DIGITAL STORAGE TECHNOLOGY NEWSLETTER

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INTRODUCTION

This is the February 2017 issue of this newsletter and the fourth issue in the 2016-2017 annual volume.

This year marks the 31th year of this newsletter, formerly called the Rigid Disk Heads and Media Newsletter (and originally published by Peripheral Research, Inc.).

Here are some **top items impacting digital storage in the fourth quarter of 2016 (and the first month of Q1 2017)**:

- Total HDD shipments in CQ3 2016 were down 1.7% compared with CQ3 2016 (M 111.5 M units in Q4 2016 versus 113.5 M units in Q3 2016). This is after a 15.2% increase for CQ3 2016 from CQ2 2016, 2.1% decline for CQ2 2016 from CQ1 2016, 12.3% decline for CQ1 2016 from CQ4 2015 and a 3.6% decline for CQ4 2015 from CQ3 2015.
- Notebook HDD shipments declined by 19.9% while desktop HDD shipments declined 18.6% Q2Q.
- CE HDD shipments were up 20.8% while branded shipments were down 7.9% Q2Q.
- High performance enterprise HDDs were down 11.3% while near line enterprise HDDs were up 1.5% Q2Q..
- 3.5-inch HDDs declined by 11.0% Q2Q. 2.5-inch HDDs increased by about 7.9% Q2Q.
- There was a 0.87% increase in ASPs in CQ4 2016 compared to CQ3 2016. There was a 1.92% increase in ASPs in CQ3 compared to CQ2 2016, an 8.82% increase in ASPs in CQ2 compared to CQ1 2016, a 0.85% decline in ASPs in CQ1 2016 compared to CQ4 2015 and a 1.7% increase in CQ4 compared to CQ3 2015. This quarter continued the increase in ASPs we saw in the prior two quarters.
- The **2016 Digital Storage in Media and Entertainment Report** is available. See sales form at the end of the newsletter.
- The ***2016 How Many IOPS Do You Really Need Report***, co-authored with Objective Analysis is now available—see sales form at the end of this newsletter.
- The **2015 Emerging Non-Volatile Memory and Storage Technology and Manufacturing Report** is available from Coughlin Associates—see sales form at end of the newsletter.

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these and other reports please see the technical papers page on the Coughlin Associates web site at www.tomcoughlin.com. To order call 408-978-8184 or email tom@tomcoughlin.com.

This issue has several guest articles by various friends of the Entertainment Storage Alliance including Steve Daniel, Jim Handy, Peter Cole, John Rotchford and Andy Marken. It also includes sales flyers for the **2016 Digital Storage in Media and Entertainment Report**, the **2016 How Many IOPS Do you Need Report** and the **2015 Emerging Non-Volatile Memory and Storage Technologies and Manufacturing Report.** We also include a flyer for the upcoming 2017 Creative Storage Conference (May 24, 2017) in Culver City, CA the 2017 Storage Visions Conference (October 16, 2017) in Milpitas, CA.

Please let your friends know about this newsletter. There is a subscription form at the end of the report. Feel free to pass this newsletter to your friends in the industry.

Thanks for being a customer!

Tom Coughlin

SYSTEMS / SUBSYSTEM STORAGE PRODUCTS

Datalink Press Release (11/5/16)
More than two-thirds of IT teams have deployed applications to a public cloud but nearly 40% have brought them back in-house, according to a new IDG survey. Among the other findings:

- **The top reasons for abandoning public cloud deployments are security (55%) and cost (52%) concerns**, followed by manageability, reliability/performance, lack of flexibility/customization, support/service issues, and concerns about the level of control over resources or data.
- **Many organizations fail to perform a thorough analysis of workload requirements before making cloud or other platform decisions,** suggesting that a more rigorous assessment process can avoid mistakes and the associated need for re-platforming.
- **Nevertheless, public cloud is the #2 near-term IT investment planned by IT teams** with 59% currently investing or planning to invest in the next 12 months**,** outstripped only by private cloud initiatives at 62%.

Inifiniband Press Release (11/29/16)
The Infiniband Trade Association announced the public availability of the InfiniBand Architecture Specification Volume 2 Release 1.3.1 and a Virtualization Annex to the InfiniBand Architecture Specification Volume 1 Release 1.3. The new Volume 2 specification release expands interoperability and performance management functionality across the InfiniBand ecosystem for both high performance computing (HPC) and enterprise data center networks. The Virtualization Annex extends support for multiple virtualized endpoints within InfiniBand hardware. Both of these publications will be essential to expanding the performance and scalability of future data centers.

The Volume 2 Release 1.3.1 specification adds flexible low-latency Forward Error Correction (FEC) upgrades. This new option enables a best of both worlds – low error rate with low latency. A second enhancement enables the subnet manager to optimize both signal integrity with the lowest power possible from the port. Improved cable management is enabled through updates to QSFP28 and CXP28 memory mapping. The new specification release also improves upon InfiniBand interoperability and test methodologies for the latest data rates, namely EDR 100 Gb/s and FDR 56 Gb/s. This enhancement is achieved through updated EDR electrical requirements, amended testing methodology for EDR Limiting Active Cables, and FDR interoperability and test specification corrections.

IDC MarketScape WW Object-Based Storage (StorageNewsletter, 12/20/16)

(Source: IDC, 2016)

IDC Opinion

The storage market has come a long way in terms of understanding object-based storage (OBS) technology and actively adopting it. The OBS landscape now sees a standardization and integration of the Amazon S3 and OpenStack Swift API, an emphasis on computing paradigms such as containers, native support for file interfaces, and a focus on vertical/use case-centric solution offerings. Many OBS solutions offer a scale-out file system that integrates with an independent but underlying OBS platform. These advancements have opened the doors for OBS so as to cater to a wide range of use cases beyond backup and archive. OBS solutions serve newer use cases that include (but are not limited to) mobility, analytics, compliance, and commercial high-performance computing areas such as media rendering/production. Today, OBS platforms are available in a variety of delivery models including appliances, software-only, and cloud services

offerings.

According to *Worldwide File- and Object-Based Storage Forecast, 2016-2020 (IDC #US41685816, September 2016)*, **object-based storage capacity is expected to grow at a CAGR of 30.7% from 2016 to 2020, reaching 293.7EB in 2020**. In terms of revenue, IDC expects the OBS market to reach $19.8 billion in 2020, much of which is driven by hyperscale environments.

In this report, IDC assesses the present commercial OBS supplier (suppliers that deliver software-defined OBS solutions as software or appliances much like other storage platforms) landscape. Cloud-based storage services based on OBS are not included in this IDC MarketScape. Since the publication of the last report on OBS, the landscape has changed dramatically - a fragmented OBS market has now somewhat consolidated. As demand for traditional external storage systems continues to decline, several mainstream storage suppliers enhanced their portfolio to include OBS solutions by developing them in-house or via acquisitions. This study assesses 12 OBS suppliers that are 'owners of IP.'

Key findings include:

- End users and suppliers are exploring the idea of all-flash array OBS solutions that will cater to not just capacity needs but also performance requirements for environments like big data/analytics, rich media, and technical computing. Some of these solutions feature scale-out architectures based on custom flash modules (CFMs) instead of SSDs with higher densities and lower cost per gigabyte than primary all-flash arrays. Such platforms, having disrupted the primary storage market, are now targeting secondary storage markets.
- An OBS solution that supports traditional (current-generation) and next-generation applications will enable end users to adopt this technology more efficiently. For example, native support for file interfaces allows a user to write and retrieve files to/from the OBS solution.

End users often appreciate the flexibility of choice not just in delivery models (appliances, software only, or cloud storage) but also in the ability to tier data based on usage to appropriate storage (HDD, cloud, tape, etc.). An OBS solution with strategic ISV and technology partnerships thus offering a strong solutions portfolio is also a key consideration for any end user.

WW Cloud IT Infrastructure Spending Up 18% in 2017 – IDC (StorageNewsletter, 1/20/17)

According to IDC, total spending on IT infrastructure products (server, enterprise storage, and Ethernet switches) for deployment in cloud environments will increase by 18.2% in 2017 to reach $44.2 billion.

Of this amount, the majority (61.2%) will be done by public cloud datacenters, while off-premises private cloud environments will contribute 14.6% of spending. With increasing adoption of private and hybrid cloud strategies within corporate

datacenters, spending on IT infrastructure for on-premises private cloud deployments will growth at 16.6%. In comparison, spending on traditional, non-cloud, IT infrastructure will decline by 3.3% in 2017 but will still account for the largest share (57.1%) of end user spending. (Note: All figures above exclude double counting between server and storage.)

In 2017, spending on IT infrastructure for off-premises cloud deployments will experience double-digit growth across all regions in a continued strong movement toward utilization of off-premises IT resources around the world. However, the majority of 2017 end user spending (57.9%) will still be done on on-premises IT infrastructure which combines on-premises private cloud and on-premises traditional IT. In on-premises settings, all regions expect to see sustained movement toward private cloud deployments with the share of traditional, non-cloud, IT shrinking across all regions.

Accelerating Cat 8 Cable Adoption (Optical Cable Corporation Press Release, 12/13/16)
Category 8 Ethernet cable will play a major role in meeting today's burgeoning needs for high-speed communications, whether in the data center, voice, video or other high bandwidth applications that run on copper cable for distances up to 30 meters.

To ensure that Category 8 adopters will effectively reach data speeds of up to 40 Gb/s – four times the speeds of many of today's users - OCC (Optical Cable Corporation) is introducing a new RJ-45 plug with integral circuit board technology that provides advanced control of crosstalk, return loss, and other impediments, ensuring consistent performance at higher frequencies up to 2000 MHz.

Prior to the introduction of this product cable engineers viewed the challenge of transmitting data at rates of up to four times faster over a standard RJ-45 connector as a major concern.

"Essentially, the new plug contains technology that provides advanced control of plug performance," says Derrick Stikeleather, OCC Copper Connectivity Manager and Member of the TIA Engineering Subcommittee TR-42.7. "In a conventional category style plug, the plug wires must be arranged in specific positions, leading to variations in performance. But when a circuit board is used, it basically eliminates the possibility of plug wire variations. It also means that electrical properties transition from a cable to a terminal in a more controlled fashion."

Stikeleather adds that the new, proprietary technology utilizes a higher performance type of circuit board material than what is contained in a standard connector. "Without this, achieving quality data transmission rates of 40 Gb/s would not be possible," he explains.

The new plug, which was recently granted a patent for circuit board layout and the advanced materials used in its construction, is ideal for direct-attach, high-speed links and data center server connections.

Stikeleather also said the plug provides consistent and reliable terminations that are guaranteed to meet or exceed the recently approved Category 8 standard when paired with compliant Category 8 cable. The new RJ-45 plug model is fully backward compatible with existing RJ-45 infrastructure used by a majority of Ethernet connection ports, including Cat 6A, Cat 6 and Cat 5e cabling. It is field installable, and should be familiar to many cable installers.

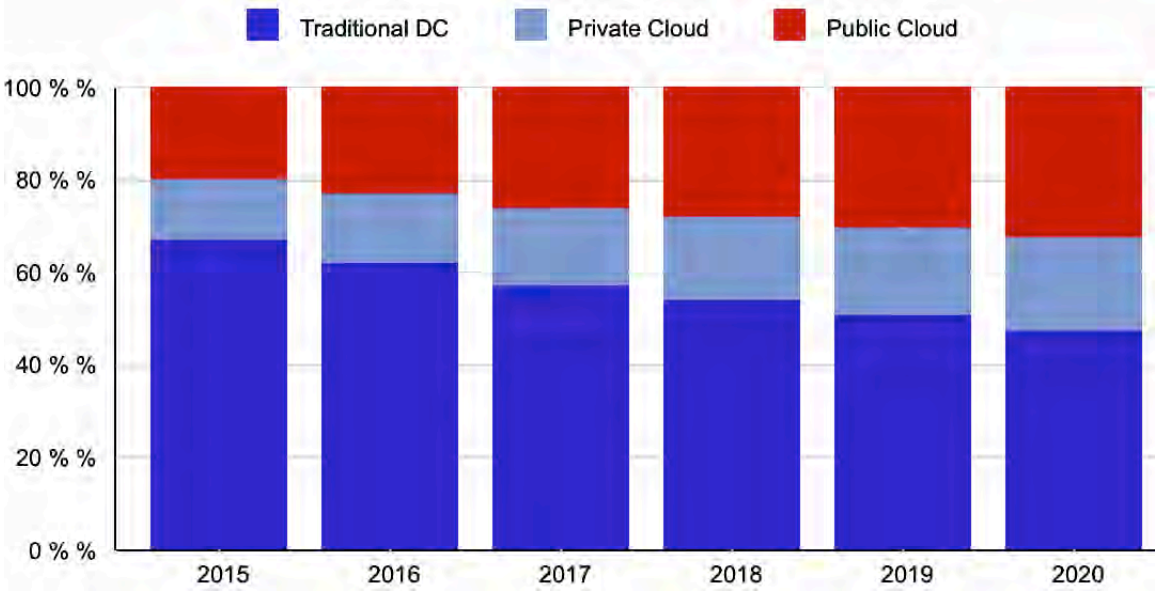
The new RJ-45 plug is also compatible with OCC's family of ruggedized RJ-45 connectors, a family of receptacles, plugs, and back shells that enables users to extend their Ethernet platforms into harsh industrial and military operating environments.

For information contact: Optical Cable Corporation, 5290 Concourse Drive, Roanoke, Virginia, 24019; Phone: (800) 622-7711, Canada (800) 443-5262; FAX: 540-265-0724; Email: info@occfiber.com; Visit the web site *www.occfiber.com*.

Ethernet switches will be fastest growing segment of cloud IT infrastructure spending, increasing 23.9% in 2017, while spending on servers and enterprise storage will grow 13.6% and 23.7%, respectively. In all three technology segments, spending on private cloud deployments will grow faster than public cloud while investments on non-cloud infrastructure will decline.

Long term, IDC expects that spending on off-premises cloud IT infrastructure will experience a 5-year CAGR of 14.2%, reaching $48.1 billion in 2020. Public cloud datacenters will account for 80.8% of this amount. Combined with on-premises private cloud, overall spending on cloud IT infrastructure will grow at a 13.9% CAGR and will surpass spending on non-cloud IT infrastructure by 2020. Spending on on-premises private cloud IT infrastructure will grow at a 12.9% CAGR, while spending on non-cloud IT (on-premises and off-premises combined) will decline at a CAGR of 1.9% during the same period.

WW Cloud IT Infrastructure Market Forecast by Deployment Type - 2015-2020 (shares based on value)



(Source: IDC Worldwide Quarterly Cloud IT Infrastructure Tracker, 3Q16)

MEDIA & ENTERTAINMENT AND SURVEILLANCE STORAGE

Quantum's New StorNext 5.4 Release Provides Greater Efficiency and Flexibility in Media Content Management (Company Press Release, 12/13/16)

Quantum announced StorNext 5.4, a new release of the company's acclaimed workflow storage platform that brings new levels of efficiency and flexibility to media content management. StorNext 5.4 enhancements include the ability to integrate existing public cloud storage accounts and third-party object storage (private cloud) — starting with Amazon Web Services, Microsoft Azure, Google Cloud, NetApp StorageGRID, IBM Cleversafe and Scality RING — as archive tiers in a StorNext®-managed media environment. Another new feature enables users to deploy applications embedded within StorNext-powered Xcellis™ workflow storage appliances.

Expanded Cloud Options

One of the most significant enhancements is a new feature in StorNext Storage Manager™ that offers automated, policy-based movement of content into and out of users' existing public and private clouds while maintaining the visibility and access that StorNext provides. As a result, customers can protect their prior investments and reduce the cost and complexity of cloud storage administration. Additional benefits include:

- Seamless integration for public and private clouds within a StorNext-managed environment that can also encompass primary disk and tape storage tiers.

- Full user and application access to media stored in the cloud without the need for additional hardware or software.
- Extended versioning across sites and the cloud.
- The ability to leverage integrated cloud transfer acceleration, a broad selection of third-party WAN acceleration tools and high-speed connectivity options for high-volume data transfers.

Xcellis Storage Support for Application Deployment By enabling applications to run inside its Xcellis Workflow Director, Quantum's new Dynamic Application Environment (DAE) capability in StorNext 5.4 allows users to leverage a converged storage architecture to reduce the time, cost and complexity of deploying and maintaining applications. The DAE supports embedded applications in self-contained virtual machines (VMs), with a hypervisor dynamically allocating resources as needed to guarantee both storage and application performance. This approach to application deployment eliminates the need for dedicated servers and networking resources, keeps applications close to content storage and helps users take full advantage of their compute resources. With support for both Windows and Linux VMs, the DAE adds application flexibility and compatibility to the storage environment.

Symply Introduces Powerful RAID Storage for Professional Media Workflows (12/14/16)
Symply is shipping SymplyRAID, a high-performance, high-throughput RAID storage system with low latency and massive capacity for large-scale media workflows.

Offering seamless integration into existing broadcast and post-production facilities, including Xsan and StorNext workflows, SymplyRAID provides a level of intuitiveness far beyond other systems on the market, enabling installation in minutes via user-friendly SymplyGO management and monitoring software. Developed in conjunction with Promise Technology, the system features a next-generation RAID Controller design based on the latest Intel® storage processor. With fast dual quad, 16Gb Fibre Channel connectivity, SymplyRAID can scale to nearly 1PB while delivering the consistent performance and low latency that is critical for handling the complex demands of media and creative workflows.

Based on a high-density rack-optimized design that packs a powerful punch, SymplyRAID includes 24 drives in 4U for maximum space efficiency. The high-availability RAID storage systems offer complete redundant power, cooling, and RAID controllers with no single point of failure. SymplyRAID is available in 3U 16-drive and 4U 24-drive configurations with capacities for any need, whether large or small. Performance and capacity scalability is easy with the addition of SymplyRAID expansion systems.

Using dual quad 16Gb Fibre Channel ports, SymplyRAID is capable of reading and writing up to 12GB and 5GB of data per second, respectively. It can handle

up to eight streams of uncompressed 10bit Quad HD or hundreds of streams of ProRes 422 content. The inclusion of multiple Fibre Channel ports builds resiliency into the system, while enhancing speed and performance. Through SymplyRAID's remote management software, SymplyGO, users can easily set up and manage the system via macOS™, Mac® OS X®, Windows®, iOS, and watchApp devices.

CONSUMER ELECTRONICS

STORAGE AND RELATED TECHNOLOGY

Hard Disk Drives

Seagate hauls out fat form factor throwback hard drive (The Register, 1/17/17)
Seagate has introduced a 3.5-inch 1TB and 2TB disk drive spinning at 7,200rpm with a slow 6Gbps SATA interface, and called it an Enterprise Capacity drive.

The new drives use ninth-generation PMR recording and are aimed at a market niche that needs an entry-level, small-capacity drive in the 3.5-inch format, not the 2.5-inch one. It's a cheap (we assume; no prices supplied) and cheerful spinner with a 128MB cache, 194MBps transfer rate, two million hours MTBF rating, five-year warranty, and supports 24x7 workloads of 550TB per year.

That's 10 times a desktop drive's workload. Seagate says the drives are built specifically to address the entry-level bulk data needs of system architects, sales engineers and owners of small to medium-sized businesses, and suggests these application areas could use it:

- Hyperscale applications/cloud data centres with replicated storage
- Scale-out data centres and big data analytics
- Legacy mainstream applications requiring 512n block size
- High-capacity density RAID storage
- Mainstream enterprise external storage arrays (SAN, NAS, DAS) Distributed file systems, including Hadoop and Ceph
- Enterprise backup and restore – D2D, virtual tape
- Centralised surveillance

Western Digital Offers Third Generation WD PiDrive Solution (Company Press Release, 11/18/16)
Western Digital announced availability of the WD® PiDrive Foundation Edition products, which combine microSD™ card and USB drive functionality with operating system installation software to provide the Raspberry Pi® community an integrated and highly affordable storage system solution for fast project creation.

Range of new products

The WD PiDrive Foundation Edition device is offered in three capacity versions: a 375GB disk drive, a 250GB disk drive and a 64GB flash drive. The 375GB and 250GB products include a WD PiDrive cable that ensures optimal powering of the hard drive and Raspberry Pi. All versions include a microSD card preloaded with the custom NOOBS OS installer. Raspberry Pi's official OS, Raspbian PIXEL, can be installed directly from the microSD card (no Internet connection required), in addition to up to five Project Spaces, depending on capacity available. Raspbian PIXEL provides a familiar desktop environment and includes a web browser, productivity applications, programming tools, games and other features typically provided on desktop computers. Project Spaces are independent portions of the drive with Raspbian Lite, a minimal OS for building efficient yet sophisticated solutions via command-line programming.

Price and Availability

Manufacturer Suggested Retail Price for the WD PiDrive Foundation Edition is $37.49 for the 375GB version, $28.99 for the 250GB version and $18.99 for the 64GB flash drive version.

Flash Memory and Solid State Storage

Prepare for ReRAM speed! Crossbar samples SMIC chips (The Register, 1/16/17)

ReRAM startup Crossbar has sampled embedded ReRAM chips from SMIC for company evaluation. SMIC is using a 40nm process with plans for a 28nm process.

The chip design uses non-conductive amorphous silicon (a-SI) technology. There is a switching layer between top and bottom electrodes and the resistance of this layer to passing electric currents is based on ionic (silver) metal motion. The resistance is changed when a sufficient voltage is applied between the two electrodes which cause nano-filaments of ions to form between the electrodes.

The company says individual cells can be controlled by a transistor in a 1 transistor per ReRAM cell – 1T1R – arrangement. Transistors have size constraints. Alternatively, and more cost-effectively, many ReRAM cells – up to 2,000 say – can be controlled by a single transistor if each cell has an in-cell selector mechanism that can select or not select individual cells – a 1TnR scheme.

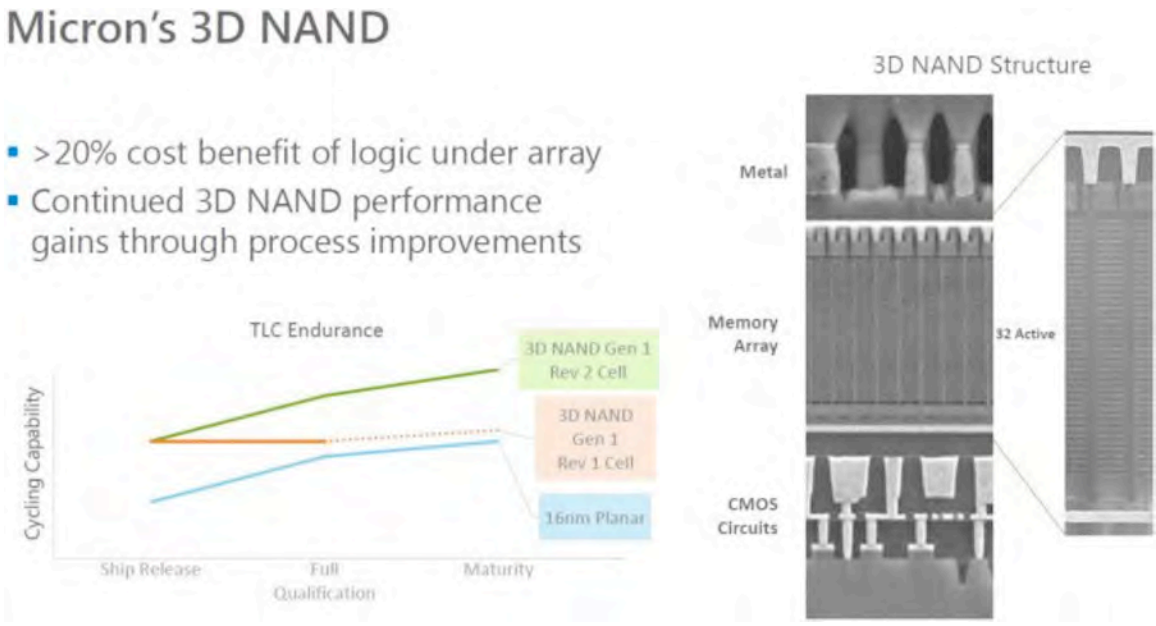
This is done by implementing a crossbar scheme, as with 3D XPoint memory, and it is also a 3D Xpoint scheme. Up to 16 levels have been suggested as being feasible.

The 1T1R scheme offers the lowest latency, while the 1TnR scheme has the best

area density efficiency. We might imagine a 1T1R scheme would be used in embedded memory applications, involving caching, with the 1TnR design used in storage drives such as SSDs in formats such as M.2 or even NVDIMMs.

Crossbar tells us that scaling ReRAM cells down to sub-10nm level will not adversely affect filament formation and destruction, unlike with NAND flash where cell scale-down results in too few electrons to retain an applied charge, causing cell bit value degradation.

Micron 3D NAND Update: 2D and 3D NAND Bit Crossover, Gen 2 Hits Production (AnandTech Blog, 12/20/17)
Ernie Maddock, CFO of Micron, said at the Barclays Technology Conference that the company had achieved a bit crossover between 2D and 3D NAND flash memory output. This means that total capacity of 3D NAND memory produced by Micron now exceeds the total capacity of 2D NAND memory made by the company. The bit crossover was a relatively easy target to hit because Micron's 2D MLC and TLC NAND devices made using 16 nm process technology can store up to 128 Gb of data, whereas the capacity of the company's 3D NAND IC is 256 Gb in MLC configuration and 384 Gb in TLC configuration. That said, once 3D wafer production started and yields hit certain levels, the balance between 2D NAND and 3D NAND output adjusts, and the bit crossover happens despite more 2D chips being produced.



While balancing 2D and 3D NAND output seems easy on paper, it is not. Manufacturing technologies involved in the production of 2D and 3D NAND are completely different. 2D NAND relies on lithography, and in order to transit to a new fabrication process one needs to switch to more advanced step-and-scan systems. 3D NAND relies on deposition and etching: first, you need to deposit many layers (38 in case of Micron's Gen 1 3D NAND) of thin films on top of a

wafer in a uniform manner (alternating stack deposition) to build up word-lines, and then you need to etch millions of holes through them (high aspect ratio etch) to pave the way for bit lines.

Everything is *much* more complex, even at a high level, but in general, the alternating stack deposition requires chemical vapor deposition (CVD) machines whereas high aspect ratio etch requires other tools. Lithography tools are not going anywhere, but the addition of extra CVD, high aspect ratio etch tools and other equipment vital to make 3D NAND to the fabs doubles or even quadruples the amount of space required to process the same amount of 2D NAND wafers (see details why at Semiconductor Engineering).

All things considered, it is not easy at all to start making 3D NAND in a fab that is already making 2D NAND. Flash memory manufacturers have to halt production of existing memory, add the equipment (which may involve removal of certain existing tools because space is precious), tune everything, and start production. Keeping in mind that Micron started high-volume manufacturing of 3D NAND sometime in early 2016, so hitting a bit output crossover in less than a year looks rather impressive given complexities with the conversion of capacities, yet predictable, given capacity improvements that the 3D NAND ICs have over planar ones.

Supply Shortage of NAND Flash Worsens (StorageNewsletter for DRAMExchange, 11/11/16)
The supply shortage of NAND flash has worsened in the fourth quarter of 2016 **due to higher demand in the smartphone and SSD industries**.

This is according to the report from DRAMeXchange, a price and supply-monitoring organisation that covers the CPU, memory and storage silicon markets.

The short supply, coupled with strong demand, has contributed to rising prices and lengthened lead times of NAND flash wafers and memory cards, as well as increased margins to suppliers at the expense of buyers.

Prices are also expected to rise for eMMC, eMCP and SSD products.

Key reasons for this shortage include:
- Continued high levels of demand for smartphones - in particular a doubling of storage capacity in new iPhone 7 options and an increase in demand from Chinese smartphone makers
- Increased demand from manufacturers for SSDs and the growing frequency of flash storage deployment by datacentre hardware makers
- Difficulties NAND flash manufacturers are experiencing in switching to 3D NAND production. 3D NAND flash stacks memory cells vertically, unlike 2D or planar flash, boosting storage capacity and density

- High demand for PCs and notebooks, with average flash adoption in notebooks expected to exceed 30% for the first time in 2016

Increasing levels of SSD deployment in personal computing and datacentre hardware are driven by the growing competitiveness in price between flash drives and spinning HDD drives, which are thought to achieve parity at some point in 2017

Capital Equipment

North American Semiconductor Equipment Industry Posts December 2016 Book-to-Bill Ratio of 1.06 (SEMi Press Release, 1/24/17)
North America-based manufacturers of semiconductor equipment posted $1.99 billion in orders worldwide in December 2016 (three-month average basis) and a book-to-bill ratio of 1.06, according to the December Equipment Market Data Subscription (EMDS) Book-to-Bill Report published today by SEMI. A book-to-bill of 1.06 means that $106 worth of orders were received for every $100 of product billed for the month.

SEMI reports that the three-month average of worldwide bookings in December 2016 was $1.99 billion. The bookings figure is 28.3 percent higher than the final November 2016 level of $1.55 billion, and is 47.8 percent higher than the December 2015 order level of $1.34 billion.

The three-month average of worldwide billings in December 2016 was $1.87 billion. The billings figure is 15.7 percent higher than the final November 2016 level of $1.61 billion, and is 38.2 percent higher than the December 2015 billings level of $1.35 billion.

“2016 ended the year with bookings levels approaching $2 billion," said Denny McGuirk, president and CEO of SEMI. “This combined with a significant increase in billings puts 2016 equipment sales of North American manufacturers well above 2015 levels and well positioned for 2017.”

The SEMI book-to-bill is a ratio of three-month moving averages of worldwide bookings and billings for North American-based semiconductor equipment manufacturers. Billings and bookings figures are in millions of U.S. dollars.

	Billings (3-mo. avg)	**Bookings** (3-mo. avg)	**Book-to-Bill**
July 2016	$1,707.9	$1,795.4	1.05
August 2016	$1,709.0	$1,753.4	1.03
September 2016	$1,493.3	$1,567.2	1.05
October 2016	$1,630.4	$1,488.4	0.91
November 2016 (final)	$1,613.3	$1,547.5	0.96
December 2016 (prelim)	$1,865.8	$1,985.4	1.06

Source: SEMI (www.semi.org), January 2017
SEMI will cease publishing the monthly North America Book-to-Bill report this year. The December 2016 report and press release is the last publication. The decision to discontinue the Book-to-Bill report is based on changes in reporting by some participants where the reporting of orders/bookings into the data collection program is no longer considered a necessary component of their industry analysis.

SEMI Reports Third Quarter 2016 Worldwide Semiconductor Equipment Figures; Billings $11.0 Billion (SEMI Press Release, 12/5/16)
SEMI reported that worldwide semiconductor manufacturing equipment billings reached US$11.0 billion in the third quarter of 2016. The billings figure is 5 percent higher than the second quarter of 2016 and 14 percent higher than the same quarter a year ago. The data is gathered jointly with the Semiconductor Equipment Association of Japan (SEAJ) from over 95 global equipment companies that provide data on a monthly basis.

Worldwide semiconductor equipment bookings were $11.3 billion in the third quarter of 2016. The figure is 30 percent higher than the same quarter a year ago and 5 percent lower than the bookings figure for the second quarter of 2016.
The quarterly billings data by region in billions of U.S. dollars, quarter-over-quarter growth and year-over-year rates by region are as follows:

	3Q2016	**2Q2016**	**3Q2015**	**3Q2016/ 2Q2016** (Qtr-over-Qtr)	**3Q2016/ 3Q2015** (Year-over-Year)
Taiwan	3.46	2.73	2.85	27%	22%
Korea	2.09	1.53	1.56	36%	34%
China	1.43	2.27	1.70	-37%	-16%
Japan	1.29	1.05	1.43	22%	-10%
Rest of World	1.13	1.31	0.58	-14%	95%
North America	1.05	1.20	1.18	-12%	-11%
Europe	0.53	0.37	0.34	42%	57%
Total	**10.98**	**10.46**	**9.64**	**5%**	**14%**

Totals may not add due to rounding; Source: SEMI/SEAJ

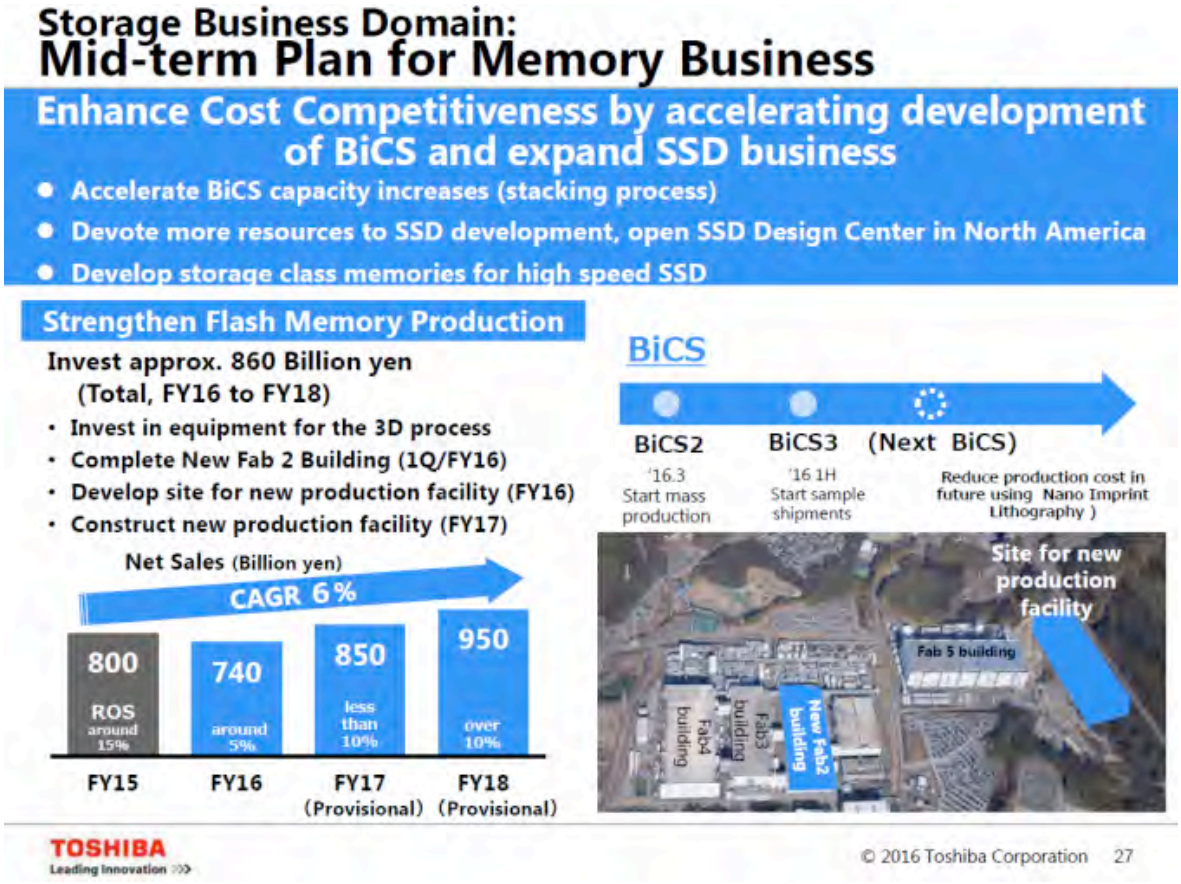
Toshiba Finalizes Plans for New 3D NAND Fab: Coming Online in 2019 (AnandTech Blog, 11/5/16)

Toshiba in the past week has finalized plans to build a new production facility to make 3D NAND flash memory. The company will start construction in early 2017 and in addition to a new manufacturing site Toshiba will also build a new R&D center. Toshiba is still talking with its partner Western Digital about joint investments in the new facility, but no matter what, the building will be completed in mid-2018 and the fab will start high volume production in 2019.

Toshiba intends to start construction of the first phase of its new fab in February 2017 and no decisions about the second phase of the project have been made so far. The building is set to be complete inside and out sometime in summer 2018 and then the company will have to move in equipment, which takes two to three quarters. If everything goes smoothly, the fab will produce its first 3D NAND wafers in late 2018, but high volume commercial production will start in calendar 2019. We are told that the building will have a quake-absorbing structure and will also use an environmentally friendly design that includes LED lighting.

The manufacturer will finalize decisions regarding exact production capacity as well as equipment investment sometime next fiscal year, which begins in April 2017 for Toshiba. While the company does not indicate planned capacities, it disclosed plans to use an AI-powered production system to boost productivity. Toshiba says that its decisions will reflect market trends, but given the fact that NAND flash memory is in short supply today, it is could be expected that the company to max out the capacity in the first phase of its next fab. Another reason why Toshiba might want to maximize production capacity of the manufacturing facility is due to the aggressive expansion of production capacities by Samsung. At the moment, Toshiba and Western Digital (which acquired Toshiba's partner

SanDisk) produce more NAND flash at the Yokkaichi Operations memory production complex in Mie prefecture than any other manufacturer and Toshiba would certainly like to keep it that way.



What's that surging down the Yangtze? It's a 3D NAND flash flood (The Register, 1/4/17)

China's Yangtze River Storage Technology (YMTC) has started building a 3D NAND flash plant. YMTC, through its ownership of contract chip manufacturer XMC, has started building a memory semiconductor fab on a 13-hectare site at the Donghu New Technology Development Zone in Wuhan. Tsinghua Unigroup, which owns 51.04 per cent of YMTC, said the fab would soak up $24bn in investment. The other 48.96 per cent of YMTC is owned by China's National Integrated Circuit Industry Investment Fund, the Hubei IC Industry Investment Fund, and the Hubei Science and Technology Investment Group.

This will be the largest memory plant in China and include three 3D NAND production lines. Volume production should start in 2018, with a run rate of 300,000 12-inch wafers a month by 2020.

ARTICLES

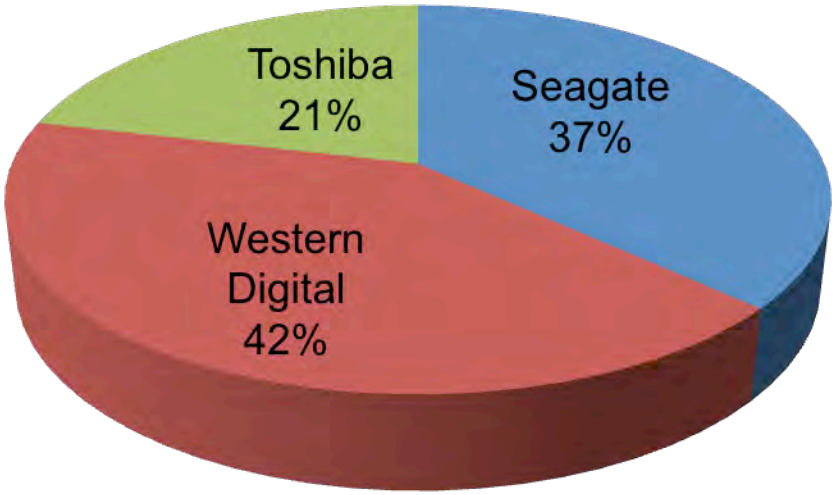
1) Hard Disk Drives Have a Come Back Quarter (Forbes, 11/1/16)
Hard disk drives shipments have had several quarters of declining shipments since the most recent high in 2014 and the peak of 653.6 million units in 2010 (before the 2011 Thailand floods). Last quarter and likely this quarter will see significant HDD shipment increases, partly making up for declining shipments in the first half of 2016.

Total HDD shipments in CQ3 2016 were up 15.2% compared with CQ2 2016 (113.5 M units in Q3 2016 versus 98.5 M units in Q2 2016). This is after a 2.1% decline for CQ2 2016 from CQ1 2016, 12.3% decline for CQ1 2016 from CQ4 2015, and a 3.6% decline for CQ4 2015 from CQ3 2015.

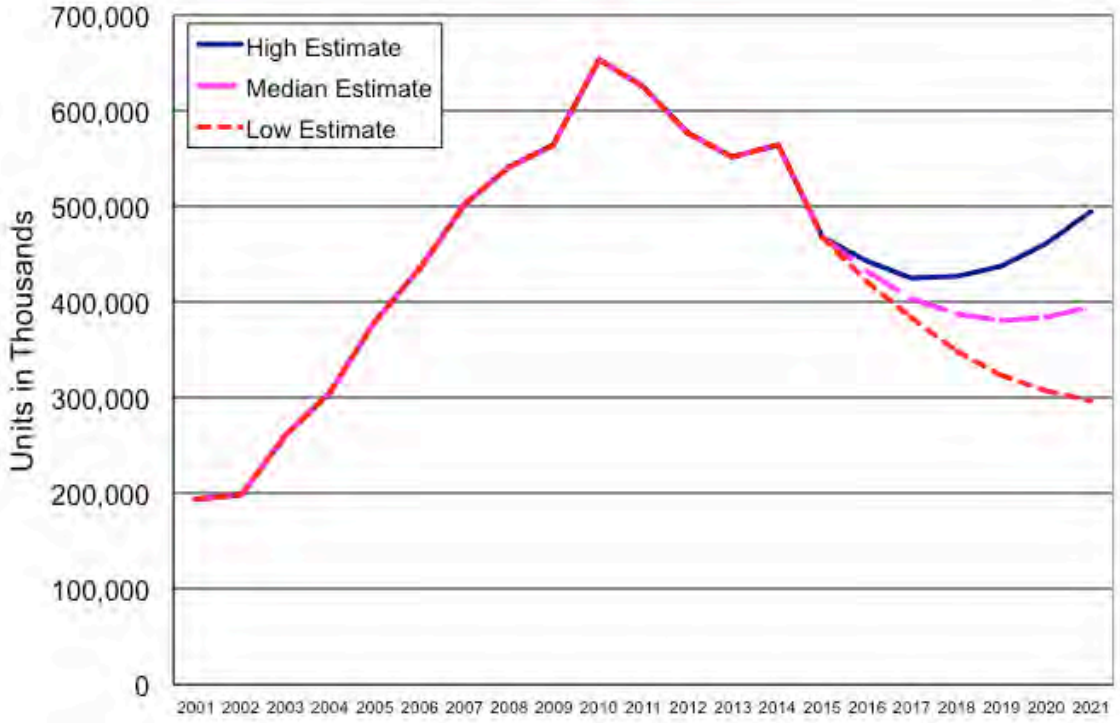
Notebook HDD shipments increased about 13% quarter to quarter in CQ3 2016 while desktop HDD shipments increased 12.4%. CE HDD shipments were up 41.3%, while branded shipments were down 4.9%. High performance enterprise storage was up 4.5%, near Line enterprise was up 6.2% Q2Q. 3.5-inch HDDs increased by 23.5%. 2.5-inch HDDs increased by about 7.7%.

