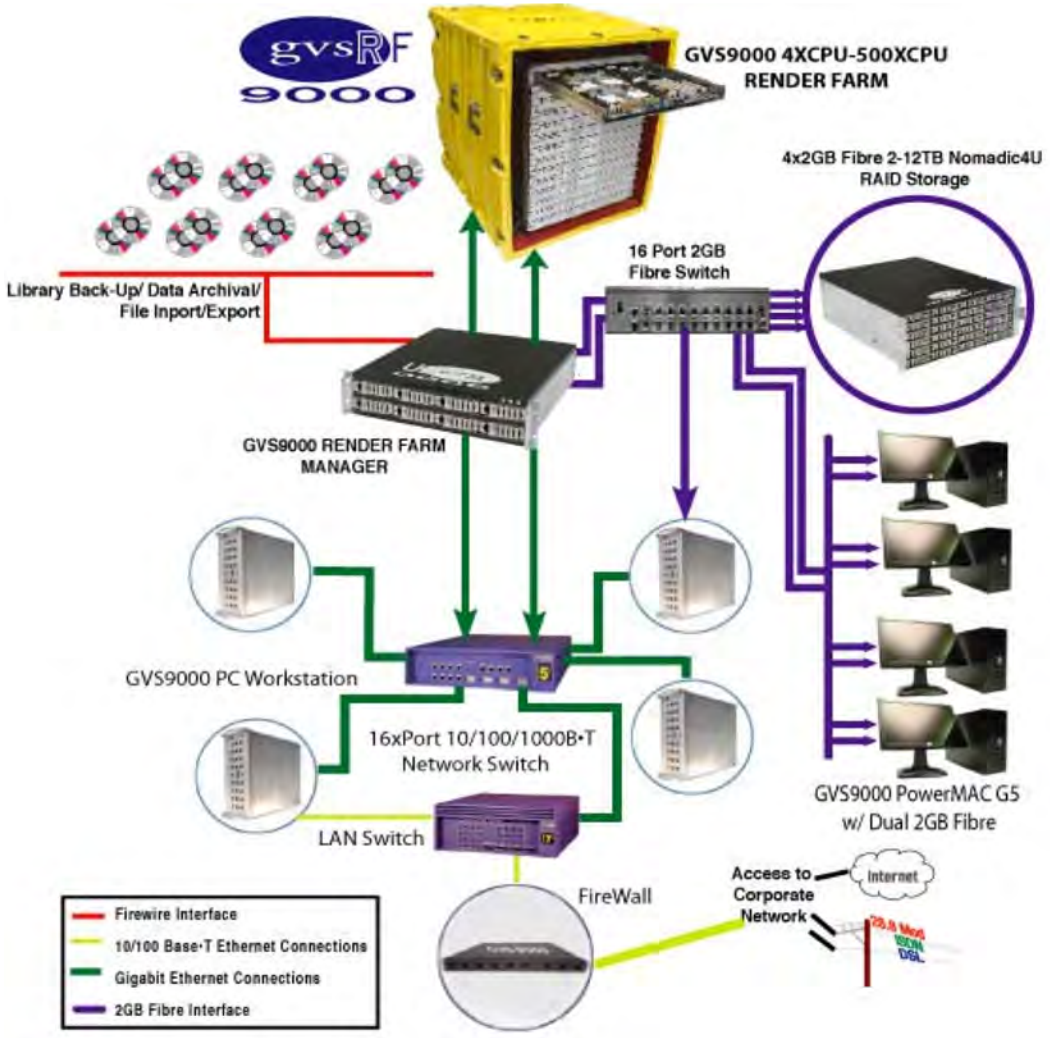


DAS vs. shared storage and number of post seats (2017 survey)

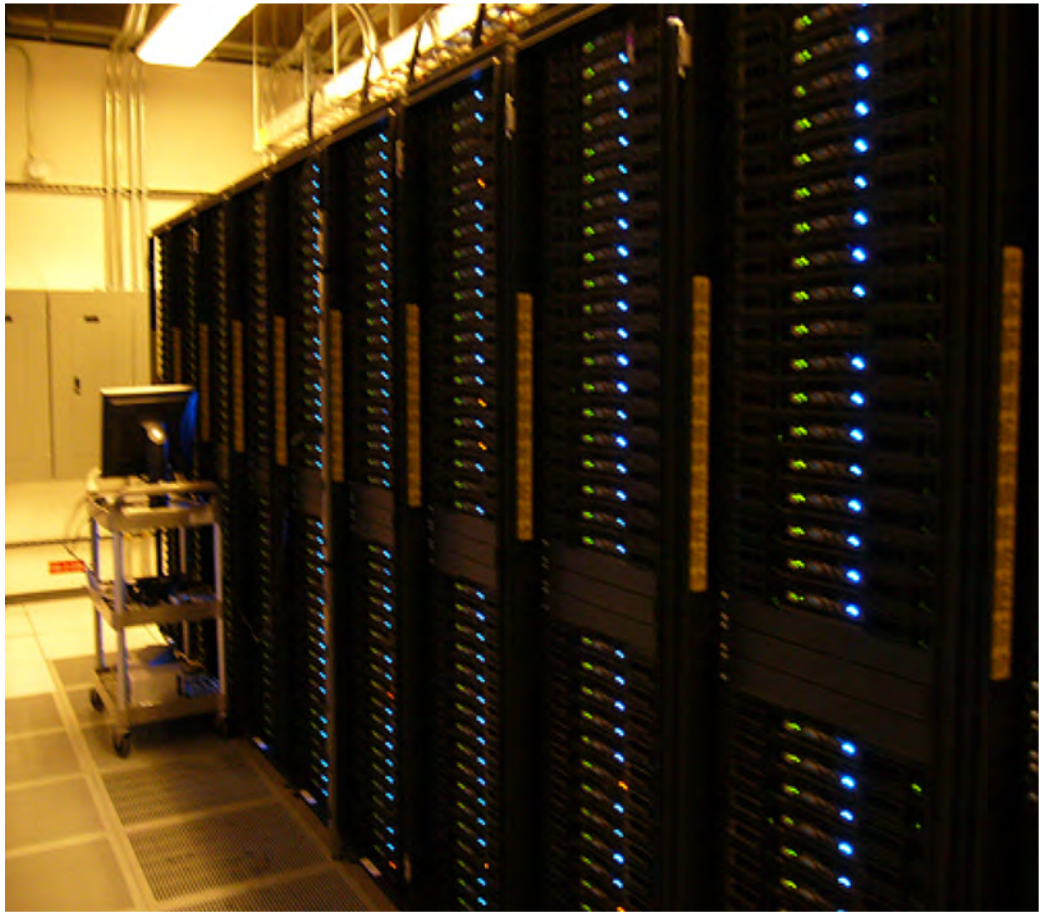


- 82.6% had DAS in 2018
- 81.0% of these had more than 1 TB of DAS, 12.1% had more than 50 TB and 12.4% had more than 500 TB of DAS
- About 12.4% used flash Memory in their post production
- 58.0% had NAS or SAN
- 57.5% had 50 TB or more of network storage, 15.0% had more than 500 TB of NAS/SAN storage

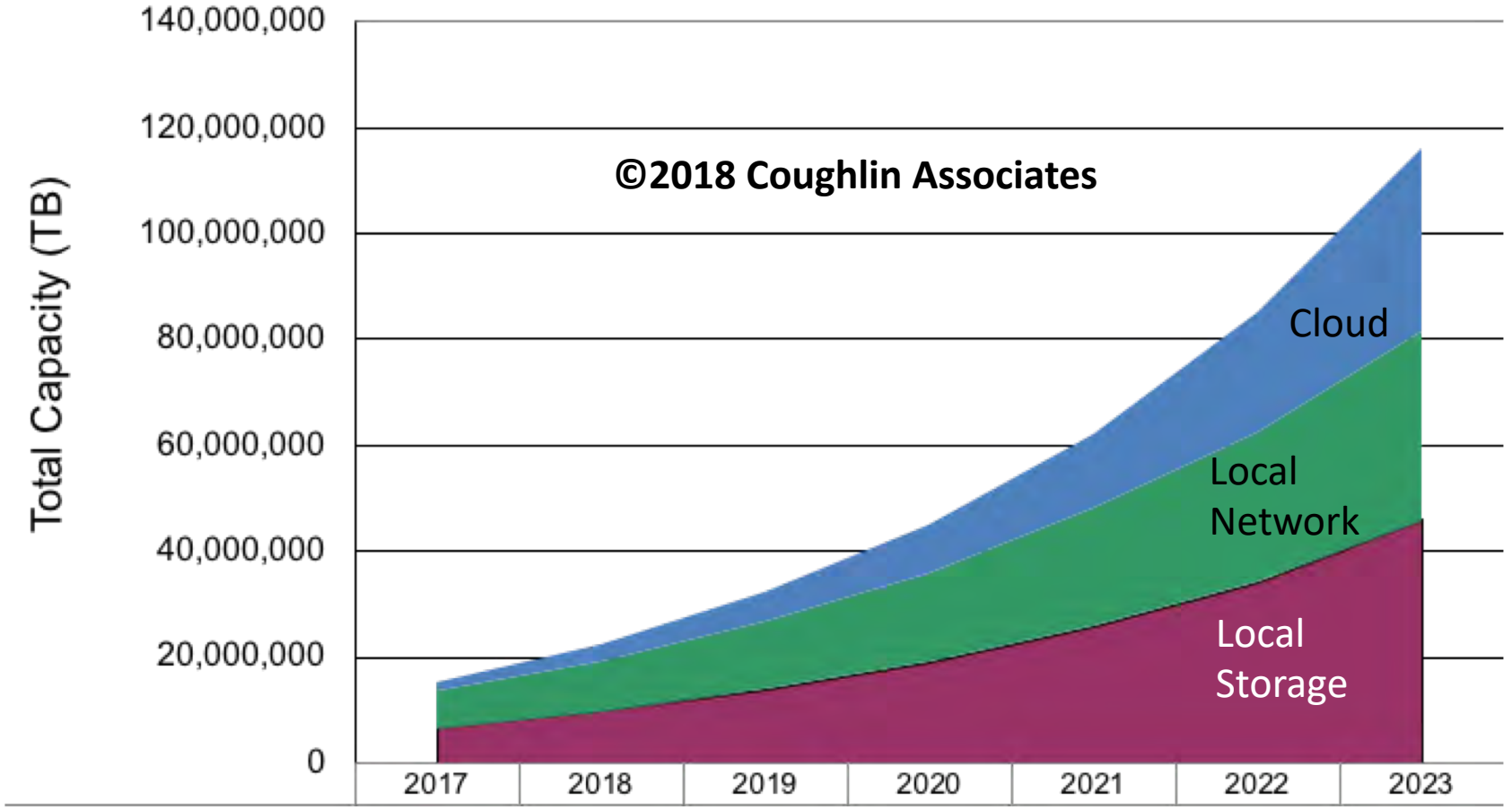
Example render farm layout



Pixar render farm



Post production storage capacity annual demand (TB)