There was a 1.92% increase in Average Sales Price (ASP) in CQ3 2016 compared to CQ2 2016. There was a 8.82% increase in ASPs in CQ2 compared to CQ1 2016, a 0.85% decline in ASPs in CQ1 2016 compared to CQ4 2015 and a 1.7% increase in CQ4 compared to CQ3 2015. ASPs declined 1.6% in CQ3

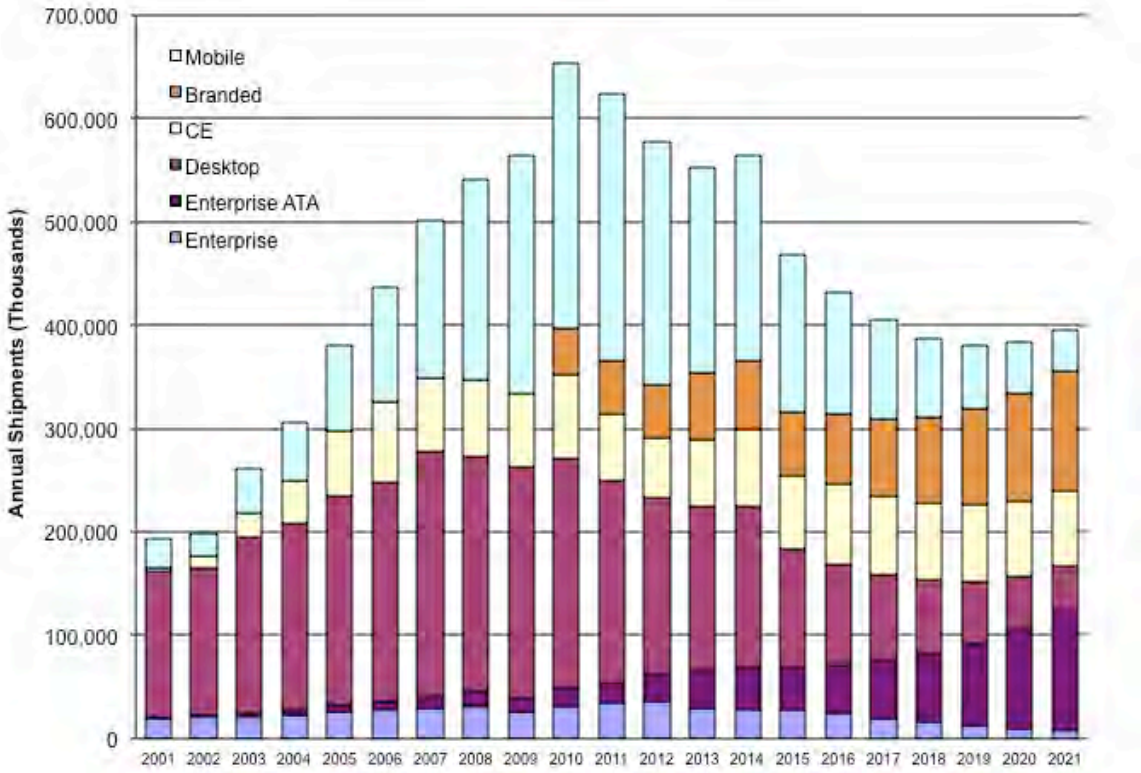
2015. This quarter continued the increase in ASPs that started last quarter.



HDD shipments so far this year were split between the three remaining HDD companies with Western Digital's market share at 42%, Seagate's at 37% and Toshiba at 21%. With positive forward guidance for CQ4 2016 the total reduction in shipped HDDs in 2016 will be less than we originally anticipated. We currently project total 2016 HDD shipments will be 432.6 M units, down 7.6% from 2015. The figure below shows high, median and low estimate of total drive unit volume estimates out to 2021.



HDD increases by the end of the decade are likely because of the growing demand for low cost storage for the vast amount of information generated by technology trends such as higher resolution media, the Internet of Things and big databases.



With a slower growth in areal density for HDDs than in the past the number of HDDs will increase, particularly for high capacity SATA enterprise hard disk drives. We also expect external HDD demand will increase in the future as these devices provide backup for homes and small businesses. It is interesting that Consumer Electronic drives have been so strong in 2016. It will be interesting to see if that trend continues.

HDDs have experienced generally lower demand over the last six years and we don't have expectations that they will experience growth until possibly towards the end of this decade, driven primarily by vast enterprise storage needs for hyperscale cloud storage. If HDDs can continue their cost per GB advantage for raw storage capacity versus SSDs, they will continue to play an important role in the future of storage.

2) The Consolidation in the Fibre Channel Industry (Forbes, 11/9/16)
Ethernet has become the communication protocol of choice for much in-house as well as cloud storage. Ethernet is the basis for Network Attached Storage (NAS) storage file sharing capabilities and iSCSI-based Storage Area Networks (SANs). Hyperscale object storage is usually done over IP-based Ethernet Networks as well. With the growth of Ethernet-based storage networks why would Broadcom want to acquire the Fibre Channel assets of Brocade Communications and sell off its IP networking business?

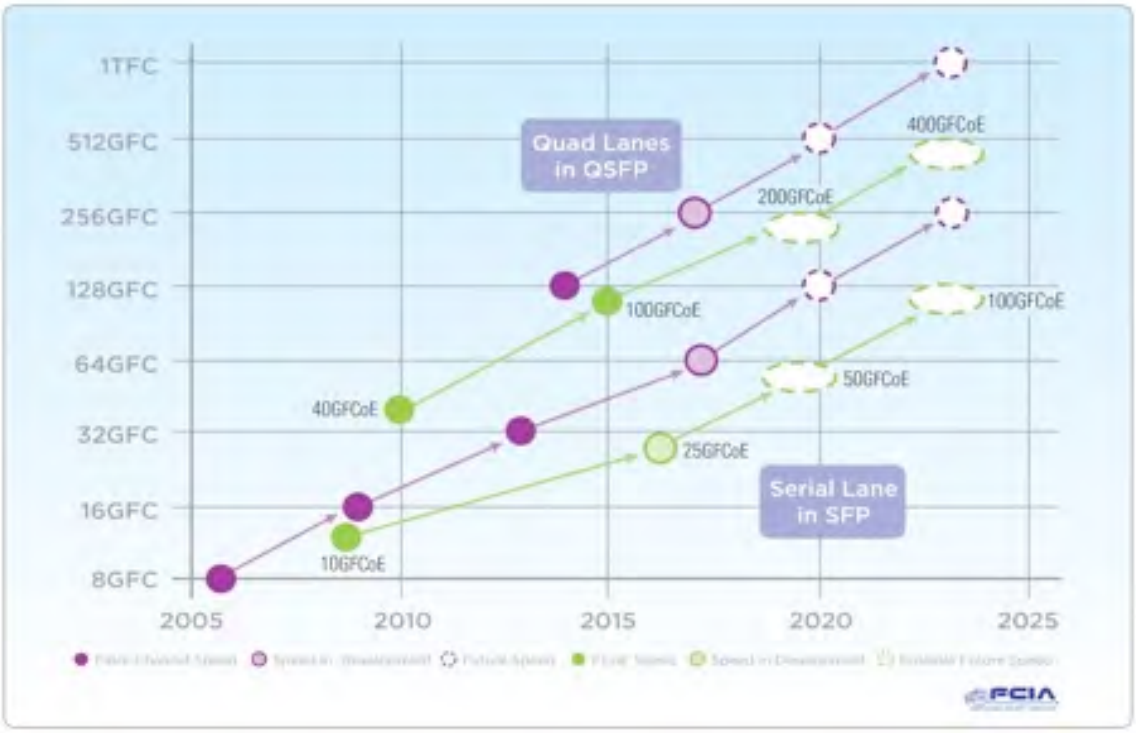
Broadcom, formerly Singapore-based Avago Technologies, before their purchase of the well know chip maker (Broadcom) serving enterprise as well as consumer markets, said that it will purchase network gear maker Brocade Communications for $5.5 B. The move is said to expand the companies fibre channel and data storage businesses. The acquisition is one of several recent acquisitions in the semiconductor industry and represents further consolidation in the important, but niche, Fibre Channel market.

Broadcom said it planned to integrate Brocade's fiber channel storage networking products used in data centers and sell the company's IP networking business. A big part of Brocade's IP networking business that Broadcom plans to divest was acquired as part of Brocade's $1.5 billion acquisition of Ruckus Wireless earlier this year. The unit generated $209 million in product revenue in the third quarter.

The reason that Broadcom made this decision is that Fibre Channel networking equipment sells for a much higher profit margin than IP storage networking gear and there is a strong established market for this low overhead local network storage technology.

According to documents on the Fibre Channel Industry Association (FCIA) web site, since 2001 more than 107.1 Million Fibre Channel ports have shipped to storage customers and it is estimated that 46 million ports are in current

operation in datacenters today. Fibre Channel continues to be the most widely used transport for enterprise storage and is estimated to store nearly 25 Exabytes of data in 2016. In fact, it is predicted that Fibre Channel will continue to lead enterprise storage capacity by 112% over all other block storage protocols at the end of 2019.



The site goes on to say that Fibre Channel's continued popularity is directly attributable to a series of distinctive design attributes:

1) It is designed for Digital Storage –Fibre Channel was designed for storage since its inception and it ensures that all storage data arrives to its network destination without loss at extreme throughput and low latency, while operating at high utilization rates without data collisions or the need for retransmission.
2) It is designed for Compatibility -- stringent industry standards require all conforming Fibre Channel products to be backwards compatible to at least two generations and ensure multi-vendor compatibility.
3) It is designed for Performance – An industry roadmap has guided Fibre Channel to doubling speeds every three-to-four years, matching typical datacenter equipment refresh cycles. Current Gen6 products are available at 32GFC single lane and 128GFC multi-lane configurations for providing over 25GB/s of bi-directional data throughput. The chart below shows the FCIA product roadmap [serial lane as well as quad (4) lane Fibre Channel] as well as Fibre Channel over Ethernet protocols.
4) It is designed for the Future –Fibre Channel predominantly transports

SCSI commands, but it was designed to support other upper level protocols as well. Future transports such as NVMe over Fabrics are in development for Fibre Channel and will allow flash storage devices to run native NVMe over a shared Fibre Channel network.

FC-NVMe leverages the new NVMe over Fabrics specification that was completed in 2016, enabling the networking of NVMe devices while preserving a significant amount of the performance benefit of local NVMe. FC-NVMe will allow native, end-to-end NVMe communication over a Fibre Channel network while concurrently passing legacy SCSI and FICON traffic. This means that NVMe devices can be deployed into existing Fibre Channel SANs, leveraging the industries philosophy of backwards compatibility and investment protection, robust interoperability and proven FC reliability.

Broadcom's acquisition of Brocade, following the Avago (now Broadcom) acquisition of Fibre Channel equipment maker Emulex in 2015, make the company a very strong player in Fibre Channel network storage. Fibre Channel storage networking appears poised to enable high margin, low overhead network storage for the future, enabling future block-based flash memory as well as spinning local storage networks.

3) How Many IOPS are Still Enough (Forbes, 11/15/16)

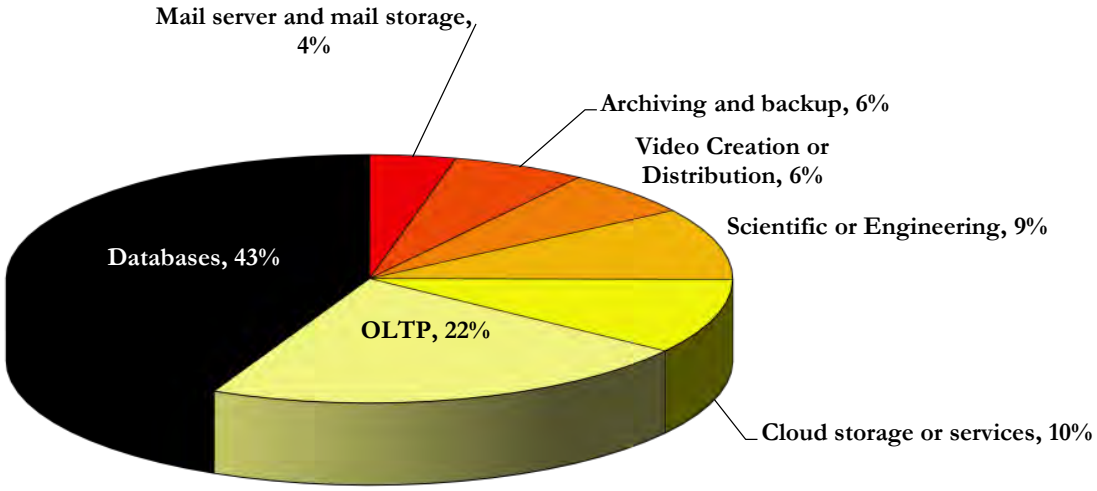
In 2012 Coughlin Associates and Objective Analysis conducted a survey of digital storage end users from a number of different industries to find out about their storage needs. In 2016 we repeated the survey to see how things have changed since the original survey in 2012. We found that over the last 4 years requirements for IOPS, latency and capacity have increased significantly. The availability of higher performance as well as less expensive storage has increased consumer expectations.

Between 2012 and 2016 the survey asked over two hundred sixty respondents to share their high-speed storage capacity and performance needs, IOPS and maximum latency, along with the speed of the rest of their system and for the application type being run on that system. We compared the results from the 2012 report on How Many IOPS is Enough with the 2016 data in the 2016 report by the same name.

The majority of our survey respondents required fast storage for the following application types:

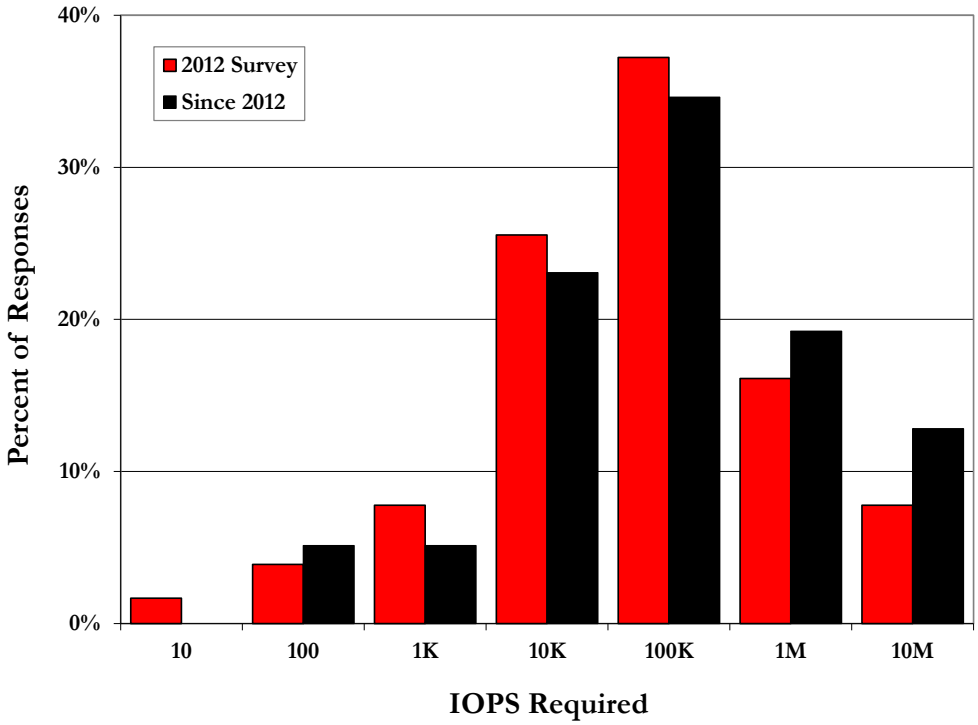
- Database
- On-Line Transaction Processing (OLTP)
- Cloud and Storage Services
- Scientific and Engineering Computing

The figure below shows the distribution of survey participant dominant applications from 2012 through 2016:



Those survey responses that changed between 2012 and 2016 generally represented increases in both speed and capacity and reductions in expected latency.

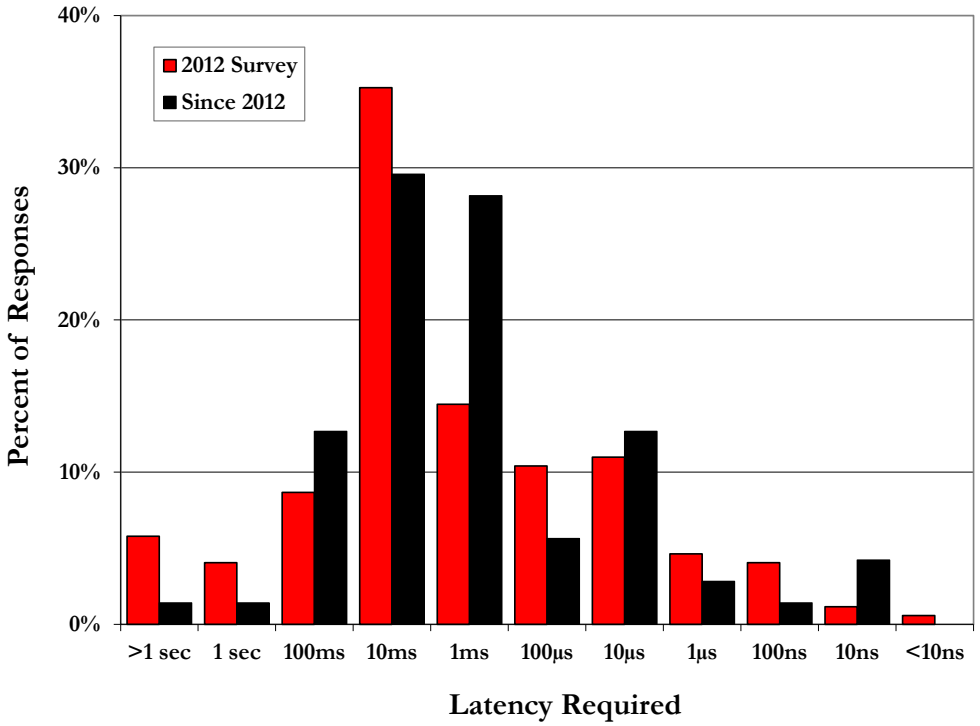
Most respondents (79%) required performance of over 1,000 but fewer than ten million IOPS over a broad range of capacities The figure below compares IOPS requirements from the 2012 survey with the post-2012 survey results.



There is a 54% difference in the mean of the two data sets, with the new survey

results requiring a mean of 1,511,338 IOPS versus 978,749 for the older survey data. The median of the newer survey data is 37% higher than the median of the old survey data (39,540 versus 54,063 IOPS)

Latency requirements had a very solid peak with 32% requiring 10 milliseconds. The figure below compares 2012 report minimum latency requirements to those post-the 2012 report. The median latency of the newer survey data is 54% lower than the old survey data, 0.92ms versus 2.0ms.



In many cases there was a reasonable correlation between two of the surveyed parameters:

- Capacity & IOPS requirements
- Capacity & Maximum Latency
- IOPS Requirements and Maximum Latency

The sample group was a respectable size, giving us a 6.0% margin of error at a 95% confidence level. We continue to collect survey data with a goal of increasing the respondent base and reducing the error margin.

The availability of higher capacity digital storage technology combined with higher performance storage technologies has increased customer expectations and needs. The How Many IOPS Is Enough survey shows these trends for IOPS, storage capacity and minimum Latency for several important applications, including correlations between these different needs.

You can find out more about the report at www.Objective-Analysis.com or http://www.tomcoughlin.com/techpapers.htm.

4) Everspin and Qumulo Advance Memory and Storage Options (Forbes 11/23/16)

Everspin gave their first quarterly earnings announcement since they went public this year showing increased capacities, greater partnerships and product demonstrations. Qumulo announced their latest software update and that they have freed their software from dependence on their own hardware.

Everspin Technologies, who recently went public, had their first quarterly earnings announcement. The company reported results for its fiscal third quarter which ended September 30. Revenue for the third quarter of 2016 was $7.1 million, compared to $7.0 million for the third quarter of 2015. Everspin's net loss for the third quarter of 2016 was $1.4 million, or $0.54 per share, compared to a net loss of $4.5 million, or $1.77 per share for the third quarter of 2015.

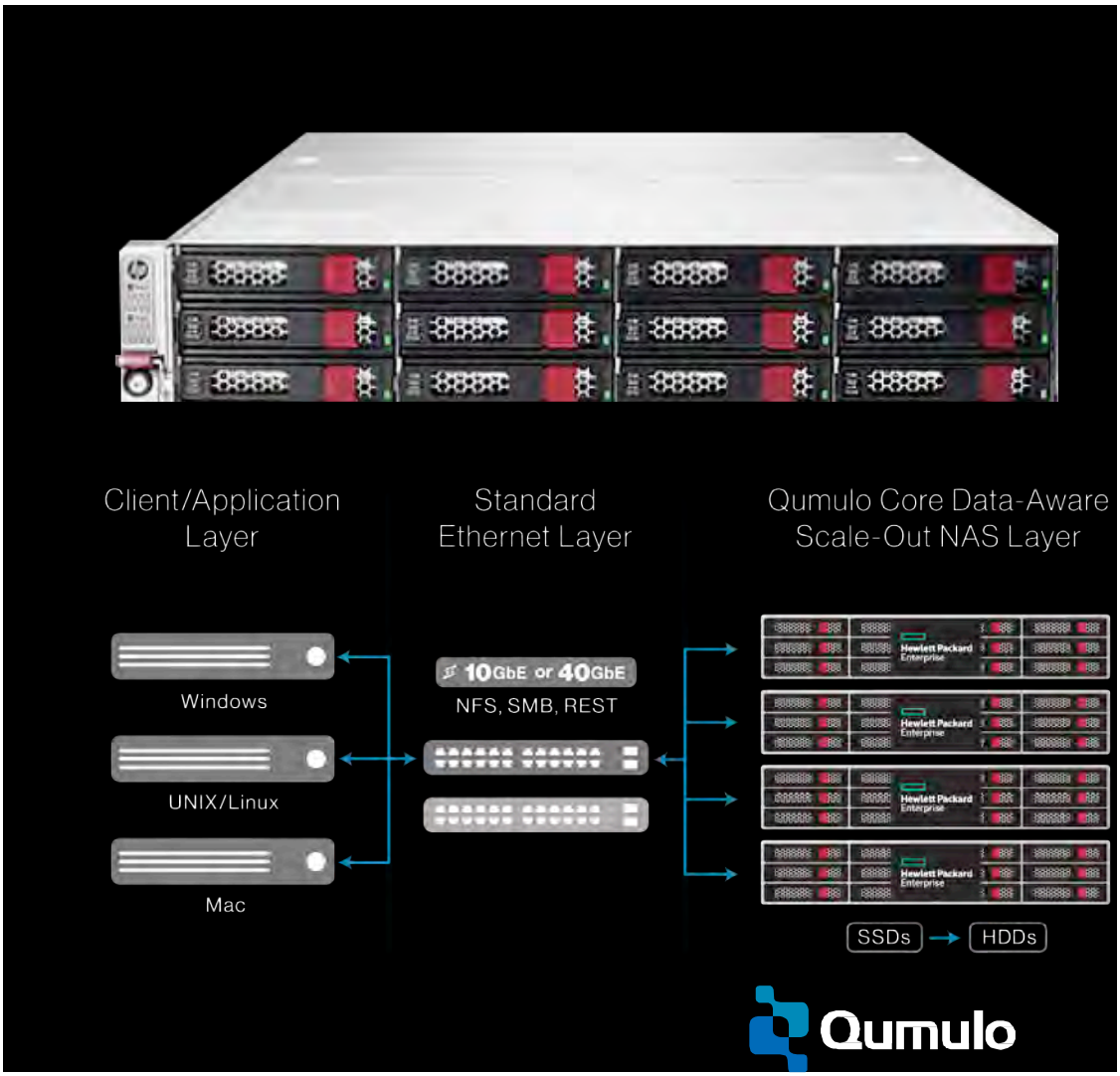
The company stated that it had the following highlights for its business so far in 2016:

- Completion of the company's IPO and private placement transaction that raised $41.9 million, net of fees.
- Demonstration of the world's fastest SSD, with continuous write operations of 1.5 million IOPS, using Everspin's perpendicular ST-MRAM technology.
- The launch of the world's first M.2 storage module from Aupera Technologies, based on Everspin's 256Mb perpendicular magnetic tunnel junction (pMTJ) discrete ST-MRAM.
- The announcement that Everspin's ST-MRAM Technology to be deployed in GLOBALFOUNDRIES 22FDX® eMRAM Platforms.
- Preview of future pMTJ based ST-MRAM products displayed at

electronica, the world's leading trade fair for electronic components, systems and applications.

- Initial wafer of industry's first 28nm 1Gb wafers processed by GLOBALFOUNDRIES.
- Initial samples of 1GByte ST-MRAM Unregistered Dual In-Line Memory Module (UDIMM) Double data rate type three (DDR3) compatible module, with quad rank and an industry standard UDIMM pin out based on Everspin's 256Mb pMTJ ST-MRAM product.

Qumulo, a start-up company offering software that helps build data-aware scale-out storage for managing large storage systems announced version 2.5 of its CORE software. This version offers Snapshots for extended data protection, erasure coding improvements to provide greater storage efficiency, throughput analytics to show how the throughput load is distributed across the file system and intelligent caching of metadata on SSDs for faster metadata operations.



The company also announced that the software will be available on HPE Apollo Servers. Previously the company had offered its software as part of its own hardware and software package. This will allow scale-out file and object storage for on-premise or private cloud networks. This announcement also demonstrates CORE hardware independence and portability for private and public clouds.

Everspin's quarterly announcement shows a broader market acceptance of MRAM memory. Their new partnerships and product announcements gives additional validity to the MRAM market and encourages additional development by MRAM start-ups and established companies working on MRAM. Qumulo's new partnership with HPE frees their storage management software from their own box, establishes them as a player in file and object storage for on premise and private cloud storage.

6) The Changing Face of Storage Systems Companies (Forbes, 11/28/16)

Storage system companies once were companies that bought components and built systems, often at much greater profit margin than the companies that built the components, such as HDDs and SSDs. Today, with the growing importance of software in making affordable storage systems that are not tied to a single storage vendors hardware and with the growth of storage component companies offering their own storage systems, things are a lot tougher for traditional storage companies. Let's look at the latest developments by storage component companies in the storage systems business.

Western Digital introduced their hyperscale focused Active Archive Storage system (with capacities up to 35 raw PB) in 2015, naturally using their capacity enterprise HDDs. They recently introduced an entry-level ActiveScale P100 object storage system for users with lower storage capacity needs than the Active Archive System. The ActiveScale P100 scales from 720 TB in 12 rack units (RU) to 19.4 PB in a full 216 RU scale-out mode. The P100 is a more economical option for on-premise and off-premise cloud customers who only need TBs of S3 object storage rather than PBs, with a list price of $0.22/GB compared with $0.49/GB for the very different Active Archive System.

WD includes in the ActiveScale as well as in their Active Archive solution its ActiveScale CM (Cloud Management) tool that allows customers to monitor and manage their storage systems. The ActiveScale P100's six drive trays each hold 12 HGST (a WD division) 10 TB Ultrastar HelioSeal hard disk drives. The P100 scales up in increments of 720 TB to 1.4 PB, or 2.2 PB per rack. The system has a maximum raw capacity of 19.4 PB.

While WD's latest product introduction focused on providing more options for archive object storage, Seagate Technology introduced a storage solution for high performance storage. The company's ClusterStor 300N with Nytro Intelligent I/O Manager is the newest addition to its family of scale-out storage systems for high-performance computing (HPC) and the first with a flash cache accelerator. According to the company, the ClusterStor 300N seamlessly runs multiple mixed workloads simultaneously on the same storage platform, eliminating performance bottlenecks that can result when data demands outpace what the existing storage architecture can accommodate.

The ClusterStor 300N is architected specifically as a common platform for both the ClusterStor, Lustre® and IBM Spectrum Scale™ storage systems as the L300N and G300N, respectively. The ClusterStor family includes the new ClusterStor L300N and G300N, as well as the ClusterStor A200 Active Archive, ClusterStor L300, ClusterStor G200, ClusterStor 9000, ClusterStor 1500, ClusterStor Secure Data Appliance and Hadoop Workflow Accelerator for ClusterStor's architecture. The ClusterStor 300N will be available in January 2017.

Companies making storage components, such as HDDs and SSDs see building storage systems that consist of many of their components as a good way to increase their profit margins. At the same time they can offer these systems at a lower cost than companies that have to buy the components from them, giving these systems a price advantage. With the advent of open storage software that does much of the storage management that proprietary storage systems used to do there are fewer barriers to storage component companies growing into storage system companies in their own right.

7) Accessing Future Memories (Forbes Blog, 12/7/16)

At the 2016 IEEE International Electron Devices (IEDM) Conference in San Francisco several exciting developments were discussed that may change the way we keep information in consumer as well as business applications and devices. Although planar (2D) flash memory less than 10 nm appears to be off the table other devices were discussed with 7 nm features (especially FinFETS) and there was even a mention or two of 5 nm features. Let's look at developments in NAND as well as emerging memory technologies, such as MRAM and even DRAM.

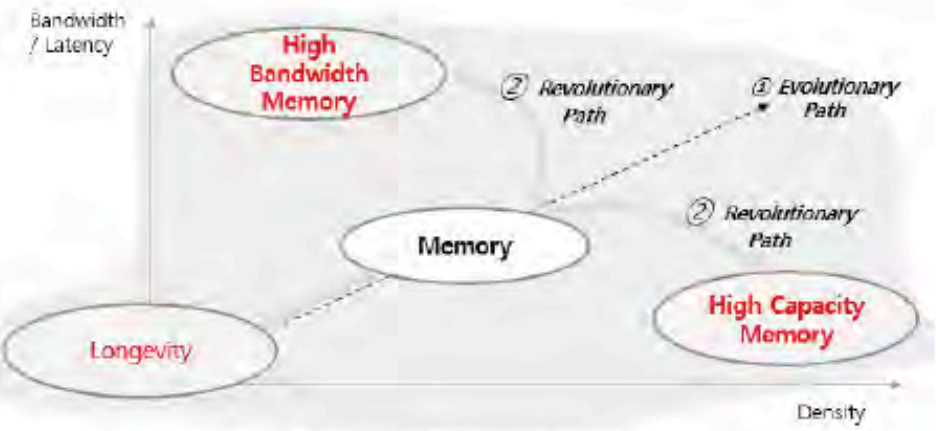


Fig. 1 (a). Revolutionary Path and Evolutionary Path.

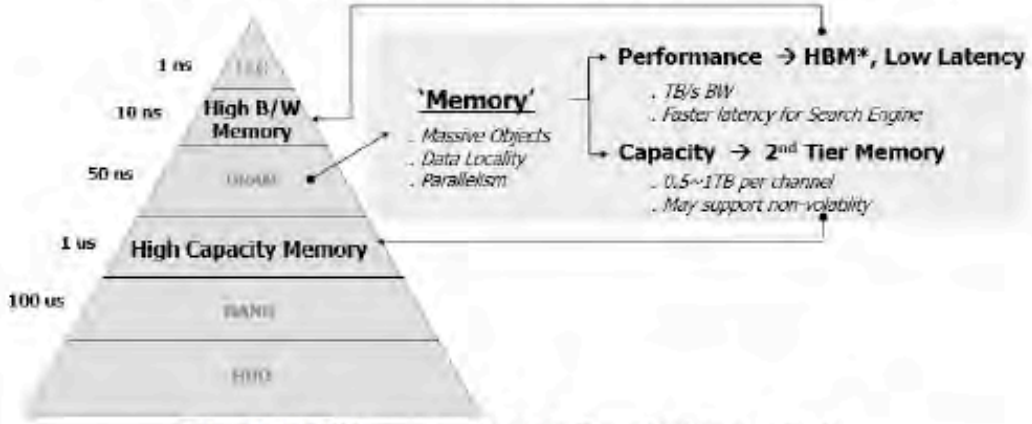


Fig. 1 (b). Memories for the Revolutionary Path.

In a plenary talk Seok-Hee Lee from SK Hynix spoke about technology scaling challenges and opportunities for memory devices. He said that single-thread CPU performance increases have slowed since 2005 and the cache speeds available to compute cores have been stagnant. As a result the overall delay of computing devices hasn't improved much recently. He indicated that evolution by itself will not be enough for the future and that memory technology needed to take two revolutionary paths. One of these paths focuses on high bandwidth memory and the other on high capacity memory, increasing the complexity of the

conventional memory/storage hierarchy.

Below 15 nm 2D flash scaling is about done and we must depend upon 3D NAND for continued NAND flash advances. 3D NAND needs more efficient cell arrays to reduce the height as cell stacks achieve 100's of layers. He discussed a concept called Z-scaling to reduce the overall stack height and enabling 356 cell layers. He also discussed the need to include peripheral electronics under the cells to allow more die per wafer. Quad-level cells to increase per cell bit density are another important development. Overall he expected 256 layer NAND flash within 5 years.

Things are moving fast in MRAM. Earlier in 2016, Everspin announced that they would have 1 Gb STT-MRAM chips before the end of 2016. In early November the company had these products on display. Everspin also introduced a 1 GB DDR3 compatible module based upon its 256 Mb DDR3 (perpendicular magnetic tunnel juniction) pMTJ STT-MRAM that it is shipping to selected customers.

In late October start-up MRAM company, Avalanche, said that it will start volume pMTJ STT-MRAM production in early 2017. While Everspin is working with manufacturing partner, Global Foundries, Avalanche is working with Sony Semiconductor Manufacturing Corporation (SSMC).

There were several sessions at the IEDM conference with MRAM papers. Among the papers there was a paper by SK Hynix and Toshiba on a 4 Gb STT-MRAM with a compact cell structure. There was also a paper from Everspin discussing the endurance and reliability of Spin-Torque MRAM products (it looks pretty good).

There was a poster session at the IEDM organized by the IEEE Magnetics Society with several interesting presentations on both MRAM storage devices as well as spin-based computing technologies (often called spintronics). Among the interesting demonstrations in this poster session was Samsung's use of 8Mb STT-MRAM combined with SRAM as a frame buffer in a video display system.

In addition to papers by universities and memory companies, companies that make the equipment for creating MRAM such as Singulus also had displays. Many other major semiconductor manufacturers also had MRAM posters including Toshiba and IBM.

Other emerging memory technologies were discuss at the IEDM. These included phase change memory (PCM), Resistive RAM (RRAM) and ferroelectric (and anti-ferroelectric) memories. A team from Stanford was able to do accurate measurements of temperature required to form or break the filaments in the target RRAM. They found that their RRAMs would switch at temperatures less than 260 F, less than the usual temperature generated in an MRAM. If this works in a functioning RRAM it means they can operate at lower temperature and thus use less energy. Another group from Stanford and Berkeley was using a 3D vertically oriented RRAM device to create a hyperdimensional computing environment that could recognize words in 21 languages.

Ferro-electric devices were discussed in a few papers. A interesting papers from researchers in Germany discussed how common materials used in manufacturing DRAM today could be used to create a non-volatile DRAM. It turns out that a ZrO_2 layer commonly used is an anti-ferroelectric. By changing the internal bias in the DRAM two stable non-volatile states can be created in the anti-ferroelectric layer. These states can be used to make a non-volatile version of DRAM. This would be a very interesting angle on a very mature process, and if it could be scaled successfully, would give some of the emerging memories a run for their money.

Parameter/NVM	MRAM	FeRAM	RRAM	**This work**	Flash	DRAM
R/W speed	<10 ns	10 ns	<10 ns	10 ns	100µs	~10 ns
Endurance	1e15	1e8	1e12	1e10	1e4	1e16
Retention	10 yrs.	10 yrs.	10 yrs.	10 yrs.	10 yrs.	64ms
Cell size	20 F^2	6 F^2	4 F^2	6 F^2	1-4 F^2	6 F^2

Table 1: Comparison of AFE-RAM with other emerging non-volatile memories and volatile DRAM. Values obtained from IEEE Solid-State Circuits Magazine. Spring 2016. Vol.8. No. 2. pp.44

Engineers are clever creatures. It is fascinating how the various materials and complex structures in modern electronic devices continue to offer ripe opportunities for new discoveries and new methods. Based upon the presentations and discussions at the 2016 IEEE IEDM conference, we should have many more years of amazing technology development ahead of us.

8) Are You Ready for a 14 TB HDD? (Forbes Blog, 12/8/16)

Western Digital just announced a new line-up of products including SSDs and HDDs. Western digital also signed an extended 8-year cross-license agreement with Samsung giving rights to each other's patents covering MLC flash memory and flash storage systems. According to Western Digital the integration of SanDisk decreses the company's exposure to a shrinking HDD market, whle flash technology is becoming a more financially attractive solution.

Western Digital is continuing its transition to 3D NAND technology, this includes introducing the SanDisk Edge, a commercial microSD card using 3D NAND storage technology. This is currently shipping to OEM customers worldwide in capacities up to 256GB.

The HGST-branded Ultrastar SN200 series NVMe PCIe SSD provides random read performance of 1.2 million IOPS. According to WD, the Ultrastar SN200 NVMe SSD Series is the highest capacity NVMe PCIe SSD available today (800GB to 7.68TB) in 2.5-inch and Half-Height, Half-Length (HH-HL) form factors. WD says this product is ideal for workload-intensive cloud and hyperscale environments that demand instant response times, such as ecommerce, search and social networks, as well as environments processing massive volumes of data in real-time, including intensive analytics.

The HGST-branded Ultrastar SS200 SAS SSD with storage capacities up to 7.68TB is currently shipping to select OEM customers providing the company's fastest and highest capacity SAS SSD to date. WD says the enterprise class Ultrastar SS200 SSD is available in two endurance classes to meet customers' needs, including 1 and 3 random drive writes per day (DWPD).

Leveraging advanced NAND management technology, the SS200 offers tremendous read performance (up to 1,800MB/s sequential/up to 250,0000 4KiB IOPS random) without compromising on write performance (up to 1,000 MB/s sequential/up to 86,000 4KiB IOPS random)5. This makes it ideal for a wide variety of data intensive, critical enterprise and cloud-based applications

The company also announced new ultra-performance flash platform technology. These products target fast cloud-scale applications using industry standard NVMe SSDs connected to multiple servers via PCIe in a 2U rack. The product has achieved 18 million IOPS. WD says it is the highest performance per rack unit in the industry.

Western Digital is sampling new 12TB HGST-branded Ultrastar He12 PMR hard drives to some cloud and hyperscale customers with either a SATA or SAS interface. The He12 is Western Digital's fourth-generation helium HDD, featuring an eight-disk design, to deliver 12TB capacity using PMR technology in a standard 3.5-inch form factor. It is the world's highest capacity hard disk drive for active random workloads

The company will be extending its helium-product lineup with a 14 TB HDD using Shingled Magnetic Recording (SMR) technology. This is a new maximum capacity in a hard disk drive.

Although the total shipment volume of HDDs is declining, these products are very useful in data centers for inexpensive bulk digital storage. The new 12 and 14 TB drives announced by Western Digital will find ready application for bulk storage in private and public clouds. At the same time WD continue the introduction of new 3D NAND products under the SanDisk brand. These will

provide the performance needs of data centers. The company appears to have a broad offering of storage technologies to fit many niches.

9) All-Flash Data Centers, Buses and Flash Partnerships, (Forbes, 12/18/16)
Storage device companies are jockeying for critical alliances, whether in component supply or special communication buses to enable new consumer products. At the same time new products are being introduced that may lead to greater use of SSDs in data center applications. Here are some recent stories on these developments.

Western Digital (through its HGST division) purchased flash memory manufacturer SanDisk in 2015. SanDisk produced consumer and professional flash card devices as well as enterprise and consumer SSDs. SanDisk was also a co-owner of flash fabrication capabilities, with Toshiba, in Japan. The SanDisk purchase gave Western Digital (WD) a strong flash memory as well as HDD presence. WD is currently the largest HDD manufacturer by volume and has a strong portfolio of HDDs and SSDs. Western Digital has introduced 12 TB and soon 14 TB He-filled enterprise capacity HDDs, while introducing new enterprise SSDs for performance applications.

Seagate also produces SSDs in addition to its extensive line of HDDs. However it has had to purchase its flash memory from external suppliers. This has resulted in arrangements with companies such as Samsung that have not given the company as strong an advantage as the SanDisk acquisition gives WD. The company had been making SSDs using Micron flash memory for a few years.

Since at least August 2016 Seagate has been using SK Hynix flash memory in its SSDs (Nytro SATA SSDs). There are recent rumors that SK Hynix and Seagate Technology may create a joint venture to expand SK Hynix's flash memory production and provide Seagate direct access to flashy memory chips, similar to that of Western Digital with its partnership with Toshiba.

Micron recently announced a family of SSD products geared to All-Flash Data Centers. The company's Enterprise 5100 SATA solid-state drivers have up to 8 TB of capacity with a SATA interface, enabling easier migration from HDDs to SSDs. The Micron 5100 comes in three models, each designed to satisfy different types of data center workloads. Micron also introduced a FlexPro firmware architecture that allows IT managers to tune specific drive features (capacity, security, endurance, power, data layout, data cleanup and performance).

The Micron 5100 ECO is focused on read intensive cloud services such as content sharing (video and media streaming). The product provides higher capacity by trading off expected endurance requirements for read-intensive applications versus storage capacity. The Micron 5100 PRO is geared for latency sensitive mixed read and write use and provides better response times for many transactional applications. The Micron 5100 MAX is designed for write-intensive applications where storage capacity needs to be traded off for enhanced write endurance. This product is geared for the needs of mission critical write-intensive applications.

Micron also announced the launching of the Xccela Consortium to promote a new high speed, low signal level interface bus and associated ecosystem. The mission of the consortium is to promote the Xccela Bus interface as an open standard for a new type of digital interconnect and data communications bus suitable for volatile and nonvolatile memories as well as other types of integrated circuits. Micron, Winbond Electronics, GigaDevice Semiconductor, and AP Memory Technology are the initial members of the consortium and will work with other member companies to accelerate the industry efforts to bring a broad set of Xccela Bus compliant memories, controllers, ASICs, SoCs, and other devices to the market.

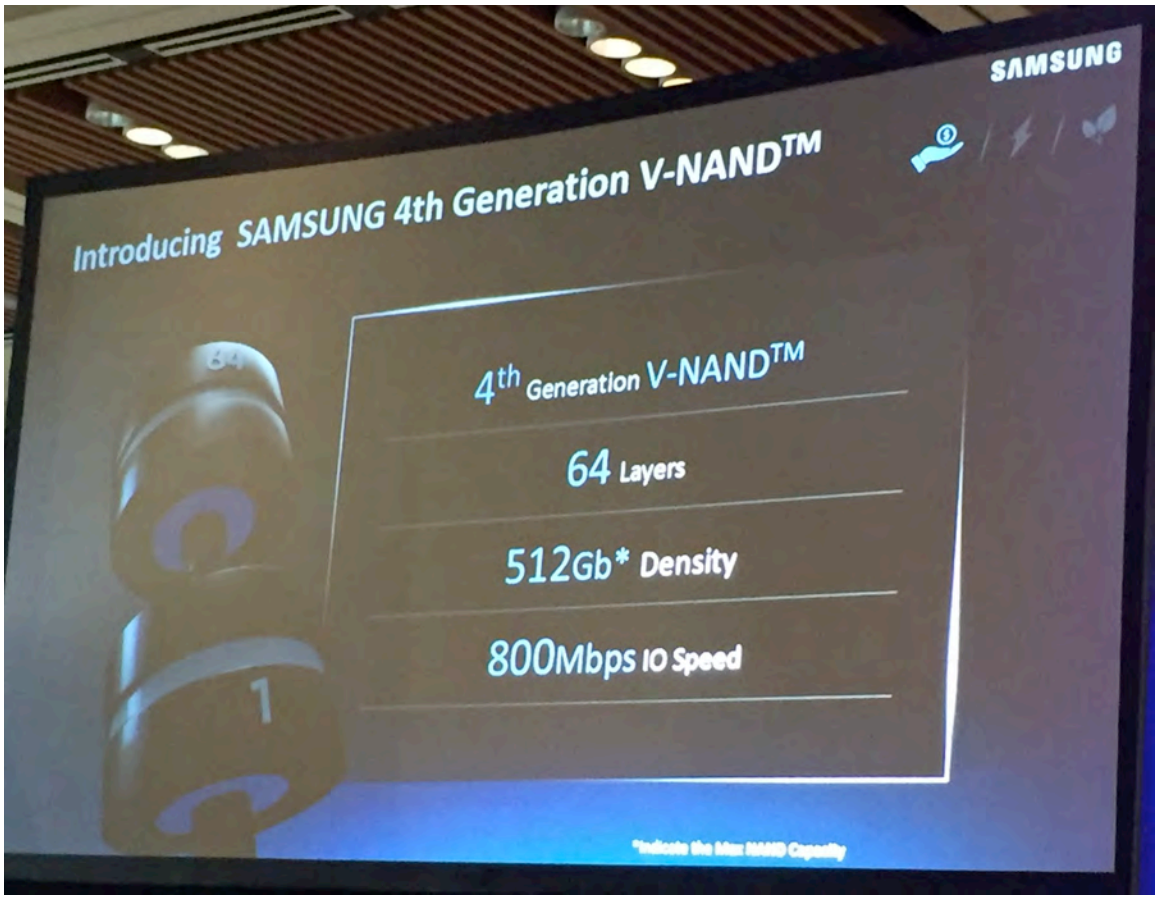
According to Micron the Xccela Bus is the next generation of system buses that combines accelerated performance with a small signal count, the best of both worlds. In its first iteration, the Xccela Bus and its interface can facilitate data transfers up to 400MB/s (3.2Gbps) utilizing just 11 active bus signals, enabling extremely fast data transfers while paving the way for simpler system designs.

This bus appears to be geared for consumer applications such as mobile devices and automobiles.

Seagate may create a joint venture with Hynix, mirroring the relationship between Western Digital and Toshiba. Micron is introducing SSDs to create all flash data centers and a communications bus for high-speed consumer electronics. There is lots of activity at the end of 2016.

10) Digital Storage Projections for 2017, Part 1 (Forbes Blog, 12/22/16)
At the end of last year we did an article looking at digital storage device trends for 2016. We will do a similar three-part piece for 2017. Let's take a look at what may be in store for device technologies, networking, interfaces and storage systems in 2017. This will include my own observations as well as comments from various industry participants.

Solid-state storage has made major advances in 2016 and is poised for continued advances in 2017. All the major flash memory manufacturers are producing 3D flash memory and new 3D fabs are being built, including those built by new industry entrants in China. 3D flash has required higher cost fabrication facilities and initial yields are less than those with planar flash memory. With increasing 3D flash volumes and improving yields 3D flash could achieve cost parity with 2D flash by later 2017 or by mid-2018.



Samsung is shipping 64 layer 3D flash today and we project that in 2017 the number of 3D stacks in announced products could approach 100 layers. Getting this many layers into a reliable product will likely require new ways to organize the 3D cell stacks to minimize the stack height. At the 2016 IEDM conference SK Hynix talked about stacking technologies that could enable over 256 memory cell layers.

There were numerous mergers, partnerships and IPOs in solid-state storage in 2016 and we expect that there be more of them in 2017. WD completed their acquisition and integration of SanDisk in 2016, and it now operates as a division of WD. Seagate, now using Micron NAND flash in its enterprise SSDs is negotiating with SK Hynix for a manufacturing partnership to provide additional NAND flash for other applications. We project that Seagate will create a joint manufacturing partnership with a NAND flash vendor in 2017, similar to the partnership that WD has with Toshiba due to the SanDisk acquisition.

Everspin, the longest running MRAM manufacturer, who has shipped over 60 M stand alone MRAM chips, did a successful IPO and it is ramping up its production of STT-MRAM chips to meet demand, while its manufacturing partner, Global Foundries, announced embedded STT-MRAM products to support industrial as well as consumer applications. MRAM is under active development

at many solid state storage companies as well as embedded systems companies.

3D XPoint, announced in 2015 by Intel and Micron will have its product introduction delayed until later in 2017 or even 2018. This gives some potential for resistive RAM (RRAM) products to be introduced with some impact on the potential 3D XPoint market.

We project that there will be RRAM product announcements in 2017 and that at least one other company will announce production of spin torque based MRAM in 2017, likely as embedded memory in processor chips for industrial and consumer applications. The emerging memory market is projected to be worth over $2B per year by 2020 according to our report projections.

NVMe solutions have been numerous in 2016 with changes ongoing in fundamental OS and other software to take advantage of the higher performance of flash based storage solutions (such as those based upon NVMe). In addition, fabrics built around the NVMe interface are in development and we expect to see significant NVMe-based fabric network storage announcements in 2017.

Flash memory continues to make inroads in the data center as the cost goes down and infrastructure to support the inherent higher performance of flash memory becomes more common. According to Lee Caswell, VP of Product, Storage and Availability Business Unit at VMWare, “The economics of flash media are now such that the performance, flexibility, and management savings of solid-state storage cannot be ignored, even by organizations with tighter purse strings. With prices plummeting, we predict that flash sales will reach a tipping point in 2017-and probably sooner rather than later in 2017.”

Micron recently introduced enterprise SSDs designed for various data center applications, with each product designed for particular workloads and with software letting system administrators tune the SSDs for their actual environment. Micron and other companies are predicting all flash data centers, but we don’t believe that these will be common for several more years.

All flash arrays continue to be a growth market with several companies providing competing products as shown in the August 2016 Gartner All Flash Array Magic Quadrant Chart. According to high performance storage company, DDN, "flash in more tiers and for more focused usage at multiple levels will dominate flash deployments. The debate will continue about how to take optimal advantage of flash – whether an all-flash array or flash as a software-defined tier is the best approach to accelerate metadata, data, and/or applications. In any case, more organizations are deploying flash to accelerate application and I/O performance. Storage vendors will have to look beyond applications and accelerate entire workflows – which means placing flash in multiple tiers of storage**.**"

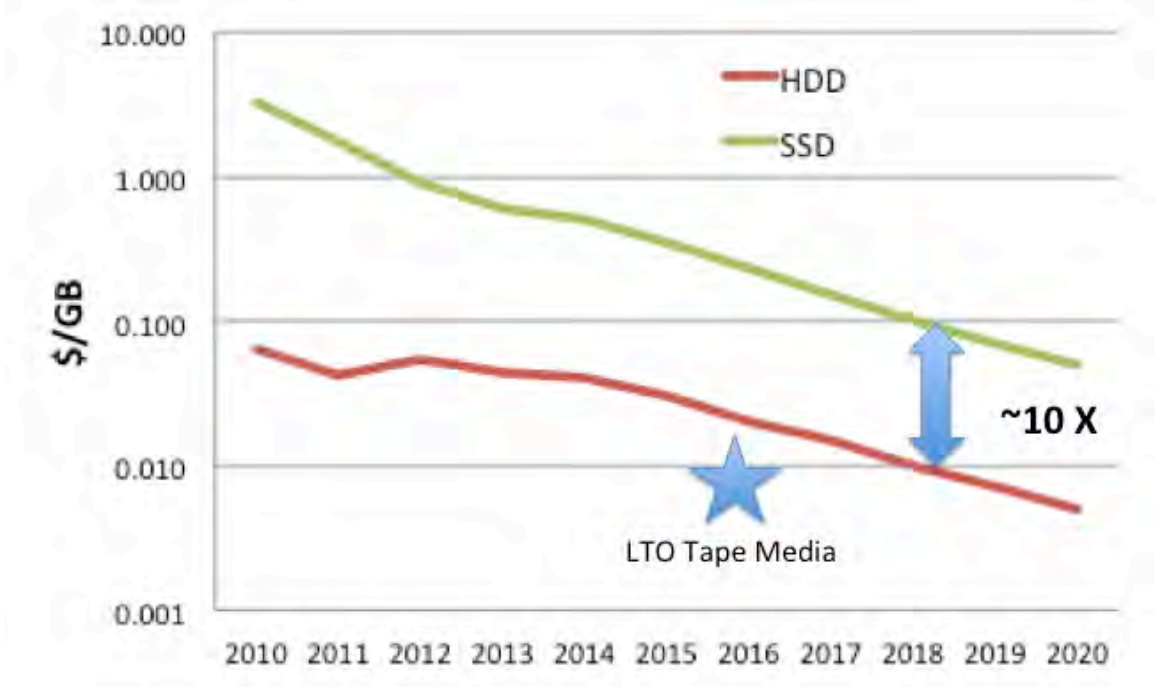
With the transition to 3D flash with somewhat lower yield and higher cost and no new planar flash memory being built we expect flash memory to be tight in 2017 and price declines on a $/GB basis to be less than general historical trends. The continuing lower cost for HDD storage (especially with the introduction of 12 TB

and soon 14 TB helium-filled HDDs for data centers) and shortages and higher prices for flash memory will favor continued dependence on HDDs for low cost volume storage, at least for the near term.

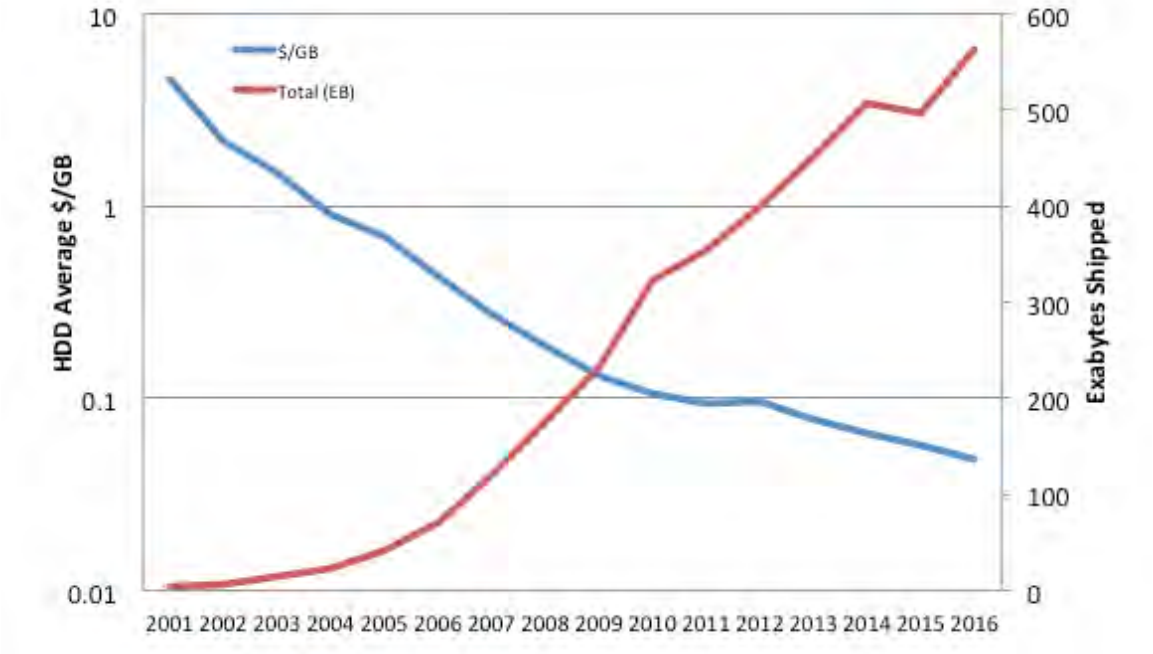
Many enterprise storage companies continue to provide hybrid HDD and flash storage systems and even client conversion to flash memory will be less than 50% of sales in 2017. The drive to 3D flash will be intense in 2017, with a chance of achieving cost parity with planar flash by the end of 2017, leading to declines in flash memory costs/GB. Software and networking protocols are now allowing storage systems and computer architectures that can take advantage of the high performance of flash and emerging non-volatile memory technologies. 2017 will see greater penetration of solid-state storage into mainstream applications.

11) Digital Storage Projections for 2017, Part 2 (Forbes Blog, 12/28/16)
Our last 2017 projection piece talked about developments in solid-state storage in 2016 and projections for 2017. Let's look at other storage technologies in common use and talk about where they have gone in 2016 and plans for 2017. These storage technologies include hard disk drives, optical discs and magnetic tape.

HDDs are becoming repositories for larger less frequently accessed data. This is due to their increasing storage capacity and lower cost per TB than technologies such as SSDs. The figure below compares the historical and projected raw storage costs for SSDs, HDDs and a data point for the LTO magnetic tape format. HDDs (particularly 3.5-inch HDDs) have maintained about a 10X difference in raw storage costs compared to SSDs and in 2016 the media cost of storage for LTO tape was available for about a penny per GB.



The figure below shows our estimates of the average $/GB for HDD and the annual shipped capacity. Except for the total shipped capacity decline in 2015 the annual shipped HDD storage capacity has been growing, even though the total shipped HDD units has declined since 2014. Western Digital's HGST division recently announced a He-filled HDD with 12 TB storage capacity that will be available in early 2017 with a 14 TB HDD using Shingled Magnetic Recording (SMR) expected later in the year. SSDs have been announced with storage capacities up to 60 TB but at a much higher unit cost and cost/GB.



It appears that the introduction of heat assisted magnetic recording (HAMR) is now pushed out to at least 2018, although engineering samples will likely be available to OEMs in 2017. In order to continue needed storage capacity increases technologies such as HAMR will be needed for HDDs to remain competitive and lower cost in $/GB. With HAMR and bit patterned media magnetic recording areal densities could increase from about 1.3 Tbpsi today to over 10 Tbpsi in less than 10 years.

Magnetic tape technology continues to advance with higher capacities per tape cartridge and the total capacity of magnetic tape shipped has increased. Magnetic tape is primarily used for cold archive data, since the access time to the data on the magnetic tape cartridges is much slower than HDDs. At the same time total units of magnetic tape have been in a gradual decline. The current LTO 7 tape format has a 6 TB raw storage capacity.

The LTO roadmap up to LTO 10 may have a 50 TB raw storage capacity and laboratory demonstrations have show that close to 200 TB tape cartridges may be possible. The increasing density of tapes, combined with file and object storage architectures as well as ways to accelerate the reading and writing of data on tapes using flash memory caches are helping this technology to stay relevant as a component in an active archive environment.

Write once optical discs for archiving have been around for several years and Sony and Panasonic have been pushing these technologies for cold storage applications. Facebook has been an early adopter of Blu-ray optical storage

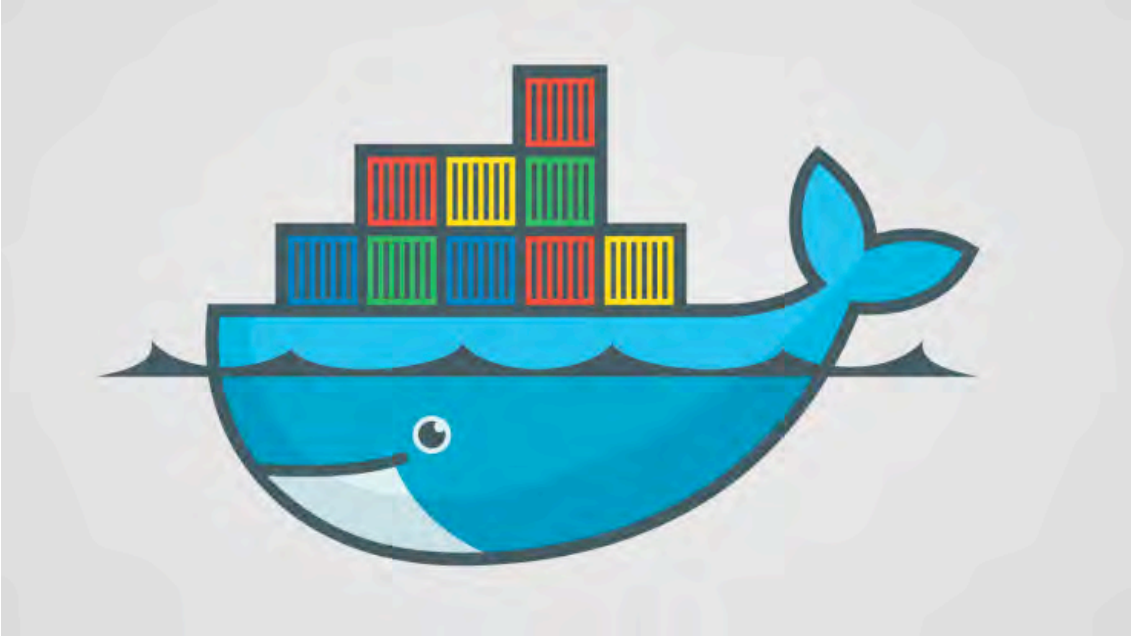
technologies with current storage capacities of 300 GB per disc and 500 GB shortly.

Although solid state storage is starting to dominate in high performance applications, displacing performance HDDs and may cost less in operating costs than HDDs in some cases, there is still a need for lower cost, lower performance storage for the large amount of longer term content. This will keep HDDs, magnetic tape and optical discs relevant to digital storage applications for some years to come.

12) Digital Storage Projections for 2017, Part 3 (Forbes Blog, 1/12/17)
Last year we made predictions for enterprise digital storage. This piece will focus on digital storage systems projections for 2017. Let's look at expectations for the growth of private and public cloud storage, container technology, Ethernet storage networking and where flash memory, hard disk drives and magnetic tape will be used in enterprise storage.

Cloud storage continues to grow with increasing use of private and public clouds as well as hybrid clouds containing some private as well as public cloud. Although the majority of private data is still file based, object-based cloud storage is growing. According to Paul Zeiter, President of ZertoCloud, "spending will continue to be on the incline, and we believe a majority of that spend will go toward hybrid cloud infrastructures; this is proving to be the sweet spot for the enterprise. Organizations that have spent a lot of time and resources on their own data center are not likely to do away with it all overnight. Adopting a hybrid cloud environment allows for a transition to cloud in a way in which feels most comfortable; a gradual approach that can provide both immense cost savings as well as recovery benefits."

According to Geoff Barrall, CTO of Nexsan, "No matter how far we look into the future, there will always be data too sensitive to trust to public cloud services. So whilst some companies will create a hybrid cloud strategy, and some may go all private, most companies, especially larger ones, will not risk their data to a 100% public cloud strategy." Private cloud storage will be replacing file-based storage in 2017.



Containers are achieving greater use in cloud storage environments. Containers allow an environment where an application can run on an isolated instance in a data center. According to Chuck Dubuque, Vice President of Production and Solution marketing at Trinti, "Containers give bare metal performance and hardware access for real-time transactional workloads, but with some of the abstraction and portability benefits of virtual machines. Containers on physical (storage) can be a solution for those hard-to-virtualize workloads where performance and latency are essential. Containers are also more lightweight and ephemeral, making them a great match for modern cloud-native workloads."

Fibre channel networks are being displaced by Ethernet-based storage. Lee Caswell, Vice President of VMware, Inc. said, "In 2017, we expect it (Fibre Channel) to wane faster than ever, with the steadily increasing speed of standard Ethernet all but eliminating the need for proprietary SAN connections and the expensive FC infrastructure that comes along with it. The acquisition of the last pure-play FC player, Brocade, by Broadcom is only the latest indicator that storage specialization is becoming a smaller part of the market. In fact, all three of the classic FC players-Brocade, Emulex, and QLogic are no longer independent companies."

Server-based hyperconverged storage continues to displace purpose built storage appliances although all flash memory arrays continue to grow. Although hard disk drives will still contain the bulk of enterprise storage high performance storage will increasingly be based upon flash memory. Flash memory use will also increase in client computing applications, especially in business laptop and tablet computers. Unfortunately the higher price of flash memory through much of 2017 will have some impact on the use of flash for less performance-based application. These higher prices are a result of the transition of flash memory from planar to 3D flash as well as the increasing demand for flash memory in ever-higher capacity Apple and Android phones and tablets.

There will be increasing use of higher capacity HDDs (up to 14 TB by the end of 2017) and magnetic tape capacity for colder storage, with flash memory used in a tiered architecture to provide the best balance of capacity cost and storage performance. There will also be some use of emerging memory technologies such as STT-MRAM, 3D XPoint and other resistive memory technologies to either replace DRAM memory or to provide an intermediate layer between DRAM and flash memory.

Although storage efficiency is increasing with continuing developments in virtualization and storage utilization is considerably higher than it was in the past, storage demand will continue to grow, causing the continued growth of storage in data centers. 4K content, increasing video surveillance and the industrial and consumer IoT will increase storage demand and the need for the means for analyzing and using this storage. 2017 will be a year of storage transition and storage capacity growth.

13) Storage in Consumer Electronics (Forbes Blog, 1/16/17)

The 2017 CES show featured the latest in consumer products and services. The CES show featured Virtual and Augmented Reality, 3D printing, Artificial intelligence with voice recognition and automated vehicles, high resolution and high dynamic range displays, health products, robots, toys and just about every other consumer product that you can think of. However one thing that all of these electronic devices have in common is their need for digital storage and memory.

Seagate and DJI (the leading Chinese drone manufacturer) announced a strategic partnership to work jointly to solve the data demands of UAV users. As drone cameras gain resolution and drone flight times grow longer, DJI and Seagate are focusing their efforts to securely and efficiently store, manage, download and share the hundreds of gigabytes of data that can be generated from a single drone mission.

The company also had an impressive exhibit area showing how various developments are driving the quantity of stored content, including drones and the internet of things, enterprise storage, games, virtual reality and professional video and archiving and digital preservation. We may write more on this in another article.

Seagate was also showing various storage hardware, including their 5TB 12-mm thick 2.5-inch form factor HDD, (announced in October 2016) and that started to

ship in December 2016. The company are focusing on two 2.5-inch form factor HDDs, the 12mm high at up to 5TB and 7 mm drives at 2TB. They were also showing their 120TB 12Big with Thunderbolt 3 using 10TB He-HDDs that started to ship in December 2016.

Western Digital announced the SanDisk Ultra MicroSD card that meets the new application performance class set by the SD association. The 256 GB microSDXC card meets the SD association's SD 5.1 specification A1 class of performance. This 256 GB microSDXC card is also UHS-1 class performance with premium transfer speeds of up to 95 MB/s.

The company also introduced its WD Black PCIe solid state drives using the new NVMe protocol. Accordng to the company, “The WD Black PCIe SSD is a performance PCIe Gen3 x4 NVMe-based SSD that delivers more than three times the sequential read speeds of current SATA SSDs. The 256GB and 512GB capacities make it ideal as a boot drive when paired with a high-capacity hard drive, or as primary storage when building a future-ready PC. Consumers who are using the new WD Black PCIe SSD to boot up, load read-intensive games or applications, or shut down a system may realize a performance improvement of more than 10 seconds when compared to SATA SSDs.”

Talking with the WD folks they said that they expected 50% NVMe drive adoption by 2018 (Forward Insights numbers). They also said that flash will be on short supply in 2017 due to increasing demand by consumer products, such as those from Apple as well as the 2D to 3D flash transition. WD is shipping 3D this year

with a transition to 64 layer 3D flash.

Toshiba was showing their HDD and flash memory products also at a hotel suite at the CES. The company is a major supplier of NAND flash and their e-MMC, UFS and other flash memory cards and SSDs were on display. They were also showing their HDD products for client as well as enterprise applications. In particular they were showing their OCZ division SSDs which are geared towards high performance applications, such as video games.

At few years ago at the CES Kingston was showing a 1TB NAND flash-based USB drive. At the 2017 CES Kingston was showing a 2TB version. The price is still a bit high (the 1 TB version is listed on-line at about $2,600).

Although not officially announced at the CES, during the CES Intel gave some clarification on their Optane solid-state storage technology. Intel said that Optane non-volatile memory will ship in the second quarter of the year as 16GB and 32GB M.2 expansion cards. Optane memory will be available as an option for new Intel-based client platforms, including Intel 7th Gen Core (Kaby Lake), and as a standalone component.

Sony, LG, Panasonic and others were also showing UHD Blu-ray players using high capacity Blu-ray discs. With bandwidth limited for many folks to receive UHD content optical discs are the best bet for new UHD display owners to enjoy real 4K video.

Many other companies were showing digital storage products at the 2017 CES. Plextor unveiled its consumer 3D NAND SSDs with software to help with write acceleration, smart caching and compression. A French start up, MOORE, was offering a USB device that it claimed allowed unlimited data access combining machine learning, the cloud and local storage to have all the files you need on the USB drive when you need it. Apparently it makes sure that files you use regularly are on the drive, while less frequently accessed data is in the cloud. Boxdrive was offering a decentralized cloud storage using peer to peer technology with clients computer excess storage capacity providing backup storage for its customers.

The CES show is always a fascinating place to see where technology applications are going. Digital storage plays a key role in making modern

consumer products work, both in the home and in the cloud.

14) Toshiba may sell Additional NAND Stake to Western Digital (Forbes Blog, 1/19/17)

Toshiba is in talks to sell a stake in its memory business to Western Digital. The company is also studying the possibility of splitting this business off as a separate business unit. The company has said that it is considering several options for its memory business but nothing concrete has been decided yet.

Toshiba and Western Digital have a joint investment in a NAND flash manufacturing plant in Yokkaichi in Mie prefecture in Japan. Western Digital acquired this stake through its acquisition of SanDisk last year. Rumors are that Toshiba may sell a 20% interest in its share of the memory business to Western Digital (and possibily other investors) and that Toshiba would remain a majority stakeholder in the resulting venture.

The discussions of selling some of its memory business would give Toshiba much needed capital to help off-set its losses in its nuclear power division. Toshiba is still on a watch list in Japan after 2015 accounting scandals.

According to industry analysts Toshiba has a market share in the NAND flash business of about 20% in 2016, ranking second to Samsung who had about a 35% market share. Adding a greater share of the flash business of the joint venture to Western Digital would give the company an even more solid position in the solid state memory/storage industry.

Increasing Western Digital's control of a significant amount of the world's NAND flash supply would further strengthen the company in its competition with Seagate, Intel, Micron and Samsung to control the future memory and storage market.

Seagate and Western Digital are still the dominant hard disk drive manufacturers but with high performance enterprise storage markets moving to NAND flash in NVMe and NVDIMM formats, having a steady supply of high quality flash memory will be a big differentiator in the coming shake out in the enterprise storage industry.

Hard disk drives are finding their best prospects as high latency inexpensive large capacity storage (such as the 10 and 12 TB drives available today). The high margin 10,000 and 15,000 RPM performance HDDs are being displaced in new storage systems by NAND flash options. Thus the highest revenues will come from the sale of flash memory, rather than HDDs, for data centers.

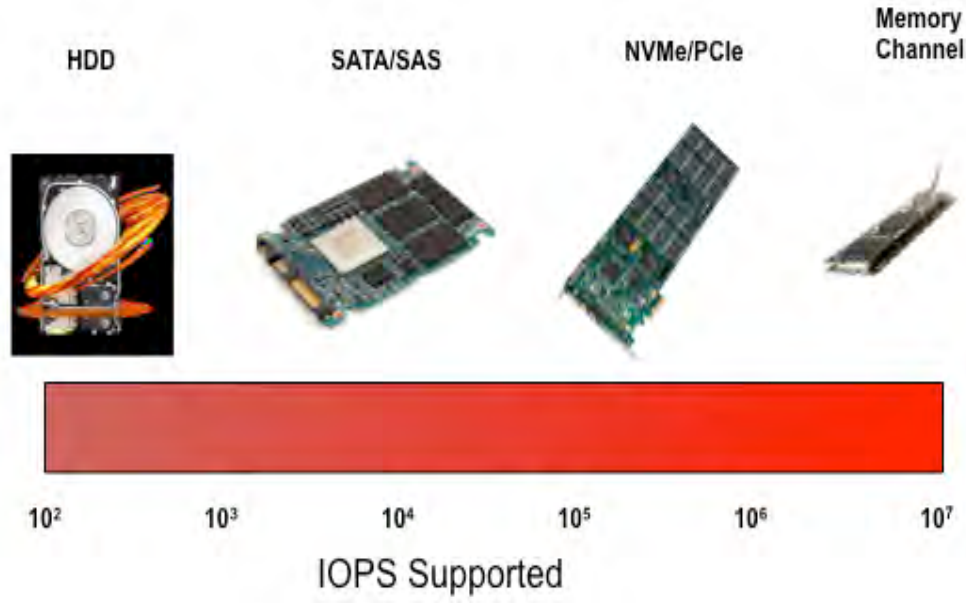
If Western Digital acquires a greater control over Toshiba's flash memory supply that would put even more pressure on Seagate to find its own firm supply of high quality flash memory. The company has been in negotiations with SK Hynix to

invest in expanding their flash memory capacity. This could put even more reason to complete such an agreement.

It may be that we are starting to see the outlines of a future consolidated solid state storage and memory industry with Samsung and possibly Western Digital becoming dominant players. A wild card in all this is the new Chinese flash plants being built focusing on 3D flash and possibly shipping product by 2018. Things are starting to get interesting!

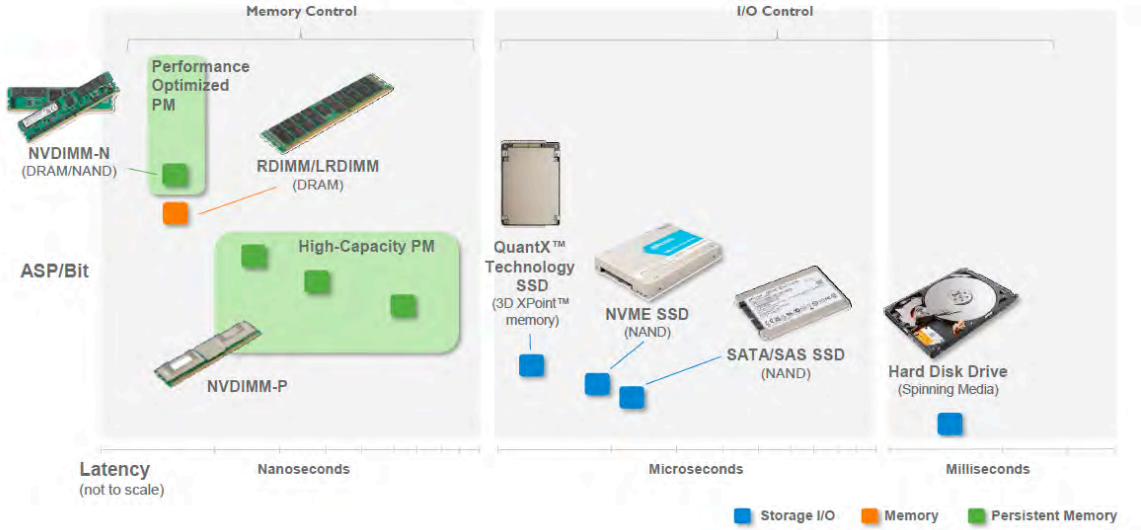
15) Persistent Memory Will Revolutionize Computing (Forbes Blog, 1/23/17)
The Storage Networking Industry Association (SNIA) put on a Persistent Memory Summit in San Jose, highlighting a major initiative of the SNIA Solid State Storage Initiative (SSSI). Persistent memory (PM) is solid-state memory providing high performance that can retain data for longer than DRAM memory without refreshing the data in the device. The Summit included experts from companies and analysts exploring the implications and implementation of various approaches to PM.

Current PM includes flash memory in PCIe interface storage devices, increasingly using the NVMe protocol. It also includes flash and DRAM/Flash devices using the computer memory bus, often referred to as NVDIMM's of various sorts. The Figure below from Jim Handy and Tom Coughlin's presentation shows a comparison of input/output operations per second (IOPS) of various digital storage and memory devices.

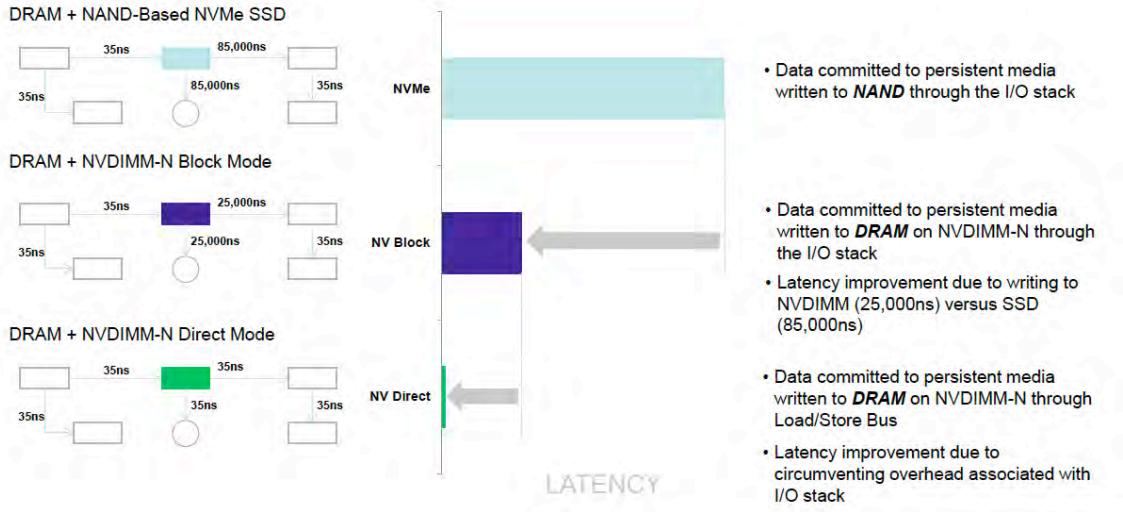


The figure below from Steve Pawlowski of Micron's presentation shows another view of this range of memory and storage device performance in terms of data latency (the time from when data is sought to when it is available). Storage devices including HDDs and SSDs, even using NVMe protocols are data storage devices under I/O control with performance down to the microsecond range

(including Micron's version of the 3D XPoint memory, QuantX). NVDIMM-P that contain a large quantity of NAND flash provides a high capacity PM while NVDIMM-N with some NAND and a lot of DRAM and traditional DIMMs with all DRAM provide even higher performance but higher memory costs.



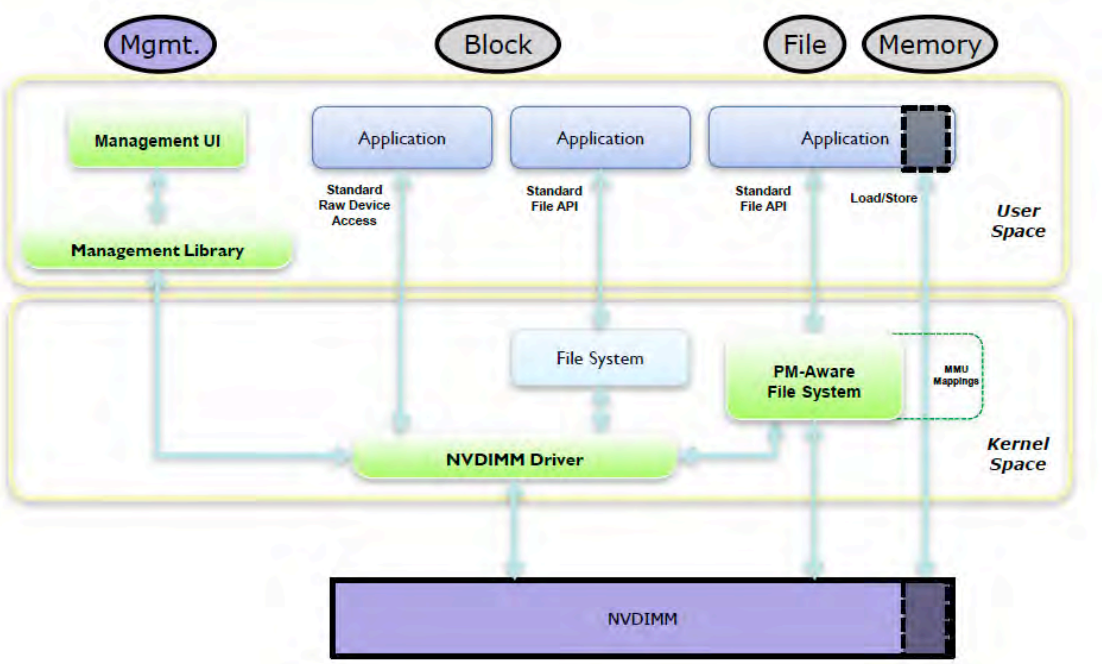
NVDIMM's can be used like traditional block based devices with access through the traditional I/O stack like traditional storage or treated like computer system memory using the Load/Store bus with direct access to stored bits. The figure below shows that the latter approach can lead to very low latencies.



In the future these technologies combined with concepts like the Hybrid Memory Cube could bring processing closer to the memory, offering opportunities for 1,000-fold decreases in the energy required for floating-point calculations.

Andy Rudoff from Intel talked about developments in the SNIA NVM

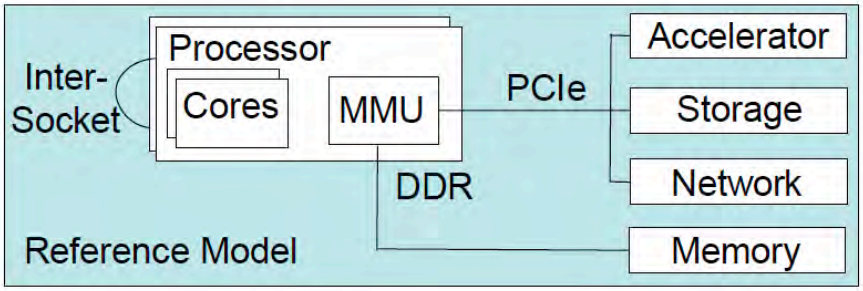
programming model that will be able to take advantage of the higher performance possible with PM. The figure below shows the latest version of the programming model.



On the far right we see a direct memory access of NVDIMM by the application, providing the highest performance. There are further increases possible by going from NAND flash to other faster persistent memory. 3D XPoint was to originally be used in DIMM configurations but now appears to be coming out in NVMe formats instead. At the PM Summit Barry Hoberman from Spin Transfer spoke about how even great performance gains are possible using spin torque transfer MRAM DIMM and other memory devices.

Doug Voigt presented information on three new system interconnect consortia introduced in October 2016 to take advantage of the potential of PM. These consortia are Gen-Z, Open CAPI and CCIX. The figure below compares these three interconnect concepts.