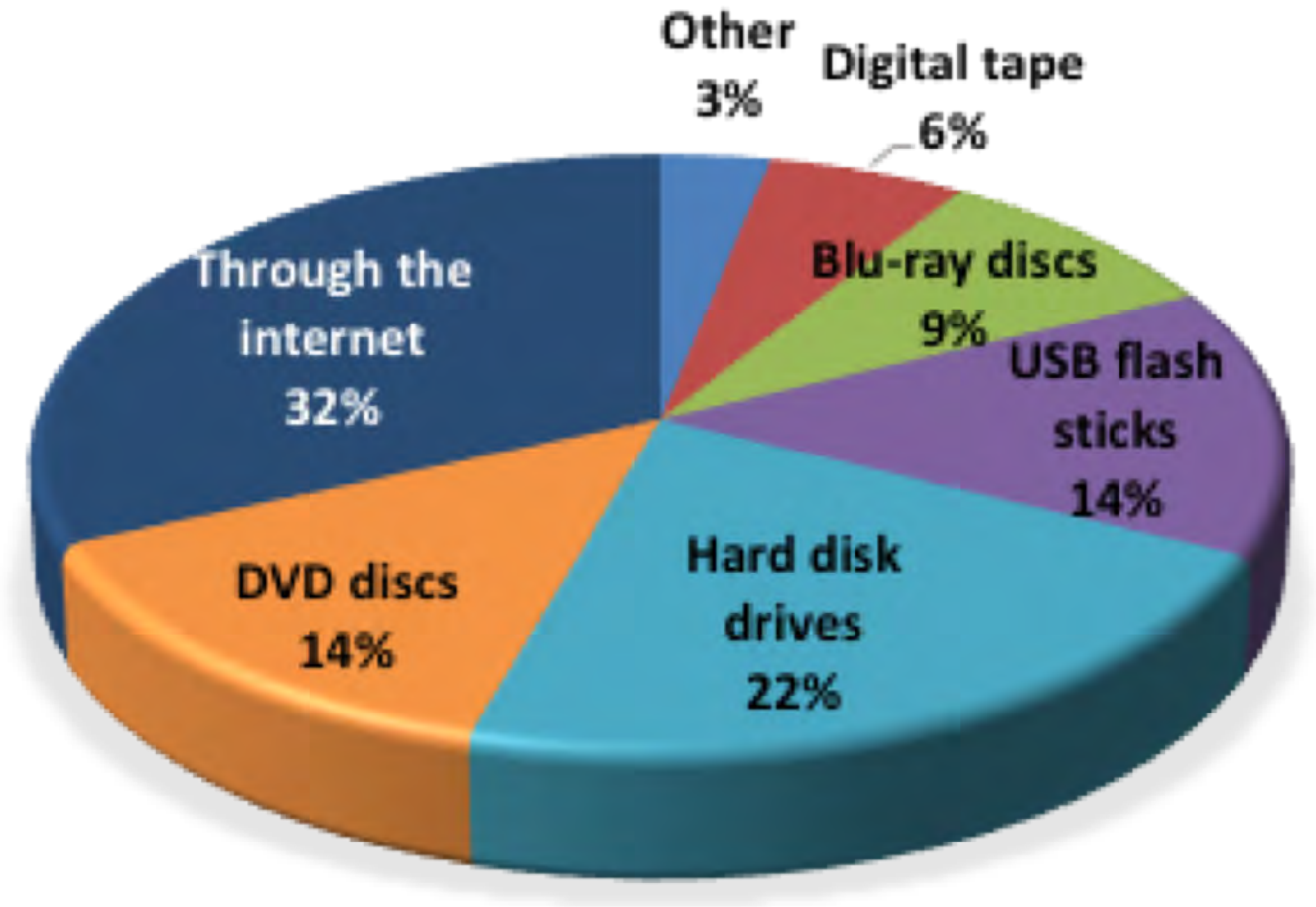


- In 2018 47.5% of responding participants said they used cloud-based storage for editing and post production
- In 2018 55.6% of the respondents said that they had 1 TB or more storage capacity in the cloud
- 2018 Digital Storage in Media and Entertainment Report, Coughlin Associates, http://www.tomcoughlin.com/techpapers.htm

Storage for Content Distribution

https://pixnio.com

Physical distribution media for proxies or completed post work (2018 Survey)



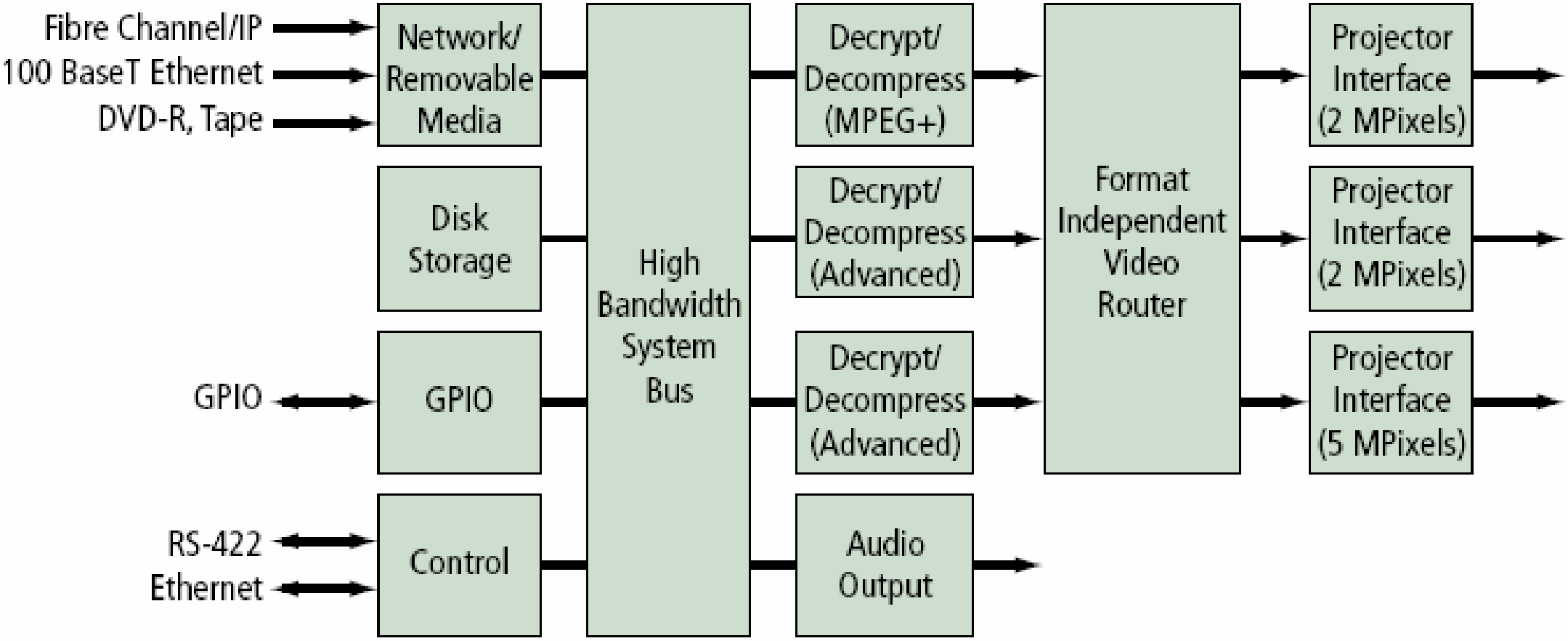
Cloud data transport solutions

- AWS also offers a truck for content to the cloud, called the Snowmobile
- Similar content transport offered from Google, Azure and Backblaze

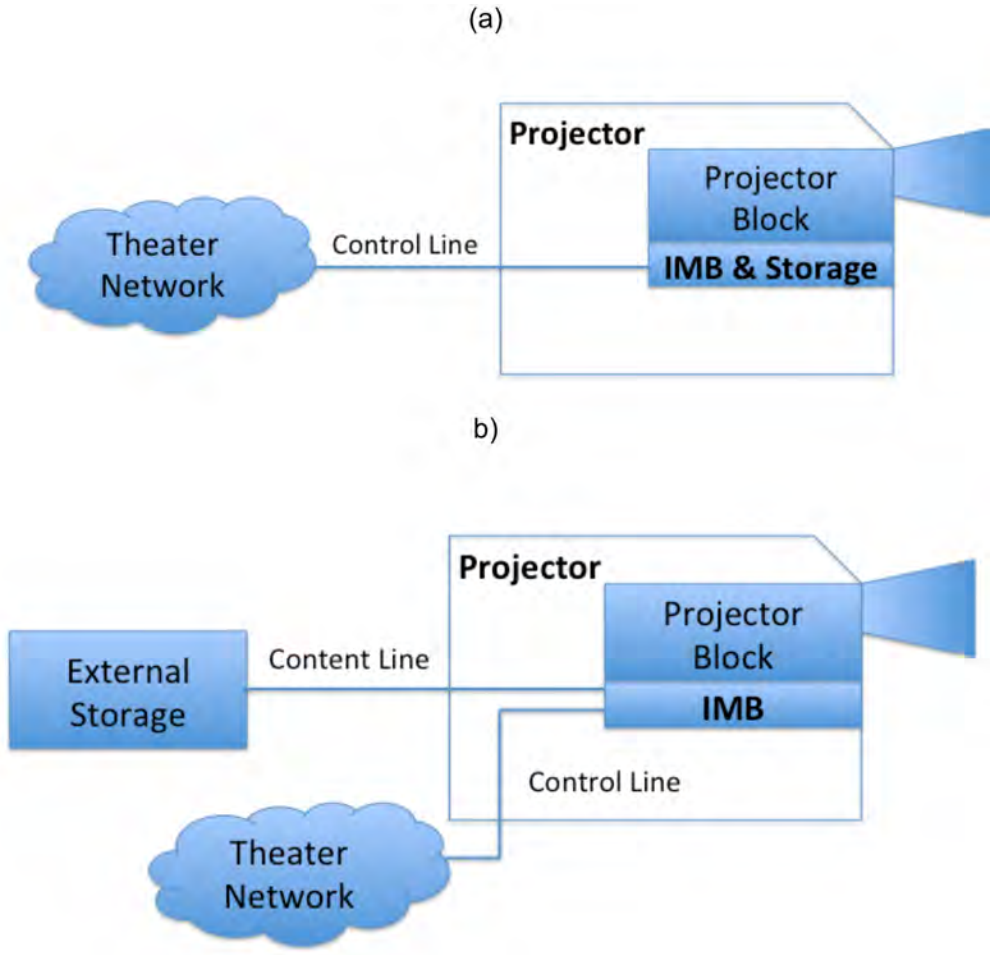
50TB of data delivered to the cloud for **$200**

Digital projection at the Mercado Theatre in Santa Clara, CA

Schematic of a play-to-screen server with functional blocks (Thompson Grass Valley)

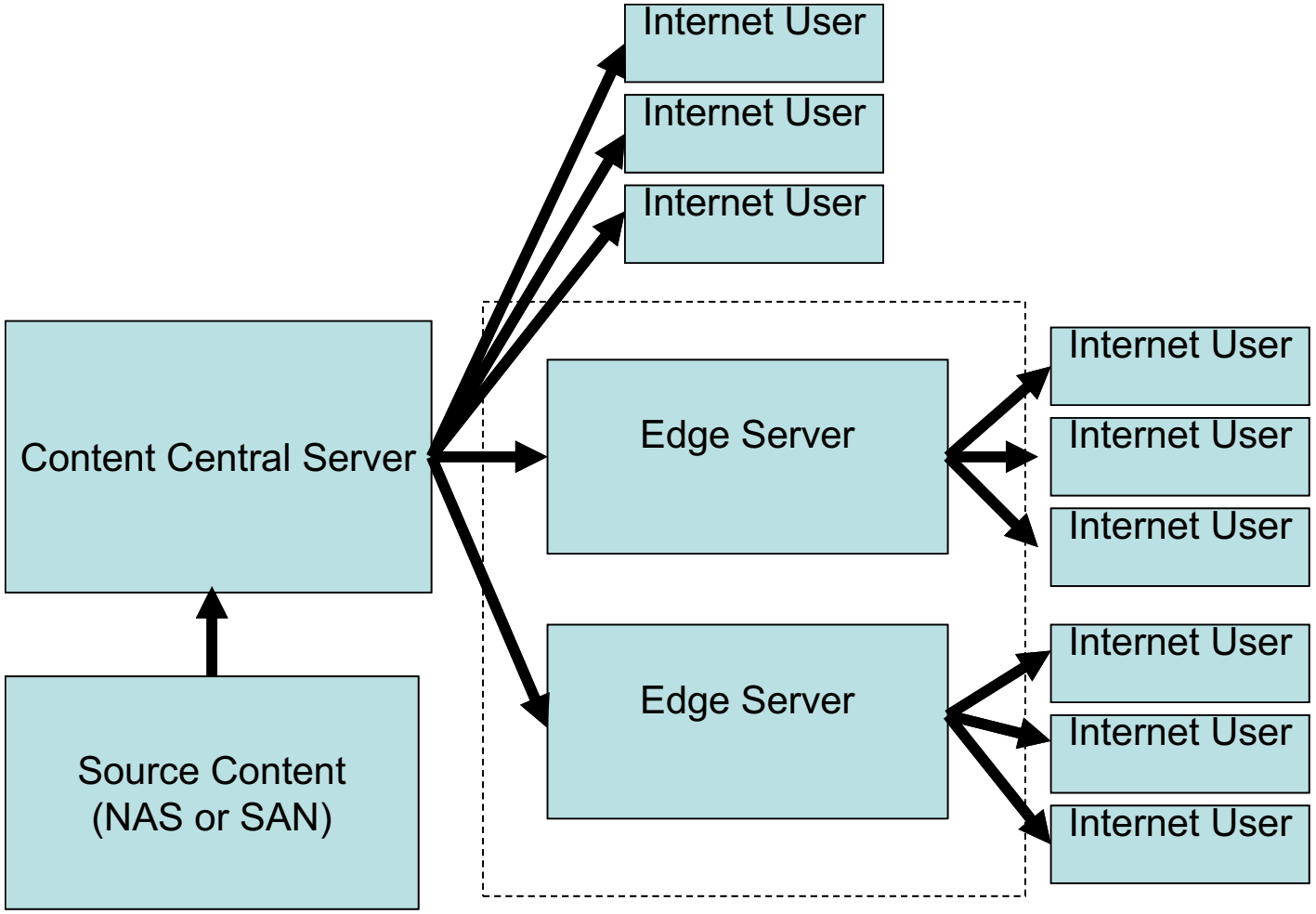


Schematic Digital Projector Showing IMB Containing Storage(a) and with storage external to the IMB(b)