Gen-Z	Processor complex to rack scale memory fabric	❖ PM pooling
Open CAPI	Cache coherent accelerator access to processor memory	❖ Accelerator access to PM
CCIX	Cache coherency across processors and accelerators	❖ Shared PM

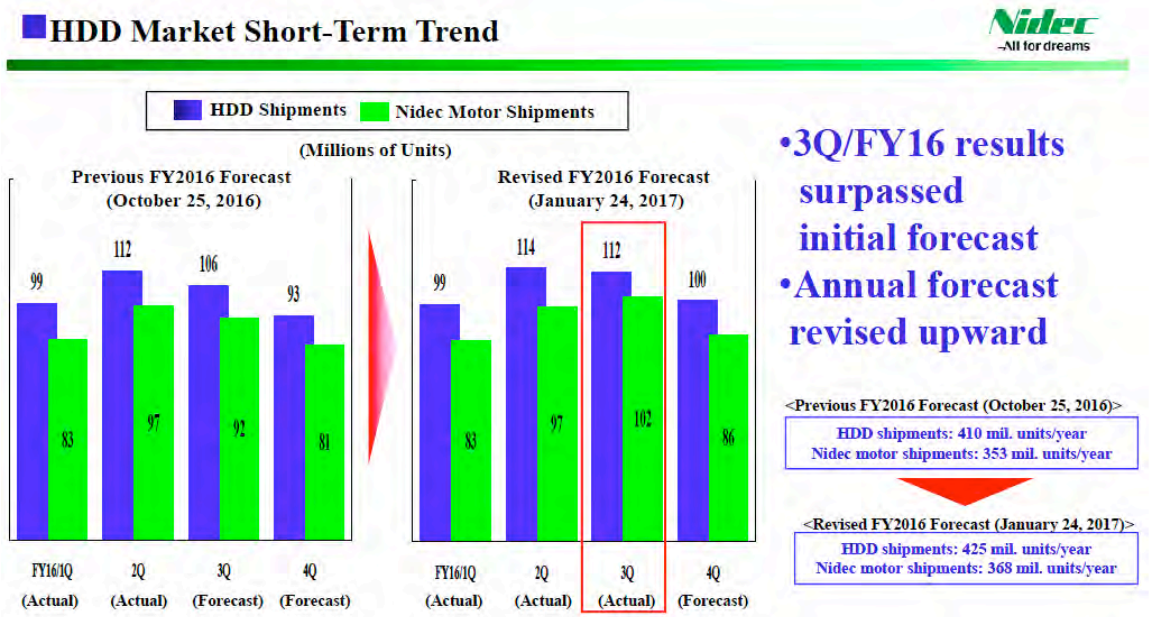


Paul Grun from Cray spoke about the OpenFabric Alliance that seeks high performance networked devices. These technologies using remote direct memory access (RDMA) technology originally developed over InfiniBand and now available with various technologies over Ethernet networks. RDMA with PM allows new network storage architectures and will be incorporated in the next generation of network storage technologies.

The replacement of DRAM memory requiring frequent data updating by new persistent memory options appears to be underway. This change will fundamentally change computer architectures, improving performance and lowering power requirements.

16) 20 TB Hard Disk Drives Must Be the Future of HDDs (Forbes Blog, 1/24/17)

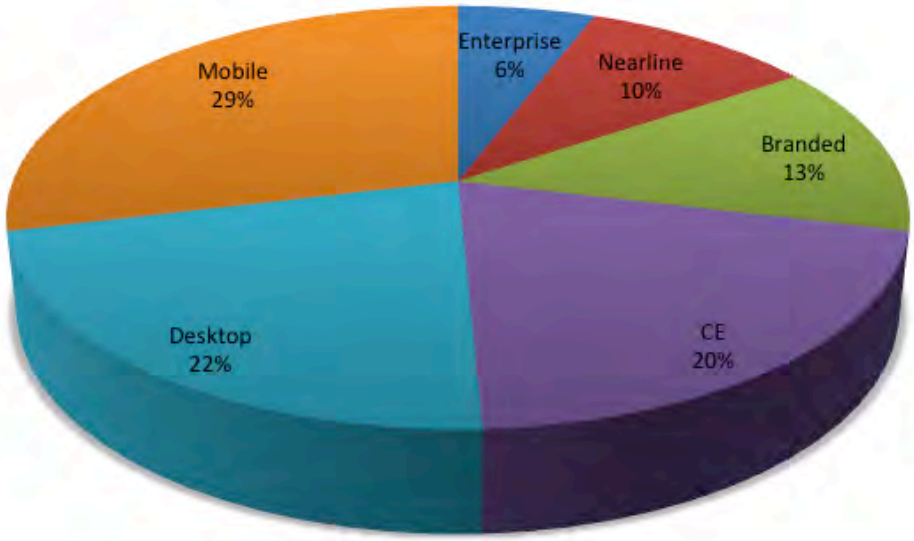
Nidec, the supplier of about 75% of HDD spindle motors, updated its projections for HDD production in CQ4 2016 and its projections for the first quarter of 2017. The company reported HDD spindle motor units were up 5% Quarter over Quarter (CQ4 2016 through CQ1 2017) and up about 6% Year over Year. The growth of HDD spindle motors correlates with the trends in HDD units. NIdec thinks the decline in HDD units from 2015 to 2016 is about 10%.



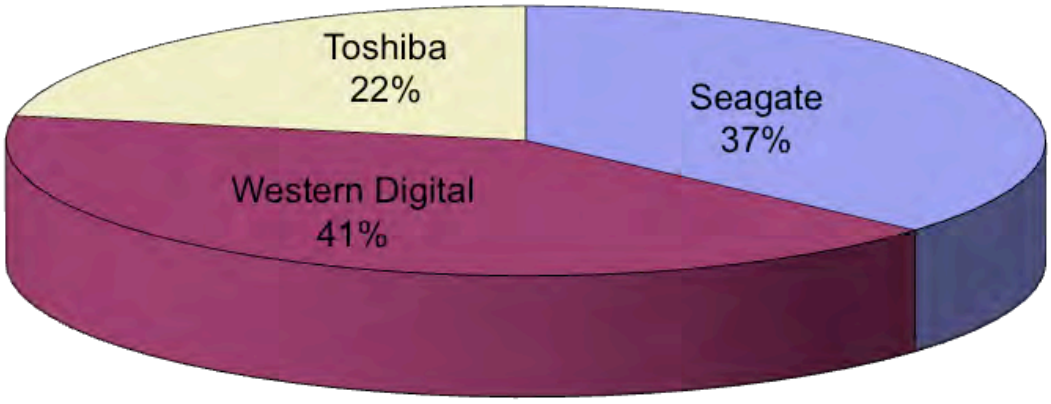
The recovery in HDD units is driven by the growth in high-capacity nearline HDDs as well as a stabilization of PC demand. Nidec also raised its HDD projections for the second quarter of 2017, although it thinks HDD units will decline 4% Y/Y in 2017.

Seagate reported their Q4 2016 quarterly results. For Seagate, CQ4 2016 HDD unit shipments were up about 2.5% over the prior quarter. For Western Digital their drive shipments were down 5.8% from Q3 2016 to Q4 2016. Toshiba HDD shipments were down about 1.1%. We project a decline of 7.2% of HDD shipments from 2016 to 2017.

Overall drive shipments in 2016 were down about 9.4% at 424 M units shipped in 2016. This was a bit better than the 10% decline predicted by Nidec. High Performance Enterprise HDDs declined 11.3% in 2016 while Nearline HDDs increased by 1.5%. Desktop HDDs declined by 18.6% while notebook HDDs declined by 19.9%. Branded (mostly external HDDs) declined by 7.9% while Consumer Electronics HDDs increased by 20.8%, driven by game storage and some set-top box sales. The distribution of each of these categories of HDDs in the total HDD shipments is shown below.



As shown in the figure below, Western Digital shipped 41% of the total HDDs in 2016, Seagate shipped 37% and Toshiba shipped 22%. Toshiba shipment percentages are up (taking market share from Seagate and Western Digital) considerably since 2015 when it was about 16% of the total. Toshiba's biggest growth appeared to be in HDDs for consumer electronics and notebook computers.



The long-term future of HDDs likely rests with high capacity HDDs, particularly in data centers serving cloud storage applications. Indeed looking at the declining shipments in high performance HDDs and computer HDDs the best path for growth would appear to be a high a capacity drive as possible. In its earnings call Seagate said that it will ship 14 and 16 TB HDDs over the next 18 months.

The company has indicated it would like to ship 20 TB HDDs by 2020. The ATSC areal density roadmap indicated that 100 TB 3.5-inch HDDs could be possible by about 2025.

GUEST ARTICLES

1) Steve Daniel, Daniel Research Group

United States Computing and Telecommunications Personal Device Market Forecast: 2017-2021

Market Overview

Table 1: United States Total Personal Device Unit Shipments (M)								
PCs	2016	2017	2018	2019	2020	2021	CAGR	Trend
Desktop PC	18.5	17.8	17.1	16.2	15.3	14.8	-4.5%	
AGR	*-8.2%*	*-4.2%*	*-3.5%*	*-5.5%*	*-5.8%*	*-3.4%*		
Mobile PCs	46.2	46.0	45.7	44.0	42.3	41.8	-2.0%	
AGR	*2.8%*	*-0.3%*	*-0.8%*	*-3.7%*	*-3.9%*	*-1.1%*		
Total PCs	64.7	63.8	62.8	60.2	57.5	56.5	-2.7%	
AGR	*-0.6%*	*-1.4%*	*-1.6%*	*-4.2%*	*-4.4%*	*-1.7%*		
Tablets								
Detachable	9.0	16.9	26.7	38.6	52.2	70.0	50.8%	
AGR	*35.3%*	*88.6%*	*57.7%*	*44.6%*	*35.5%*	*33.9%*		
Slate	40.8	37.6	34.1	30.0	25.8	23.3	-10.6%	
AGR	*35.3%*	*88.6%*	*57.7%*	*44.6%*	*35.5%*	*33.9%*		
Total Tablets	49.8	54.5	60.8	68.5	78.1	93.3	13.4%	
AGR	*-4.0%*	*9.5%*	*11.5%*	*12.8%*	*13.9%*	*19.5%*		
Total Computers								
Total Computers	114.5	118.3	123.6	128.7	135.6	149.9	5.5%	
AGR	*-2.1%*	*3.3%*	*4.5%*	*4.1%*	*5.4%*	*10.5%*		
Mobile Phones								
Stardard Phone	22.3	19.5	17.0	13.9	11.6	9.4	-15.8%	
AGR	*-23.5%*	*-12.5%*	*-12.9%*	*-18.0%*	*-16.8%*	*-18.8%*		
SmartPhone	180.5	198.0	214.0	221.6	226.7	244.2	6.2%	
AGR	*3.3%*	*9.7%*	*8.1%*	*3.5%*	*2.3%*	*7.7%*		
Total Mobile Phones	202.7	217.5	231.0	235.5	238.3	253.5	4.6%	
AGR	*-0.5%*	*7.3%*	*6.2%*	*2.0%*	*1.2%*	*6.4%*		
Total Devices								
Total Devices	317.2	335.8	354.6	364.2	373.9	403.4	4.9%	
AGR	*-1.1%*	*5.9%*	*5.6%*	*2.7%*	*2.7%*	*7.9%*		
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Table 2: United States Consumer Personal Device Unit Shipments (M)								
PCs	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**CAGR**	**Trend**
Desktop PC	5.1	5.2	5.4	5.4	5.4	5.5	1.3%	
AGR	*-11.6%*	*2.3%*	*2.8%*	*0.0%*	*-0.3%*	*1.8%*		
Mobile PCs	19.9	18.1	16.5	14.7	13.0	11.9	-9.8%	
AGR	*-8.8%*	*-9.4%*	*-8.9%*	*-10.8%*	*-11.2%*	*-8.9%*		
Total PCs	25.1	23.3	21.8	20.1	18.4	17.3	-7.1%	
AGR	*-9.4%*	*-7.0%*	*-6.3%*	*-8.1%*	*-8.3%*	*-5.8%*		
Tablets								
Detachable	8.1	15.1	22.7	30.4	37.7	46.1	41.6%	
AGR	*33.2%*	*86.1%*	*50.6%*	*33.8%*	*24.3%*	*22.1%*		
Slate	36.7	33.1	29.0	24.8	20.9	18.0	-13.3%	
AGR	*33.2%*	*86.1%*	*50.6%*	*33.8%*	*24.3%*	*22.1%*		
Total Tablets	44.8	48.2	51.7	55.2	58.6	64.1	7.4%	
AGR	*-3.4%*	*7.4%*	*7.3%*	*6.8%*	*6.3%*	*9.3%*		
Total Computers								
Total Computers	69.9	71.5	73.5	75.2	77.1	81.4	3.1%	
AGR	*-5.7%*	*2.2%*	*2.9%*	*2.4%*	*2.4%*	*5.7%*		
Mobile Phones								
Stardard Phone	22.0	19.2	16.7	13.6	11.2	9.0	-16.4%	
AGR	*-20.5%*	*-12.7%*	*-13.3%*	*-18.5%*	*-17.3%*	*-19.8%*		
SmartPhone	168.8	189.1	206.7	216.4	222.9	241.1	7.4%	
AGR	*3.5%*	*12.1%*	*9.3%*	*4.7%*	*3.0%*	*8.1%*		
Total Mobile Phones	190.8	208.4	223.4	230.0	234.1	250.1	5.6%	
AGR	*0.0%*	*9.2%*	*7.2%*	*2.9%*	*1.8%*	*6.8%*		
Total Devices								
Total Devices	260.7	279.8	296.9	305.2	311.2	331.5	4.9%	
AGR	*-1.6%*	*7.3%*	*6.1%*	*2.8%*	*2.0%*	*6.5%*		
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Table 3: United States Enterprise Personal Device Unit Shipments (M)								
PCs	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**CAGR**	**Trend**
Desktop PC	13.4	12.5	11.8	10.8	9.9	9.3	-7.1%	
AGR	*-6.8%*	*-6.6%*	*-6.1%*	*-8.1%*	*-8.5%*	*-6.1%*		
Mobile PCs	26.3	28.0	29.2	29.3	29.2	29.9	2.6%	
AGR	*13.8%*	*6.5%*	*4.4%*	*0.2%*	*-0.2%*	*2.4%*		
Total PCs	39.7	40.5	41.0	40.1	39.1	39.2	-0.2%	
AGR	*5.9%*	*2.1%*	*1.2%*	*-2.1%*	*-2.4%*	*0.2%*		
Tablets								
Detachable	0.9	1.9	4.0	8.2	14.5	23.9	93.7%	
AGR	*58.0%*	*110.9%*	*115.4%*	*105.7%*	*77.1%*	*64.6%*		
Slate	4.1	4.5	5.1	5.1	4.9	5.3	5.5%	
AGR	*58.0%*	*110.9%*	*115.4%*	*105.7%*	*77.1%*	*64.6%*		
Total Tablets	4.9	6.3	9.1	13.4	19.4	29.2	42.6%	
AGR	*-8.9%*	*28.0%*	*43.9%*	*46.6%*	*45.5%*	*50.4%*		
Total Computers								
Total Computers	44.6	46.8	50.1	53.4	58.6	68.4	8.9%	
AGR	*4.0%*	*4.9%*	*6.9%*	*6.7%*	*9.6%*	*16.9%*		
Mobile Phones								
Stardard Phone	0.2	0.2	0.3	0.3	0.3	0.4	12.9%	
AGR	*-84.9%*	*13.1%*	*23.4%*	*13.1%*	*2.8%*	*13.1%*		
SmartPhone	11.7	8.9	7.3	5.2	3.8	3.1	-23.4%	
AGR	*0.6%*	*-23.7%*	*-17.8%*	*-28.7%*	*-27.2%*	*-19.0%*		
Total Mobile Phones	11.9	9.2	7.6	5.6	4.1	3.5	-21.9%	
AGR	*-8.3%*	*-23.0%*	*-16.8%*	*-27.1%*	*-25.5%*	*-16.5%*		
Total Devices								
Total Devices	56.5	56.0	57.7	59.0	62.7	71.9	4.9%	
AGR	*1.1%*	*-1.0%*	*3.1%*	*2.3%*	*6.3%*	*14.7%*		
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Three major new influences will drive the United States Personal Device market over the next five years and represent a significant break with many of the trends observed over the previous five years. Those influences are:

- The **Average Installed Base Age** for many of the Personal Devices has reached historic highs. Many of these devices no longer meet users evolving needs and

will be replaced over the next two years **driving down both Average Installed Base Age and Replacement Cycle Lengths.**

- A **mild economic slow-down** in the 2019-2020 period will temporarily inhibit demand in the consumer sector as household discretionary income will decrease and the number of businesses will decrease in the enterprise sector. The economy will recover in 2021 allowing replacements rates to accelerate once again towards the end of the cycle.

- **IoT and User/Device interfaces and interaction processes technologies -** such as voice and wearables - will increase productivity in the enterprise sector, as well as utility in the consumer sector. This will manifest itself in driving penetration rates and densities (Installed Base Units per Penetrated TAM unit), as well through increasing replacement rates.

- **Three major tends** operating over the past five years will continue to significantly influence the United States Personal Device market over the next five years.

- The **Enterprise Sector** will show stronger growth than the Consumer Sector as the new innovative IoT data capture technologies are implemented in the supply chain management systems in many physical product industries.

- **Mobile** computing devices as a percent of total computing devices will continue to increase.

- **Mobile PCs and Detachable Tablets** will become indistinguishable and effectively become one product.

Over the Next Five Years: Personal Computers and Tablets

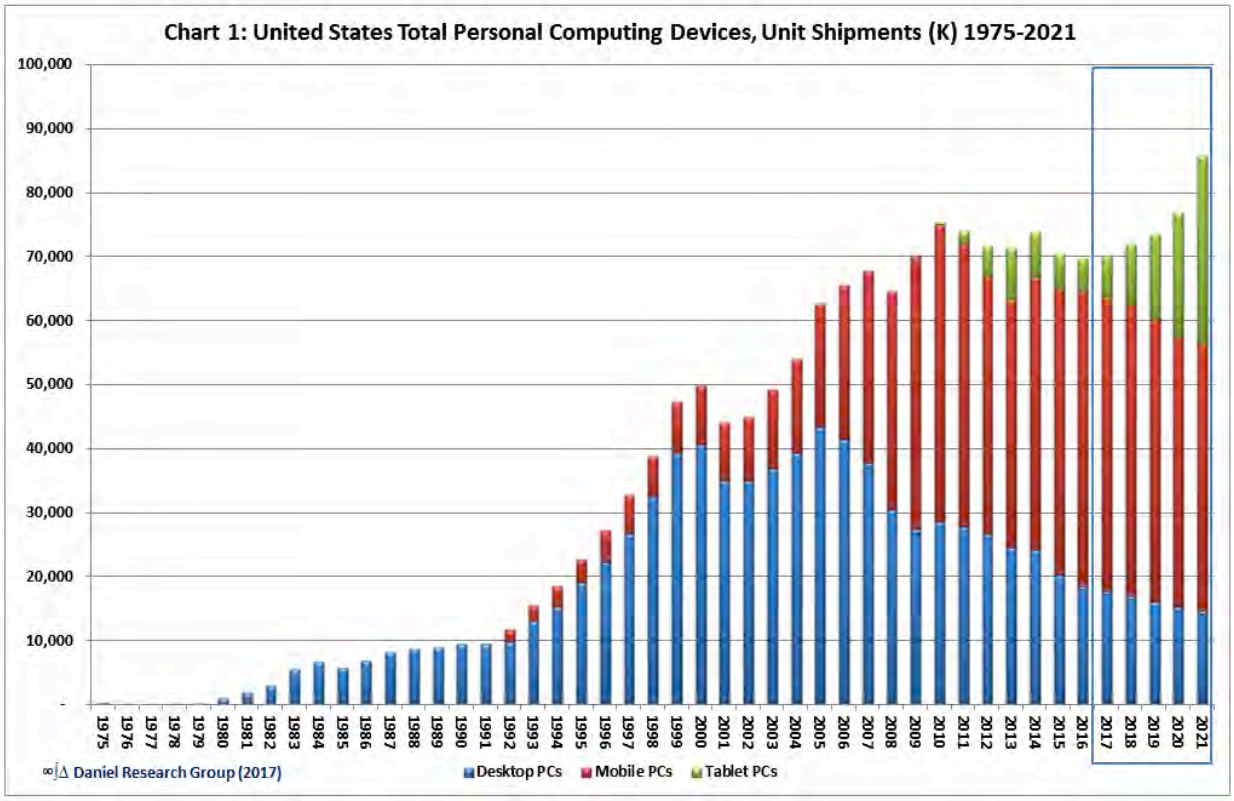
- 656 million PCs and Tablets will be purchased by households and businesses

- 87% will be replacements for older PCs and Tablets.

- Over 5.9 million households and 188,000 businesses will buy a PC or Tablet for the first time.

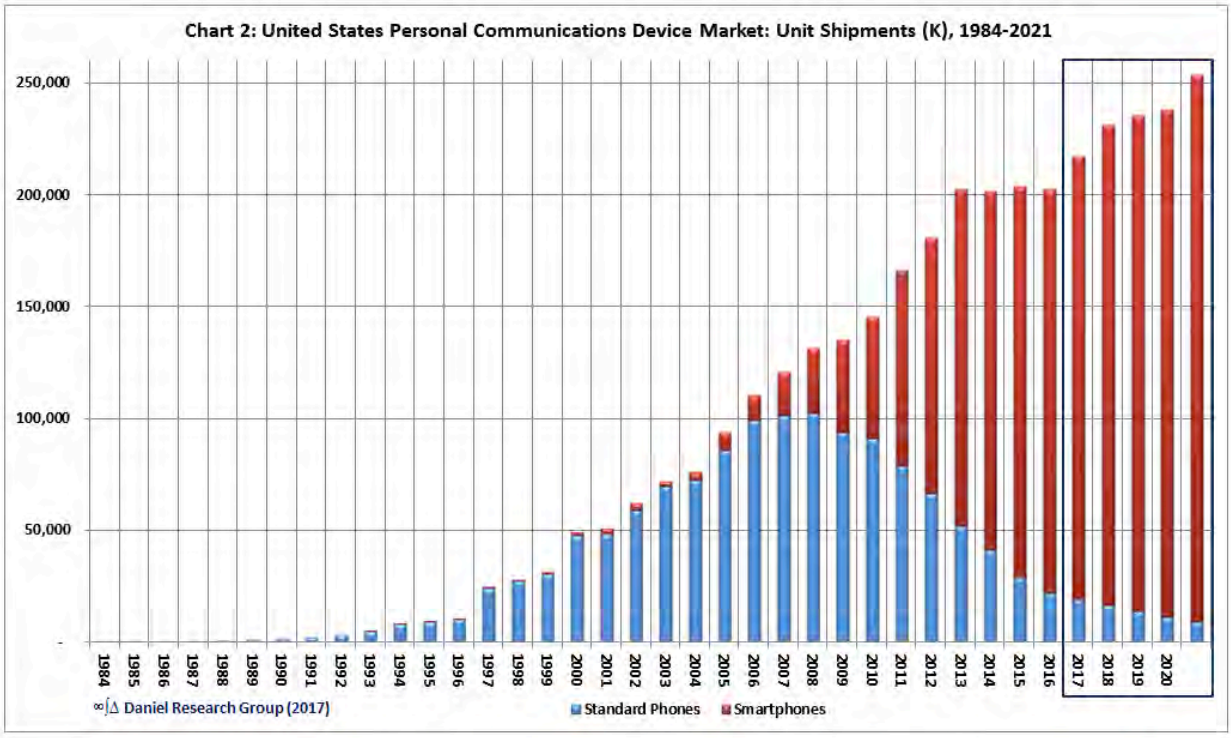
- The average number of personal computing devices per business will increase by 8.9 reaching almost 41 devices per business, while households will add an average of only .2 computing devices over the next five years, reaching 2.9 devices per household.

- The time required to replace all of the installed personal computing devices will decrease by almost of full year, lowering to 5.8 years by 2021.

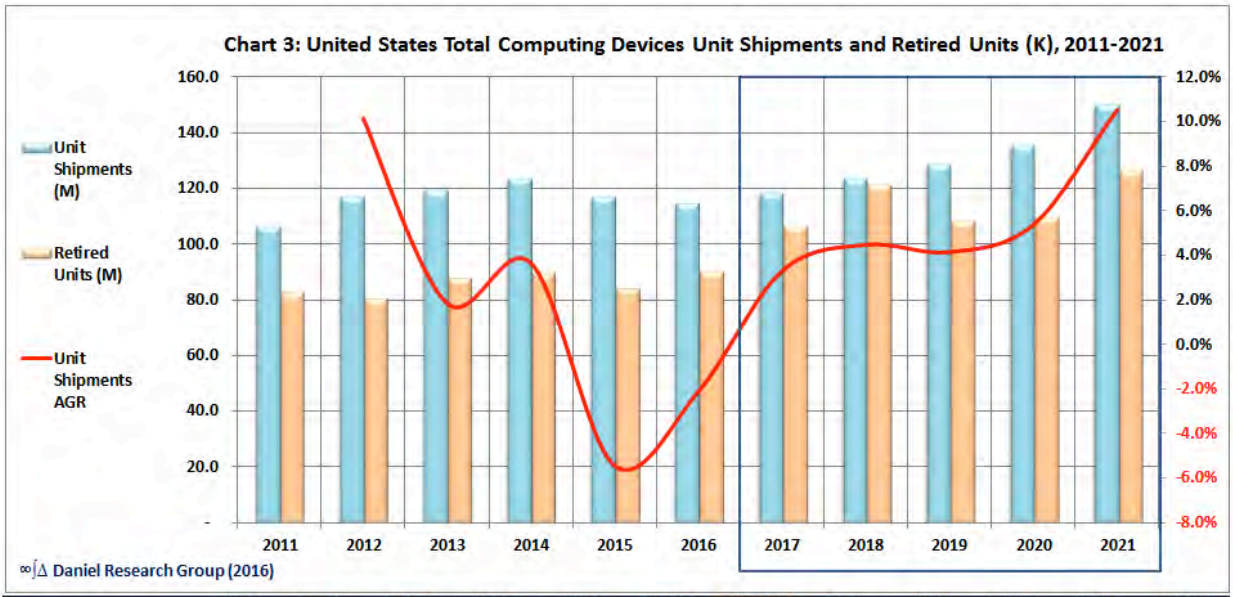


Over the Next Five Years: Mobile Phones

- 1.2 billion Mobile Phones will be purchased.
- 93% will be replacements for older mobile phones.
- 13.5 million Households will buy a mobile phone for the first time bringing the household penetration to 97.1%.
- The average number of Smartphones per household will increase by almost 0.5. to 2.9 per household
- The average age of a mobile phone in use will stabilize at 2 years
- The time required to replace all of the mobile phones in use will also stabilize at 2.6 years



After three years of declining unit shipments, the United States Personal Computing Device market will return to growth in 2017.



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	CAGR
Unit Shipments (M)	106.4	117.2	119.4	123.7	117.0	114.5	118.3	123.6	128.7	135.6	149.9	5.5%
Retired Units (M)	82.7	80.5	87.8	89.6	84.0	90.2	106.3	121.0	108.3	109.8	126.4	7.0%
Unit Shipments AGR		10.1%	1.8%	3.6%	-5.4%	-2.1%	3.3%	4.5%	4.1%	5.4%	10.5%	

The **DRG United States Personal Device** Forecast reflects the following major influences and trends:

- Strong growth in Enterprise Mobility applications

- Continued, although slow, increase in market penetration in both the Consumer and Enterprise Sectors

- Moderate growth in Density in the Consumer Sector and significant growth in Density in the Enterprise Sector

- An increase in replacement rates starting in 2017 driven by both natural and incented obsolescence.

- A decrease in replacement rates during an anticipated economic slow-down in 2019-2020. Replacements rates will increase again in 2021

- A deceleration of the decline of the Desktop PC market as the core base of inventory of applications that require the power and capabilities of Desktop PCs stabilizes.

- Convergence of the Mobile PC and Detachable Tablet products such that they become indistinguishable in terms of meeting user needs.

- Saturation of the Mobile Phone Market is increasing reliance on shortening replacement rates to sustain unit shipments.

The opportunity to migrate more legacy and manual business processes in the enterprise sector, and life management tasks in the consumer sector, to personal computing and communication devices continues to drive demand. This has always been, and will continue to be, the primary growth driver. Over the next five year, growth in enterprise mobility applications that specifically exploit the adaptability of current and anticipated Detachable Tablets will drive most of the market growth. Additionally, interface processes utilizing voice and wearables emerging technologies will increase the utility of mobile computing devices as part of the overall adoption of IoT in the enterprise sector.

Current penetrated households and business will add more devices increasing densities. Additionally, both real and incented obsolescence will increase replacement rates. Finally, the total available market of households as well as the penetration rates will continue to increase. While the anticipated 2019-2020 economic slow-down will reduce the number of businesses, employment will continue to increase.

Introducing a New Personal Device Taxonomy

Occasionally it is useful to review why we forecast technology markets in the first place. Forecasts, as well as all market research, have value only in the context of the decisions facing the buyers or users of that research. Many of you are missioned with developing, manufacturing, marketing, and supporting technology products and services. As you are well aware, forecasts are defined in terms of metrics and taxonomies - what we measure, and how we organize. However, to be useful for the users of forecasts, taxonomies need to accurately reflect the natural segmentation of the market in terms of how the products and services are made, sold, and used.

DRG believes that the common taxonomy that we have been using for some time now, Desktop PCs, Mobile PCs, Tablets and Mobile Phones, is obsolete and no longer useful. We believe the following taxonomy, focused on location and primary purpose, more accurately reflects the natural segmentation of the United States Personal Device Market. In this report, we will present our forecast using both the current-traditional and the proposed new taxonomies.

Primary User Benefit	Fixed Location	Mobile
Capture and Creation	Desktop PCs	Mobile PCs Detachable Tablets
Content Delivery		Slate Tablets e-Readers
Communication		Mobile Phones

Table 4: United States Total Personal Device Unit Shipments (M), New Taxonomy								
Capture and Creation	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**CAGR**	**Trend**
Fixed Capture and Creation	18.5	17.8	17.1	16.2	15.3	14.8	-4.5%	
AGR	*-8.2%*	*-4.2%*	*-3.5%*	*-5.5%*	*-5.8%*	*-3.4%*		
Mobile Capture and Creation	55.2	62.9	72.3	82.5	94.5	111.8	15.2%	
AGR	*7.0%*	*14.1%*	*14.9%*	*14.1%*	*14.5%*	*18.3%*		
Total Capture and Creation	73.7	80.7	89.5	98.7	109.8	126.5	11.4%	
AGR	*2.7%*	*9.5%*	*10.9%*	*10.3%*	*11.2%*	*15.3%*		
Delivery								
Mobile Delivery	47.4	43.5	39.6	35.0	30.5	27.7	-10.2%	
AGR	*-10.1%*	*-8.2%*	*-9.2%*	*-11.5%*	*-13.0%*	*-9.1%*		
Capture, Creation and Delivery								
Total Capture, Creations and Delivery	121.1	124.3	129.0	133.7	140.2	154.2	4.9%	
AGR	*-2.7%*	*2.6%*	*3.8%*	*3.6%*	*4.9%*	*10.0%*		
Communications								
Mobile Communication	203.7	202.7	217.5	231.0	235.5	238.3	3.2%	
AGR	*-0.5%*	*7.3%*	*6.2%*	*2.0%*	*1.2%*	*6.4%*		
Total Devices								
Total Devices	323.9	341.8	360.0	369.2	378.5	407.8	4.7%	
AGR	*-1.3%*	*5.5%*	*5.3%*	*2.6%*	*2.5%*	*7.7%*		
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Table 5: United States Consumer Personal Device Unit Shipments (M), New Taxonomy								
Capture and Creation	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**CAGR**	**Trend**
Fixed Capture and Creation	5.1	5.2	5.4	5.4	5.4	5.5	1.3%	
AGR	*-11.6%*	*2.3%*	*2.8%*	*0.0%*	*-0.3%*	*1.8%*		
Mobile Capture and Creation	28.0	33.1	39.1	45.0	50.8	57.9	15.6%	
AGR	*0.4%*	*18.2%*	*18.2%*	*15.1%*	*12.7%*	*14.2%*		
Total Capture and Creation	33.1	38.4	44.5	50.4	56.1	63.4	13.9%	
AGR	*-1.7%*	*15.7%*	*16.1%*	*13.2%*	*11.3%*	*13.0%*		
Delivery								
Mobile Delivery	43.4	39.1	34.4	29.9	25.6	22.4	-12.4%	
AGR	*-9.4%*	*-9.9%*	*-11.9%*	*-13.3%*	*-14.4%*	*-12.4%*		
Capture, Creation and Delivery								
Total Capture, Creations and Delivery	76.5	77.4	79.0	80.3	81.7	85.8	2.3%	
AGR	*-6.2%*	*1.2%*	*2.0%*	*1.7%*	*1.7%*	*5.0%*		
Communications								
Mobile Communication	190.8	190.8	208.4	223.4	230.0	234.1	4.2%	
AGR	*0.0%*	*9.2%*	*7.2%*	*2.9%*	*1.8%*	*6.8%*		
Total Devices								
Total Devices	267.3	285.8	302.3	310.2	315.8	335.9	4.7%	
AGR	*-1.8%*	*6.9%*	*5.8%*	*2.6%*	*1.8%*	*6.4%*		
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Table 6: United States Enterprise Personal Device Unit Shipments (M), New Taxonomy								
Capture and Creation	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**CAGR**	**Trend**
Fixed Capture and Creation	13.4	12.5	11.8	10.8	9.9	9.3	-7.1%	
AGR	*-6.8%*	*-6.6%*	*-6.1%*	*-8.1%*	*-8.5%*	*-6.1%*		
Mobile Capture and Creation	27.1	29.8	33.2	37.5	43.8	53.8	14.7%	
AGR	*14.8%*	*9.9%*	*11.3%*	*12.9%*	*16.7%*	*23.0%*		
Total Capture and Creation	40.6	42.4	45.0	48.3	53.7	63.1	9.2%	
AGR	*6.6%*	*4.4%*	*6.2%*	*7.4%*	*11.1%*	*17.6%*		
Delivery								
Mobile Delivery	4.1	4.5	5.1	5.1	4.9	5.3	5.5%	
AGR	*-16.5%*	*10.1%*	*14.3%*	*0.5%*	*-4.8%*	*8.3%*		
Capture, Creation and Delivery								
Total Capture, Creations and Delivery	44.6	46.8	50.1	53.4	58.6	68.4	8.9%	
AGR	*4.0%*	*4.9%*	*6.9%*	*6.7%*	*9.6%*	*16.9%*		
Communications								
Mobile Communication	13.0	11.9	9.2	7.6	5.6	4.1	-20.4%	
AGR	*-8.3%*	*-23.0%*	*-16.8%*	*-27.1%*	*-25.5%*	*-16.5%*		
Total Devices								
Total Devices	56.5	56.0	57.7	59.0	62.7	71.9	4.9%	
AGR	*1.1%*	*-1.0%*	*3.1%*	*2.3%*	*6.3%*	*14.7%*		
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Long-Term Trends – Penetration, Density, and Replacement Rate

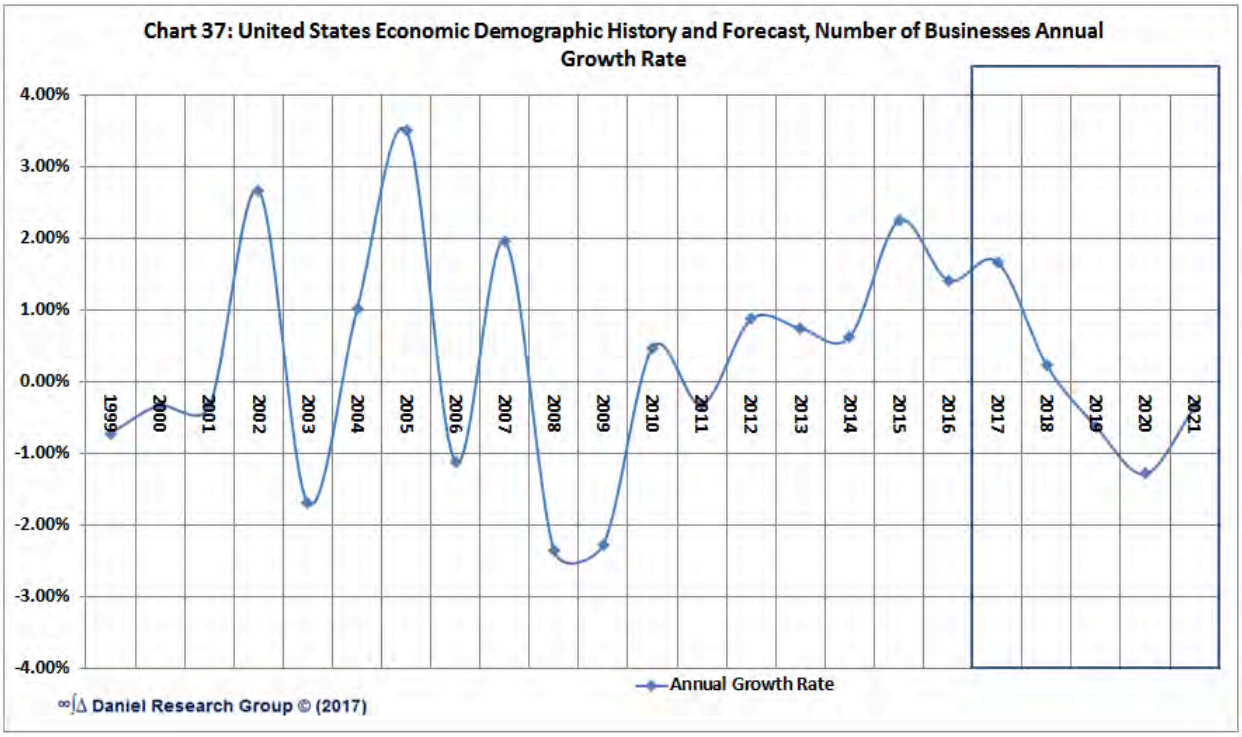
Many technology market analysts' forecasts rely primarily on projecting Unit Shipments based on year-over-year and quarter-over-quarter trend analysis augmented by predictions and estimates provided by supply-side and demand-side sources. When these methods fail, sometimes dramatically as they did frequently over the last year few years, the causes usually are found to be resident in other influencing forces such as replacement rates, market penetration, and density.

We understand the misguided emphasis is on unit shipments - it is a direct path from this metric to revenues, profits, and ultimately earnings per share.

However, while an analysis of past unit shipment trends are necessary to provide context for a forecasts, they do not in and of themselves possess strong predictive properties. If other metrics are the causal drivers, let us start there?

TAM, Penetration and Density

DRG defines Total Available Market (**TAM**) in terms of the most common buying decision-making entities, **households** for consumer products and services, and **enterprises-businesses** for commercial products and services. The following charts present the actual history and the **DRG** forecast for the various TAMs operating in this market.