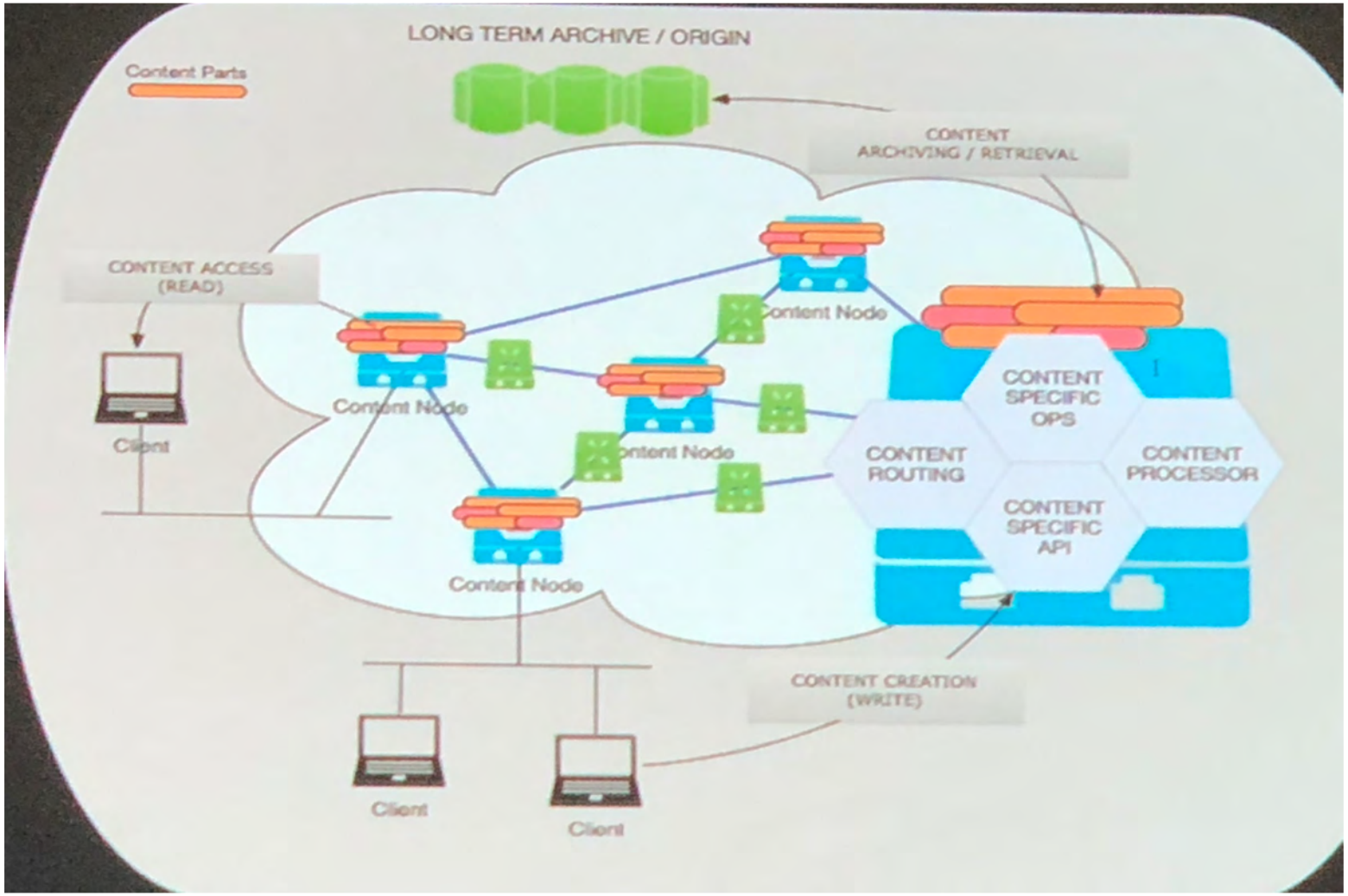


Projector Integrated Media Block (with HDDs)

Conventional Internet content distribution system (CDN)



Eluv.io's Software Content Fabric

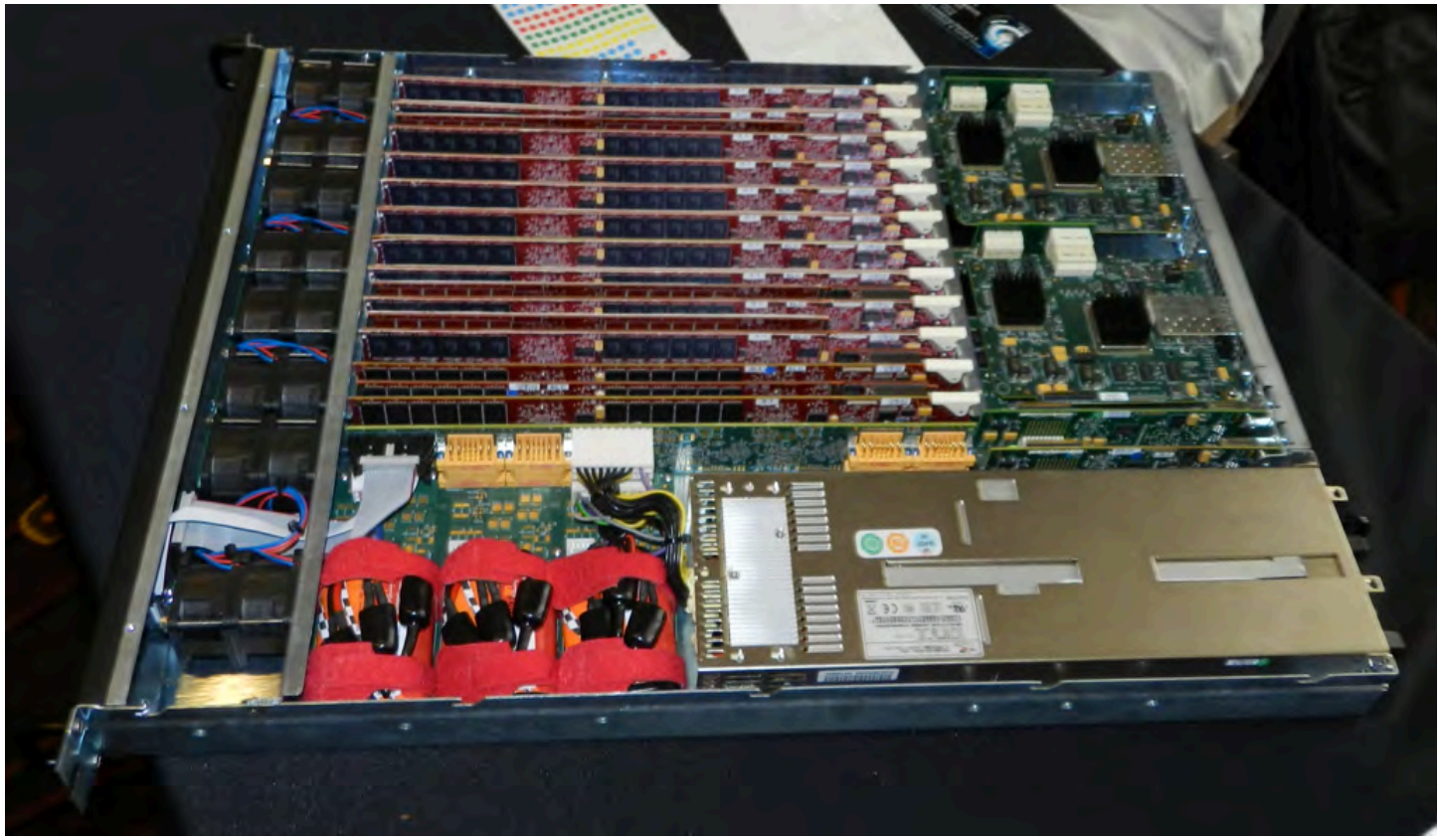


- Peer-to-peer, distributed content delivery, without masters
- Authenticated using distributed ledgers to create an audit trail and facilitate transactions

IBM flash-based content-delivery server

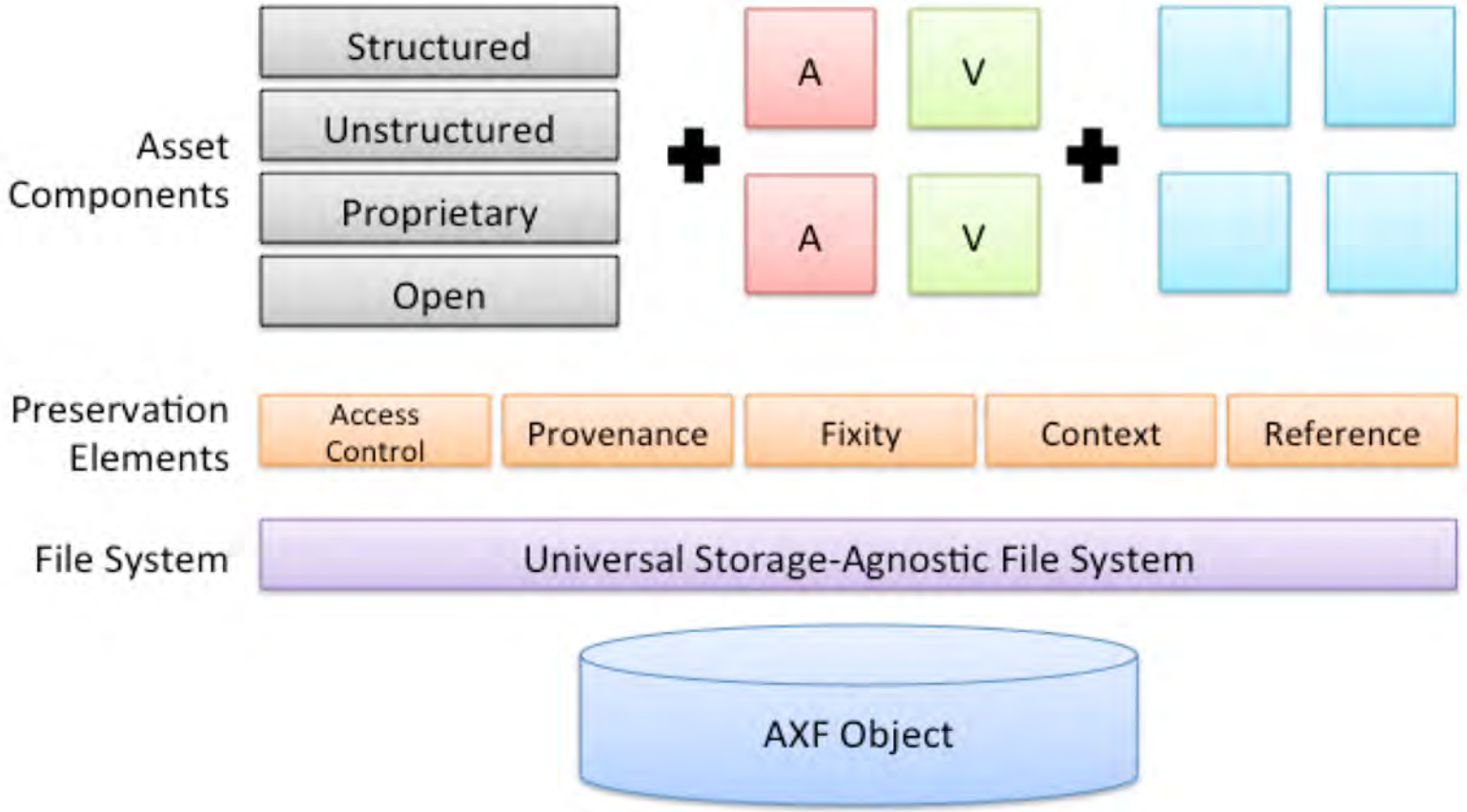
Survey Results for VOD:

- Average hours on central content delivery system was about 1,241 hours in 2018.
- There was an average of 372 hours ingested monthly in 2018
- In 2018 42.8% of respondents had more than 5% of their content on edge servers
- About 48% used flash memory on their edge servers in 2018
- In 2018 39% of survey respondents said that they used flash memory in their central delivery servers.



Archiving and Preservation

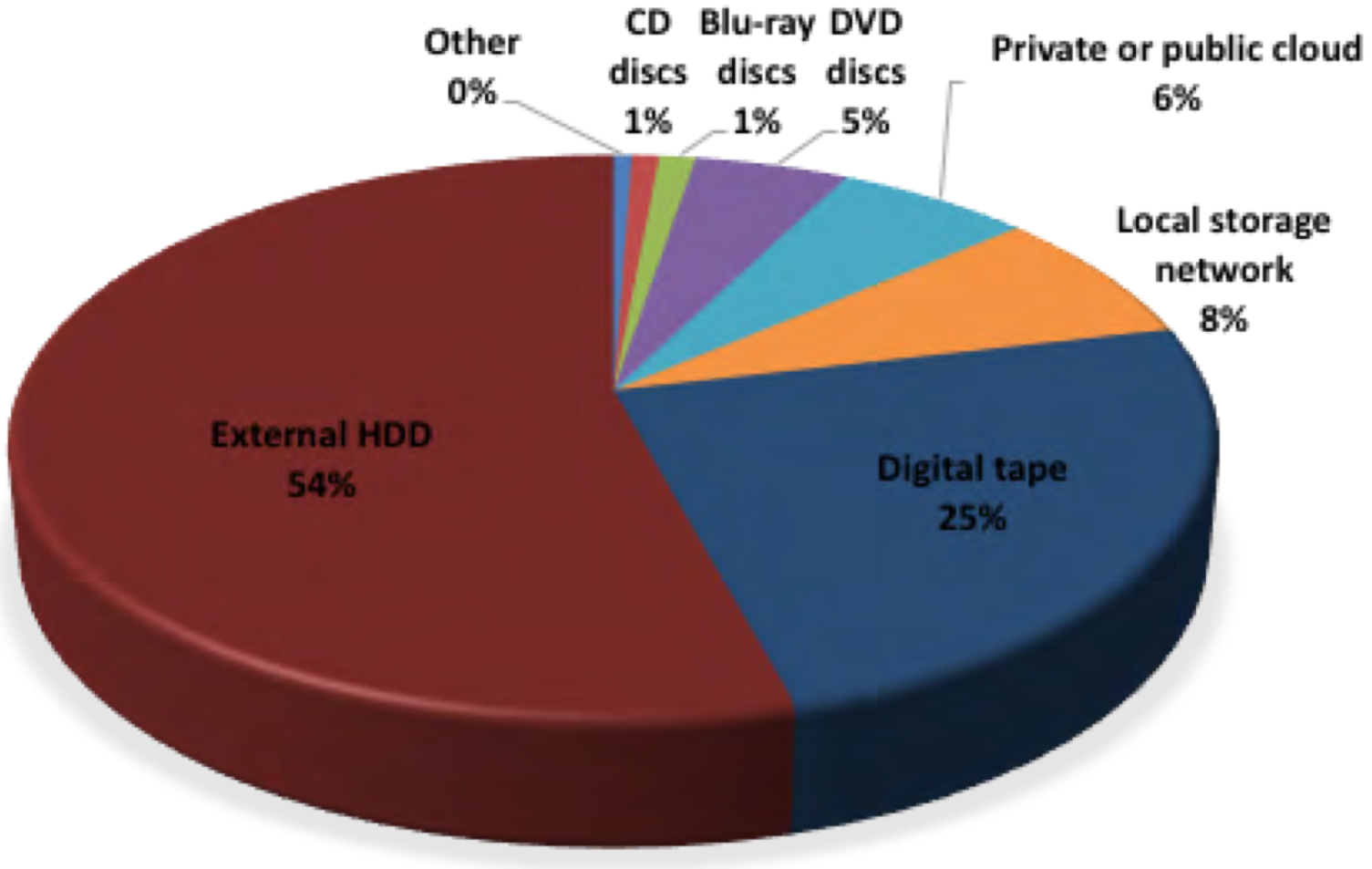
Elements in an AXF Object Wrapper



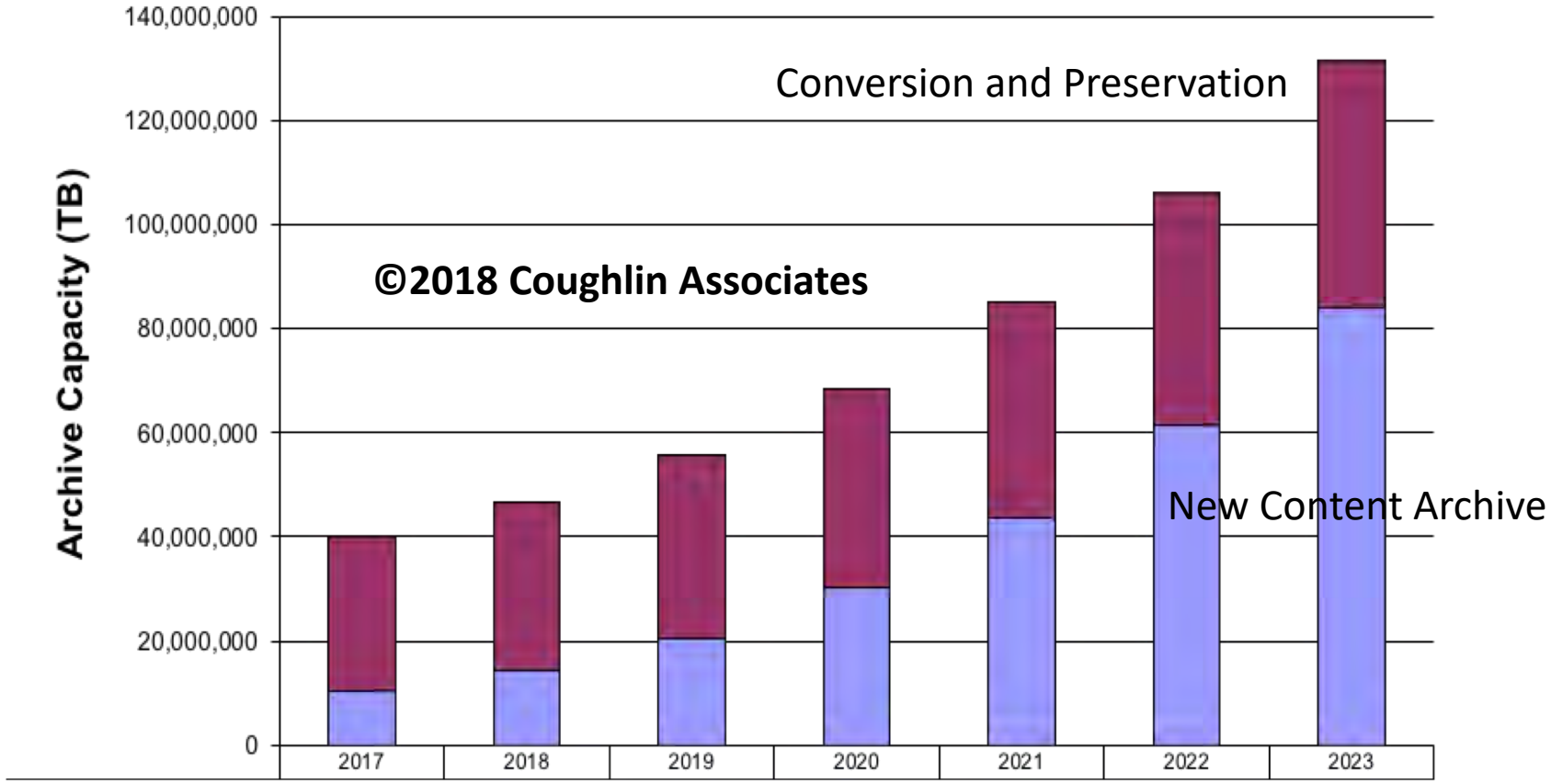
- Modern digital archiving needs to preserve data essence and metadata together (e.g. in a wrapper)
- New tools (often using AI) will allow generation of metadata directly from content

Percentage of Digital Long-Term Archives on Various Media

- For the last two years the survey has shown HDDs percentage higher than magnetic tape
- LTO is the biggest percentage of tape storage at 74%
- Growth in archiving content in the cloud among survey participants



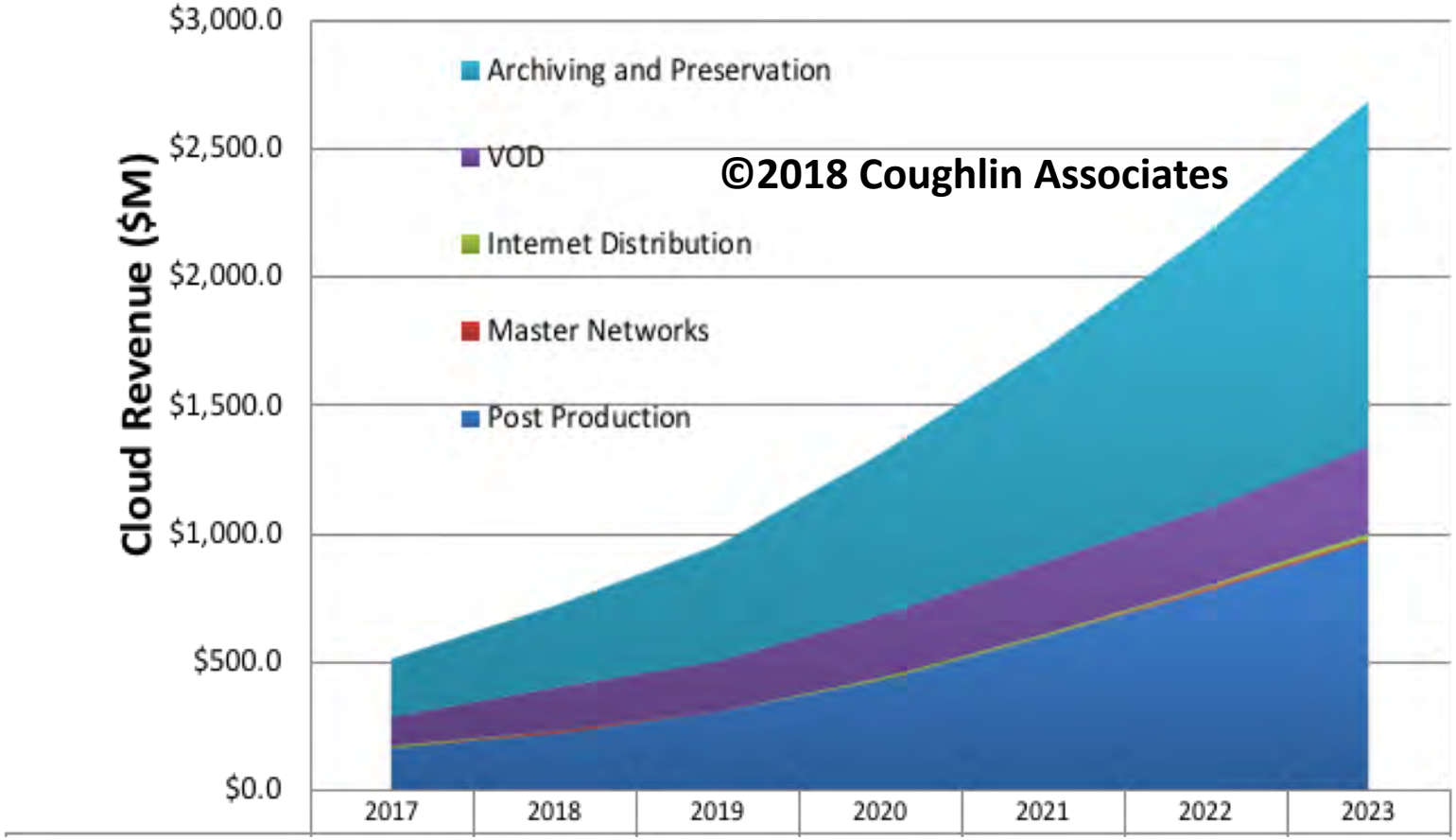
Total annual digital storage demand projections for archiving and digital content conversion & preservation