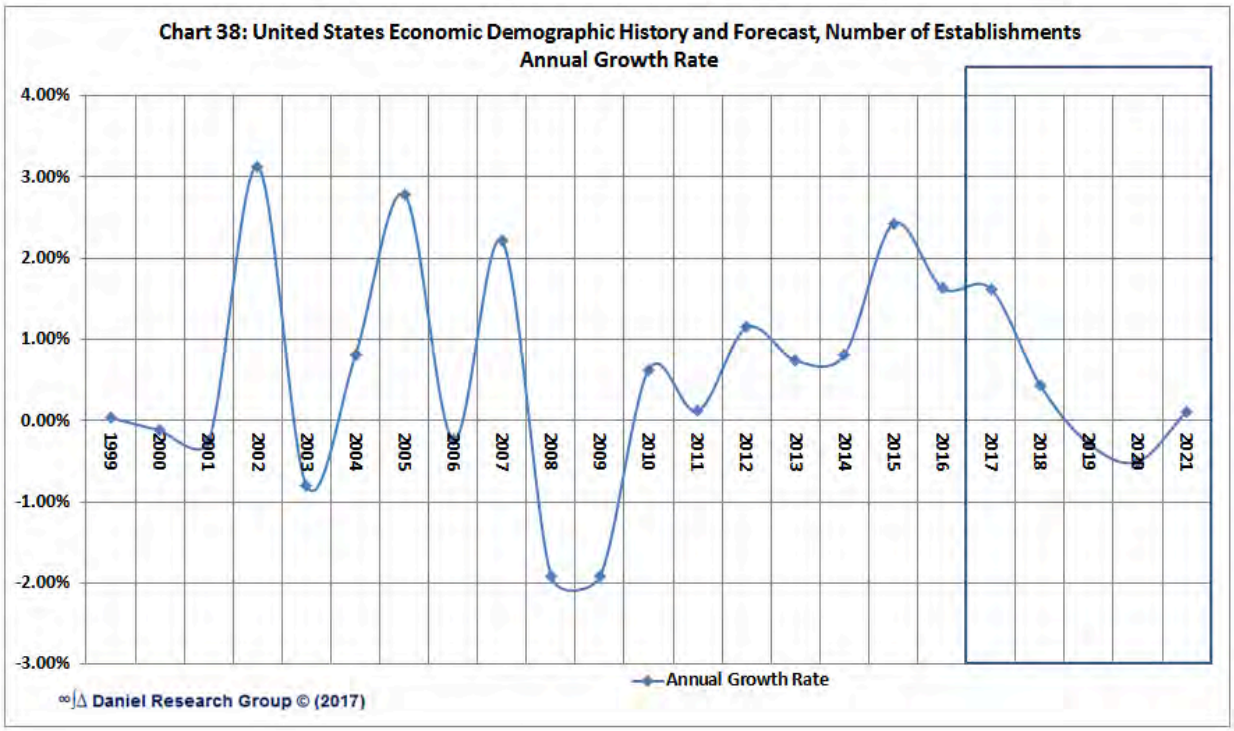


Chart 38: United States Economic Demographic History and Forecast, Number of Establishments Annual Growth Rate
4.00%
3.00%
2.00%
1.00%
0.00%
-1.00%
-2.00%
-3.00%
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
Annual Growth Rate
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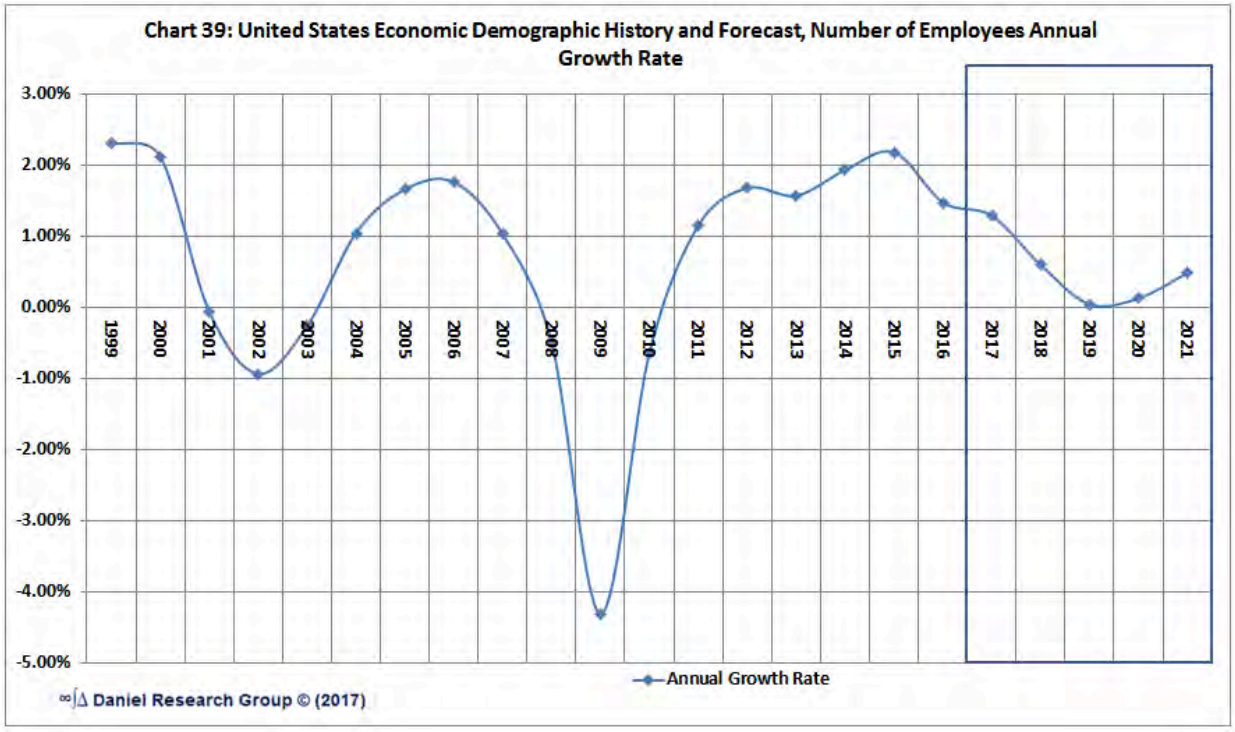
Chart 39: United States Economic Demographic History and Forecast, Number of Employees Annual Growth Rate
3.00%
2.00%
1.00%
0.00%
-1.00%
-2.00%
-3.00%
-4.00%
-5.00%
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
Annual Growth Rate
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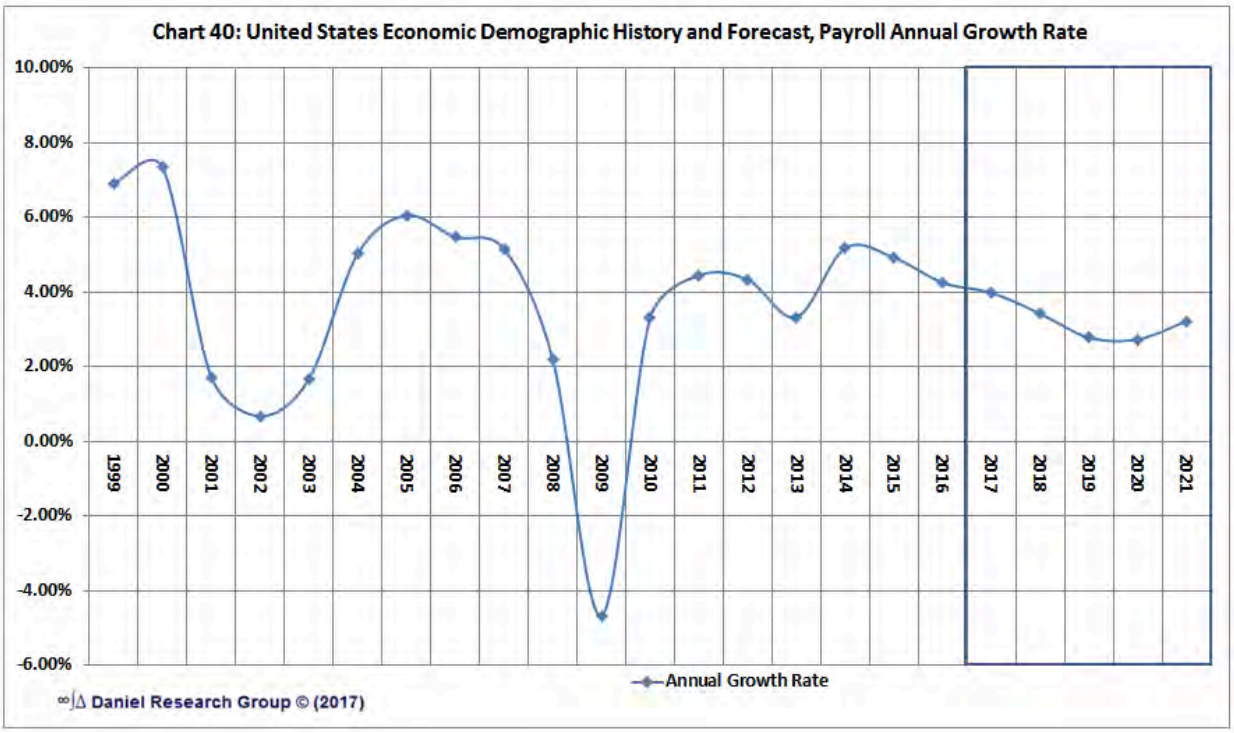

The buying decision making unit for Personal Computing and Communication Devices in the Enterprise can be the individual employee, a business units (such as an establishment or department), or the entire enterprise, (the business). For forecasting purposes, the **DRG EQS** models use the business as the TAM in the Enterprise sector. All three economic demographic metrics, Businesses, Establishments, and Employees show a decline in the Annual Growth Rate in the 2017-2020 period, with most of the slow-down in 2019 and 2020.

DRG uses Households as the buying decision making TAM for the Consumer Sector recognizing that many of the Personal Computing and Communication Devices buying decisions are made at the individual level. However, **DRG** believes that the majority of the buying decisions for these devices are household consensus rather than individual buying decisions. A slowing of the employment rate, Business Unit Growth, and Employee Payroll will all have a negative impact on both discretionary disposable income, and consumer sentiment.

Penetration is defined as the percent of the TAM entities **owning and using** the product or service.

Density is defined as the average number of units of product or services, currently owned and used by the penetrated TAM entities.

Forecast Detail Tables

Table 12: United States Total Personal Devices								
	2016	2017	2018	2019	2020	2021	CAGR	Trend
Unit Shipments (K)	317,224	335,800	354,582	364,208	373,894	403,420	*4.9%*	
AGR	*-1.1%*	*5.9%*	*5.6%*	*2.7%*	*2.7%*	*7.9%*		
Revenue ($M)	108,702	116,145	127,003	135,144	145,803	164,274	*8.6%*	
AGR	*-4.6%*	*6.8%*	*9.3%*	*6.4%*	*7.9%*	*12.7%*		
Average Price ($)	342.67	345.88	358.18	371.06	389.96	407.20	*3.5%*	
AGR	*-3.6%*	*0.9%*	*3.6%*	*3.6%*	*5.1%*	*4.4%*		
Installed Base (K)	813,880	841,381	854,460	892,296	938,614	980,146	*3.8%*	
AGR	*5.8%*	*3.4%*	*1.6%*	*4.4%*	*5.2%*	*4.4%*		
Installed Base Age (Y)	2.64	2.67	2.67	2.66	2.66	2.65	*0.1%*	
AGR	*2.1%*	*1.2%*	*0.2%*	*-0.4%*	*-0.1%*	*-0.5%*		
Replacement Cycle Length (Y)	3.99	3.73	3.50	3.73	3.87	3.71	*-1.4%*	
AGR	*7.6%*	*-6.5%*	*-6.1%*	*6.6%*	*3.5%*	*-4.1%*		
Units per Households and Businesses (#)	6.14	6.28	6.31	6.53	6.80	7.04	*2.8%*	
AGR	*4.8%*	*2.3%*	*0.5%*	*3.4%*	*4.2%*	*3.5%*		
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**Change**	**Trend**
Market Penetration (%)	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*0.0%*	
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Table 13: United States Consumer Personal Devices								
	2016	2017	2018	2019	2020	2021	CAGR	Trend
Unit Shipments (K)	260,693	279,806	296,876	305,202	311,198	331,531	*4.9%*	
AGR	*-1.6%*	*7.3%*	*6.1%*	*2.8%*	*2.0%*	*6.5%*		
Revenue ($M)	77,286	84,327	93,703	101,378	110,067	124,922	*10.1%*	
AGR	*-8.8%*	*9.1%*	*11.1%*	*8.2%*	*8.6%*	*13.5%*		
Average Price ($)	296.46	301.38	315.63	332.17	353.69	376.80	*4.9%*	
AGR	*-7.4%*	*1.7%*	*4.7%*	*5.2%*	*6.5%*	*6.5%*		
Installed Base (K)	584,230	606,507	617,285	645,546	675,877	699,348	*3.7%*	
AGR	*6.4%*	*3.8%*	*1.8%*	*4.6%*	*4.7%*	*3.5%*		
Installed Base Age (Y)	2.47	2.49	2.49	2.48	2.48	2.47	*0.0%*	
AGR	*2.4%*	*1.0%*	*0.0%*	*-0.6%*	*-0.1%*	*-0.3%*		
Replacement Cycle Length (Y)	3.59	3.36	3.16	3.33	3.41	3.27	*-1.9%*	
AGR	*7.3%*	*-6.6%*	*-5.9%*	*5.5%*	*2.3%*	*-4.0%*		
Units per Households (#)	4.64	4.77	4.80	4.97	5.15	5.28	*2.6%*	
AGR	*5.4%*	*2.8%*	*0.7%*	*3.5%*	*3.6%*	*2.5%*		
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**Change**	**Trend**
Market Penetration (%)	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*0.0%*	
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Table 14: United States Enterprise Personal Devices								
	2016	2017	2018	2019	2020	2021	CAGR	Trend
Unit Shipments (K)	56,532	55,995	57,706	59,006	62,696	71,888	*4.9%*	
AGR	*1.1%*	*-1.0%*	*3.1%*	*2.3%*	*6.3%*	*14.7%*		
Revenue ($M)	31,417	31,818	33,301	33,767	35,736	39,352	*4.6%*	
AGR	*7.5%*	*1.3%*	*4.7%*	*1.4%*	*5.8%*	*10.1%*		
Average Price ($)	555.73	568.24	577.07	572.26	569.99	547.40	*-0.3%*	
AGR	*6.3%*	*2.3%*	*1.6%*	*-0.8%*	*-0.4%*	*-4.0%*		
Installed Base (K)	229,649	234,875	237,176	246,750	262,738	280,797	*4.1%*	
AGR	*4.3%*	*2.3%*	*1.0%*	*4.0%*	*6.5%*	*6.9%*		
Installed Base Age (Y)	3.31	3.39	3.43	3.46	3.47	3.43	*0.7%*	
AGR	*2.2%*	*2.2%*	*1.3%*	*0.9%*	*0.4%*	*-1.3%*		
Replacement Cycle Length (Y)	5.87	5.63	5.28	5.99	6.63	6.22	*1.1%*	
AGR	*9.6%*	*-4.2%*	*-6.1%*	*13.5%*	*10.6%*	*-6.2%*		
Units per Businesses (#)	33.82	34.02	34.27	35.88	38.70	41.50	*4.2%*	
AGR	*2.8%*	*0.6%*	*0.7%*	*4.7%*	*7.9%*	*7.3%*		
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**Change**	**Trend**
Market Penetration (%)	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*0.0%*	
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Table 15: United States Total PCs and Tablets								
	2016	2017	2018	2019	2020	2021	CAGR	Trend
Unit Shipments (K)	114,515	118,289	123,577	128,698	135,610	149,876	*5.5%*	
AGR	*-2.1%*	*3.3%*	*4.5%*	*4.1%*	*5.4%*	*10.5%*		
Revenue ($M)	60,126	64,068	70,816	77,660	87,796	102,406	*11.2%*	
AGR	*1.7%*	*6.6%*	*10.5%*	*9.7%*	*13.1%*	*16.6%*		
Average Price ($)	525.05	541.62	573.05	603.43	647.41	683.27	*5.4%*	
AGR	*3.9%*	*3.2%*	*5.8%*	*5.3%*	*7.3%*	*5.5%*		
Installed Base (K)	516,885	528,887	531,428	551,818	577,641	601,156	*3.1%*	
AGR	*4.9%*	*2.3%*	*0.5%*	*3.8%*	*4.7%*	*4.1%*		
Installed Base Age (Y)	3.42	3.51	3.55	3.56	3.55	3.50	*0.4%*	
AGR	*3.8%*	*2.6%*	*1.1%*	*0.3%*	*-0.3%*	*-1.5%*		
Replacement Cycle Length (Y)	6.73	5.98	5.39	6.09	6.26	5.76	*-3.1%*	
AGR	*-1.9%*	*-11.2%*	*-9.8%*	*13.1%*	*2.7%*	*-8.0%*		
Units per Households and Businesses (#)	4.54	4.59	4.56	4.69	4.86	5.01	*2.0%*	
AGR	*3.7%*	*1.1%*	*-0.6%*	*2.7%*	*3.7%*	*3.1%*		
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**Change**	**Trend**
Market Penetration (%)	*85.9%*	*86.0%*	*86.0%*	*86.1%*	*86.1%*	*86.2%*	*0.1%*	
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Table 16: United States Consumer PCs and Tables								
	2016	2017	2018	2019	2020	2021	CAGR	Trend
Unit Shipments (K)	69,883	71,453	73,494	75,249	77,057	81,449	3.1%	
AGR	-5.7%	2.2%	2.9%	2.4%	2.4%	5.7%		
Revenue ($M)	31,757	34,548	39,419	45,249	53,041	63,849	15.0%	
AGR	-5.2%	8.8%	14.1%	14.8%	17.2%	20.4%		
Average Price ($)	454.44	483.50	536.35	601.32	688.33	783.91	11.5%	
AGR	0.5%	6.4%	10.9%	12.1%	14.5%	13.9%		
Installed Base (K)	308,316	311,210	307,735	315,828	323,620	327,325	1.2%	
AGR	4.0%	0.9%	-1.1%	2.6%	2.5%	1.1%		
Installed Base Age (Y)	3.32	3.45	3.51	3.53	3.53	3.50	1.0%	
AGR	5.8%	3.8%	1.8%	0.6%	0.0%	-0.9%		
Replacement Cycle Length (Y)	6.32	5.54	5.00	5.70	5.67	5.21	-3.8%	
AGR	-4.6%	-12.4%	-9.8%	14.1%	-0.5%	-8.1%		
Units per Households (#)	2.87	2.87	2.80	2.84	2.88	2.89	0.1%	
AGR	2.8%	-0.1%	-2.2%	1.5%	1.4%	0.1%		
	2016	2017	2018	2019	2020	2021	Change	Trend
Market Penetration (%)	85.4%	85.4%	85.5%	85.5%	85.6%	85.6%	0.1%	
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Table 17: United States Enterprise PCs and Tablets								
	2016	2017	2018	2019	2020	2021	CAGR	Trend
Unit Shipments (K)	44,632	46,836	50,083	53,448	58,553	68,427	8.9%	
AGR	4.0%	4.9%	6.9%	6.7%	9.6%	16.9%		
Revenue ($M)	28,369	29,520	31,397	32,411	34,755	38,558	6.3%	
AGR	10.8%	4.1%	6.4%	3.2%	7.2%	10.9%		
Average Price ($)	635.61	630.28	626.89	606.40	593.56	563.48	-2.4%	
AGR	6.6%	-0.8%	-0.5%	-3.3%	-2.1%	-5.1%		
Installed Base (K)	208,568	217,677	223,693	235,990	254,021	273,831	5.6%	
AGR	6.3%	4.4%	2.8%	5.5%	7.6%	7.8%		
Installed Base Age (Y)	3.61	3.63	3.62	3.61	3.59	3.50	-0.6%	
AGR	0.8%	0.6%	-0.2%	-0.4%	-0.7%	-2.3%		
Replacement Cycle Length (Y)	7.47	6.77	6.08	6.73	7.27	6.63	-2.3%	
AGR	2.8%	-9.3%	-10.2%	10.8%	7.9%	-8.8%		
Units per Businesses (#)	32.41	32.97	33.55	35.39	38.39	41.35	5.0%	
AGR	3.7%	1.7%	1.8%	5.5%	8.5%	7.7%		
	2016	2017	2018	2019	2020	2021	Change	Trend
Market Penetration (%)	94.8%	95.6%	96.3%	97.0%	97.5%	97.9%	0.6%	
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Table 18: United States Total Total PCs								
	2016	2017	2018	2019	2020	2021	CAGR	Trend
Unit Shipments (K)	64,738	63,807	62,814	60,162	57,529	56,546	-2.7%	
AGR	-0.6%	-1.4%	-1.6%	-4.2%	-4.4%	-1.7%		
Revenue ($M)	43,261	41,498	39,760	36,596	33,827	32,192	-5.7%	
AGR	2.7%	-4.1%	-4.2%	-8.0%	-7.6%	-4.8%		
Average Price ($)	668.25	650.37	632.98	608.29	587.99	569.31	-3.2%	
AGR	3.4%	-2.7%	-2.7%	-3.9%	-3.3%	-3.2%		
Installed Base (K)	346,394	348,243	342,626	342,667	344,812	340,555	-0.3%	
AGR	2.9%	0.5%	-1.6%	0.0%	0.6%	-1.2%		
Installed Base Age (Y)	3.89	3.94	3.97	4.02	4.09	4.15	1.3%	
AGR	1.6%	1.3%	0.7%	1.3%	1.9%	1.3%		
Replacement Cycle Length (Y)	7.30	6.62	6.01	6.70	7.23	6.60	-2.0%	
AGR	-0.3%	-9.2%	-9.3%	11.5%	7.9%	-8.6%		
Units per Households and Businesses (#)	3.25	3.18	3.04	2.97	2.92	2.82	-2.8%	
AGR	1.1%	-2.3%	-4.2%	-2.5%	-1.7%	-3.4%		
	2016	2017	2018	2019	2020	2021	Change	Trend
Market Penetration (%)	80.3%	81.7%	83.1%	84.4%	85.6%	86.8%	1.6%	
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Table 19: United States Consumer Total PCs								
	2016	2017	2018	2019	2020	2021	CAGR	Trend
Unit Shipments (K)	25,053	23,302	21,840	20,065	18,407	17,340	-7.1%	
AGR	-9.4%	-7.0%	-6.3%	-8.1%	-8.3%	-5.8%		
Revenue ($M)	17,518	15,599	13,999	12,480	11,035	10,155	-10.3%	
AGR	-7.4%	-11.0%	-10.3%	-10.9%	-11.6%	-8.0%		
Average Price ($)	699.26	669.40	641.01	621.98	599.50	585.63	-3.5%	
AGR	2.2%	-4.3%	-4.2%	-3.0%	-3.6%	-2.3%		
Installed Base (K)	156,097	150,269	141,697	136,020	131,376	124,653	-4.4%	
AGR	-1.1%	-3.7%	-5.7%	-4.0%	-3.4%	-5.1%		
Installed Base Age (Y)	4.07	4.19	4.27	4.36	4.45	4.52	2.1%	
AGR	3.9%	3.0%	2.0%	2.0%	2.2%	1.5%		
Replacement Cycle Length (Y)	6.83	6.16	5.66	6.28	6.70	6.18	-2.0%	
AGR	-6.1%	-9.9%	-8.1%	11.0%	6.6%	-7.7%		
Units per Households (#)	1.55	1.45	1.33	1.24	1.17	1.08	-6.8%	
AGR	-2.7%	-6.4%	-8.3%	-6.5%	-5.8%	-7.3%		
	2016	2017	2018	2019	2020	2021	Change	Trend
Market Penetration (%)	80.3%	81.7%	83.1%	84.4%	85.6%	86.8%	1.6%	
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Table 20: United States Enterprise Total PCs								
	2016	2017	2018	2019	2020	2021	CAGR	Trend
Unit Shipments (K)	39,685	40,504	40,975	40,097	39,122	39,205	-0.2%	
AGR	*5.9%*	*2.1%*	*1.2%*	*-2.1%*	*-2.4%*	*0.2%*		
Revenue ($M)	25,743	25,900	25,761	24,116	22,792	22,037	-3.1%	
AGR	*11.0%*	*0.6%*	*-0.5%*	*-6.4%*	*-5.5%*	*-3.3%*		
Average Price ($)	648.68	639.43	628.70	601.43	582.58	562.10	-2.8%	
AGR	*4.9%*	*-1.4%*	*-1.7%*	*-4.3%*	*-3.1%*	*-3.5%*		
Installed Base (K)	190,297	197,973	200,929	206,647	213,436	215,902	2.6%	
AGR	*6.4%*	*4.0%*	*1.5%*	*2.8%*	*3.3%*	*1.2%*		
Installed Base Age (Y)	3.74	3.75	3.75	3.80	3.88	3.94	1.0%	
AGR	*-0.2%*	*0.1%*	*0.2%*	*1.2%*	*2.0%*	*1.6%*		
Replacement Cycle Length (Y)	7.73	7.03	6.28	7.01	7.60	6.88	-2.3%	
AGR	*5.1%*	*-9.1%*	*-10.6%*	*11.5%*	*8.4%*	*-9.5%*		
Units per Businesses (#)	34.91	35.08	34.93	35.60	36.72	36.79	1.1%	
AGR	*4.2%*	*0.5%*	*-0.4%*	*1.9%*	*3.1%*	*0.2%*		
	2016	2017	2018	2019	2020	2021	Change	Trend
Market Penetration (%)	*80.3%*	*81.7%*	*83.1%*	*84.4%*	*85.6%*	*86.8%*	*1.6%*	
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Table 21: United States Total Desktop PCs								
	2016	2017	2018	2019	2020	2021	CAGR	Trend
Unit Shipments (K)	18,542	17,771	17,148	16,198	15,265	14,752	-4.5%	
AGR	*-8.2%*	*-4.2%*	*-3.5%*	*-5.5%*	*-5.8%*	*-3.4%*		
Revenue ($M)	10,967	10,163	9,424	8,500	7,579	6,992	-8.6%	
AGR	*-3.5%*	*-7.3%*	*-7.3%*	*-9.8%*	*-10.8%*	*-7.7%*		
Average Price ($)	591.49	571.91	549.57	524.77	496.52	473.99	-4.3%	
AGR	*5.1%*	*-3.3%*	*-3.9%*	*-4.5%*	*-5.4%*	*-4.5%*		
Installed Base (K)	124,262	117,349	108,739	102,803	98,733	93,144	-5.6%	
AGR	*-3.4%*	*-5.6%*	*-7.3%*	*-5.5%*	*-4.0%*	*-5.7%*		
Installed Base Age (Y)	4.24	4.30	4.32	4.34	4.36	4.35	0.5%	
AGR	*2.3%*	*1.5%*	*0.5%*	*0.4%*	*0.5%*	*-0.3%*		
Replacement Cycle Length (Y)	6.42	5.75	5.22	5.64	6.11	5.58	-2.8%	
AGR	*-1.6%*	*-10.4%*	*-9.2%*	*8.1%*	*8.2%*	*-8.6%*		
Units per Households and Businesses (#)	4.00	4.02	3.98	4.02	4.13	4.18	0.9%	
AGR	*2.5%*	*0.4%*	*-1.2%*	*1.1%*	*2.9%*	*1.2%*		
	2016	2017	2018	2019	2020	2021	Change	Trend
Market Penetration (%)	*23.4%*	*21.8%*	*20.2%*	*18.7%*	*17.3%*	*16.0%*	*-7.3%*	
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Table 22: United States Consumer Desktop PCs								
	2016	2017	2018	2019	2020	2021	CAGR	Trend
Unit Shipments (K)	5,119	5,236	5,382	5,383	5,367	5,461	1.3%	
AGR	*-11.6%*	*2.3%*	*2.8%*	*0.0%*	*-0.3%*	*1.8%*		
Revenue ($M)	2,815	2,835	2,864	2,766	2,688	2,687	-0.9%	
AGR	*-13.3%*	*0.7%*	*1.0%*	*-3.4%*	*-2.8%*	*-0.1%*		
Average Price ($)	549.82	541.51	532.25	513.84	500.94	491.95	-2.2%	
AGR	*-1.8%*	*-1.5%*	*-1.7%*	*-3.5%*	*-2.5%*	*-1.8%*		
Installed Base (K)	37,917	35,186	32,700	31,139	30,299	29,523	-4.9%	
AGR	*-7.0%*	*-7.2%*	*-7.1%*	*-4.8%*	*-2.7%*	*-2.6%*		
Installed Base Age (Y)	4.41	4.44	4.40	4.32	4.24	4.14	-1.2%	
AGR	*2.6%*	*0.8%*	*-1.0%*	*-1.7%*	*-1.9%*	*-2.4%*		
Replacement Cycle Length (Y)	5.75	5.42	5.16	5.48	5.88	5.73	0.0%	
AGR	*-8.2%*	*-5.7%*	*-4.8%*	*6.4%*	*7.2%*	*-2.5%*		
Units per Households (#)	1.36	1.34	1.32	1.34	1.38	1.44	1.1%	
AGR	*-1.6%*	*-1.6%*	*-1.4%*	*1.2%*	*3.5%*	*3.8%*		
	2016	2017	2018	2019	2020	2021	Change	Trend
Market Penetration (%)	*22.1%*	*20.7%*	*19.3%*	*18.0%*	*16.7%*	*15.5%*	-6.9%	
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Table 23: United States Enterprise Desktop PCs								
	2016	2017	2018	2019	2020	2021	CAGR	Trend
Unit Shipments (K)	13,422	12,535	11,766	10,816	9,898	9,291	-7.1%	
AGR	*-6.8%*	*-6.6%*	*-6.1%*	*-8.1%*	*-8.5%*	*-6.1%*		
Revenue ($M)	8,152	7,328	6,559	5,735	4,891	4,306	-12.0%	
AGR	*0.4%*	*-10.1%*	*-10.5%*	*-12.6%*	*-14.7%*	*-12.0%*		
Average Price ($)	607.38	584.61	557.50	530.21	494.13	463.44	-5.3%	
AGR	*7.7%*	*-3.7%*	*-4.6%*	*-4.9%*	*-6.8%*	*-6.2%*		
Installed Base (K)	86,345	82,163	76,040	71,664	68,434	63,621	-5.9%	
AGR	*-1.7%*	*-4.8%*	*-7.5%*	*-5.8%*	*-4.5%*	*-7.0%*		
Installed Base Age (Y)	4.16	4.24	4.29	4.35	4.42	4.45	1.4%	
AGR	*2.2%*	*1.9%*	*1.2%*	*1.3%*	*1.6%*	*0.8%*		
Replacement Cycle Length (Y)	6.78	5.91	5.25	5.72	6.21	5.51	-4.1%	
AGR	*1.9%*	*-12.8%*	*-11.2%*	*8.9%*	*8.7%*	*-11.3%*		
Units per Businesses (#)	27.30	28.42	29.44	31.60	34.87	37.39	6.5%	
AGR	*6.3%*	*4.1%*	*3.6%*	*7.3%*	*10.4%*	*7.2%*		
	2016	2017	2018	2019	2020	2021	Change	Trend
Market Penetration (%)	*46.6%*	*41.9%*	*37.3%*	*33.0%*	*28.9%*	*25.1%*	-11.6%	
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Table 24: United States Total Mobile PCs								
	2016	2017	2018	2019	2020	2021	CAGR	Trend
Unit Shipments (K)	46,196	46,036	45,666	43,964	42,264	41,794	-2.0%	
AGR	*2.8%*	*-0.3%*	*-0.8%*	*-3.7%*	*-3.9%*	*-1.1%*		
Revenue ($M)	32,294	31,335	30,336	28,096	26,247	25,200	-4.8%	
AGR	*5.0%*	*-3.0%*	*-3.2%*	*-7.4%*	*-6.6%*	*-4.0%*		
Average Price ($)	699.07	680.66	664.30	639.06	621.03	602.96	-2.9%	
AGR	*2.2%*	*-2.6%*	*-2.4%*	*-3.8%*	*-2.8%*	*-2.9%*		
Installed Base (K)	222,131	230,894	233,887	239,864	246,079	247,411	2.2%	
AGR	*6.8%*	*3.9%*	*1.3%*	*2.6%*	*2.6%*	*0.5%*		
Installed Base Age (Y)	3.69	3.75	3.80	3.88	3.98	4.06	1.9%	
AGR	*1.7%*	*1.6%*	*1.3%*	*2.0%*	*2.7%*	*2.1%*		
Replacement Cycle Length (Y)	7.92	7.19	6.48	7.31	7.83	7.11	-2.1%	
AGR	*-0.2%*	*-9.1%*	*-9.9%*	*12.9%*	*7.0%*	*-9.1%*		
Units per Households and Businesses (#)	2.38	2.40	2.51	2.66	2.84	2.98	4.6%	
AGR	*2.3%*	*0.9%*	*4.4%*	*6.2%*	*6.7%*	*5.1%*		
	2016	2017	2018	2019	2020	2021	Change	Trend
Market Penetration (%)	*70.4%*	*71.7%*	*68.9%*	*65.9%*	*62.8%*	*59.5%*	-3.3%	
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Table 25: United States Consumer Mobile PCs								
	2016	2017	2018	2019	2020	2021	CAGR	Trend
Unit Shipments (K)	19,933	18,066	16,458	14,683	13,041	11,879	-9.8%	
AGR	*-8.8%*	*-9.4%*	*-8.9%*	*-10.8%*	*-11.2%*	*-8.9%*		
Revenue ($M)	14,703	12,763	11,135	9,714	8,347	7,468	-12.7%	
AGR	*-6.2%*	*-13.2%*	*-12.8%*	*-12.8%*	*-14.1%*	*-10.5%*		
Average Price ($)	737.64	706.47	676.57	661.62	640.05	628.69	-3.1%	
AGR	*2.8%*	*-4.2%*	*-4.2%*	*-2.2%*	*-3.3%*	*-1.8%*		
Installed Base (K)	118,179	115,084	108,997	104,882	101,077	95,130	-4.2%	
AGR	*1.0%*	*-2.6%*	*-5.3%*	*-3.8%*	*-3.6%*	*-5.9%*		
Installed Base Age (Y)	3.95	4.11	4.23	4.37	4.52	4.64	3.3%	
AGR	*4.6%*	*3.9%*	*3.0%*	*3.2%*	*3.5%*	*2.8%*		
Replacement Cycle Length (Y)	7.30	6.44	5.83	6.58	7.00	6.34	-2.8%	
AGR	*-5.7%*	*-11.8%*	*-9.4%*	*12.8%*	*6.4%*	*-9.5%*		
Units per Households (#)	1.34	1.27	1.24	1.23	1.24	1.22	-1.8%	
AGR	*-3.2%*	*-5.4%*	*-2.3%*	*-0.3%*	*0.4%*	*-1.5%*		
	2016	2017	2018	2019	2020	2021	Change	Trend
Market Penetration (%)	*70.2%*	*71.5%*	*68.6%*	*65.5%*	*62.2%*	*58.9%*	-3.5%	
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Table 26: United States Enterprise Mobile PCs								
	2016	2017	2018	2019	2020	2021	CAGR	Trend
Unit Shipments (K)	26,263	27,969	29,209	29,282	29,224	29,915	2.6%	
AGR	*13.8%*	*6.5%*	*4.4%*	*0.2%*	*-0.2%*	*2.4%*		
Revenue ($M)	17,590	18,571	19,201	18,381	17,901	17,731	0.2%	
AGR	*16.7%*	*5.6%*	*3.4%*	*-4.3%*	*-2.6%*	*-0.9%*		
Average Price ($)	669.79	663.99	657.38	627.74	612.53	592.74	-2.4%	
AGR	*2.6%*	*-0.9%*	*-1.0%*	*-4.5%*	*-2.4%*	*-3.2%*		
Installed Base (K)	103,952	115,811	124,889	134,982	145,002	152,281	7.9%	
AGR	*14.2%*	*11.4%*	*7.8%*	*8.1%*	*7.4%*	*5.0%*		
Installed Base Age (Y)	3.39	3.39	3.42	3.50	3.62	3.72	1.8%	
AGR	*-1.3%*	*0.0%*	*0.8%*	*2.3%*	*3.3%*	*2.8%*		
Replacement Cycle Length (Y)	8.79	8.19	7.20	8.03	8.55	7.73	-2.6%	
AGR	*7.1%*	*-6.9%*	*-12.0%*	*11.5%*	*6.4%*	*-9.6%*		
Units per Businesses (#)	20.99	22.31	24.20	26.55	29.14	30.99	8.1%	
AGR	*8.0%*	*6.3%*	*8.5%*	*9.7%*	*9.8%*	*6.4%*		
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**Change**	**Trend**
Market Penetration (%)	*72.9%*	*75.2%*	*74.6%*	*73.9%*	*73.3%*	*72.6%*	*-0.1%*	
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Table 27: United States Total Tablets								
	2016	2017	2018	2019	2020	2021	CAGR	Trend
Unit Shipments (K)	49,778	54,482	60,763	68,535	78,081	93,331	13.4%	
AGR	*-4.0%*	*9.5%*	*11.5%*	*12.8%*	*13.9%*	*19.5%*		
Revenue ($M)	16,865	22,570	31,055	41,064	53,969	70,214	33.0%	
AGR	*-0.7%*	*33.8%*	*37.6%*	*32.2%*	*31.4%*	*30.1%*		
Average Price ($)	338.81	414.26	511.09	599.17	691.19	752.32	17.3%	
AGR	*3.4%*	*22.3%*	*23.4%*	*17.2%*	*15.4%*	*8.8%*		
Installed Base (K)	170,491	180,644	188,802	209,151	232,829	260,601	8.9%	
AGR	*9.4%*	*6.0%*	*4.5%*	*10.8%*	*11.3%*	*11.9%*		
Installed Base Age (Y)	2.81	2.99	3.06	3.04	2.99	2.91	0.7%	
AGR	*11.7%*	*6.5%*	*2.3%*	*-0.7%*	*-1.6%*	*-2.6%*		
Replacement Cycle Length (Y)	5.85	5.08	4.59	5.34	5.28	4.98	-3.2%	
AGR	*-3.7%*	*-13.2%*	*-9.6%*	*16.4%*	*-1.1%*	*-5.8%*		
Units per Households and Businesses (#)	2.05	1.93	1.83	1.88	1.96	2.09	0.4%	
AGR	*-2.8%*	*-5.7%*	*-5.1%*	*2.4%*	*4.5%*	*6.5%*		
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**Change**	**Trend**
Market Penetration (%)	*62.8%*	*69.8%*	*76.1%*	*81.5%*	*86.1%*	*89.7%*	*7.4%*	
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Table 28: United States Consumer Tablets								
	2016	2017	2018	2019	2020	2021	CAGR	Trend
Unit Shipments (K)	44,830	48,151	51,655	55,184	58,649	64,109	*7.4%*	
AGR	*-3.4%*	*7.4%*	*7.3%*	*6.8%*	*6.3%*	*9.3%*		
Revenue ($M)	14,239	18,949	25,420	32,769	42,006	53,694	*30.4%*	
AGR	*-2.3%*	*33.1%*	*34.1%*	*28.9%*	*28.2%*	*27.8%*		
Average Price ($)	317.62	393.54	492.11	593.80	716.22	837.55	*21.4%*	
AGR	*1.1%*	*23.9%*	*25.0%*	*20.7%*	*20.6%*	*16.9%*		
Installed Base (K)	152,220	160,940	166,038	179,808	192,244	202,672	*5.9%*	
AGR	*9.8%*	*5.7%*	*3.2%*	*8.3%*	*6.9%*	*5.4%*		
Installed Base Age (Y)	2.81	2.99	3.09	3.10	3.11	3.09	*1.9%*	
AGR	*11.1%*	*6.5%*	*3.1%*	*0.6%*	*0.1%*	*-0.6%*		
Replacement Cycle Length (Y)	5.88	5.08	4.57	5.34	5.16	4.78	*-4.1%*	
AGR	*-2.4%*	*-13.6%*	*-10.1%*	*17.0%*	*-3.4%*	*-7.5%*		
Units per Households (#)	1.85	1.75	1.65	1.66	1.67	1.69	*-1.8%*	
AGR	*-2.5%*	*-5.5%*	*-5.8%*	*0.7%*	*0.9%*	*0.8%*		
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**Change**	**Trend**
Market Penetration (%)	*65.4%*	*72.4%*	*78.5%*	*83.5%*	*87.5%*	*90.7%*	*6.8%*	
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Table 29: United States Enterprise Tablets								
	2016	2017	2018	2019	2020	2021	CAGR	Trend
Unit Shipments (K)	4,948	6,331	9,109	13,351	19,432	29,222	*42.6%*	
AGR	*-8.9%*	*28.0%*	*43.9%*	*46.6%*	*45.5%*	*50.4%*		
Revenue ($M)	2,626	3,620	5,636	8,295	11,963	16,520	*44.5%*	
AGR	*9.1%*	*37.9%*	*55.7%*	*47.2%*	*44.2%*	*38.1%*		
Average Price ($)	530.78	571.81	618.73	621.33	615.66	565.34	*1.3%*	
AGR	*19.7%*	*7.7%*	*8.2%*	*0.4%*	*-0.9%*	*-8.2%*		
Installed Base (K)	18,271	19,704	22,764	29,343	40,585	57,929	*26.0%*	
AGR	*5.6%*	*7.8%*	*15.5%*	*28.9%*	*38.3%*	*42.7%*		
Installed Base Age (Y)	2.79	2.95	2.86	2.63	2.42	2.28	*-4.0%*	
AGR	*16.7%*	*6.1%*	*-3.1%*	*-8.2%*	*-8.0%*	*-6.0%*		
Replacement Cycle Length (Y)	5.59	5.02	4.76	5.33	5.96	5.88	*1.0%*	
AGR	*-13.4%*	*-10.1%*	*-5.2%*	*12.0%*	*11.7%*	*-1.3%*		
Units per Businesses (#)	18.80	13.00	10.23	9.61	10.43	12.35	*-8.1%*	
AGR	*1.8%*	*-30.9%*	*-21.3%*	*-6.0%*	*8.4%*	*18.4%*		
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**Change**	**Trend**
Market Penetration (%)	*14.3%*	*22.0%*	*32.1%*	*44.4%*	*57.3%*	*69.4%*	*37.1%*	
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Table 30: United States Total Slate Tablets								
	2016	2017	2018	2019	2020	2021	CAGR	Trend
Unit Shipments (K)	40,810	37,573	34,092	29,980	25,835	23,349	-10.6%	
AGR	-9.8%	-7.9%	-9.3%	-12.1%	-13.8%	-9.6%		
Revenue ($M)	9,846	8,196	6,832	5,493	4,332	3,738	-17.6%	
AGR	-20.8%	-16.8%	-16.6%	-19.6%	-21.1%	-13.7%		
Average Price ($)	241.28	218.13	200.41	183.23	167.66	160.10	-7.9%	
AGR	-12.3%	-9.6%	-8.1%	-8.6%	-8.5%	-4.5%		
Installed Base (K)	154,629	153,413	144,674	140,325	130,802	117,884	-5.3%	
AGR	5.8%	-0.8%	-5.7%	-3.0%	-6.8%	-9.9%		
Installed Base Age (Y)	2.90	3.19	3.41	3.58	3.74	3.84	5.8%	
AGR	13.3%	9.9%	7.0%	5.1%	4.3%	2.8%		
Replacement Cycle Length (Y)	5.79	4.96	4.38	5.09	4.70	4.25	-6.0%	
AGR	-4.8%	-14.4%	-11.7%	16.2%	-7.6%	-9.6%		
Units per Households and Businesses (#)	3.07	3.52	3.49	3.57	3.53	3.39	2.0%	
AGR	19.4%	14.4%	-0.6%	2.3%	-1.1%	-3.9%		
	2016	2017	2018	2019	2020	2021	Change	Trend
Market Penetration (%)	38.0%	32.6%	30.6%	28.7%	26.8%	24.9%	-8.1%	
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Table 31: United States Consumer Slate Tablets								
	2016	2017	2018	2019	2020	2021	CAGR	Trend
Unit Shipments (K)	36,739	33,092	28,970	24,830	20,931	18,038	-13.3%	
AGR	-8.9%	-9.9%	-12.5%	-14.3%	-15.7%	-13.8%		
Revenue ($M)	8,104	6,413	4,914	3,666	2,677	2,011	-24.3%	
AGR	-23.1%	-20.9%	-23.4%	-25.4%	-27.0%	-24.9%		
Average Price ($)	220.59	193.80	169.62	147.65	127.91	111.50	-12.8%	
AGR	-15.5%	-12.1%	-12.5%	-13.0%	-13.4%	-12.8%		
Installed Base (K)	137,993	136,641	127,649	122,772	112,700	99,277	-6.4%	
AGR	6.3%	-1.0%	-6.6%	-3.8%	-8.2%	-11.9%		
Installed Base Age (Y)	2.91	3.19	3.43	3.63	3.81	3.95	6.3%	
AGR	12.7%	9.9%	7.6%	5.8%	4.9%	3.6%		
Replacement Cycle Length (Y)	5.83	4.97	4.36	5.13	4.63	4.16	-6.5%	
AGR	-3.5%	-14.7%	-12.2%	17.7%	-9.7%	-10.3%		
Units per Households (#)	2.80	3.22	3.19	3.26	3.18	3.00	1.4%	
AGR	20.5%	15.0%	-0.9%	2.2%	-2.2%	-5.9%		
	2016	2017	2018	2019	2020	2021	Change	Trend
Market Penetration (%)	39.2%	33.4%	31.2%	29.0%	27.0%	25.0%	-8.6%	
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Table 32: United States Enterprise Slate Tablets								
	2016	2017	2018	2019	2020	2021	CAGR	Trend
Unit Shipments (K)	4,070	4,481	5,122	5,150	4,903	5,311	5.5%	
AGR	*-16.5%*	*10.1%*	*14.3%*	*0.5%*	*-4.8%*	*8.3%*		
Revenue ($M)	1,742	1,783	1,918	1,827	1,654	1,727	-0.2%	
AGR	*-8.4%*	*2.3%*	*7.6%*	*-4.8%*	*-9.5%*	*4.4%*		
Average Price ($)	428.01	397.87	374.53	354.79	337.37	325.16	-5.3%	
AGR	*9.7%*	*-7.0%*	*-5.9%*	*-5.3%*	*-4.9%*	*-3.6%*		
Installed Base (K)	16,636	16,773	17,025	17,553	18,103	18,607	2.3%	
AGR	*2.3%*	*0.8%*	*1.5%*	*3.1%*	*3.1%*	*2.8%*		
Installed Base Age (Y)	2.86	3.13	3.23	3.25	3.28	3.26	2.7%	
AGR	*18.3%*	*9.6%*	*2.9%*	*0.8%*	*1.0%*	*-0.6%*		
Replacement Cycle Length (Y)	5.50	4.86	4.50	4.80	5.16	4.87	-2.4%	
AGR	*-14.6%*	*-11.7%*	*-7.5%*	*6.7%*	*7.5%*	*-5.6%*		
Units per Businesses (#)	16.70	14.56	12.83	11.25	11.07	11.57	-7.1%	
AGR	*-9.9%*	*-12.8%*	*-11.9%*	*-12.4%*	*-1.5%*	*4.4%*		
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**Change**	**Trend**
Market Penetration (%)	*14.7%*	*16.7%*	*19.2%*	*22.7%*	*24.1%*	*23.8%*	*10.1%*	
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Table 33: United States Total Detachable Tablets								
	2016	2017	2018	2019	2020	2021	CAGR	Trend
Unit Shipments (K)	8,968	16,910	26,671	38,556	52,246	69,981	50.8%	
AGR	*35.3%*	*88.6%*	*57.7%*	*44.6%*	*35.5%*	*33.9%*		
Revenue ($M)	7,019	14,374	24,223	35,571	49,638	66,476	56.8%	
AGR	*54.2%*	*104.8%*	*68.5%*	*46.8%*	*39.5%*	*33.9%*		
Average Price ($)	782.62	850.03	908.21	922.59	950.07	949.91	4.0%	
AGR	*14.0%*	*8.6%*	*6.8%*	*1.6%*	*3.0%*	*0.0%*		
Installed Base (K)	15,862	27,231	44,128	68,826	102,026	142,717	55.2%	
AGR	*62.2%*	*71.7%*	*62.1%*	*56.0%*	*48.2%*	*39.9%*		
Installed Base Age (Y)	1.92	1.90	1.92	1.98	2.08	2.17	2.4%	
AGR	*4.4%*	*-1.5%*	*1.4%*	*3.2%*	*4.7%*	*4.6%*		
Replacement Cycle Length (Y)	6.50	5.91	5.51	5.97	6.36	5.87	-2.0%	
AGR	*9.3%*	*-9.0%*	*-6.8%*	*8.2%*	*6.5%*	*-7.6%*		
Units per Households and Businesses (#)	1.10	1.10	1.12	1.16	1.22	1.31	3.5%	
AGR	*-5.9%*	*-0.2%*	*1.4%*	*3.6%*	*5.4%*	*7.5%*		
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**Change**	**Trend**
Market Penetration (%)	*10.9%*	*18.5%*	*29.2%*	*43.6%*	*60.7%*	*78.3%*	*48.5%*	
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Table 34: United States Consumer Detachable Tablets								
	2016	2017	2018	2019	2020	2021	CAGR	Trend
Unit Shipments (K)	8,091	15,059	22,685	30,354	37,718	46,070	*41.6%*	
AGR	*33.2%*	*86.1%*	*50.6%*	*33.8%*	*24.3%*	*22.1%*		
Revenue ($M)	6,135	12,536	20,506	29,103	39,328	51,683	*53.1%*	
AGR	*51.6%*	*104.4%*	*63.6%*	*41.9%*	*35.1%*	*31.4%*		
Average Price ($)	758.23	832.46	903.94	958.76	1,042.70	1,121.82	*8.1%*	
AGR	*13.8%*	*9.8%*	*8.6%*	*6.1%*	*8.8%*	*7.6%*		
Installed Base (K)	14,227	24,299	38,389	57,036	79,545	103,395	*48.7%*	
AGR	*62.9%*	*70.8%*	*58.0%*	*48.6%*	*39.5%*	*30.0%*		
Installed Base Age (Y)	1.91	1.89	1.94	2.04	2.17	2.30	*3.8%*	
AGR	*4.5%*	*-1.1%*	*2.6%*	*5.0%*	*6.3%*	*6.2%*		
Replacement Cycle Length (Y)	6.48	5.87	5.47	5.87	6.23	5.65	*-2.7%*	
AGR	*10.3%*	*-9.3%*	*-6.9%*	*7.4%*	*6.1%*	*-9.3%*		
Units per Households (#)	1.00	1.00	1.00	1.00	1.00	1.00		
AGR	*-5.1%*							
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**Change**	**Trend**
Market Penetration (%)	*11.3%*	*19.1%*	*29.9%*	*43.9%*	*60.6%*	*78.0%*	*47.2%*	
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Table 35: United States Enterprise Detachable Tablets								
	2016	2017	2018	2019	2020	2021	CAGR	Trend
Unit Shipments (K)	877	1,851	3,986	8,201	14,528	23,911	*93.7%*	
AGR	*58.0%*	*110.9%*	*115.4%*	*105.7%*	*77.1%*	*64.6%*		
Revenue ($M)	884	1,838	3,717	6,468	10,309	14,794	*75.7%*	
AGR	*75.0%*	*107.9%*	*102.3%*	*74.0%*	*59.4%*	*43.5%*		
Average Price ($)	1,007.57	992.95	932.51	788.70	709.59	618.69	*-9.3%*	
AGR	*10.8%*	*-1.5%*	*-6.1%*	*-15.4%*	*-10.0%*	*-12.8%*		
Installed Base (K)	1,635	2,931	5,739	11,791	22,482	39,322	*88.9%*	
AGR	*56.4%*	*79.2%*	*95.8%*	*105.5%*	*90.7%*	*74.9%*		
Installed Base Age (Y)	2.02	1.91	1.77	1.70	1.74	1.82	*-2.1%*	
AGR	*4.5%*	*-5.5%*	*-6.9%*	*-4.1%*	*2.1%*	*4.6%*		
Replacement Cycle Length (Y)	6.69	6.28	5.87	6.49	6.86	6.56	*-0.4%*	
AGR	*0.1%*	*-6.1%*	*-6.6%*	*10.5%*	*5.8%*	*-4.3%*		
Units per Businesses (#)	10.00	6.41	4.90	4.65	5.28	7.02	*-6.8%*	
AGR	*-42.4%*	*-35.9%*	*-23.6%*	*-5.2%*	*13.7%*	*32.8%*		
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**Change**	**Trend**
Market Penetration (%)	*2.4%*	*6.6%*	*16.9%*	*36.9%*	*62.7%*	*82.8%*	*102.9%*	
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Table 36: United States Total Mobile PCs and Tablets								
	2016	2017	2018	2019	2020	2021	CAGR	Trend
Unit Shipments (K)	95,973	100,518	106,430	112,499	120,345	135,124	7.1%	
AGR	*-0.8%*	*4.7%*	*5.9%*	*5.7%*	*7.0%*	*12.3%*		
Revenue ($M)	49,159	53,905	61,392	69,160	80,216	95,414	14.2%	
AGR	*3.0%*	*9.7%*	*13.9%*	*12.7%*	*16.0%*	*18.9%*		
Average Price ($)	512.21	536.27	576.83	614.76	666.55	706.12	6.6%	
AGR	*3.9%*	*4.7%*	*7.6%*	*6.6%*	*8.4%*	*5.9%*		
Installed Base (K)	392,622	411,538	422,688	449,015	478,908	508,012	5.3%	
AGR	*7.9%*	*4.8%*	*2.7%*	*6.2%*	*6.7%*	*6.1%*		
Installed Base Age (Y)	3.16	3.29	3.36	3.38	3.38	3.34	1.1%	
AGR	*6.0%*	*4.2%*	*2.2%*	*0.6%*	*0.0%*	*-1.3%*		
Replacement Cycle Length (Y)	6.84	6.04	5.44	6.21	6.29	5.79	-3.3%	
AGR	*-2.2%*	*-11.6%*	*-10.0%*	*14.2%*	*1.4%*	*-8.0%*		
Units per Households and Businesses (#)	3.63	3.63	3.58	3.67	3.80	3.92	1.6%	
AGR	*3.2%*	*-0.1%*	*-1.4%*	*2.5%*	*3.5%*	*3.3%*		
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**Change**	**Trend**
Market Penetration (%)	*81.6%*	*84.6%*	*87.3%*	*89.6%*	*91.4%*	*93.0%*	2.7%	
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Table 37: United States Consumer Mobile PCs and Tablets								
	2016	2017	2018	2019	2020	2021	CAGR	Trend
Unit Shipments (K)	64,763	66,218	68,112	69,867	71,690	75,988	3.2%	
AGR	*-5.1%*	*2.2%*	*2.9%*	*2.6%*	*2.6%*	*6.0%*		
Revenue ($M)	28,942	31,713	36,554	42,483	50,352	61,162	16.1%	
AGR	*-4.3%*	*9.6%*	*15.3%*	*16.2%*	*18.5%*	*21.5%*		
Average Price ($)	446.90	478.92	536.68	608.06	702.36	804.90	12.5%	
AGR	*0.9%*	*7.2%*	*12.1%*	*13.3%*	*15.5%*	*14.6%*		
Installed Base (K)	270,399	276,024	275,035	284,690	293,321	297,802	1.9%	
AGR	*5.8%*	*2.1%*	*-0.4%*	*3.5%*	*3.0%*	*1.5%*		
Installed Base Age (Y)	3.13	3.30	3.39	3.42	3.42	3.40	1.6%	
AGR	*7.8%*	*5.3%*	*2.9%*	*0.7%*	*0.2%*	*-0.7%*		
Replacement Cycle Length (Y)	6.41	5.56	4.98	5.73	5.65	5.16	-4.2%	
AGR	*-4.1%*	*-13.4%*	*-10.4%*	*15.0%*	*-1.3%*	*-8.6%*		
Units per Households (#)	2.64	2.57	2.46	2.45	2.45	2.42	-1.8%	
AGR	*1.2%*	*-2.7%*	*-4.5%*	*-0.2%*	*-0.2%*	*-1.2%*		
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**Change**	**Trend**
Market Penetration (%)	*81.3%*	*84.4%*	*87.1%*	*89.4%*	*91.3%*	*92.9%*	2.7%	
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Table 38: United States Enterprise Mobile PCs and Tablets								
	2016	2017	2018	2019	2020	2021	CAGR	Trend
Unit Shipments (K)	31,210	34,301	38,317	42,632	48,655	59,137	*13.6%*	
AGR	*9.4%*	*9.9%*	*11.7%*	*11.3%*	*14.1%*	*21.5%*		
Revenue ($M)	20,216	22,192	24,837	26,677	29,864	34,252	*11.1%*	
AGR	*15.7%*	*9.8%*	*11.9%*	*7.4%*	*11.9%*	*14.7%*		
Average Price ($)	647.75	646.98	648.19	625.73	613.78	579.20	*-2.2%*	
AGR	*5.7%*	*-0.1%*	*0.2%*	*-3.5%*	*-1.9%*	*-5.6%*		
Installed Base (K)	122,223	135,515	147,653	164,326	185,587	210,210	*11.5%*	
AGR	*12.8%*	*10.9%*	*9.0%*	*11.3%*	*12.9%*	*13.3%*		
Installed Base Age (Y)	3.24	3.28	3.30	3.30	3.30	3.23	*-0.1%*	
AGR	*1.2%*	*1.2%*	*0.5%*	*0.2%*	*-0.2%*	*-1.8%*		
Replacement Cycle Length (Y)	8.06	7.45	6.64	7.33	7.77	7.09	*-2.5%*	
AGR	*2.5%*	*-7.5%*	*-10.9%*	*10.4%*	*6.1%*	*-8.8%*		
Units per Businesses (#)	20.86	22.11	23.49	25.81	29.08	32.65	*9.4%*	
AGR	*8.3%*	*6.0%*	*6.2%*	*9.9%*	*12.7%*	*12.3%*		
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**Change**	**Trend**
Market Penetration (%)	*86.3%*	*88.8%*	*90.8%*	*92.6%*	*94.0%*	*95.2%*	*2.0%*	
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Table 39: United States Total Mobile PCs and Tablets Detachable								
	2016	2017	2018	2019	2020	2021	CAGR	Trend
Unit Shipments (K)	55,164	62,946	72,338	82,520	94,511	111,775	*15.2%*	
AGR	*7.0%*	*14.1%*	*14.9%*	*14.1%*	*14.5%*	*18.3%*		
Revenue ($M)	39,312	45,709	54,559	63,666	75,885	91,676	*18.5%*	
AGR	*11.4%*	*16.3%*	*19.4%*	*16.7%*	*19.2%*	*20.8%*		
Average Price ($)	712.65	726.16	754.23	771.53	802.92	820.18	*2.9%*	
AGR	*4.1%*	*1.9%*	*3.9%*	*2.3%*	*4.1%*	*2.1%*		
Installed Base (K)	237,993	258,125	278,015	308,690	348,106	390,128	*10.4%*	
AGR	*9.3%*	*8.5%*	*7.7%*	*11.0%*	*12.8%*	*12.1%*		
Installed Base Age (Y)	3.54	3.50	3.42	3.34	3.27	3.20	*-2.0%*	
AGR	*0.4%*	*-1.1%*	*-2.3%*	*-2.3%*	*-1.9%*	*-2.3%*		
Replacement Cycle Length (Y)	7.80	7.03	6.30	6.95	7.32	6.59	*-3.3%*	
AGR	*-0.2%*	*-9.9%*	*-10.4%*	*10.4%*	*5.2%*	*-9.9%*		
Units per Households and Businesses (#)	2.33	2.40	2.47	2.64	2.88	3.13	*6.0%*	
AGR	*5.1%*	*3.1%*	*3.0%*	*6.7%*	*8.9%*	*8.7%*		
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**Change**	**Trend**
Market Penetration (%)	*77.0%*	*80.1%*	*83.0%*	*85.5%*	*87.7%*	*89.6%*	*3.1%*	
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Table 40: United States Consumer Mobile PCs and Tablets Detachable								
	2016	2017	2018	2019	2020	2021	CAGR	Trend
Unit Shipments (K)	28,024	33,126	39,143	45,037	50,759	57,950	15.6%	
AGR	*0.4%*	*18.2%*	*18.2%*	*15.1%*	*12.7%*	*14.2%*		
Revenue ($M)	20,838	25,300	31,640	38,817	47,675	59,151	23.2%	
AGR	*5.7%*	*21.4%*	*25.1%*	*22.7%*	*22.8%*	*24.1%*		
Average Price ($)	743.58	763.75	808.34	861.89	939.25	########	6.5%	
AGR	*5.3%*	*2.7%*	*5.8%*	*6.6%*	*9.0%*	*8.7%*		
Installed Base (K)	132,406	139,383	147,387	161,917	180,621	198,525	8.4%	
AGR	*5.3%*	*5.3%*	*5.7%*	*9.9%*	*11.6%*	*9.9%*		
Installed Base Age (Y)	3.67	3.62	3.49	3.35	3.25	3.17	-2.9%	
AGR	*1.9%*	*-1.4%*	*-3.7%*	*-4.0%*	*-3.0%*	*-2.4%*		
Replacement Cycle Length (Y)	7.20	6.33	5.73	6.31	6.63	5.96	-3.7%	
AGR	*-4.8%*	*-12.0%*	*-9.4%*	*10.0%*	*5.2%*	*-10.2%*		
Units per Households (#)	1.36	1.36	1.38	1.45	1.57	1.67	4.1%	
AGR	*1.4%*	*0.0%*	*1.0%*	*5.5%*	*7.7%*	*6.6%*		
	2016	2017	2018	2019	2020	2021	Change	Trend
Market Penetration (%)	*77.2%*	*80.4%*	*83.2%*	*85.7%*	*87.9%*	*89.8%*	3.1%	
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Table 41: United States Enterprise Mobile PCs and Tablets Detachable								
	2016	2017	2018	2019	2020	2021	CAGR	Trend
Unit Shipments (K)	27,140	29,820	33,195	37,483	43,752	53,826	14.7%	
AGR	*14.8%*	*9.9%*	*11.3%*	*12.9%*	*16.7%*	*23.0%*		
Revenue ($M)	18,474	20,409	22,919	24,850	28,210	32,525	12.0%	
AGR	*18.6%*	*10.5%*	*12.3%*	*8.4%*	*13.5%*	*15.3%*		
Average Price ($)	680.71	684.41	690.42	662.96	644.76	604.26	-2.4%	
AGR	*3.3%*	*0.5%*	*0.9%*	*-4.0%*	*-2.7%*	*-6.3%*		
Installed Base (K)	105,588	118,742	130,628	146,773	167,484	191,603	12.7%	
AGR	*14.7%*	*12.5%*	*10.0%*	*12.4%*	*14.1%*	*14.4%*		
Installed Base Age (Y)	3.37	3.35	3.33	3.32	3.30	3.24	-0.8%	
AGR	*-1.5%*	*-0.6%*	*-0.5%*	*-0.3%*	*-0.6%*	*-2.1%*		
Replacement Cycle Length (Y)	8.75	8.12	7.13	7.88	8.27	7.45	-3.2%	
AGR	*6.8%*	*-7.1%*	*-12.2%*	*10.5%*	*5.0%*	*-9.9%*		
Units per Businesses (#)	21.28	22.68	24.08	26.44	29.76	33.38	9.4%	
AGR	*8.7%*	*6.6%*	*6.2%*	*9.8%*	*12.6%*	*12.2%*		
	2016	2017	2018	2019	2020	2021	Change	Trend
Market Penetration (%)	*73.1%*	*75.8%*	*78.4%*	*80.7%*	*82.9%*	*84.8%*	3.0%	
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Table 42: United States Consumer e-Readers								
	2016	2017	2018	2019	2020	2021	CAGR	Trend
Unit Shipments (K)	6,630	5,971	5,462	5,036	4,633	4,359	-8.0%	
AGR	-12.0%	-9.9%	-8.5%	-7.8%	-8.0%	-5.9%		
Revenue ($M)	477	448	426	403	371	349	-6.1%	
AGR	-9.5%	-6.2%	-4.9%	-5.4%	-8.0%	-5.8%		
Average Price ($)	72.00	75.00	78.00	80.00	80.00	80.13	2.2%	
AGR	2.9%	4.2%	4.0%	2.6%		0.2%		
Installed Base (K)	42,380	38,206	32,970	28,331	24,232	20,575	-13.5%	
AGR	-4.3%	-9.8%	-13.7%	-14.1%	-14.5%	-15.1%		
Installed Base Age (Y)	3.91	4.15	4.27	4.28	4.21	4.08	0.9%	
AGR	10.0%	6.3%	2.9%	0.2%	-1.7%	-2.9%		
Replacement Cycle Length (Y)	5.97	4.77	4.08	3.93	3.78	3.57	-9.8%	
AGR	-18.4%	-20.2%	-14.4%	-3.8%	-3.9%	-5.5%		
Units per Households (#)	1.21	1.22	1.18	1.14	1.10	1.06	-2.6%	
AGR	6.3%	0.6%	-3.3%	-3.3%	-3.3%	-3.6%		
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**Change**	**Trend**
Market Penetration (%)	27.8%	24.7%	21.8%	19.1%	16.8%	14.6%	-12.1%	
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Table 43: United States Total Slate Tablets and e-Readers								
	2016	2017	2018	2019	2020	2021	CAGR	Trend
Unit Shipments (K)	47,439	43,544	39,554	35,016	30,468	27,708	-10.2%	
AGR	-10.1%	-8.2%	-9.2%	-11.5%	-13.0%	-9.1%		
Revenue ($M)	10,324	8,644	7,258	5,896	4,702	4,087	-16.9%	
AGR	-20.4%	-16.3%	-16.0%	-18.8%	-20.2%	-13.1%		
Average Price ($)	217.62	198.51	183.50	168.38	154.33	147.52	-7.5%	
AGR	-11.4%	-8.8%	-7.6%	-8.2%	-8.3%	-4.4%		
Installed Base (K)	197,009	191,619	177,644	168,657	155,035	138,459	-6.8%	
AGR	3.5%	-2.7%	-7.3%	-5.1%	-8.1%	-10.7%		
Installed Base Age (Y)	3.07	3.34	3.54	3.69	3.81	3.88	4.8%	
AGR	11.9%	8.8%	6.0%	4.1%	3.3%	1.8%		
Replacement Cycle Length (Y)	5.83	4.92	4.32	4.83	4.52	4.13	-6.7%	
AGR	-7.8%	-15.6%	-12.2%	11.9%	-6.5%	-8.6%		
Units per Households and Businesses (#)	2.77	2.89	2.89	2.96	2.94	2.90	1.0%	
AGR	16.0%	4.7%	-0.1%	2.4%	-0.6%	-1.3%		
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**Change**	**Trend**
Market Penetration (%)	53.7%	49.4%	45.4%	41.7%	38.2%	34.2%	-8.6%	
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Table 44: United States Consumer Slate Tablets and e-Readers								
	2016	2017	2018	2019	2020	2021	CAGR	Trend
Unit Shipments (K)	43,369	39,063	34,432	29,866	25,564	22,397	-12.4%	
AGR	-9.4%	-9.9%	-11.9%	-13.3%	-14.4%	-12.4%		
Revenue ($M)	8,582	6,861	5,340	4,069	3,048	2,361	-22.8%	
AGR	-22.4%	-20.1%	-22.2%	-23.8%	-25.1%	-22.6%		
Average Price ($)	197.88	175.64	155.09	136.24	119.23	105.40	-11.8%	
AGR	-14.3%	-11.2%	-11.7%	-12.2%	-12.5%	-11.6%		
Installed Base (K)	180,374	174,847	160,619	151,104	136,932	119,852	-7.9%	
AGR	3.6%	-3.1%	-8.1%	-5.9%	-9.4%	-12.5%		
Installed Base Age (Y)	3.09	3.36	3.58	3.74	3.88	3.97	5.1%	
AGR	11.4%	8.7%	6.4%	4.6%	3.7%	2.4%		
Replacement Cycle Length (Y)	5.86	4.92	4.30	4.84	4.45	4.04	-7.2%	
AGR	-7.2%	-16.0%	-12.6%	12.5%	-8.1%	-9.2%		
Units per Households (#)	2.57	2.69	2.67	2.73	2.68	2.60	0.3%	
AGR	16.5%	4.7%	-0.6%	2.1%	-1.6%	-3.0%		
	2016	2017	2018	2019	2020	2021	Change	Trend
Market Penetration (%)	55.8%	51.2%	46.8%	42.7%	38.9%	34.8%	-9.0%	
∞∫Δ Daniel Research Group © (2017)								