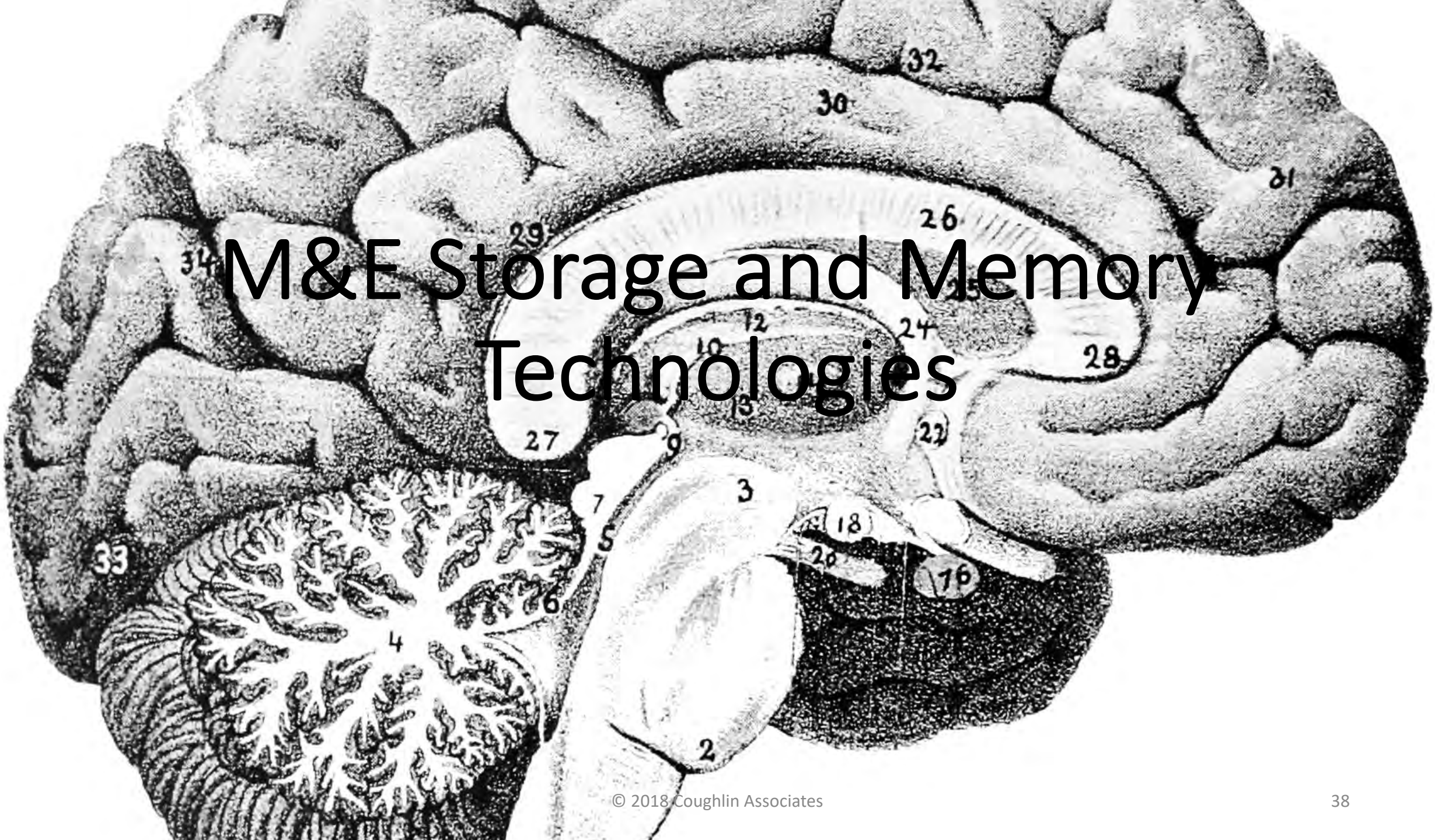


- Over the next few years content that will be digitized will start to diminish
- Increasing size of new content will drive archive growth

The Cloud in Media and Entertainment

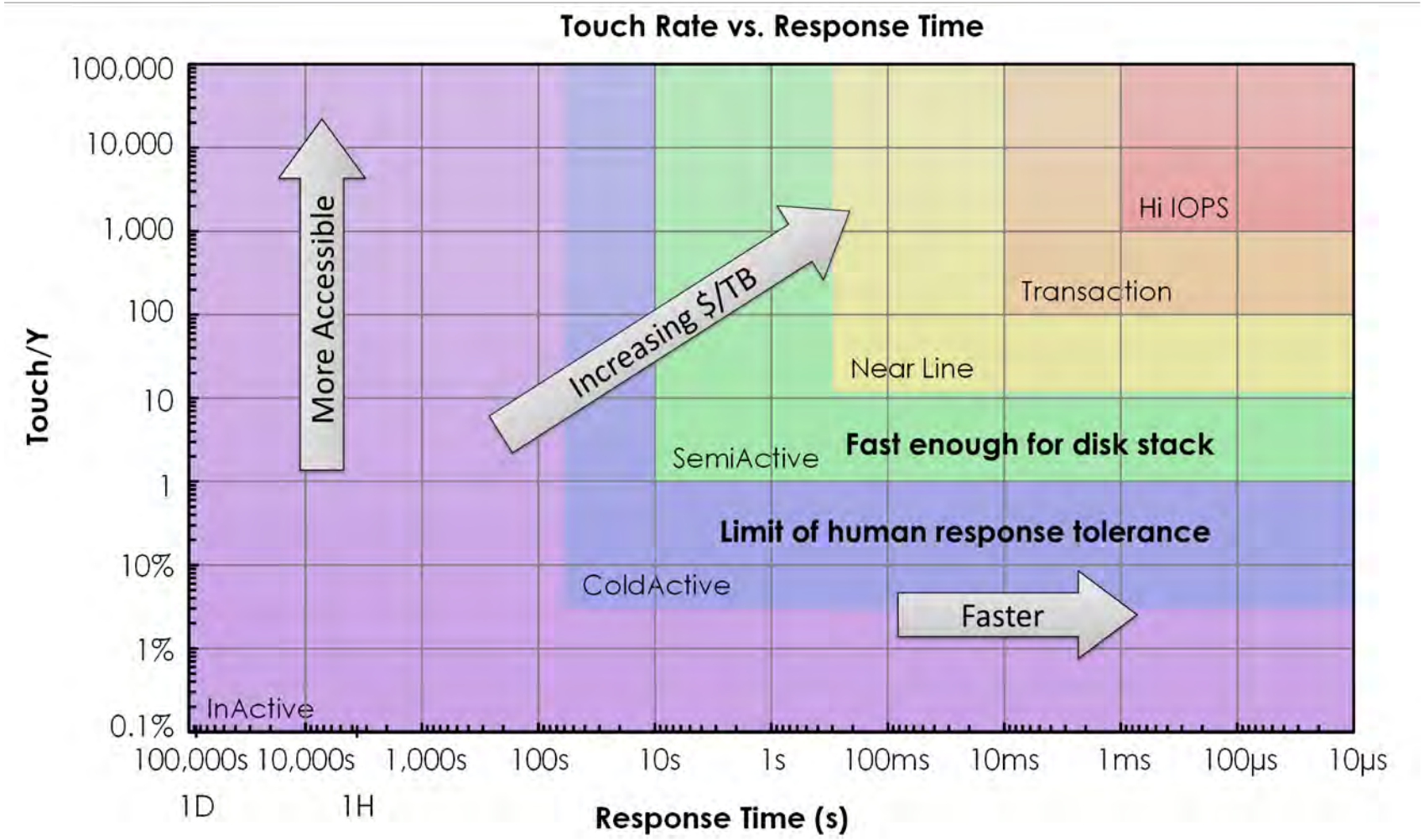
- 77% said that they did proxy distribution through the Internet
- 6% said that they archived on a private or public cloud in 2018
- 66% said they would use a private or public cloud for archiving in 2018





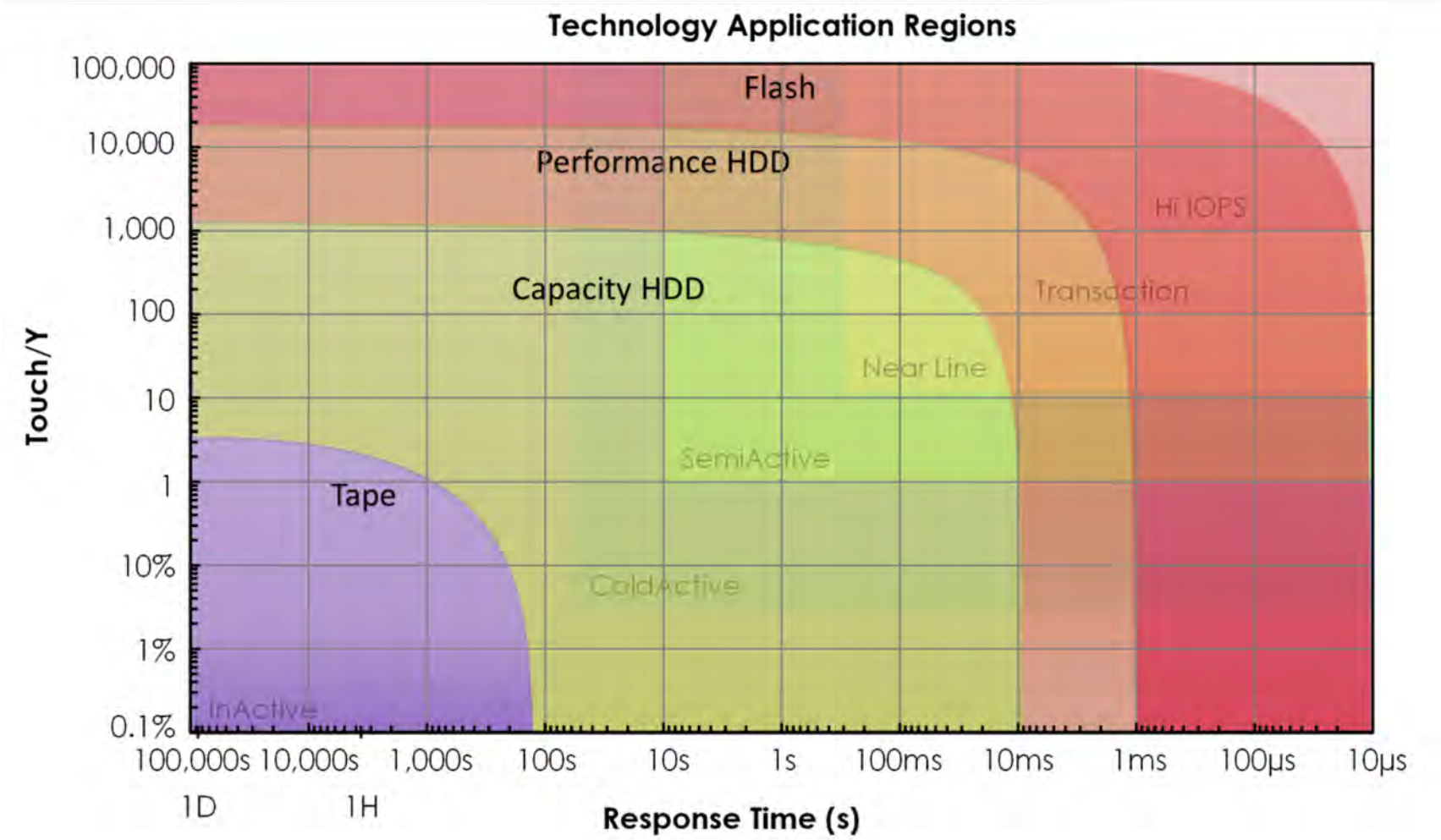
M&E Storage and Memory Technologies

Touch rate versus response time indicating various types of uses



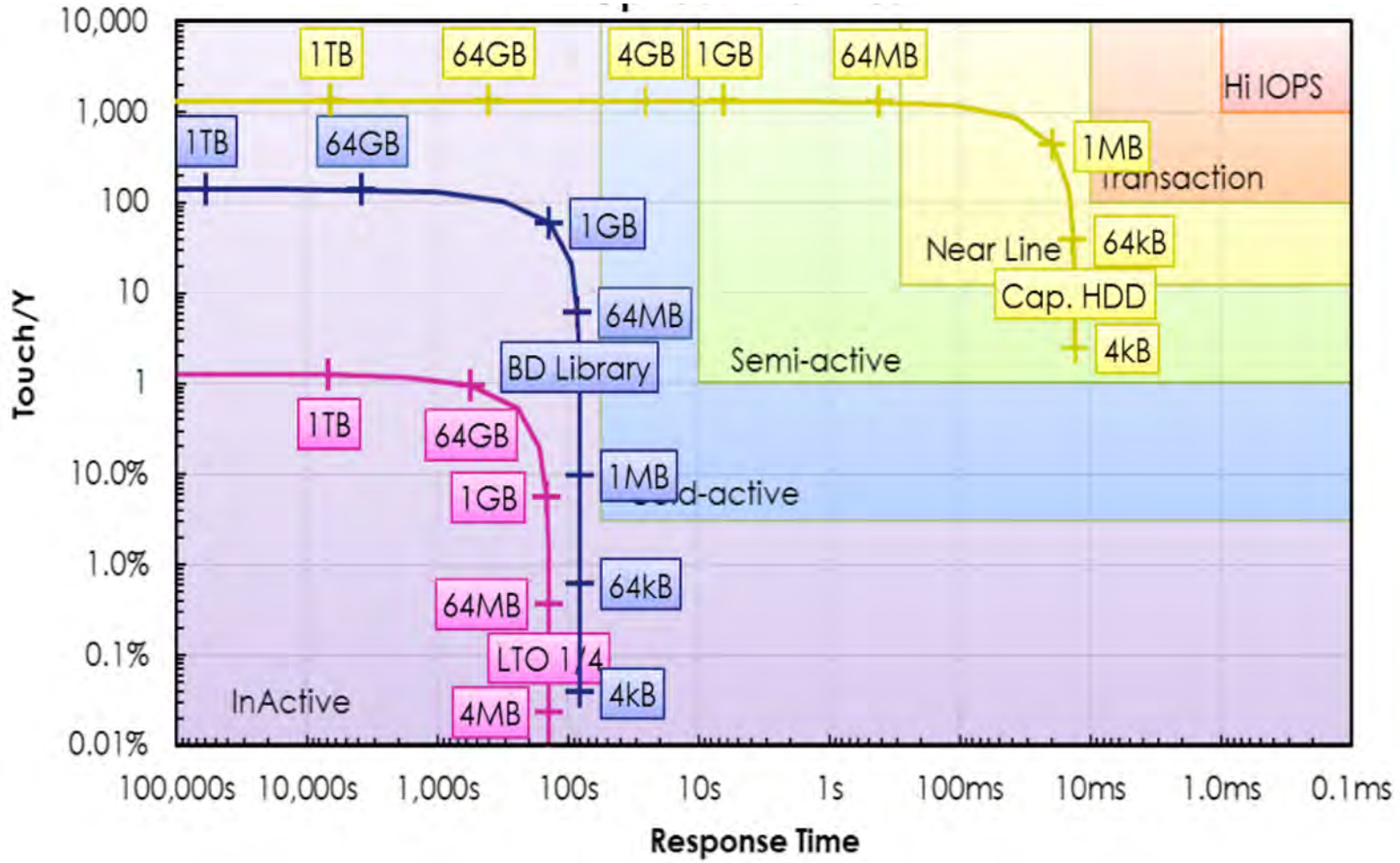
Touch Rate: A metric for analyzing storage system performance, Steve Hetzler and Tom Coughlin, 2015

Digital storage technologies regions overlaid on the Touch Rate/Response Time chart



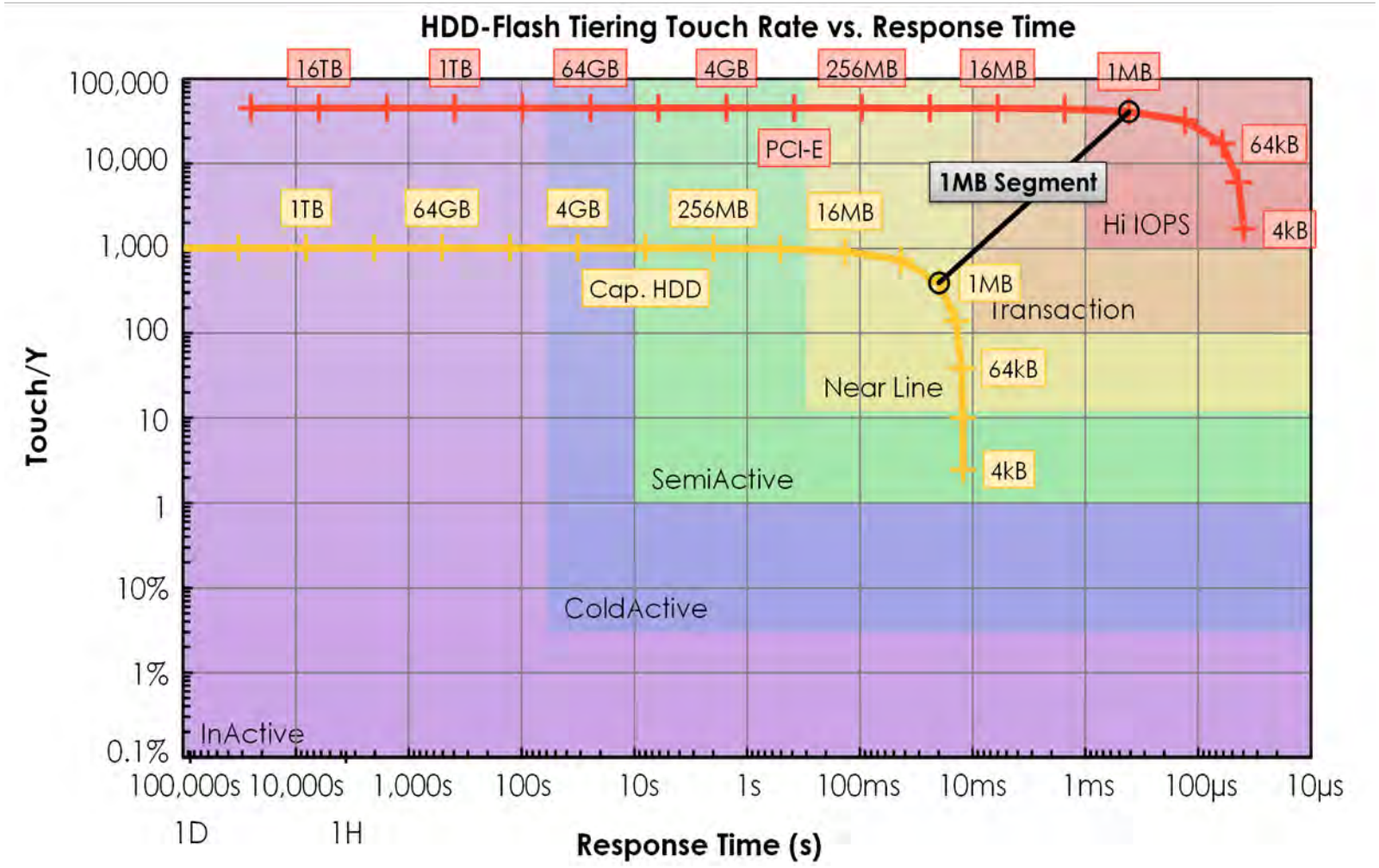
Touch Rate: A metric for analyzing storage system performance, Steve Hetzler and Tom Coughlin, 2015

Touch/Y and response time for 4 TB capacity HDD, LTO Tape and Blu-ray Discs



Touch Rate: A metric for analyzing storage system performance, Steve Hetzler and Tom Coughlin, 2015

HDD-Flash tiering/caching touch rate chart



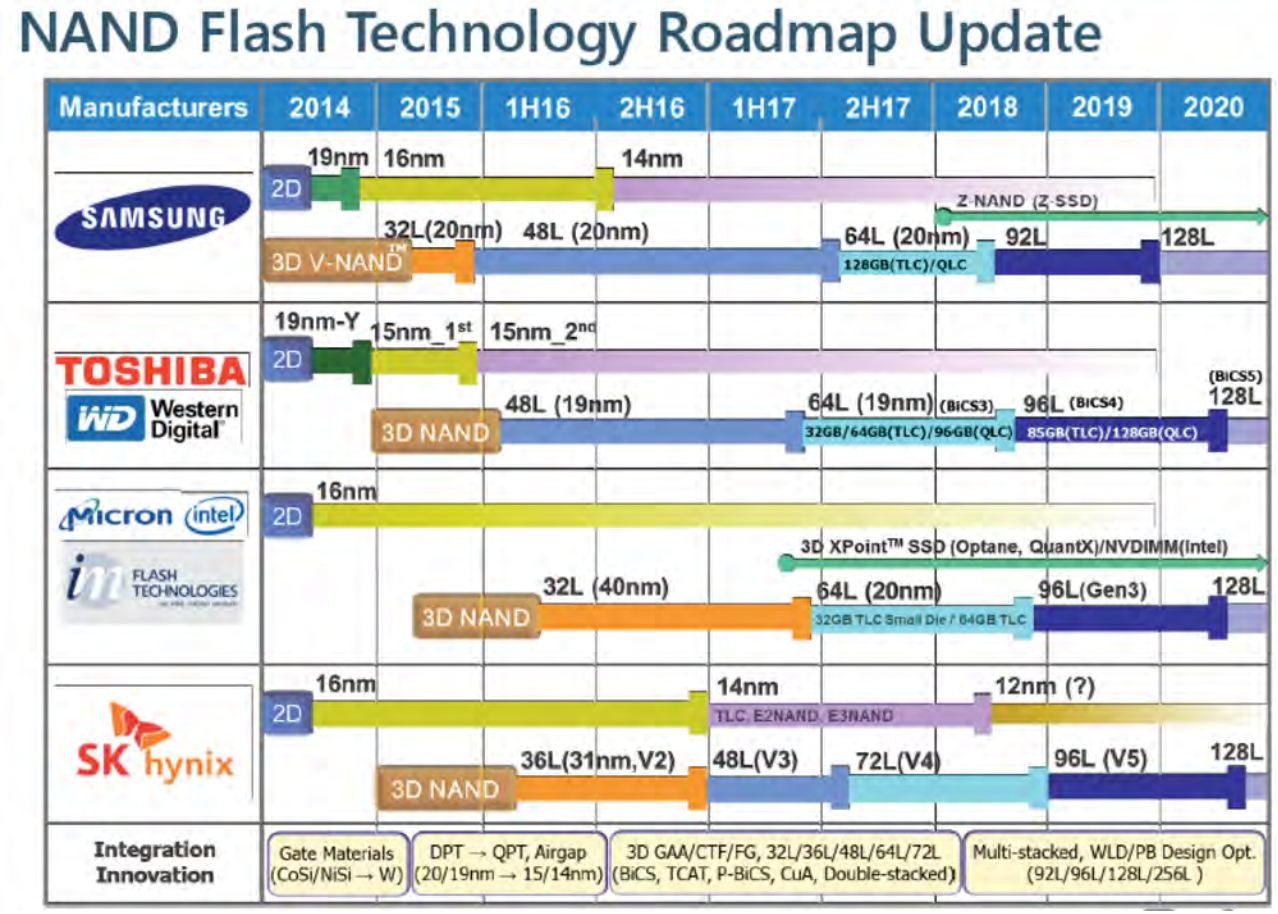
Touch Rate: A metric for analyzing storage system performance, Steve Hetzler and Tom Coughlin, 2015

Flash Memory

- Flash memory is increasing in storage capacity (density) and decreasing in $/GB pricing but still more expensive than HDDs
- Flash memory is winning more applications as its price ($/GB) drops
- Development of NVMe and NVMe-oF has enabled better access to the performance capabilities of flash memory
- In many data center applications, flash memory is now the primary storage
- Flash Memory can also handle more rugged environments, making this a favored storage media for remote location—such as for edge storage

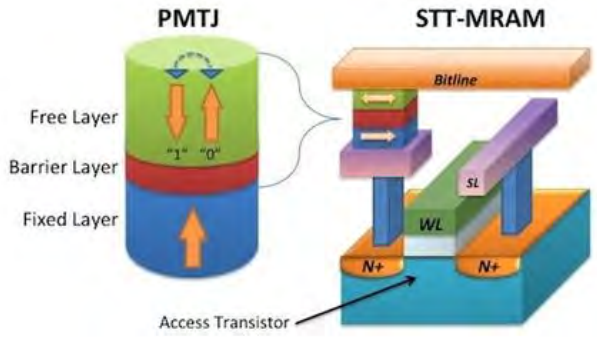
NAND Flash Expectations

- Flash Memory has moved from primarily planar to planar + 3D flash
- New 3D flash fab has reached parity with planar production in 2018, easing supply constraints
- This has resulted in a drop in flash prices in 2018
- Projections that 3D flash could go out many generations—
- The price reductions for 96 layer and higher will be less than going to 64 layer, because of slower process speeds

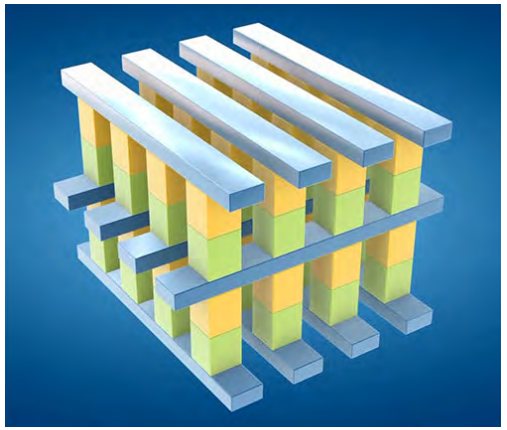


Persistent memory types

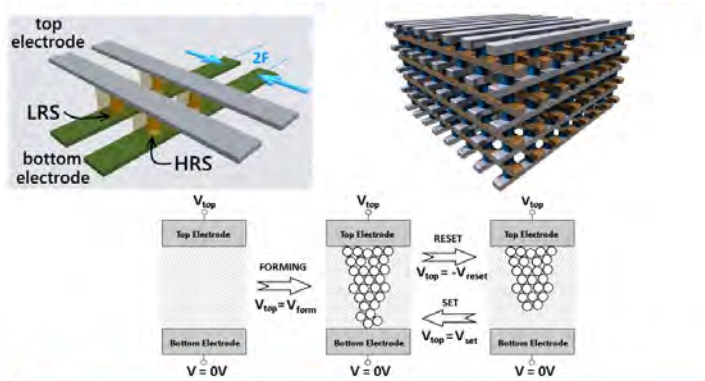
MRAM



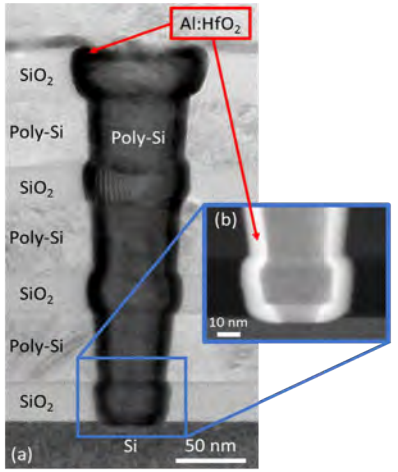
PCM



ReRAM



FRAM



MRAM and PRAM

- MRAM
  - Everspin shipped over 70 M MRAM Chips. Company has partnership with Global Foundries, who is building 300 mm wafers and targeting embedded memory applications
  - Samsung--plans to ship STT MRAM product samples by 2018.
  - Seagate was showing an Everspin MRAM boot SSD at the 2017 FMS
- PRAM
  - Intel Optane NVMe products shipped in 2017.
  - Micron planning to introduce DIMM-based 3D XPoint product
  - Intel introduced their Optane DIMM products in June 2018
- Emerging NVM market could exceed $6B by 2023 (Emerging Memories are Poised to Explode, Coughlin Associates and Objective Analysis, http://www.tomcoughlin.com/techpapers.htm