Forecast Updates

DRG will update these forecasts periodically as actual year-to-date results become available. Utilizing the **DRG ProjectionSolver** algorithm, new current year projections based on historic trended quarterly or monthly patterns are computed. Based on these projections, adjustments may be made to the primary **EQS** models

About Daniel Research Group

Daniel Research Group is a market research and consulting firm servicing technology clients. Our primary focus is developing custom market models and forecasts. We support clients three ways.

1. We work independently or collaboratively with the client's own analysts to **produce custom** technology product/service **market models and forecasts**.
2. We work collaboratively with the client's own analysts to **design and develop the modeling applications** that they will use to develop their own market models and forecasts.
3. We **train client's analysts** in the theory and practice of technology market modeling and forecasting.

Most of our work utilizes the inventory of proprietary methodologies and algorithms that we have developed over more than 30 years. We have built technology forecasting market models for many major technology vendors, market research firms, and industry organizations. While our core competency is forecasting, our subject experience covers the entire technology and technology-enabled product/service landscape. We also support our engagements with traditional qualitative and quantitative research, as well as tactical and strategic consulting services.

Stephen J. Daniel - President

With three decades in the Information Technology Industry, Mr. Daniel has developed a unique blend of Market and Technology experience coupled with a deep understanding of Market Research Methodology. His primary strength is in understanding the decision-making context within which the results of his research will be applied. This is manifested by his ability to design and execute studies that precisely meet client objectives in a timely fashion and at reasonable costs.

Mr. Daniel received his BS in Finance from Northeastern University and earned an MBA in Quantitative Analysis from New York University. He is a member of the American Statistical Association, The Market Research Association of America, the American Marketing Association and the Qualitative Research Association of America.

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2) By 2041, It's All About You… And Your Entertainment, Andy Marken

Source - "*Arrival*, " 20 Laps Entertainment

"Language is the first weapon drawn in a conflict." **Ian Donnelly, "*Arrival*," 20 Laps Entertainment, 2016**

Arrival is like the art films I used to enjoy in college, filled with a lot of underlying meaning and ideas that made you think long and hard.

It's like the opening voiceover was written for the M&E (media & entertainment) industry … "*Even in our world of instant and ubiquitous communication, we have fear and distrust of newcomers and each other."*

Everything is changing at the speed of light … everything is in flux … everything is in play when it comes to creation, delivery and consumption.

As long as you understand what the content industry will be like in 2041 (25 years from now), tomorrow will take care of itself.

2041 Snapshot

Source – UX Magazine

Your Visual World – *In 25 years, you will have complete control over your visual entertainment. Enjoyment will follow you and will be instantly available, thanks to intelligent systems.*

Overview of 2041:

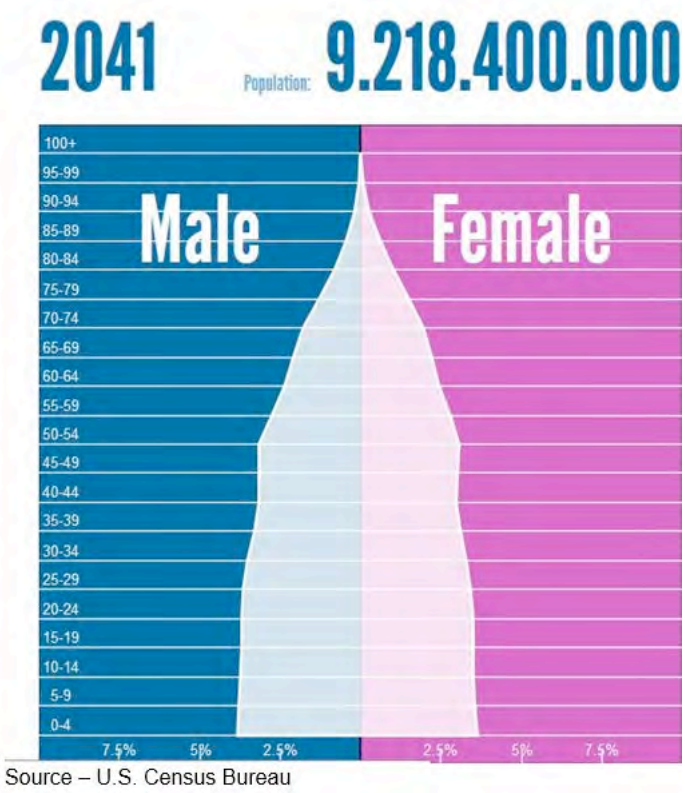
- The world population will hit 9.2B (up from 7.4B in 2016)
- There will be about 6B Internet users with 1Gbps standard
- 50 percent of the 4.5B population of current undeveloped countries will be connected with tremendous political and economic impact
- Electric vehicle sales will hit about 20.5M; driverless cars will be abundant in urban markets
- Yottaflop supercomputers will be humming
- India's economy will rival China and the U.S.
- Fusion and orbital solar power will be introduced
- People will control, change memories and personality but men still won't understand women and women will still be shaking their heads
- Money and resources will be focused on education, healthcare, transport, environmental programs; improving living standards; economic opportunities
- Power over wireless will begin replacing the aging power grid
- Implantables, wearables (under the skin, contact lenses) will have virtually eliminated communications devices
- Manned trips to Mars will begin to reach affordability
- Mac computers will be 50 years old
- Male, female salaries will be approaching parity
- Everything/everyone will be connected. Personal data will still be personal but easily shared/used
- To eliminate cybercrime, every person will have a personal digital identifier to ensure accurate, precise digital identity

- Content providers will deliver the information/content you want, no matter where you are
- We will produce, process, disseminate, consume as much as 4,000[4] kilobytes, (two yottabytes) of data annually
- Personalized, AI-based data analysis/decision systems will help you do what you want in your professional and personal lives

Creators

By 2041, there will be no one left that remembers the days that movies were sprocketed, 35mm moved up to 70mm, and stereo sound was popular with just an analog trace on the edge of the film.

Today's digital natives will be Millennials in 2041, carrying forward the habits they developed in their early years.



Source – U.S. Census Bureau

Population Mix – *People will be healthier and active longer. Population growth will be relatively static while the need for employees--especially in the service and technology development/implementation fields-- will remain strong leading to a widely age diverse workforce.*

The 2041 Millennials will simultaneously create content, edit it, post it on social media and carry on conversations with a constantly changing pool of "friends."

They will literally be documenting/uploading/sharing everything instantly.

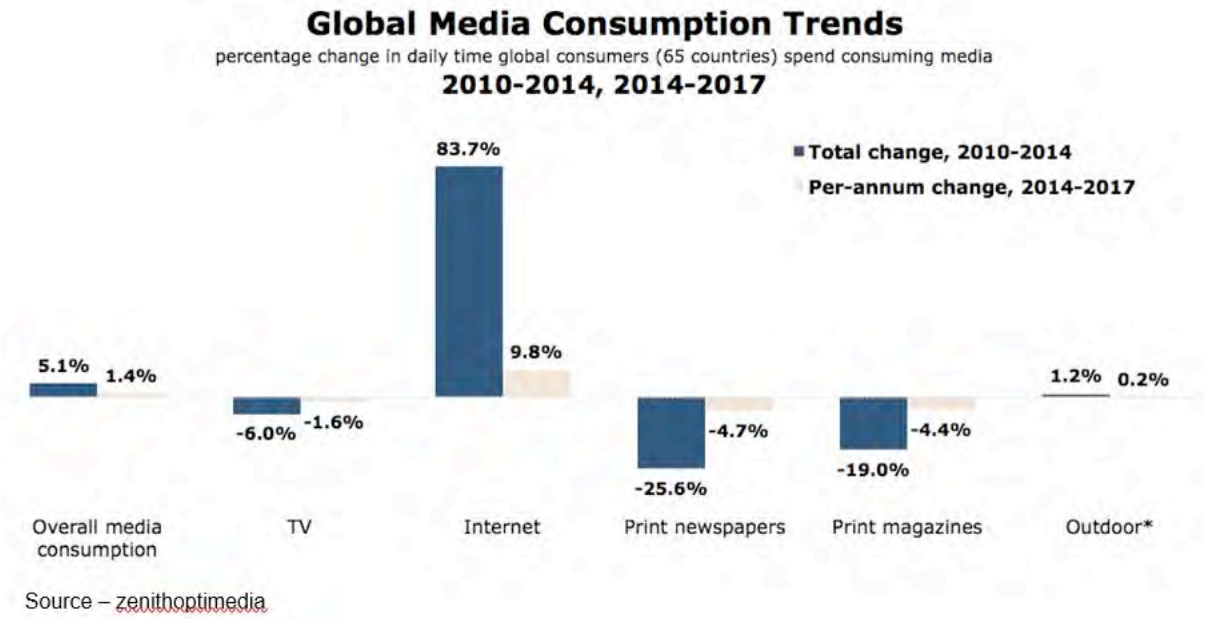
And they will lose interest just as fast.

Social media video services such as Facebook Live, YouTube Red, SnapChat, Instagram, Tencent, Alibaba, TaTa Sky, HDTV India and other online services will serve as repositories and distributors of tens of thousands of hours of 8K content shot by Millennials (It used to be Gen Z but they aged.) and Gen Alphas.

The 1- to 5-minute life/impulse moments delivered to people based on their interests, mood, needs and curiosities; will be supported by very appropriate/personal ads.

Or, individuals will avoid ads by paying a modest streaming fee

Either way, all of their personal data will be tracked, compiled and used; but that will be of little concern 25 years from now.



Constant Consumer - *Internet traffic, including social media, online video and digital TV will be streams of your choice. Where it is seen will be more individual and less communal.*

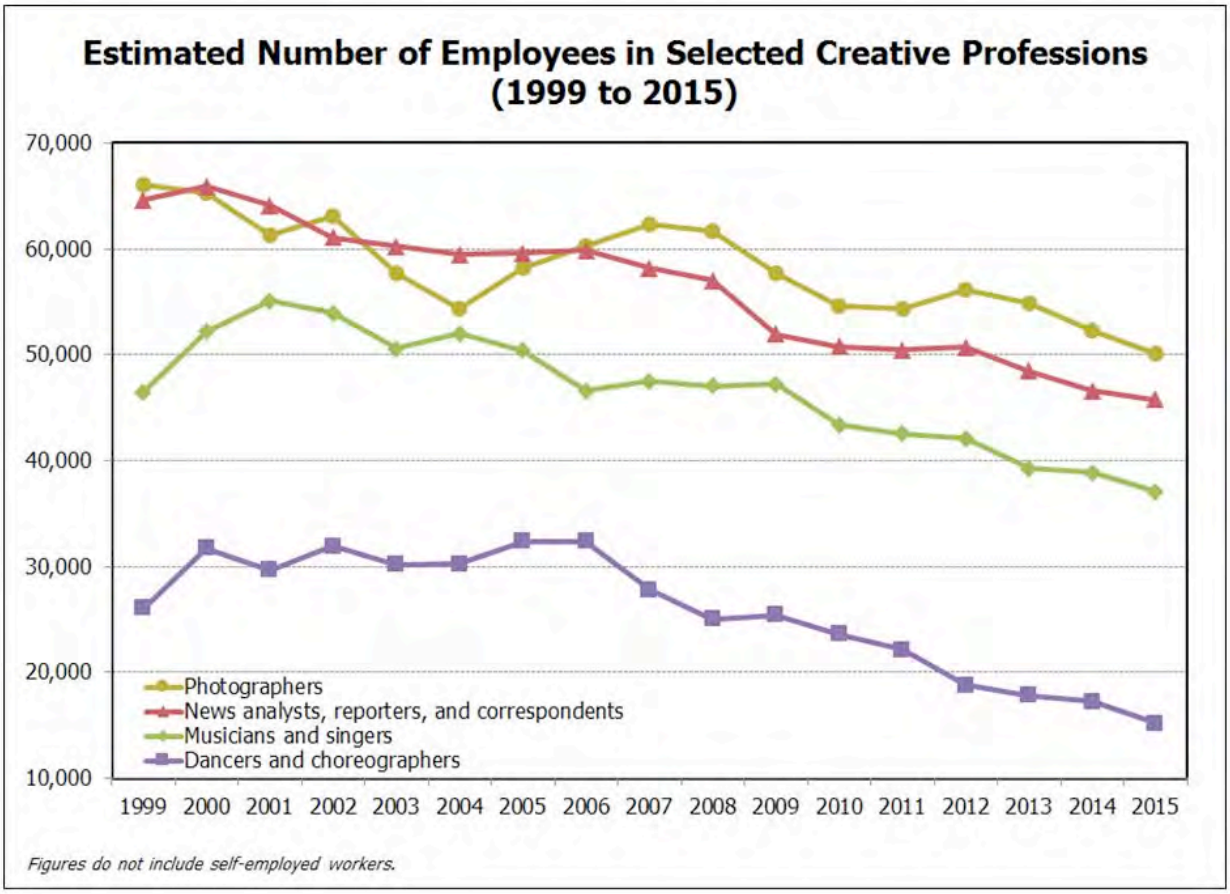
The short attention span viewing may appear to be the death-knell of professional filmmakers but it will actually open new opportunities for visual storytellers and creatives as they shift their focus.

Communal venues such as theaters will have all but disappeared because like-thinking people will be connected and will be able to share the most minute details/excitement of the film.

Skilled, fire-in-the-gut storytellers (about 40,000 Indies worldwide today) will be using 16K HDR, VR cameras to create 10-30-minute serialized content – documentaries, informational/educational material and pure entertainment.

The good news is filmmakers will have more outlet options to monetize their activities:

- Sale or shared revenue with social media streamers like YouTube Red, Facebook, TaTa Sky and others
- S/AVOD (syndicated/advertising video-on-demand) services – Amazon, LeEco, Netflix, Disney with customized – content/price - viewing bundles



Source – Bureau of Labor Statistics

Steady Video Work – *While everyone will be creating video and visual content to be posted and shared, professional filmmakers – even with self-employed filmmakers not being counted - will still be the foundation for interesting, exciting, immersive storytelling. It takes a special talent to tell a story well.*

In addition to the conventional 16K ultra high dynamic range 22-channel surround sound fare, there will also be a refined immersive VR/AR (MR – mixed reality) films shot by filmmakers.

Viewers will then play an active role in determining the flow and direction of the content and dispensing it with real and animated characters.

While the ability to stream all of this content would be impossible over today's broadband and Wi-Fi networks; with new codec solutions, 5G wireless and widespread availability of reliable 500+ Mbps network connectivity; video material will be easily enjoyed.

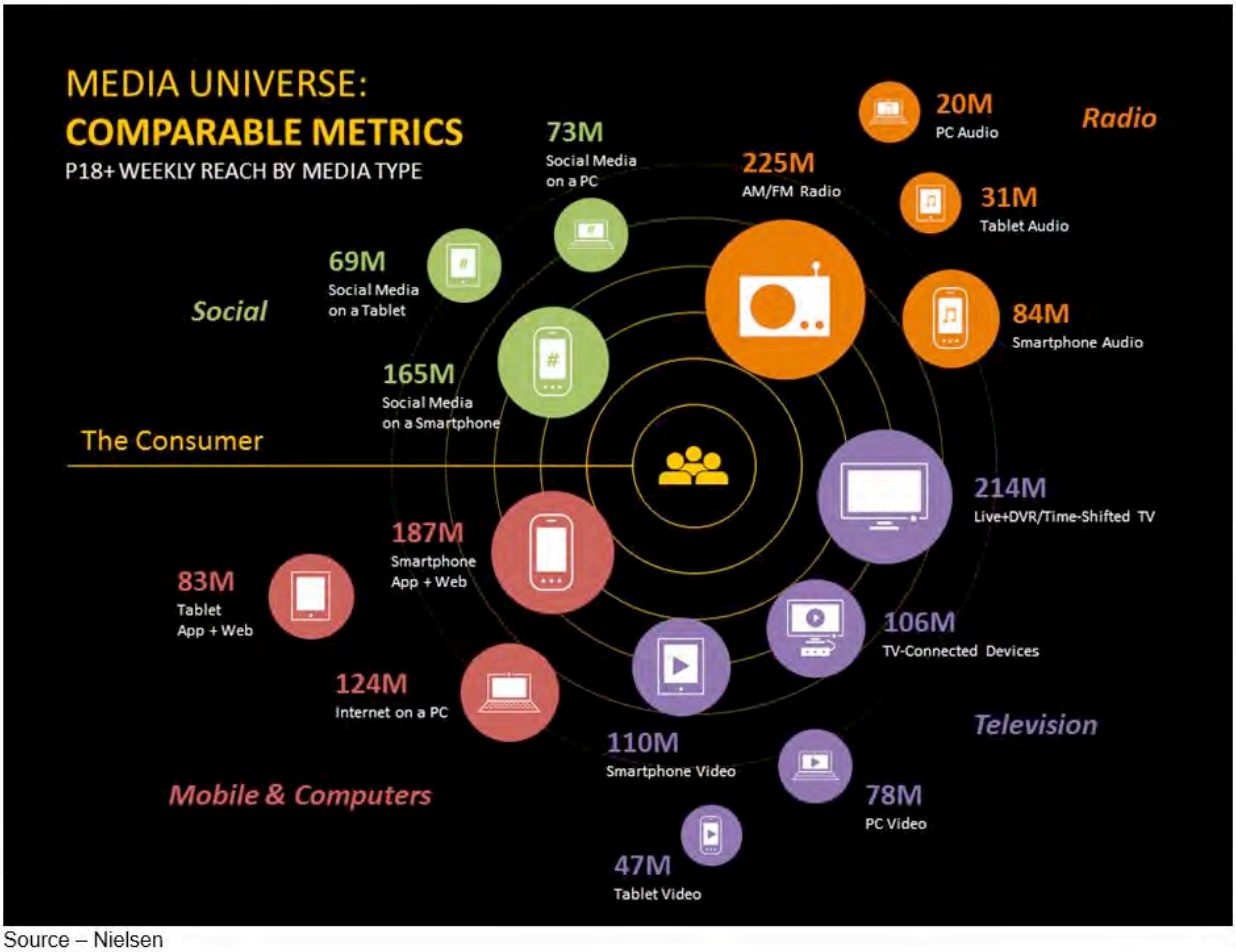
Thanks to the rapid development of AI-based content and DAM (digital asset management) solutions, content will be personalized and managed.

For professional filmmakers, AI-based solutions running on IBM Watson-type platforms will be closely tied to content metadata throughout the production process.