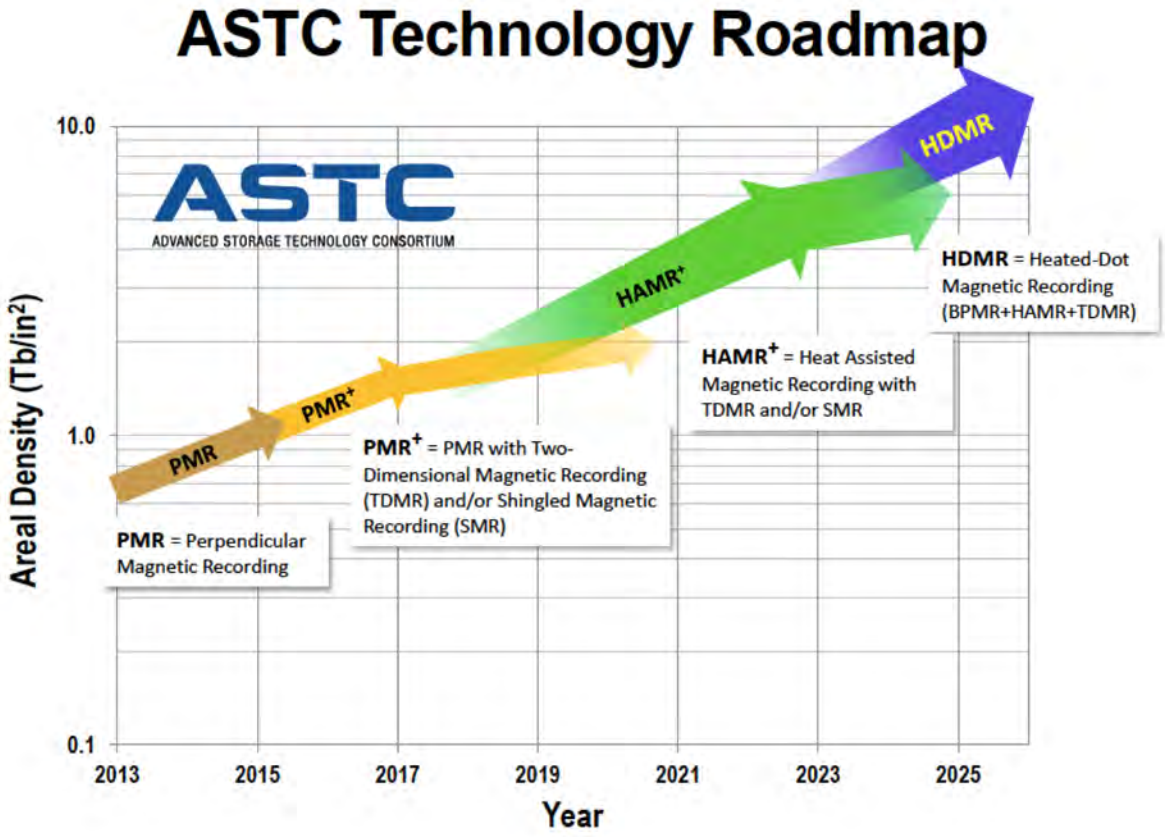
Memory Technology comparison

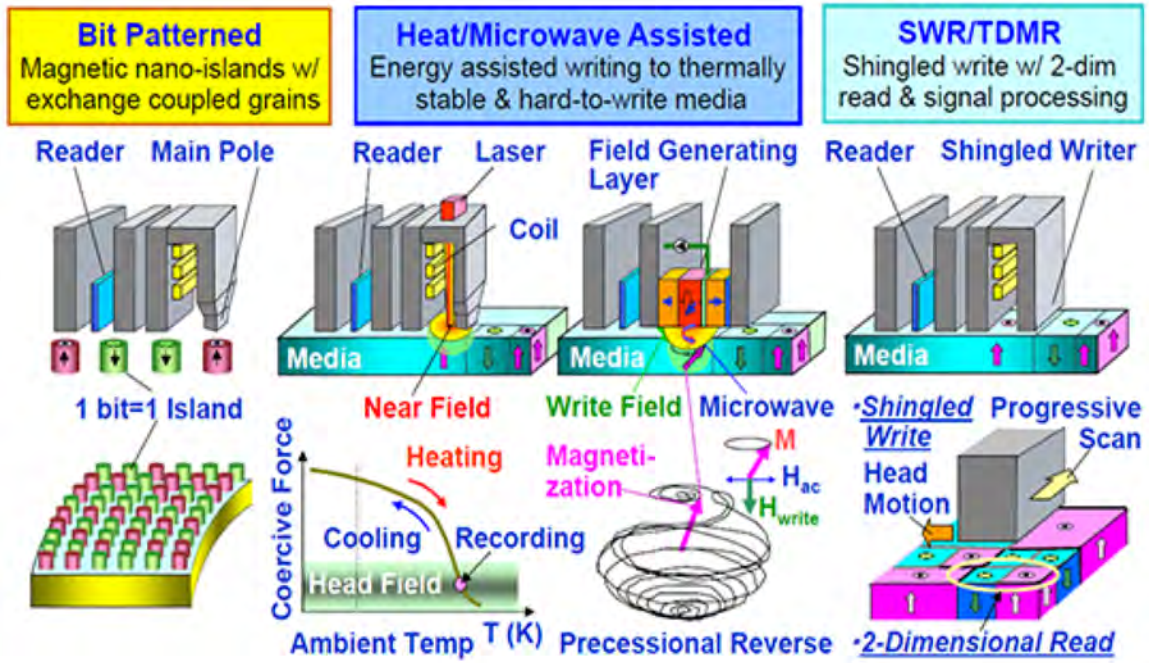
Technology	FeRAM	MRAM	ReRAM	PCM	DRAM	NAND Flash
Nonvolatile	Yes	Yes	Yes	Yes	No	Yes
Endurance	10^{12}	10^{12}	10^{6}	10^{8}	∞	10^{3}
Write Time	100ns	~10ns	~50ns	~75ns	10ns	10µs
Read Time	70ns	10ns	10ns	20ns	10ns	25µs
Power Consumption	Low	Medium/Low	Low	Medium	Very High	Very High
Cell Size (f^2)	15-20	6-12	6-12	1-4	6-10	4
Cost ($/Gb)	$10/Gb	$30-70/Gb	Currently High	$0.16/Gb	$0.6/Gb	$0.03/Gb

Hard disk drives (HDD)

- Current capacities with CMR up to 14 TB using He-sealed HDDs
- With HAMR or MAMR expected 20 TB drives in near future and 40 TB in next decade
- Some talk about HDDs in a vacuum to reduce head to medium distance and achieve even higher areal density (information per areas of disk surface)
- Growth market for HDDs is colder storage for enterprise and cloud applications
- Gradual decline in HDDs versus flash memory (or cloud storage) in other applications

Official ASTC HDD roadmap





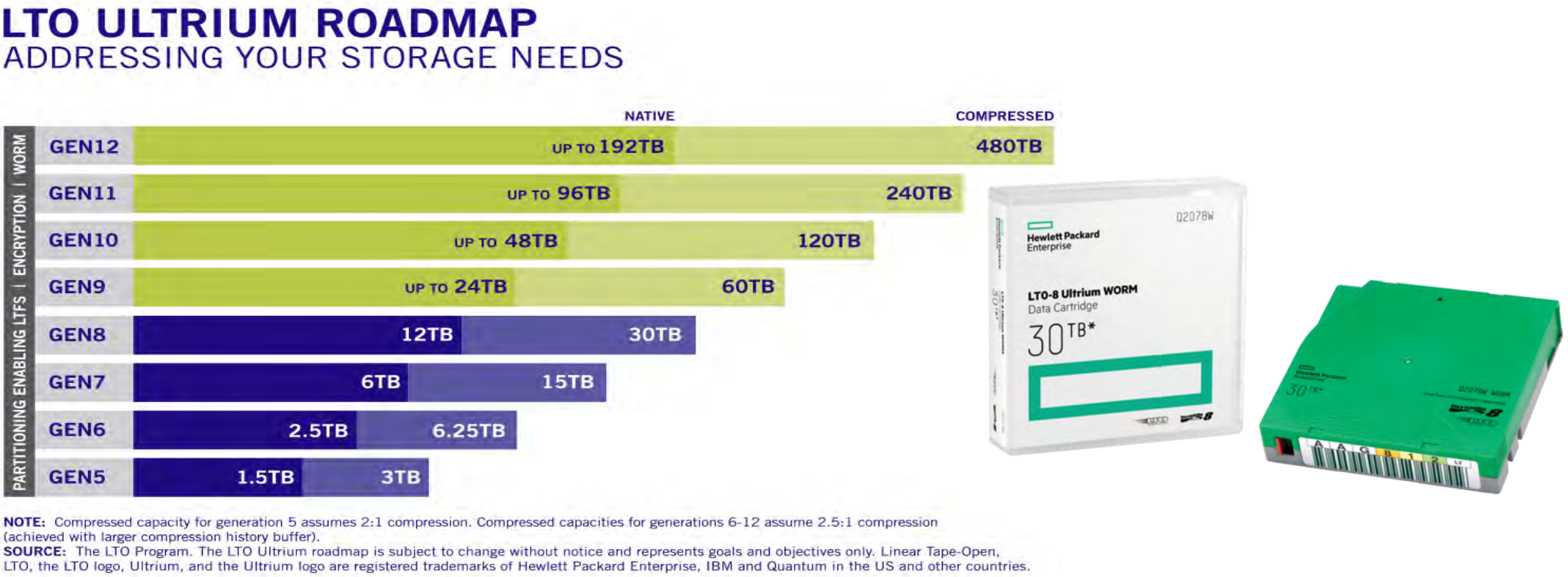
From TMRC 2014 Web Site

Some HDD storage systems

Spectra Logic SMR HDD archive storage system

WD OpenFlex D3000 NVMe over Fabric HDD enclosure

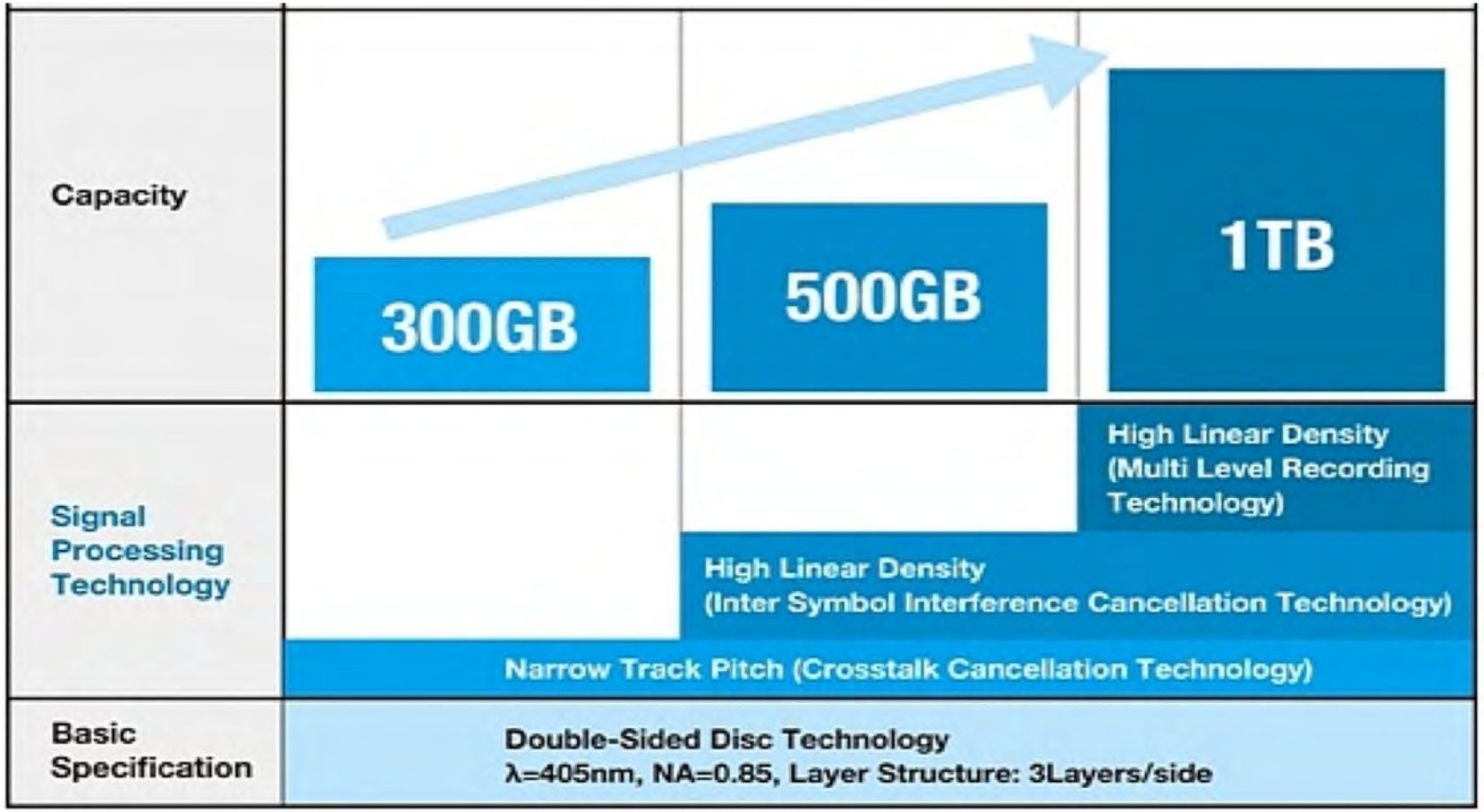
LTO projected tape generations
(Current LTO-8 holds 15 TB native)



Magnetic tape technology

- Tape currently at 15 TB native capacities
- Laboratory demonstrations of over 400 TB per tape
- IBM enterprise tape offering RoCE ethernet networking using tape systems
- Tape supports file systems and even object storage using LTFS
- Tape promoted for air-gapped backups and long term storage

Sony/Panasonic optical archive roadmap



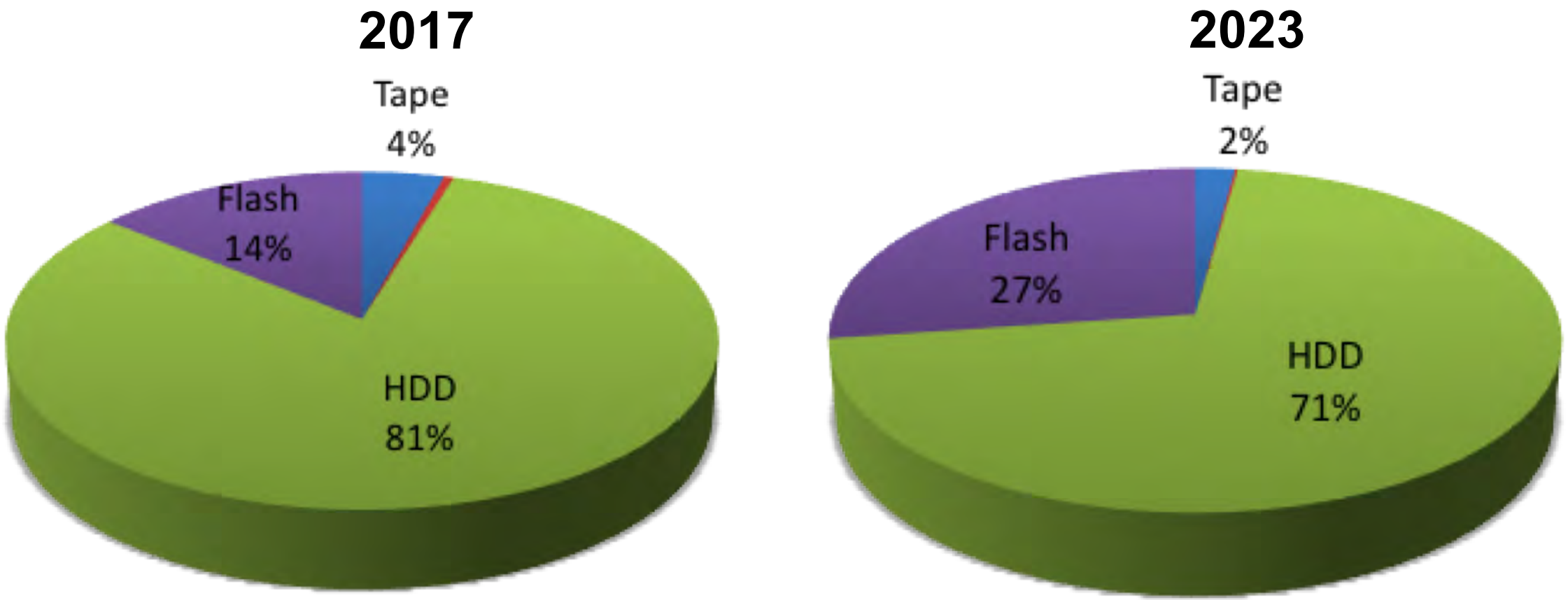
Storage libraries

XenData tape and optical disc library

Spectra Logic Tape library

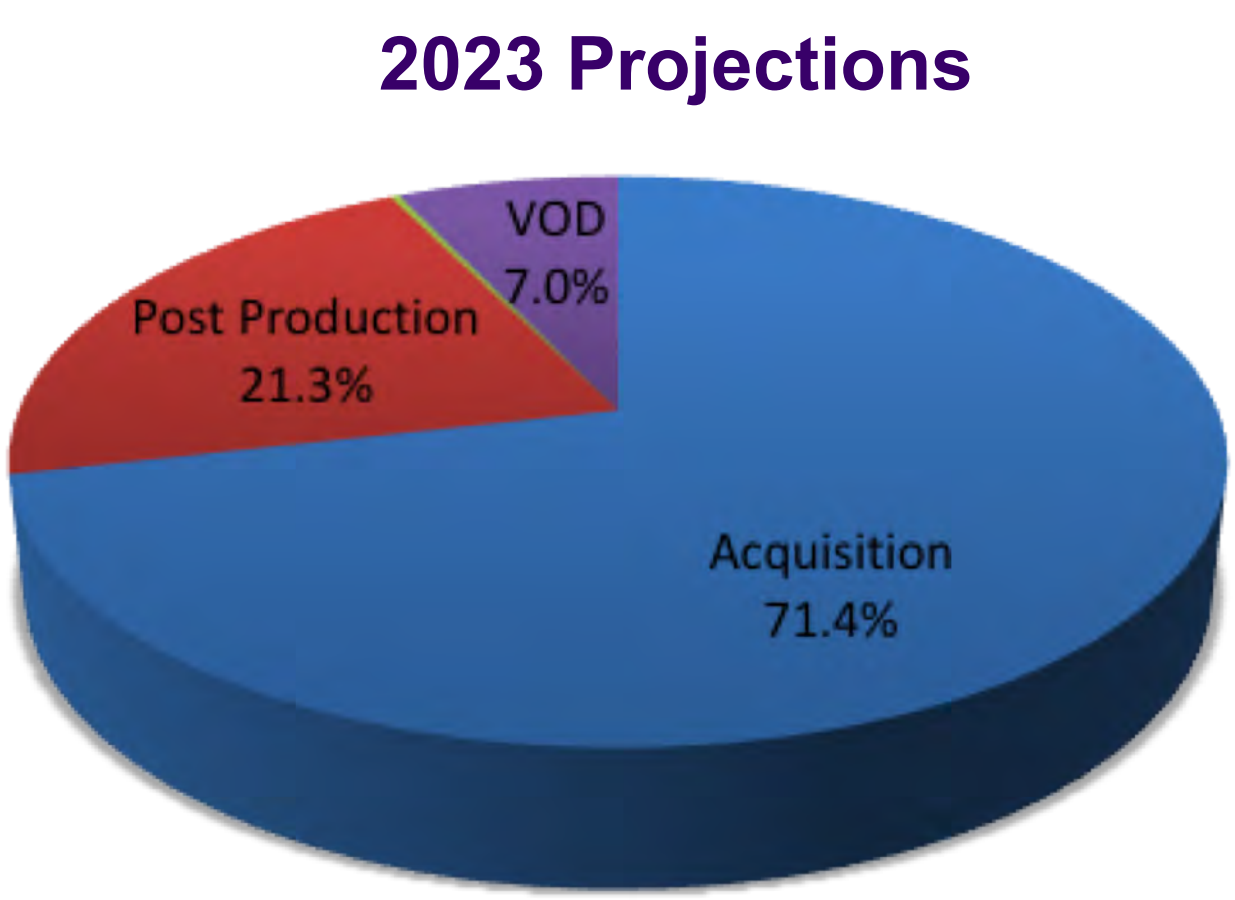
Summary & Conclusions

Flash Revenue Share Growing in Media & Entertainment (Revenue by Media Type)



2018 Digital Storage in Media and Entertainment Report, Coughlin Associates

Where Will This Flash Be Used?



- Flash memory used in professional video camera media by 56% of survey participants in 2018
- Use of flash in post production is expected to grow
- For CDN content delivery about 39% used flash memory on their edge servers in 2018

2018 Digital Storage in Media and Entertainment Report, Coughlin Associates

Media and entertainment storage trends

- Increasing resolution, higher dynamic range, higher frame rate and multiple camera projects will drive M&E storage demand
- Flash memory use will grow as price declines and bandwidth demands increase
- Cloud storage (public and private) will play an increasingly important role in all aspects of professional media and entertainment.
- HDDs, optical discs and tape will serve a bulk storage role.

2018 DIGITAL STORAGE FOR MEDIA AND ENTERTAINMENT REPORT

This updated and expanded report is the fourteenth annual comprehensive reference document on this topic. The report analyzes requirements and trends in worldwide data storage for entertainment content acquisition; editing; archiving and digital preservation; as well as digital cinema; broadcast; satellite; cable; network; internet and OTT and VOD distribution. Capacity and performance trends as well as media projections are made for each of the various market segments. Industry storage capacity and revenue projections include direct attached storage, cloud (including object storage), real-time as well as near-line network storage.

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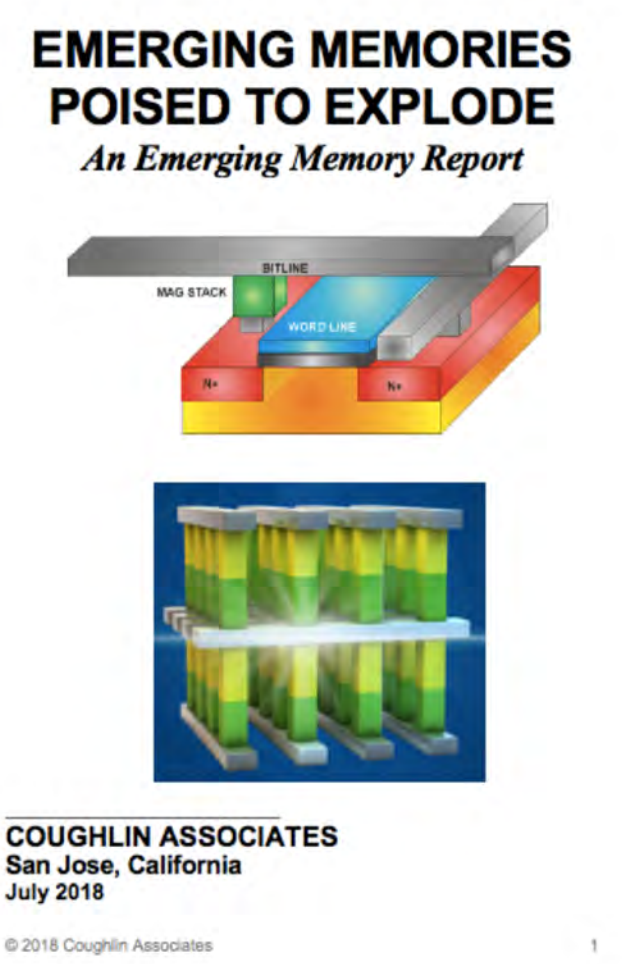
New Report on Emerging Memories

- Flash memory will remain a dominant solid-state memory for several generations with all manufacturers having moved to 3D flash.
- The 3D X-Point technology is poised to impact DRAM production while STT MRAM will impact SRAM, NOR and some DRAM.
- Resistive RAM (ReRAM) appears to be a potential replacement for flash memory sometime in the nex decade.
- The memories addressed in this 161-page report, containing 31 tables and 111 figures, include PCM, ReRAM, FeRAM and MRAM Technology as well as a variety of less mainstream technologies.



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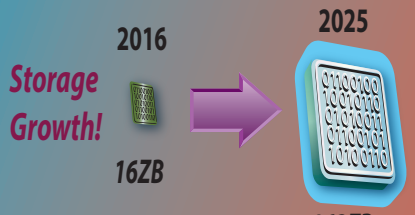

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- Challenges and Promise Of Ubiquitous Data
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- **2018 Digital Storage in Media and Entertainment Report,** Coughlin Associates, , http://www.tomcoughlin.com/techpapers.htm
- **2018 Emerging Memories Poised to Explode: An Emerging Memory Report**, http://www.tomcoughlin.com/techpapers.htm


Thanks