Piracy will no longer be an issue because content will be tied back to the specific storyteller. As a result, individual creators can be compensated electronically (and automatically) for their efforts.

You won't have to choose whether you're watching on your 16K/HDR TV in your living room, bedroom, family or media room. And you won't have to choose your communications device.

A fixed screen will be something you only see at your grandpa's house because he stubbornly resists moving to a newer, better viewing experience.



Source – Nielsen

Personal Screen – *Your video viewing screen will evolve from a growing array of devices/options to a point where the content follows you and is available when you want it. The use of personal identifiers and AI will keep track of what you like and where you are.*

Screens (with cameras) will be everywhere – offices/home surfaces, modes of transportation, everywhere; as in ***Minority Report.*** They may not be glass as in Corning's YouTube videos – ***A Day Made of Glass*** - but the AI-based content delivery system will be tracking you, gathering information on what you want/need at any given time. New services to negate your presence will be available, but tracked.

TV channels will take their place in the evolutionary history of content (along with set-top boxes and apps) with personal channels built around individual preferences and his/her constantly changing communities.

Want some real alone time?

Source – Corning

Tell Me a Story – *VR/MR film adventures, holographic entertainment and the ability to actively put yourself in the center of the action will keep you occupied no matter where you are.*

"Tune in," your always available personal screen to enjoy a holographic story, challenge yourself with an immersive MR adventure or experience new places, new activities.

Want some content for a few minutes or an hour? Just say the word and the content system will deliver your channel instantly through intelligent meta-data resources.

Content management firms including studios, OTT delivery services (AT&T, Verizon, Rogers, Turner, Viacom, AMC, NBC, Univision, MediaCorp, CCTV, Colors Odia, China Telecom, Telstra, AWS, AZURE, Tata and other local, national, international carriers) will store, stage and deliver content no matter where you are from your interest bundle (subscription or ad supported).

All of the providers will use AI-based DAM (digital asset management) and analytical/accounting solutions that intelligently learn your entertainment tastes to refine offerings when you want to take a mental break.

It's not everywhere/everyone streaming entertainment, it's individual content that ensures that everyone is happy with the results – content owner, content distributor, advertiser and viewer.

The Big Hurdle

When you consider that some of the 16K, VR/MR 30-minute films could require Petabytes of storage, the constant production of tens of thousands of hours of content will require a tremendous amount of storage

It means robust demand for storage as filmmakers, content managers and file distributors produce, gather and archive content as well as the data regarding the content and viewer from the four corners of the globe.

"*Tomorrow's content production will produce digital assets that are both deep and wide, said* Allan McLennan of the PADEM Media Group. *"The emerging AI solutions will track all of the content and predict the viewer's desires based on prior behavior and comparing it with video assets that are available down to the frame level.*

"The assets will be stored in almost any cloud service but will then be staged closer to the viewer in a personalized, private, detailed manner," he continued. *"When the individual is ready; the content will be accurately, transparently and instantly served up because of the learned ability of the AI solution."*

The software, hosting and storage will move from single servers and monoliths toward distributed systems with fog-hosting (decentralized networking) that provides greater efficiency, reduced pressure on the networks and an improved user experience.

Source – Microsoft

Intelligent Storage – *While intelligent systems will keep track of who produced what, where it is and who has viewed it, the challenge will be to ensure that content is reliably stored. This will give stimulus to new storage technologies.*

To meet the demand, cloud service organizations such as Amazon, Microsoft, IBM, Oracle, Apple, TaTa and others have added data center capacity while refining advanced storage management software and working on next-generation storage devices.

By 2041, tape and HD technology will have reached end-of-life as engineers refine 10-layer flash, holographic and DNA storage technologies to provide the best balance of capacity, performance and cost for the service provider.

Holographic technology uses laser beams to store computer-generated data in three dimensions. Data is recorded throughout the medium and multiple images can be stored in the same area (light at different angles) to provide high content density in small devices.

One gram of DNA has the potential of storing 1ZB of data that could be stored, saved and used for up to 1,000 years.

Taking advantage of the speed and Moore's Law capacity growth, flash-based memory will be used to store the content in decentralized fog or cloudlette centers. This will provide the optimum balance of near-instant content delivery (folks will have zero wait tolerance and minimal attention span) as well as high-capacity, low-cost content preservation.

Thanks to the refinement of personal identity tracking and AI-based content management/delivery, channel surfing and buffering will only be things your grandparents talk about in 2041.

It all sounds like a lotta' work to kids just starting out in their filmmaking career; but it will provide an amazing level of cultural engagement once they embrace it.

Source - "*Arrival*," 20 Laps Entertainment

And why would anyone want to sit for an hour to watch something when you could busy yourself doing multiple things and your content would just be with you?

When 2041 rolls around, Dr. Louse Banks will look at her screen and say in a satisfied tone, "*I feel like that everything that happens comes down to the two of us."*

# # #

3) Video Content…Lust Overcomes Needs, Andy Marken

"Don't talk to me about contracts, Wonka, I use them myself. They're strictly for suckers." **– Sam Beauregarde, Willy Wonka & the Chocolate Factory (1971), Wolper Pictures Ltd.**

What is the preoccupation with television?

The worldwide broadcast industry gathered at IBC to figure out how they were going to survive and make money with the growing demand for online video and audio content.

Then, at IDF (Intel Developers Forum), CEO Otellini proclaimed the world is infatuated with the wonderful possibilities of Smart TV.

The PC people -- tablet, notebook, desktop, server -- continue to try to figure out how they are going to get into the living/family room.

Oh sure, you heard the "content source" story for the last 10 years but hey…it's a good story.

PCTV
Otellini hasn't given up on getting the Smart PC connected to the Smart TV.

Figure 2 -- Embrace the Vision – While Intel advanced a long laundry list of initiatives at this year's IDF (Intel Developers Forum), a pivotal goal for CEO Paul Otellini was SmartTV/PC, content everywhere.

He told IDFers, *"Our vision is to create a continuum of personal computing experiences that provides consistency and interoperability across all Internet-connected devices in the home, car, office or in your pocket."*

The new PCs (all flavors) are suddenly very smart, very powerful, very economic, according to some intuitive as to your viewing desires.

But they still act like computers!

YouTube-type, live-streaming video service is still sitting on a PC. But you get a hint of the array of content…online video talk shows, how-to videos, TV stuff, more.

Of course, networks, Hollywood, cable folks aren't warm to Google managing their fortunes, but come on guys…all Eric wants is a few cents out of every eyeball view.

Then again, the late adopters and mainstream people (70+% of the buying public) just won't put the computer in the room where they relax.

Apple tried with the AppleTV I and II. Even with Jobs' sainthood, it's still a "hobby."

Hard drive people saw the Apple TV and figured what the heck.

They've done as well as Apple…they still provide a PC add-on/accessory.

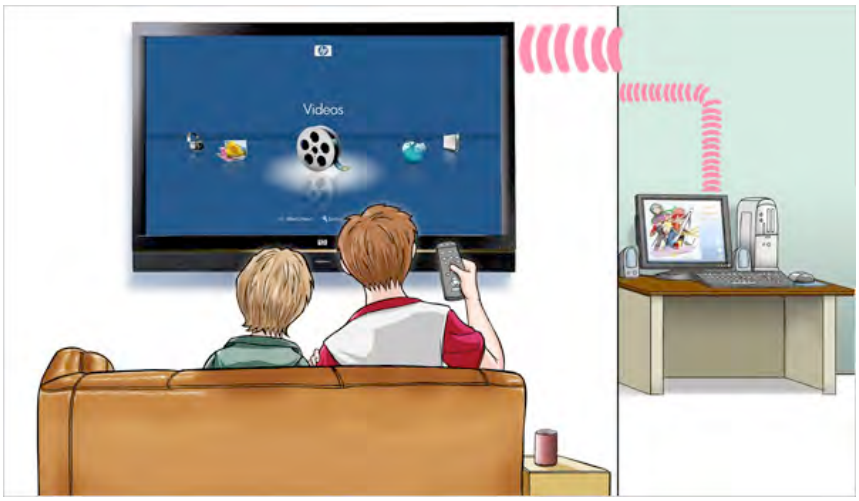


Figure 3 -- Hide the Cords – One of the biggest challenges for the PC industry's home entertainment network initiative is a fast, easy (really, really easy) way for people to move content from the PC in the back of the house to the TV in the living room. New wireless solutions could bring the idea even closer.

Willy noted that it hasn't slowed them though, *"They're certainly not showing any sign that they are slowing!"*

Even timeshifting poster child, TiVo, is still around.

New solutions like Roku's aggressively priced units that don't rely on the cable guy are being made available -- one-time payments, low monthly fees, more features/capabilities/options have given new meaning to "I TiVoed the show."

Poor Old TiVo

TiVo should have listened to the psychiatrist when he said, *"To believe in one's dreams is a manifestation of insanity. And the sooner you accept this, the sooner you'll get well."*

They face a serious struggle for TV-top space with the Wii, PS3, Xbox that are already Internet-connected and streaming NetFlix.

As another option, you can buy a new TV set with cable, Internet connectivity as well as 3D and …

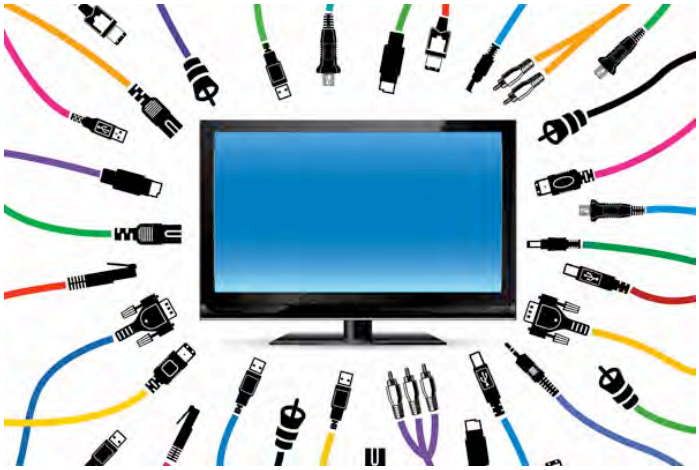


Figure 4 -- Connections Everywhere – Pick a connector standard and there is a variation that people are certain will meet the needs of the TV viewing public. Being uncomplicated and plug-and-play have become frequently used words that engineers throw around with ease. Easy for them, not for you. **Illustration – NY Times**

The idea of dropping $1,000 + on ***another*** new set when good enough is good enough and tough to justify.

Willy looked at his set and said, ***"****A thing of beauty is a joy forever."*

To give people the streaming content and more, there are some low-cost add-in solutions that work with your wireless networks and simply connect to your present TV set.

Unlike expensive complete, end-to-end "ultimate" experiences and mish-mash shopping cart stuff, people simply want an inexpensive, easy-to-install and use answer. You know, one that can be used with any TV set, a natural controller solution and has the ability to add anywhere, anytime enjoyment.

As Grandpa Joe said*, "It could change the world!"*

With the exception of premium events broadcasters are putting their content on the Internet. It usually is online less than 24-hours after the show.

But it's still a PC monitor or an Ethernet cable running to the TV.

Here But…
True, WiFi solutions require a little work, but as Willie says, *"So much time and so little to do. Wait a minute. Strike that. Reverse "*

Streaming without cables is something you can get used to!!!

Then too, you want a solution that works at home and on your smartphone away

from home.

PC approaches work ok at home.

The hard drive, set-top units -- again at home.

Most of the smartphone streaming content apps work only for the smartphone -- Apple iOS or Android.

Figure 5 -- Kids In a Candy Store – Increasingly, people want all the content they can get and enjoy on their terms – the time of choice, the device of choice, the location of choice. Hardware, software, content providers are struggling to meet the consumer's wants…and make money at the same time.

Extendable solutions are needed that allow you to seamlessly grab, show content when/where you want, how you want.

Some set-top providers offer solutions that "change" the content which can lead to lock-out or "blockages" by content owners/providers.

Content owners aren't certain how they're going to make money off of the streaming -- serious money that is -- but they darned well are not going to allow Eric or Steve-come-latelies take money out of their pockets.

Figure 6 -- The Money Proposition – While content owners are repurposing their shows so they can be viewed on computers, tablets, smartphones; they are still struggling to deliver content and get paid for it as well. The helping hands from Google and Apple have yet to be warmly grasped. Something to do with past track records.

Most of the networks and studios have turned a cold-shoulder to Apple's "generous" offer.

They saw how music industry lost control and they're not going to repeat their mistakes.

Going Live
There's a dramatic growth in indie and consumer-level video.

The stuff is actually pretty good…as good as most of today's reality shows.

It's available from a variety of audio/video sites.

All content viewing is going to change with a mixing and matching of professional and "other" content in the next 12+ months.

Will people pay subscription fees for the content?

Some will.

There's always a market for pay-for-view serious theater viewing, special events/sporting venues.

But the mainstream stuff will continue to be subsidized.

Figure 7 – Rose-colored Glasses – While premium, pay-for-view content will have a place, even in the continuous online video world, most consumers will still opt for the subsidized (advertising) entertainment. New generations of technology will enable people to watch their shows, their way with ads that are designed specifically for their wants, interests.

Putting up with ads is a small payment for the vast majority of people.

By streaming over the Internet, you're going to be able to view a different breed of ads. Advertisers will personalize their ads for the individual.

Even with the CW network's very tight audience profile, they ignore about 60 percent of the audience.

The cable guy has been able to group ads by specific neighborhoods and fairly broad audience profiles. That's still wasting a lot of the advertisers' dollars (and time).

New software algorithms will change all that.

The idea is to profile your viewing habits but keep that info on your system.

Content sellers and advertisers then make available a number of ads that precisely fit you and are rotated for your viewing.

Watch the content and the ads don't intrude..

The content owner/distributor will get more per view because it is a precise target.

Your info isn't shared, everyone is happy.

New View
You'll never look at "commercial TV" the same way again!

Chris Anderson's ***Long Tail*** is going to be easier to enjoy.

The cable 250-500 channels will probably stick around for old folks.

But watch the kids.

Figure 8 -- Channel of One – The emerging generation of viewers won't recall the challenges and frustration of struggling with a TV remote to find the specific channel, specific show they just "have to see." In the near future, we'll be able to experience a channel of one…YOU!!

The iGeners (10 and below) won't remember a time when they couldn't watch anything on their own personal channels.

It won't be channel 36 or 360.

They will have the stuff they want to watch it, when they want to watch it, where they want to watch.

The PC/Internet will play a key role in the TV of the future.

As Charlie Bucket said, *"A million pieces take a long time to put together."*

# # #

4) Politics Pushes Business, Semiconductors

Tom Starnes and Jim Handy, Objective Analysis

For Decades, Semis have been a Global Industry

Some key political events late in 2016 could start having an effect on the electronics and semiconductor industries in terms of the countries in which work is performed and finances are attributed. However, the basic mechanisms that drive semiconductor cycles are still very much alive, with under- and over-supplies creating rapid growth and spectacular collapses. It is difficult to determine how the overlay of new policy will play out in the near term, so Objective Analysis (www.Objective-Analysis.com) will apply traditional techniques to forecasting 2017, while pointing out new factors that could cause turbulence in 2017 and coming years. Right now, 2017 promises solid chip revenue growth.

National Policymakers Reflect Citizens

A relatively small portion of the population of Great Britain voted to put greater distance between the country's finances and those of the European Union (EU) in an event referred to as the The Brexit referendum. Shortly thereafter and possibly independently, the EU declared that Apple owed Ireland, and therefore the EU, billions in back taxes saying that Ireland should not have granted exemption over many prior years.

In the United States, real estate mogul Donald Trump was elected President while making numerous dramatic statements that he would bring jobs back to the US, keep US-based companies from opening factories elsewhere, and "repatriating" profits to the US with tax and tariff changes. Although the details of such policy and political changes are pretty murky, there is no doubt that nations' economies and corporations' business will be impacted. This is against a backdrop of a enigmatic position of China with a controlling central government and a way of handling business that is still evolving. In electronics, the automotive, industrial, and consumer industries are likely to be most affected, with semiconductors having to adjust in its own way.

Finance and economics will drive much of the change, which is somewhat unnatural for technology researchers and design engineers who pride themselves on constant improvement in terms of capabilities, performance, and efficiencies, with lower costs being a natural outcome of their efforts, resulting in widespread use of technology that betters mankind.

The Path of Least Resistance

Corporations answer not only to their customer base but also to their stockholders in light of their competitors. Profitability is a benchmark next to market growth judged for each company. This means that the value of the product must be high enough to justify the price to the customer and the cost to

build the product – with a proper amortization of the design, development, and software costs.

A few companies hold a special advantage over most, where they can command an unusually high price for their products or services, but even the rich keep a keen eye on costs while keeping their quality high. But certainly, most technology companies are scared that another company will take away their customers with a lower-cost offering and are in a constant struggle to produce their products for as little as possible. Every customer brings higher production volume, which incrementally and directly lowers cost.

The cost without overhead to produce each additional unit is still a significant portion of the total cost allocated to the part. Therefore, the materials, time, and labor to build a batch of parts are regularly reviewed to assure that they are the lowest possible while keeping quality up to standard. Of course, the cost of the multi-billion dollar fabs that make semiconductors loads up the burdened part of the cost equation, the errant seed of the quip "we'll make it up in volume."

Silicon Clusters and Sharing

Local entities (states, regions, cities…) often grant tax, utility, and infrastructure concessions or cooperation to attract the construction, engineering, and production jobs associated with high-tech and semiconductor facilities. Additionally, the associated support businesses (AMAT, et al), conferences, and highly-skilled talent pool and housing that come with a cluster of semiconductor facilities in the area, feeds money and prosperity back to the local community in numerous ways. These exist in many areas, affectionately known as Silicon Valleys, Hills, Glens, Deserts, Prairies, Corridors, and Alleys, where companies large and small take advantage of such concentrations.

Over the past 25 years the electronics industry has moved from a vertically-integrated business model (e.g. Motorola made radios, circuit boards they were made from, and chips the boards were made from) to distinct specialized (horizontal) entities where fabs, packaging, test facilities, distribution, and great quantities of software are individual businesses offering services to many companies under contract. This lets many companies, large and small, take advantage of leading-edge (or commodity) technologies at low prices without "re-inventing the wheel" with their own research and development (R&D) investments. "Economy of scale" lets many vendors enjoy the benefits of low cost. In some ways this is considered "the food chain". Many diverse industries have similar supply-chain scenarios from electronics and automobiles to clothing, construction, and … food. However, high technology is so sophisticated that the relationships and dependencies between partner companies are very intricate and not easily changed.

It turns out that these specialized centers-of-excellence are scattered around the world (as described at http://www.strategysanity.com/extend.html#Regions), but

the reasons vary. Often, those locations happen to be where a group of people put great focus on a particular technology or tried a new approach to business, invested appropriately, and partnered with other companies, the stars aligned, and they ended up being successful.

Money Makes the World Go Around

All companies are driven by profits, with Wall Street and investors dissecting corporate revenue, growth, outlook, and stock prices in relation to competitors. Continuous scrutiny and quarterly checkpoints force companies to keep their costs down while building value for their product and services to justify higher prices to customers and greater market acceptance.

Deep in the financial formulae for determining product cost are shipping costs and taxes. Moving sub-assemblies and partially-built product around between geographic locations accumulates delays and costs for an enterprise. If those locations are in different cities, states, or countries, then taxes may also be accrued. The shipping costs and taxes offset lower material costs and labor rates in the locales – eroding profits.

Corporations must work within a maze of laws and regulations of the governments and jurisdictions everywhere they operate. When regulations and taxes change, companies must adapt to those changes. Small changes may not force discernable adjustments, but large or immediate changes can have a dramatic effect. Significant changes in taxes and tariffs, import and export limits, government department, agency, or ministry policies, and rulings handed down by courts of law can send companies scrambling to shift their strategies to minimize any financial or market downside.

Government policy changes can have short-term effects – and long-term effects that may be harder to foresee. Crushing cars that are deemed "clunkers" may have spurred new car sales in 2009 in the US, while car in the streets of Cuba today appear to be locked in a 1960's Twilight Zone program (but in color) – each situation was caused by a very different governmental intervention.

Policy Influences on Business

- Prime interest rate increases from near-zero
- Currency manipulation
- Corporate tax rates
- Retroactive tax collections (ala, Ireland)
- Employee benefit burdens
- Work Visas
- International trade agreements and constraints
- Import and export tariffs
- Trade sanctions
- Financing shifts between government, private equity, and venture capital
- Bank regulation
- Public company scrutiny
- Agency regulations
- Hurdles/streamlining of approval processes
- Patent and intellectual property (IP) enforcement

Note: Resolution and opinions from the Judicial System also effectively constitute policy

Few electronic products today are built from the ground up using materials and labor from only one country. Should new regulations, import duties, national pride, or just public shaming make it more costly or difficult to provide goods and services in a locale, then the supply chain could be disrupted, costs could go up, and different companies or products could end up being the winners compared to today's market. That would be simply due to policy changes, not technology advances or better insights to customer needs.

However, frequently there are ancillary effects – often negative – that also disturb the known, if not free, market when policy changes are hastily enacted. Uncertainty and "unintended consequences" can drive the stock prices of affected companies sharply up and down. Such changes also affect the ability of businesses to attract and secure capital investments – critical to fast-growing companies in competitive markets.

A Robot in China

It can be argued that starting with the Industrial Revolution, the number of people needed to produce goods has been in decline, somewhat offset by higher wages, and against a background of an increasing population with longer lifespans. As leverage and machines replaced animals, water, steam, electricity, and internal combustion engines as power sources, looms, machinery, and hydraulics took over highly repetitive or possibly dangerous jobs.

Computers and electronics made "knowledge workers" more productive, particularly triggered by the personal computer, productivity software, and personal printers. More recently, digital networking has allowed information sharing and human interaction on a scale and timeframe never seen before, accelerating advancement of ideas and shrinking the world more than aircraft did.

Electronic controls have taken over all but the heaviest hydraulic industrial systems in recent years. More connected, intelligent sensors and controllers – the Internet of Things (IoT) – will accelerate the number of electronic devices that can uniquely serve individual humans.

As electronic equipment has become so inexpensive, demand has soared and expanded into purely entertainment and luxury electronics. About 1 billion new mobile phones were bought last year and there are only 7 billion people on the planet, not all living in the US or Europe.

"A robot can build a product in any country for about the same price"

Each of these advances took more people out of the process of getting a product built or a job done, reducing variable costs.

But, a robot can build a product in any country for about the same price – it's only human labor that has a highly variable rate from country to country. One reason China became a recent leader in manufacturing was due to its large labor force willing to work for wages much lower than required in Europe, the US, and Japan. But as automation has increasingly allowed the mass production to reach the levels it has, fewer people are necessary in the process. Computer vision and exotic sensors have even eliminated much of the alignment and final inspection that was so dependent on humans many years ago.

The computerized factory floor dominates most of the electronics industry and certainly semiconductor manufacturing. The infinitesimal scale of every feature and tolerance in the semiconductor chip and fabrication process clearly requires the most precise machines to build these wondrous devices. For decades, humans have been pushed out of the fabs just to keep their contaminants carried in the air from destroying the costly die being created.

As fewer people are part of the manufacturing process, the cost of labor is a smaller portion of the product unit cost, and $50/hour or $5/hour may not be that critical to cost savings. On the other hand, the men and women who do still run and maintain the equipment and construct the building, let alone those who design, lay out, program, and install the custom production line are highly educated, skilled, and experienced, and their wages can vary greatly, country-by-

country.

2017 May be Pivotal, but Time will Tell

2016 was rife with political rhetoric – often harsh and dramatic. There were governmental agency surprises, sanctions lowered and lifted, judicial proceedings and judgments, currency shifts, protests, shipping strikes, scandals, posturing, laws enacted and softened, referendums, executive orders, tax proposals, accusations, threats, promises, saber rattling, and untold Internet dribble. But usually, specifics were vague.

While recent years have seen much movement on social issues, 2017 may be a pivotal time for business and the resulting economic effects. The electronics industry's primary role in social change has been circulating voices on the Internet and airwaves. The intricate balance of the electronics industry will be impacted more directly, as the US, the EU, China, and other countries enact policies that revise the rules for doing business, and adjustments will have to be made.

The political machine is messy and typically moves slowly, but that may change with non-politicians at the helm. The effect could be slower than the cause, with long-term ramifications taking years materialize. But some things may change quickly.

Multi-billion dollar manufacturing plants can't be moved, equipped, and populated in 12 months, even to save 15% that will fall to the bottom line. Logistics, contracts, and qualifications must all be managed, even if the plans are nearly "shovel-ready". However, product shipments to a region can stop "on a dime" (a small, peculiar US coin) when dangerous chemicals are discovered, people are poisoned, cars, skateboards, or computers catch fire, court orders are executed, or tax and regulation changes suddenly take effect. Products caught in limbo may have to be dumped.

If countries start manipulating their currency valuation, interest rates, and trade policies in peculiar ways to pull trade and technology toward them or in response to other countries' actions, and companies scramble to make the best of the changes, it could take years before the ultimate effects prove out, as one country's loss becomes another's gain.

As 2017 begins, we may start to see the extent to which political rhetoric, campaign promises, and obscure ideas turn into policies and actions that alter the way businesses operate and make investments. The electronics and semiconductor industry may have to accept some difficult changes.

Objective Analysis Pins Down 2017

For the 2017 semiconductor forecast Objective Analysis accounted as follows for the three most important of the above issues:

China's high level of capital spending will not result in significant production capacity in 2017 and not likely to make much impact until 2019. When it does, though, it is likely to have a very detrimental effect on chip prices. (A report exploring China's upcoming role in the memory chip market is coming soon.)
Although much has been said in the US about renegotiating trade agreements and charging "Border Adjustment Taxes" via a "Territorial Tax System" (which appear to be new names for tariffs), and although the new administration has promised to encourage tax reform to repatriate US companies' foreign profits, these changes will need to go through legislative processes and corporations will subsequently respond after evaluating the new laws. Likewise, the governments of other countries that are negatively impacted by such changes will create their own responses in order to tip the balance back into their own favor. The slow speed of this process implies that very little change, if any, will occur in 2017.

It has been half a year since the population of Great Britain voted to leave the European Union and Britain's policymakers also move slowly. 2017 will see some changes, with shifts in financial power between the United Kingdom and the EU, but these will not affect semiconductors much, since Europe's chip demand is relatively low at less than 10% of the worldwide total. Where the impact is more likely to be felt is in end-user system demand as the change takes a toll on consumer spending. Since many consumer products are made in the Far East, reduced European system demand will translate into lower demand for chips by Asia. This means that any negative consequences of Brexit will be too small to tip the market from its cyclical shortage to an oversupply.

Moore, Memory, Supply and Demand Still Lead Semiconductors
Having accounted for the above, Objective Analysis expects 2017 to be a year of solid growth, forecasting semiconductor revenues to increase by 20%. This is based on the following assumptions:

Chip prices flatten during a shortage, rather than follow the steady cost decreases that are driven by Moore's Law.

3D NAND flash memory, which is already 3 years late ramping to volume production, will continue to prove difficult to master, and this year will not live up to its goal of providing a lower cost structure than its planar counterpart. This will result in inefficient capacity utilization, resulting in an ongoing shortage.
To ease the shortage, companies that produce both DRAM and NAND flash may use a portion of their DRAM production capacity to produce planar NAND, driving a sympathetic DRAM shortage.

Since the memory market accounts for 25-35% of total semiconductor revenues, this by itself would cause total semiconductor revenues to increase.
The NAND/DRAM shortage will be accompanied by tightness in other chips thanks to a return to health of two key end-user markets: Smart phones and PCs.

Prices in these non-memory chip markets will also stabilize.

In semiconductors, short supply causes prices to stabilize, but rarely do prices increase by an appreciable amount. In addition, flat prices fail to cause any short-term decrease in demand. With flat pricing and steady demand growth, chip revenues are destined to rise.

Therefore, Objective Analysis's semiconductor forecast calls for 30% memory revenue growth, driving total semiconductor revenue growth to approach 20%, to bring total market revenues to $390 billion.

Summary

Corporations will shift design resources, manufacturing, and service hosting to different countries to benefit from major policy changes. However, it will take time to make such changes or it may be only the new projects that are relocated. This year will be a year of chip shortages and semiconductor revenue growth, even as the political climate is moving toward changes that are likely to suppress that growth over the longer term. Through its solid understanding of the dynamics of the chip market and the impact of supply and demand on pricing Objective Analysis is able to confidently predict that chip revenues will approach the $400 billion mark for the first time.

Companies that would like to use the insight and understanding of Objective Analysis to further their goals in the chip market are welcome to make contact through the website: http://Objective-Analysis.com .

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5) 2016 Storage Market Review, John Rotchford, SASI

S A S I
STRATEGIC ADVISORY SERVICES INTERNATIONAL, LLC

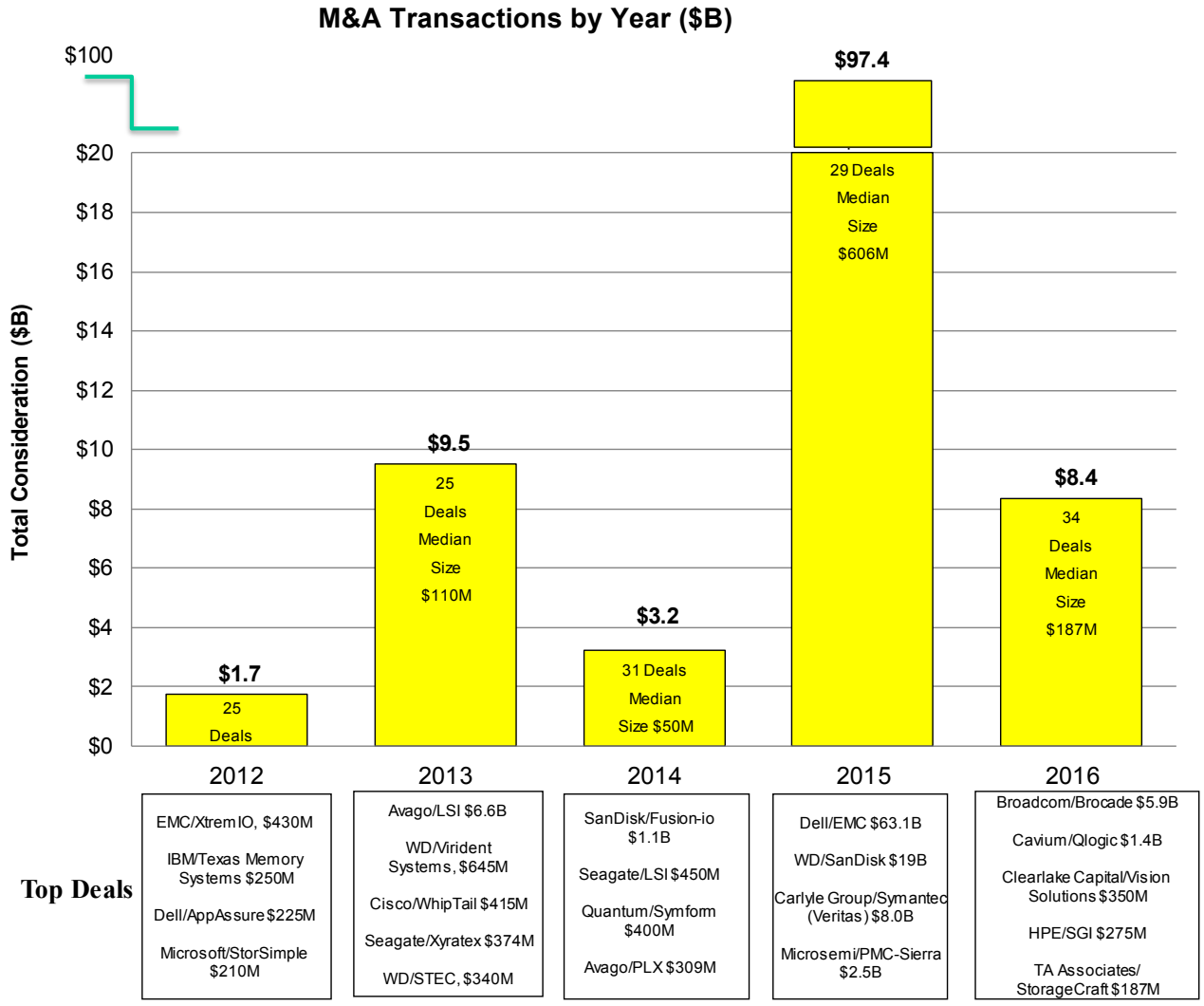
2016 Storage Market Review

"M&A House Cleaning with a Funding Diet for Chubby Unicorns"

2016 Storage M&A Review

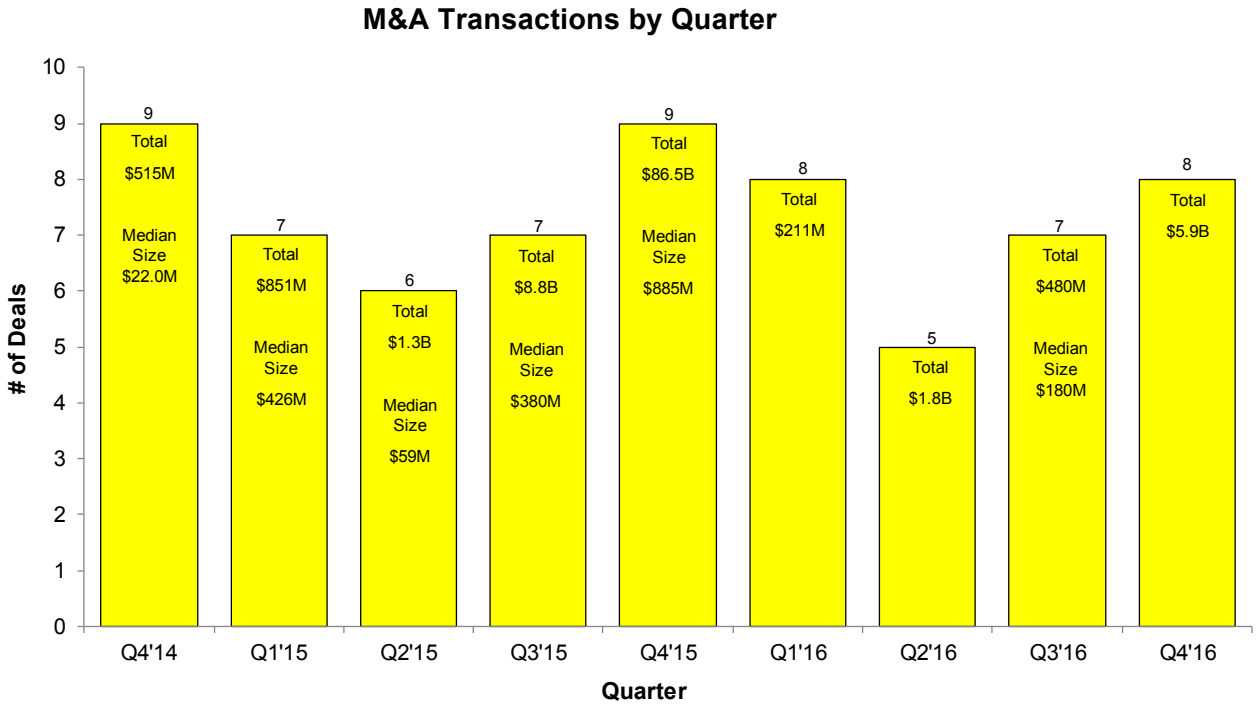
2016 dropped back down to historical levels in terms of total consideration while

the deal count increased to 34 announced transactions, up from 29 in 2015. While there was certainly some larger trades as noted below, the year was driven by smaller, consolidation/clean up deals driven more by business and market dynamics than the promise of new, disruptive technologies. Proof of this can be seen with J2 Global leading all buyers with 11 announced deals representing roughly 1/3 of all deals for the year. J2 Global is known for buying established SaaS companies in consolidating sectors with solid business models and more mature technologies. It is also worth noting that many of the larger strategic acquirers were simply not active in 2016 as they were busy integrating 2015 acquisitions and/or focused on internal restructuring. For 2017, we expect to see a resurgence of technology driven, strategic M&A by leading players as internal restructuring initiatives in 2016 gives way to finding new avenues for product differentiation and top line growth through M&A.



2016 started and ended strong with 8 deals each quarter, with Q4 consideration

accounting for 70% of the year's total consideration.



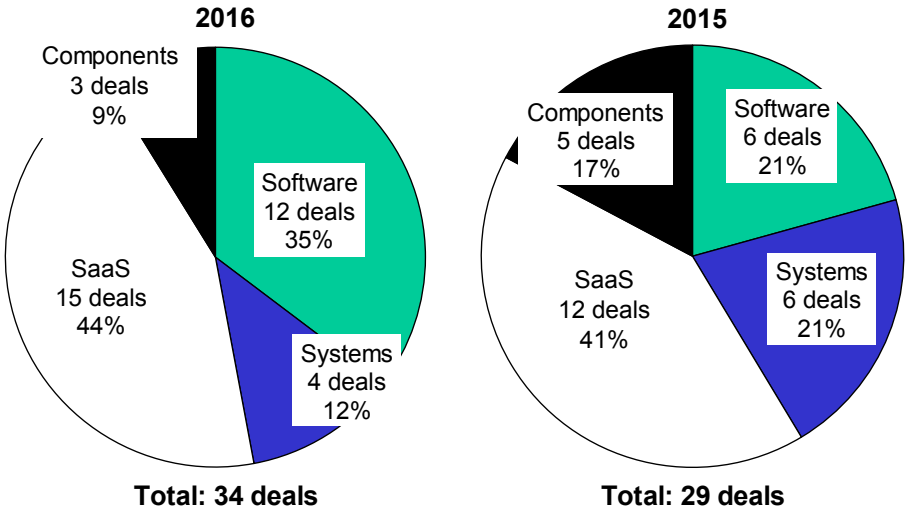
Of the 34 deals in 2016, 13 were technology focused while 21 were business focused. Business deals totaled $8.1B with a median deal size of $187M and a price to revenue multiple of 2.4X. On the technology side, we lacked detailed deal metrics to calculate meaningful median values.

	2010	2011	2012	2013	2014	2015	2016
# Deals	**34**	**32**	**25**	**25**	**31**	**29**	**34**
Total $ Consideration	$9.1B	$9.7B	$1.7B	$9.5B	$3.2B	$97.4B	$8.4B
Median Deal Size ($M)	$140M	$65M	$102M	$110M	$50M	$606M	$187M
Median Price/Revenue Multiple	3.0X	4.5X	5.0X	5.0X	3.3X	3.0X	2.4X
# of Technology Focused Deals	22	20	22	17	24	13	13
Median Deal Size ($M)	$112M	$11M	$90M	$98M	$23M	$152M	N/A
Median Price/Revenue Multiple	8.3X	5.8X	7.5X	6.0X	6.0X	4.9X	N/A
# of Business Focused Deals	12	12	3	8	7	16	21
Median Deal Size ($M)	$239M	$480M	$208M	$214M	$355M	$694M	$187M
Median Price/Revenue Multiple	0.9X	1.3X	1.7X	1.0X	2.9X	2.6X	2.4X

SASI defines technology focused deals as mainly strategic deals whereby an enabling technology holds great promise for market disruption and revenue but has little proof to date of that promise. Conversely, a business focused transaction tends to be more tactical and opportunistic with financial metrics and known market metrics driving deal consideration.

Total # of Deals by Segment

Similar to 2015, the SaaS segment led the year with 15 deals accounting for 44% of the 34 total deals. The SaaS segment was driven by J2 Global's 11 SaaS deals. It is worth mentioning that 2 of the 3 Component deals were the Broadcom/Brocade $5.9B deal and the Cavium/Qlogic $1.4B deal. Notable software deals include two private Equity deals (Clearlake/Vision Solutions at $350M and TA Associates/StorageCraft at $187M) along with Nutanix's acquisition of PernixData, a server-side caching and storage virtualization startup for $25.3M.



2016 Storage Related M&A Details ($M)

Date Announced	Buyer	Seller	Seller Description	Price	Seller Revenue	Price/ Revenue
12/6/2016	Docker	Infinit International	Provides open source storage software	ND		
11/30/2016	Spear Point Capital	Nexsan Corp.	Provider of disk-based NAS, SAN and data archiving systems	ND		
11/14/2016	Micro Focus/SUSE	openATTIC Storage Management	Provides software-defined storage management software	ND		
11/4/2016	Broadcom	Brocade Communications	Provides FC SAN and IP networking products	$5,900.0	$2,300.0	2.57x
10/27/2016	IBM	Sanovi Technologies	Provides hybrid cloud recovery, cloud migration and BC software	ND		
10/11/2016	j2 Global	Dakota Cloud Recovery	Provides data protection, backup and recovery services	ND		
10/11/2016	j2 Global	DataProtect Cloud	Provides data protection, backup and recovery services	ND		
10/4/2016	Micro Focus/SUSE	GWAVA	Provides unified messaging archiving, security and disaster recovery software	ND		
9/19/2016	StorageCraft Technology	Gillware Data Services	Provides online backup solutions	ND		
8/29/2016	Nutanix	PernixData	Provides server-side caching and storage virtualization software	$25.3	ND	ND
8/17/2016	Datapipe	Adapt Services	Provider of managed cloud security, storage and migration services	$180.0	$66.7	2.70x
8/12/2016	HPE	SGI	Provides products and services for HPC and big data analytics	$275.0	$533.0	0.52x
7/11/2016	j2 Global	Electronic Vaulting Services	Provides backup and DR services	ND		
7/11/2016	j2 Global	Safebackup	Provides backup services	ND		
7/11/2016	j2 Global	24sevenbackup	Provides online backup services	ND		
6/15/2016	Cavium Networks	Qlogic	Provider of storage networking components	$1,360.0	$618.2	2.20x
6/1/2016	eFolder	Replibit	Provides backup and recovery software	ND		

2016 Storage Related M&A Details ($M) (con't)

Date Announced	Buyer	Seller	Seller Description	Price	Seller Revenue	Price/ Revenue
5/26/2016	MGT Capital	Demonsaw	Provides secure file sharing software	$50.4	ND	ND
5/17/2016	Ennoconn Corp (Foxconn)	Thecus Technology	Provides NAS and DAS products	ND		
5/12/2016	Clearlake Capital	Vision Solutions (Thoma Bravo)	Provides backup, disaster recovery, data protection and cloud migration software	$350.0	$320.0	1.09x
4/1/2016	ETI-NET	Crossroads	Provides virtual tape systems and Sphinx backup and disaster recovery software	ND		
3/29/2016	Load DynamiX	Virtual Instruments	Provides storage management and performance software	ND		
3/1/2016	j2 Global	Backup Solutions (assets)	Provides online back up services	ND		
3/1/2016	j2 Global	Global Data Vault (assets)	Provides online back up services	ND		
3/1/2016	j2 Global	Yotta280	Provides online back up services	ND		
3/1/2016	j2 Global	VaultLogix	Provides online back up services	ND		
2/24/2016	HPE	Trilead AG	Provides backup and recovery software	ND		
2/23/2016	Datacastle	Seagate (End Point Data Protection Assets)	Provides a range of storage products	ND		
2/19/2016	J2 Global	InterCloud Systems (back-up assets)	Provides software, infrastructure and network solutions	$24.0	ND	ND
2/9/2016	Kingston	Imation (IronKey USB and Technology Assets)	Provider of storage solutions	ND		
2/9/2016	DataLocker	Imation (IronKey Enterprise Management Services Assets)	Provider of storage solutions	ND		
1/28/2016	Pivot3	NexGen Storage	Provider of hybrid flash arrays	ND	$5.0	ND
1/13/2016	TA Associates	StorageCraft Technology	Provides backup and disaster recovery software	$187.0	$75.0	2.49x
1/12/2016	j2Global	On Demand Recovery	Provides online backup services	ND		

2016 Total Consideration	**$8.35B**
Median Deal Size	**$187.0M**
Median Price/Revenue Index	**2.35x**

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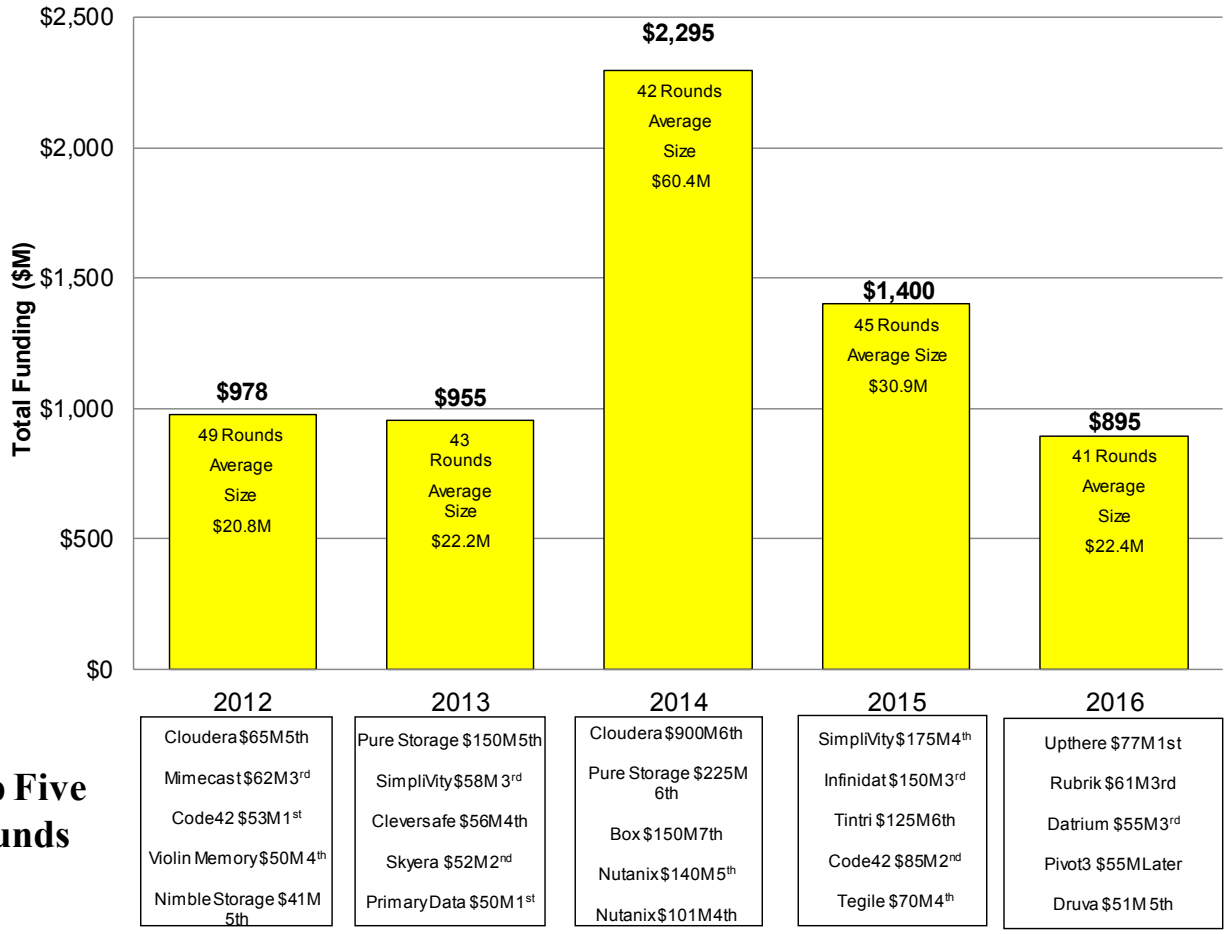
2016 Storage Venture Funding Review

In 2016, it was hard to find new Unicorn's and those that had post money valuations greater than $1B seem to be on a funding diet. What did occur in 2016 was a modest year of 41 rounds of funding with an average round size of $22.4M. While $895M of funding is the lowest level in the last 5 years, the round mix has moved significantly to 1st and 2nd rounds of funding which represented almost half of the funding rounds at a total of 19 out of the 41 rounds of funding. This is a strong vote for more disruption and innovation coming from early stage storage start-ups.

Storage Venture Funding by Year ($M)

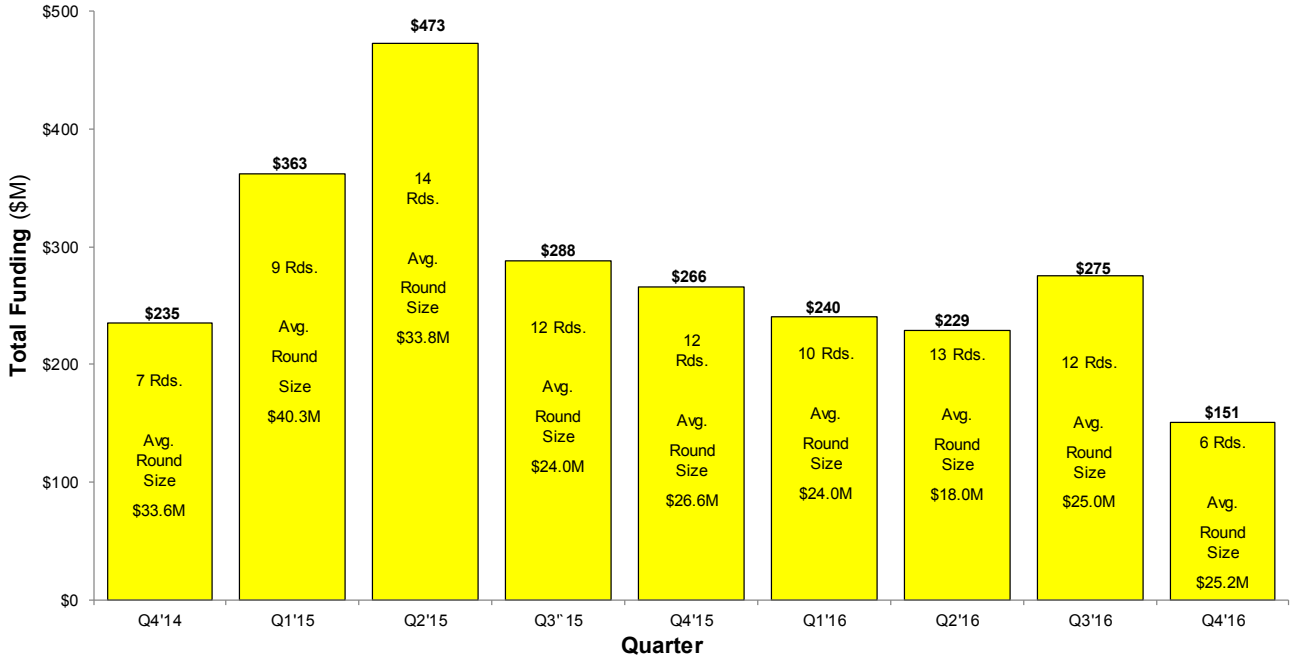


Top Five Rounds

2012	2013	2014	2015	2016
Cloudera $65M 5th	Pure Storage $150M 5th	Cloudera $900M 6th	SimpliVity $175M 4th	Upthere $77M 1st
Mimecast $62M 3rd	SimpliVity $58M 3rd	Pure Storage $225M 6th	Infinidat $150M 3rd	Rubrik $61M 3rd
Code42 $53M 1st	Cleversafe $56M 4th	Box $150M 7th	Tintri $125M 6th	Datrium $55M 3rd
Violin Memory $50M 4th	Skyera $52M 2nd	Nutanix $140M 5th	Code42 $85M 2nd	Pivot3 $55M Later
Nimble Storage $41M 5th	Primary Data $50M 1st	Nutanix $101M 4th	Tegile $70M 4th	Druva $51M 5th

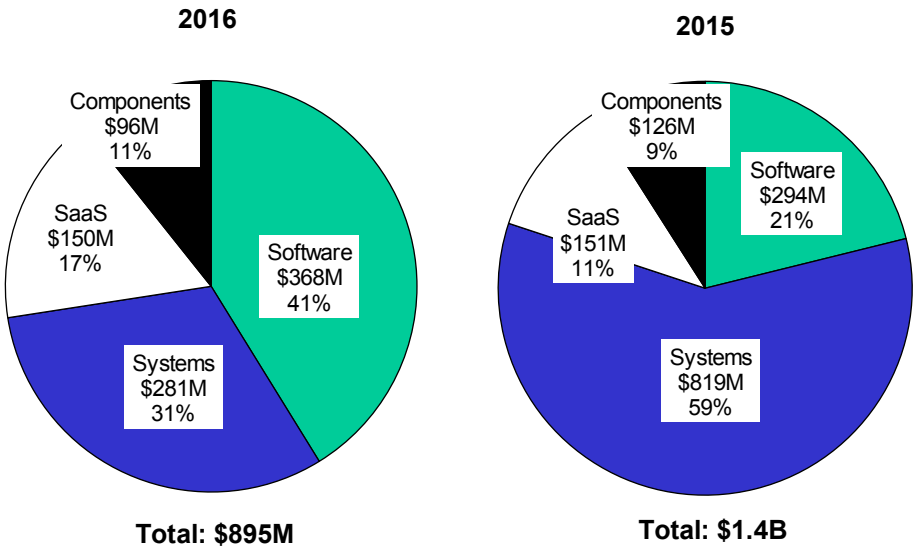
Quarterly declines continued into Q1 and Q2 of 2016 followed but a nice jump up in Q3 to $275M led by Rubrik bringing in $61.1M and Upthere collecting $77M. Venture wallets closed up in Q4 with just 6 rounds of funding totaling $151. The $151M is the lowest quarterly level since Q2 2013 which was at $136M representing 12 rounds.

Storage Venture Funding Rounds by Quarter



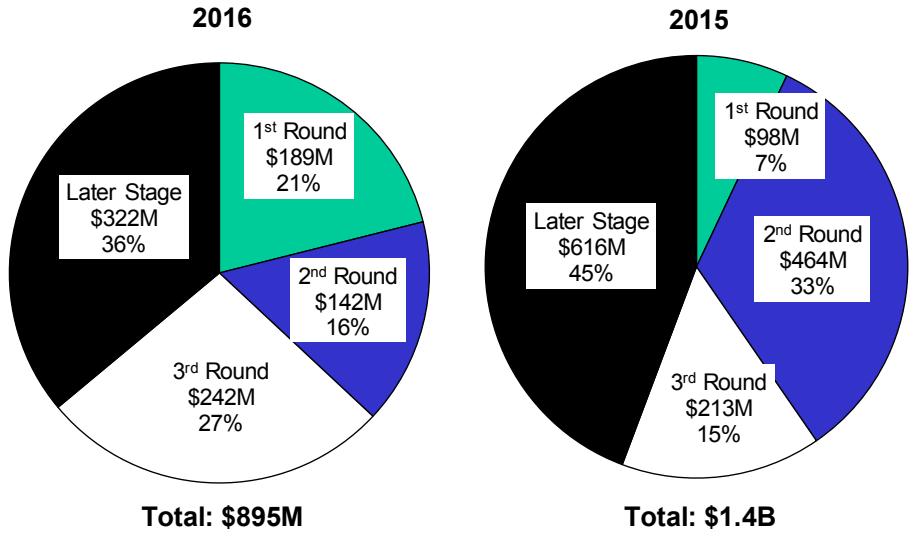
The Software segment received the most funding at $368M or 41% of total funding, with Systems a strong second at $281M or 31% of total funding. The Software segment's largest rounds were Datrium at $55M, Zerto at $50M and Datera at $40M. Systems had 10 rounds and included two of the top five largest rounds of the year, Rubrik at $61M and Pivot3 at $55M. The largest round was Upthere at $77M in the SaaS segment which also included another top five round, Druva at $51M.

Annual Funding by Segment



2016 had a healthy distribution across all rounds which continues a two-year trend away from dominate years of later stage funding which peaked at 86% of the total funding in 2014.

Annual Funding by Round



2016 Storage Related Funding Details ($M)

Date Announced	Company	Description	Segment	Amount Raised	Round	Total Raised
12/13/16	Nasuni	Provides cloud gateway solutions	Systems	$17.5	5th	$70.5
12/12/16	Nantero	Provides non-volatile RAM for storage to replace flash and DRAM	Components	$21.0	6th	$110.0
12/7/16	BlueArchive	Provider of data archiving cloud services	SaaS	$6.2	1st	$8.2
12/5/16	Datrium	Provides an open convergence platform for storage and compute software	Software	$55.0	3rd	$110.0
11/10/16	Avalanche Technology	Provider of MRAM memory	Components	$10.3	7th	$116.5
10/27/16	Cloudian	Provides hybrid cloud object storage systems	Systems	$41.0	4th	$79.0
9/30/16	Caringo	Provides object storage software	Software	$8.8	4th	$31.5
9/29/16	Druva	Provides integrated cloud backup, file sharing and data analytics solutions	SaaS	$51.0	5th	$118.0
9/14/16	Ctera Networks	Provider of cloud storage and data protection solutions	Systems	$25.0	4th	$70.0
9/7/16	Zettabox	Provider of cloud-based storage, collaboration and big-file transfer services	SaaS	ND	1st	
8/17/16	SmartFile	Provider of business file sharing & automation, storage management, secure FTP & custom transfer solutions	SaaS	$1.1	1st	$1.1
8/16/16	Rubrik	Provides a converged data protection platform	Systems	$61.1	3rd	$112.0
8/4/16	Velostrata	Provider of on-demand hybrid cloud software	Software	$17.5	2nd	$31.5
8/3/16	Diablo Technologies	Provider of solid-state storage devices for data-intensive applications	Components	$18.0	3rd	$87.0

2016 Storage Related Funding Details ($M) (con't)

Date Announced	Company	Description	Segment	Amount Raised	Round	Total Raised
7/29/16	Upthere Inc.	Provider of personal storage services and applications	SaaS	$77.0	1st	$77.0
7/22/16	Kazan Networks	Provider of NVMe over Fabrics	Components	$4.5	1st	$4.5
7/15/16	Mangstor	Provider of high-performance NVMe solid state storage solutions	Systems	$5.0	3rd	$19.2
7/13/16	Formation Data Systems	Provides a converged data platform for block, file and object storage across flash, disk and cloud storage	Software	$6.0	2nd	$20.0
6/21/16	Zerto	Provides backup, data recovery and replication software for virtual environments	Software	$20.0	6th	$132.8
6/9/16	Weka.IO	Provides scale out software defined storage solutions	Software	$22.5	2nd	$32.0
6/15/16	Elastifile	Elastifile develops a new elastic, scale-out, and converged storage solution for next-generation data centers	Software	$15.0	2nd	$58.0
6/15/16	Cloudistics	Provider converged virtualization software (compute, storage, network) to optimize application performance	Software	$15.0	1st	$15.0
6/6/16	Qumulo	Provider of data-aware scale-out NAS	Systems	$32.5	3rd	$97.0
6/3/16	CoreOS	Provides hyperscale, container-enabled storage infrastructure software	Software	$28.0	2nd	$48.0
5/23/16	DriveScale	Provider of scale-out computing and storage software	Software	$15.0	1st	$15.0
5/19/16	eFileCabinet	Provider of enterprise on-premise and online document storage and file sharing services	SaaS	$5.0	3rd	$30.1
5/11/16	E8 Storage	Provider of a software-defined NVMe techology-based array appliances	Systems	$12.0	2nd	$12.0
4/29/16	Levyx	Provider of software for real-time processing of big data workloads	Software	$5.4	1st	$5.4
4/20/16	Diamanti (Datwaise.io)	Provider of converged infrastructure for containers	Systems	$12.5	1st	$12.5
4/16/16	CloudEndure	Provider of live-migration and DR solutions	Software	$6.0	2nd	$18.2
4/13/16	Datera	Provides block storage software that integrates with Cloud Service Providers and Enterprise infastructure	Software	$40.0	1st	$40.0
3/25/16	NVM Durance	Provider of software to extend the life of SSDs, laptops, tablets, mobile phones,etc	Software	$2.5	1st	$3.7
3/23/16	Stratoscale	Provides converged compute, storage and networking software	Software	$27.0	3rd	$69.0
3/17/16	Pivot3	Provider of hyper-converged infrastructure appliances	Systems	$55.0	Later	$247.0
2/5/16	OwnBackup	Provides cloud-to-cloud backup and recovery services	SaaS	$3.5	1st	$3.5
2/3/16	Avalanche Technologies	Provider of MRAM memory	Components	$23.0	6th	$106.5
1/27/16	Gridstore	Provides optimized storage systems for Windows Servers and Hyper-V that accelerates application I/O	Systems	$19.0	3rd	$45.0
1/21/16	estmob/Send Anywhere	Provides a solution to send any file type, across any platform, all without logging in or signing up	SaaS	$6.0	1st	$7.0
1/13/16	Diablo Technologies	Provider of "flash-in-the-DRAM" for storage	Components	$19.0	3rd	$69.0
1/13/16	Elastifile	Elastifile develops a new elastic, scale-out, and converged storage solution for next-generation data centers	Software	$35.0	2nd	$43.0
1/13/16	Zerto	Provides backup, data recovery and replication software for virtual environments	Software	$50.0	5th	$112.8
		Total Venture Funding		**$894.9**		
		Average Round Size		**$22.4**		

6) Update on Storage and Related Stocks, Peter Cole

(Twelve months ended December 30, 2016)

Recall that with few exceptions 2015 was a terrible year for stocks. Among our group of fourteen storage-related companies only one stock advanced, BRCM, thanks to a buyout offer. The average decline among this group was 30% and the median decline was 34%. Among our group of "other technology companies more than 50% registered declines. Among the major averages the DOW Industrials declined 3% and the S&P 500 declined 1% excluding dividends, for its first losing year since 2008. However results would have been far worse if not for a handful of giant stocks that propped up the market indexes. Turning to 2016 we find that the first half was more of the same with the DOW up a mere 2.7%, the S&P 500 up only 2.7% and NASDAQ up 3.3%. Among our "storage and related stocks" there was only one stock that increased and was QLGC thanks to a buyout offer. Seven of the old twelve stocks declined and two sold out, EMC and BRCD.

However the second half was completely the opposite particularly post the election of Trump. As things turned out stocks rallied strongly surprising the pundits – the DOW ended up with a gain for the full year of 13.4% excluding dividends, the S&P increased 9.5%, NASDAQ increased 6.0%, the Transports increased 20.4% and the S&P 500 Information Technology Index increased 12.1%. Among the nine remaining storage & related stocks only NMBL declined in 2016 with the average gain being 22.6% and the median gain being 13.8%. The group was led by MRVL up 57.3% followed by MU up 54.8%. Among the list of "other technology stocks" seven registered declines while eighteen advanced. The average gain was 17.4% and the median gain was 9.9%. Finally the four stocks known as the "FANGs" – Facebook, Amazon, Netflix and Google – that were outperformers in 2015 were underperformers in 2016. FB increased only 9.9% in 2016 while AMZN increased only10.8%, NFLX 8.2% and GOOGL 1.8%.

	52-WK Low	52-WK High	12-30-15	12-30-16	% change
INDU	15370	19999	17425	19763	+ 13.4
S&P 500	1810	2282	2044	2239	+ 9.5
NASDAQ	4210	5536	5007	5383	+ 6.0
DJTA (TRAN)	6403	9490	7509	9044	+ 20.4
S&P 500 Inform Tech	626	824	721	808	+ 12.1
Storage & related companies					
MRVL	7.40	15.00	8.82	13.87	+ 57.3
MU	9.31	23.64	14.16	21.92	+ 54.8
VMW	43.25	83.00	56.57	78.73	+ 39.2

NTAP	20.66	39.00	26.53	35.27	+ 32.9
SYMC	16.14	25.72	22.00	23.89	+ 13.8
WDC	34.99	72.13	60.05	67.95	+ 13.2
STX	18.42	41.45	36.66	38.17	+ 4.1
TDC	21.98	33.09	26.42	27.17	+ 2.8
NMBL	5.64	9.90	9.20	7.92	- 14.0

Technology stocks in general continue to be adversely impacted by the continued weakness in capital and IT spending, technological disruption and the strengthening US dollar that further impacted growth opportunities for companies doing business outside the US as purchases are typically in US dollars.

There are a number of factors that continue to adversely impact storage spending including: (a) the adoption of storage optimization technologies, (b) the trend toward keeping systems longer by fine-tuning existing systems, (c) economic and political uncertainties, (d) customers employing cloud offerings rather than internal systems, and (e) the shift in IT spending toward security. But other factors are also at work including for instance: (1) de-dupe and compression technologies that often result in less demand for storage, (2) Software Defined Storage or SDS that reduces demand for storage capacity marginally offset by an increase in storage software revenue.

Other technology stocks -

	52-WK Low	52-WK High	12-30-15	06-30-16	% change
NVDA	24.75	119.93	32.96	106.74	+ 223.8
CRUS	25.09	60.00	29.53	56.54	+ 91.5
UBNT	25.75	59.43	31.69	57.80	+ 82.4
FFIV	*86.03*	*148.34*	*96.96*	*144.72*	*+ 49.3*
QCOM	*42.24*	*71.62*	*49.99*	*65.20*	*+ 30.4*
AKAM	*39.43*	*71.04*	*52.63*	*66.68*	*+ 26.7*
HPQ	*8.91*	*16.25*	*11.84*	*14.84*	*+ 25.3*
IBM	117	170	137.62	165.99	+ 20.6
MSFT	*48.04*	*64.10*	*55.48*	*62.17*	*+ 12.0*
CSCO	*22.46*	*31.95*	*27.16*	*30.22*	*+ 11.3*
AMZN	474	847	676	749	+ 10.8
AAPL	*89.47*	*118.69*	*105.26*	*115.85*	*+ 10.1*
FB	*89.37*	*133.50*	*104.66*	*115.05*	*+ 9.9*
NFLX	*79.95*	*133.88*	*114.41*	*123.80*	*+ 8.2*
BABA	59.25	109.87	81.27	87.81	+ 8.0
INTC	*27.68*	*38.36*	*34.44*	*36.30*	*+ 5.4*
JNPR	*21.18*	*29.21*	*27.60*	*28.26*	*+ 2.4*
GOOG	*593*	*810*	*778*	*792*	*+ 1.8*
CRM	*52.60*	*84.48*	*78.40*	*68.46*	*- 12.7*
SPLK	29.85	65.75	58.81	51.15	- 13.0
WDAY	47.32	93.35	79.68	66.09	- 17.1

BBRY	*6.23*	*8.46*	*9.28*	*6.89*	*- 25.8*
PANW	111.09	165.86	176.14	125.05	- 29.0
FEYE	10.87	19.63	20.74	11.90	- 42.6
DATA	36.60	90.99	94.22	42.15	- 56.3

So what lies ahead? *Is the IT environment about to change due to the Trump victory? We'll have to wait and see but for the past several years the worldwide economic recovery has been very sluggish with country after county adopting policies changes to counter slow growth due to the increasing threat of deflation. However these efforts have born little fruit as companies remained reluctant to spend due to weak growth, political uncertainties and hostility. Instead they preferred to simply increase dividends and buyback stock. And with such low interest rates companies just continued to issue debt at record levels with most if not all of the funds going toward either share buybacks or increased dividends.*

One would expect that sluggish worldwide growth would put pressure on capital and IT spending. And indeed it has, as according to Gartner, worldwide IT spending declined 4.7% in 2016 and was down 0.6% in 2016. However they are optimistic about 2017 and project a 2.7% increase. But analysts are typically optimistic at the start of the new-year and we note that Gartner initially projected a marginal increase in IT spending for 2016. Post the Trump victory there was some rotation out of technology companies without good growth prospects into sectors that were thought to benefit more from Trump's policies.

So what might all this mean for stocks? Much attention has been on Trump and what his economic policies will mean for the market. Note that the last 17 elections going back to 1953, if the time from the election to the inauguration was positive, 76% of the time so was the following year - and vice versa. There were only four exceptions to this: 1953 - Eisenhower's 1st term, 1977 - Nixon's 2nd term, 1981 - Regan's 1st term, and 2009 - Obama's 1st term. With only four exceptions, the market's performance over the succeeding year has matched the performance from election to inauguration. With that insight, the 6.2% increase of the S&P 500 between Trump's election and his inauguration suggests a positive outlook for the year ahead. Finally it is interesting to note that the previous 8 elections dating back to 1985 have had a perfect track record.

Company Announcements

ATP Company Press Release (11/15/16)

ATP Electronics Inc., displayed a complete product line of its next generation storage solutions designed, manufactured, and tested from NAND wafer to finished SSD. New product line displays include new industrial temperature MLC and SLC memory cards, and embedded SSDs utilizing 3D NAND flash

HPE Press Release (11/28/16)

Hewlett Packard Enterprise (HPE) announced a new initiative to address demand for flexible storage consumption models, accelerate all-flash data center adoption, assure the right level of resiliency, and help customers transform to a hybrid IT infrastructure.

Over the past several years, the industry has seen flash storage rapidly evolve from niche application performance accelerator to the default media for critical workloads. During this time, HPE's 3PAR StoreServ Storage platform has emerged as a leader in all-flash array market share growth, performance, and economics. The new HPE 3PAR Flash Now initiative gives customers a way to acquire this leading all-flash technology on-premises starting at $0.03 per usable Gigabyte per month, a fraction of the cost of public cloud solutions.

NVMe Press Release (1/24/17)

NVM Express, inc. the organization that developed the NVM Express specification for accessing SSDs on a PCIe bus, announced the results of its recent board elections.

Elected to promoter positions were Facebook, Micron, Microsoft, Samsung, Seagate, Toshiba, and Western Digital. Facebook and Toshiba are new to the promoter level, and the others are incumbents. The election winners join existing promoters Cisco, Dell EMC, Intel, Microsemi, NetApp and Oracle, whose current terms expire at the end of 2017.

Representatives from the 13 promoter companies form the NVM Express, Inc. board of directors, which governs the organization, including setting strategic direction. All contributor and promoter member companies are eligible to run for promoter positions, where there are elections each year for roughly half the positions.

HDS Press Release (11/16/16)

Hitachi Data Systems (HDS), a wholly owned subsidiary of Hitachi, Ltd. announced Hitachi Content Intelligence, an addition to its trusted Hitachi Content Portfolio (HCP), making it the industry's only object storage portfolio with search and analytics capabilities. The new intelligence solution rounds out the HCP portfolio, which already offers a seamlessly integrated cloud-file gateway and enterprise file sync and sharing, and continues to improves organizations' ability

to strategically manage data.

Deal Closed: Nexsan to Prosper With Private Equity Capital Infusion (Nexsan Press Release, 1/24/17)
Nexsan announced that the transaction between Imation Corp. ("Imation") and NXSN Acquisition Corp. ("NXSN"), an affiliate of Spear Point Capital Management LLC ("Spear Point"), pursuant to which all of the issued and outstanding common stock of Nexsan was sold to NXSN, has closed. Imation's leaders Bob Fernander, its Interim Chief Executive Officer, and Geoff Barrall, its Chief Technology Officer, will continue to run the Nexsan business as Chief Executive Officer and Chief Technology Officer of Nexsan, respectively, and will have seats on the new Nexsan board.

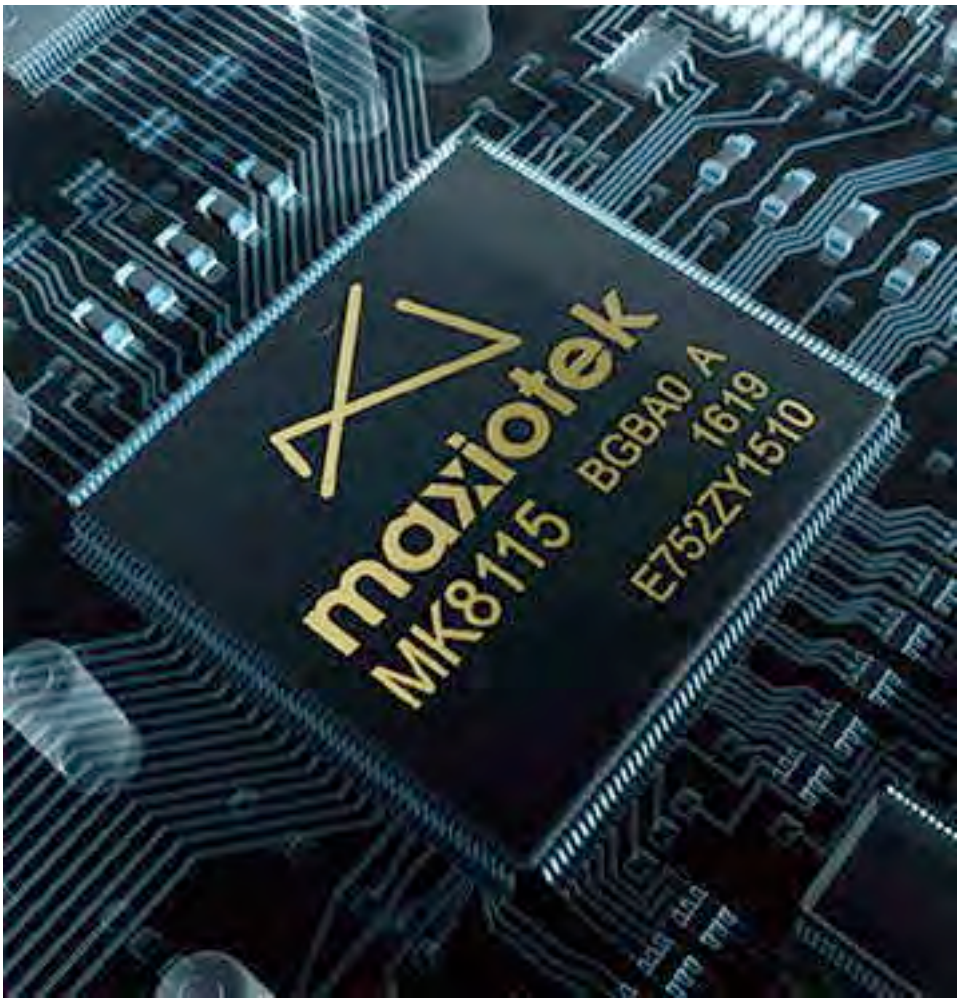
The transaction is designed to enhance Nexsan's plans for both organic and inorganic growth, as Nexsan will be infused with up to $10 million in fresh private equity capital. The transaction is a strategic final step in the restructuring plan of Imation, which received 50% of the issued and outstanding common stock of NXSN and a $25 million senior secured convertible promissory note, by providing for third-party investment in the Nexsan business to enhance Nexsan's growth and support its recent product developments.

As a result of the deal, Nexsan plans to make additional investments in sales, marketing and geographic expansion. Nexsan is continuing its 100 percent channel model worldwide, and will increase account coverage, including channel assistance and marketing initiatives in order to drive growth and customer adoption. Over the last year, Nexsan has stabilized its revenue and we expect it will continue to grow following the closing of the transaction.

Paragon Software's Collaboration with Microsoft Empowers Customers to Easily Share Large Data Between Storage and Mobile Devices (Paragon Press Release, 1/23/17)
Paragon announced *Paragon exFAT for Android* – the industry's first consumer edition of the exFAT (Extended File Allocation System) file system technology for Android users that makes it possible to exchange data between external storage media larger than 32 GB and all the latest consumer electronics. *Paragon exFAT for Android* is a component of *Paragon USB Plugin for Total Commander* to offer instant, non-root, offline access to exFAT data from external storage drives directly on Android smartphones and tablets. For better on-the-go organization and easy mobile access, Paragon exFAT for Android allows users to easily view, backup, copy, and edit important documents, photos, videos, music, and other files between Android mobile devices and portable hard drives or flash drives. For this tool, Paragon Software Group is partnering with Microsoft.

Maxiotek Beginning Mass-Production of MK8115 DRAM-Less 6Gb SATA SSD Controller (StorageNewsletter, 12/27/16)

Maxiotek began mass production of the MK8115, a DRAM-less 6Gb SATA SSD controller, adopted by major SSD brands.



The MK8115 is an 3D-NAND-supported DRAM-less SSD controller, designed for the growing SSD market segment that values performance as the major metrics. Company's proprietary controller architecture paired with its intelligent firmware features such as AgileECC, WriteBooster, Virtual Parity
Recovery, etc., pushes the performance of the MK8115 to levels that compete DRAM-class SSDs in typical workloads.

Support for 3D-MLC, 3D-TLC, SLC, and MLC with performance
The MK8115 builds in dual processors to yield a satisfactory data transmission performance with the latest NAND flash memory, including 3D-MLC and 3D-TLC. It also supports NAND flash memory of SLC 2x, and MLC 1x/1y/1z/3D.

Benefits from MK8115:

Capacity of MK8115 single side M.2 form factor design can reach to 1TB

The MK8115's DRAM-less design gives customers freedom in designing PCB to fit in more NAND chips than those DRAM-class SSD controllers.

Furthermore, it allows a 1TB M.2 SSD to place all NAND flash memory chips on the same one side. As a result of that, there will emerge some creative small form factor (SSF) designs in a variety of applications.

MK8115 is a choice to tap into or expand the consumer and industrial SSD markets.

Key features:

- Performance of the MK8115 with 3D-MLC / 3D-TLC:
  - Sequential read up to 560 MB/s
  - Sequential write up to 525 MB/s
  - Random read up to 90,000 IO/s
  - Random write up to 75,000 IO/s

AgileECC

- Supports best-in-class flexible flash protection provides well-balanced reliability and throughput to NAND flashes.
- Supports firm's hardware-based RAID engine VPR (Virtual Parity Recovery).

WriteBooster

- The feature hugely enhances the transmission speed and sustained performance with 3D-TLC.

Comprehensive NAND flash support

- SLC 2x,
- MLC 1x/1y/1z/3D, and

- TLC 3D

Strengthen security

- Supports hardware-based **AES-256 encryption.**
- Supports **TCG-OPAL 2.0** compliant and **SED** (Self-Encrypted Drive) models which provide the ability to comply with various standards the end-users might need.

Supports commercial (0°C ~ 70°C) and industrial (-40°C ~ 85°C) grades.

Micron Acquired Inotera Memories of Taiwan for $4 Biilion (StorageNewsletter, 12/6/17)

Micron completed the acquisition of Inotera Memories, Inc. It acquired all of Inotera's outstanding shares for consideration worth $0.94 per share. This represents a transaction value of approximately $4.0 billion, net of cash and debt at Inotera, to acquire the equity not already owned by Micron.

Acronis True Image 2017 New Generation Personal Backup Solution Offers Must Have Groundbreaking Anti-Ransomware and Blockchain-Based Capabilities (Company Press Release, 1/18/17)

announced Acronis True Image 2017 New Generation with Acronis Active Protection™ — active protection against ransomware attacks on user data, Acronis Notary™— blockchain-based data certification and verification capabilities — and Acronis ASign™ — the most consumer-friendly electronic document signing service. Acronis True Image is the first and only backup solution in the market that introduces Active Protection technology to detect and prevent ransomware attacks in real-time, automatically recover all data from the backup, self-protect backups and the backup application.

Acronis True Image 2017 New Generation is the most secure backup on the market due to new unique data protection capabilities:

- **Acronis Active Protection for real-time active protection against ransomware.** Acronis Active Protection identifies unusual activity on computers and prevents malicious applications from damaging user data, backups, and backup software. Cutting-edge behavioral heuristics detect and prevent new and known ransomware attacks, making the backup more secure, and reducing a number of times data need to be restored from the backup.

- **Acronis Notary for Blockchain-based data authentication**. Acronis Notary offers certification of the content of any file and verification of content modifications against the original version. Unique, “digital file fingerprints” are stored in a distributed, immutable database based on blockchain technology. Blockchain allows users to verify the authenticity of the information at any time. This is especially important for valuable documents such as contracts, medical records, and financial documents.

- **Acronis ASign for blockchain-based document certification.** Acronis ASign allows multiple parties to execute and certify a document with a secure and publicly auditable digital signature. Users can protect their backed-up documents, which are verified with Acronis Notary and electronically signed – all within the same reliable backup solution.

Phison PS8311 Universal Flash Storage Controller Supporting 3D TLC NAND (StorageNewsletter, 12/19/17)
Phison introduced its PS8311 UFS 2.1 controller. It delivers performance and user experience through an upgrade in hardware and firmware architectures over the traditional eMMC design. This solution supports the latest 3D TLCs from different NAND manufacturers, addressing increasing storage capacity demands from the mobile market. The UFS controller has been qualified with major UFS mobile chipsets and is scheduled for **Q1 2017 production**.

UFS, or Universal Flash Storage, is a standard aimed to replace eMMC in mobile phones and SD cards in memory card applications. The latest UFS 2.1 specification is equipped with much higher data rates and a differential-signaling serial interface compared to eMMC 5.1 which is capped at 400MB/s interface. UFS 2.1 also allows for full-duplex operation and command queuing. PS8311 is the first in a series of company's UFS controllers, enabling one-lane throughput that is 30% faster than eMMC in sequential reads. Additionally, PS8311's 28,500 random read and 26,500 random write IO/s performances are two to three times higher than the fastest eMMC solutions today, for multitasking smartphone users.

The PS8311 UFS controller is equipped with **StrongECC technology**, a compact and low-power ECC engine designed for 3D TLC NAND memory.

This ECC technology saves 70% of power consumption over legacy BCH ECC engines and has a 30% higher decoding capability. StrongECC on PS8311 makes it possible for 3D TLC NAND to reach the embedded memory endurance requirements and reduces time to market.

Targeted for higher densities, PS8311 can support a maximum of eight NAND dice, enabling UFS solutions with capacities ranging from **16GB to 256GB** based on 2D and 3D TLC. Additionally, the firm is developing a new two-lane solution targeting **512GB and 1TB capacities by the end of 2017**.

PS8311 controller features:
- UFS 2.1 compliant, high-speed Gear 3, single lane throughput
- CoXProcessor architecture, inherited from PCIe, for NAND operation management resulting in lower system latency and higher random performance
- In-house M-PHY (high-speed Gear 3, 2-lane), UniPro and UFS IP
- StrongECC technology with both Hard Bit and Soft Bit enhanced decisions
- Maximum 3D TLC sequential R/W - 410/235MB/s

Maximum 3D TLC 4K random R/W - 28,500/26,500 IO/s

Veritas Launches Enterprise Data Management Solution Powered by NetBackup 8.0 to Accelerate Digital Transformation (Company Press Release, 12/1/16)
Veritas announced the launch of NetBackup 8.0 and the availability of an integrated Enterprise Data Management solution to help organizations manage data in the cloud and extract new business value as they transform for the future. The new solution builds on the foundation of Veritas' NetBackup Platform to integrate data visibility, application resiliency and copy data management so organizations can uphold their most critical asset—data.

Scality Announces Version 6.4 of S3 Server for RING With Enhanced Security for Enterprise Cloud (Company Press Release, 11/28/16)
The new release includes new security features for data protection, network security and user management and access control. Key features include:

- Encryption at rest, with integration in customer's key management service (KMS)
- Extension of the S3 IAM model to deliver secure multi-tenancy and granular access control
- Integration with AWS REST and native tools for user management
- Support for groups and access control policies
- Extended single-sign-on capabilities to support temporary credential leasing and expiration
- Support for S3 based bucket and object versioning to support compliance
- Disaster Recovery Mode providing business continuance even in the event of a datacenter failure and simultaneous component (disk or server) failures in the remaining datacenter.

Scality RING 6.4 also includes operational enterprise features prioritized by our existing customers. System monitoring now includes component-level API probes, health-status checks, integrated metadata backup/restore, hot-standby and recovery for multi-site S3. Integrated billing and chargeback RESTful APIs include metrics such as storage capacity, number of objects, bandwidth and operations per time unit. RING 6.4 continues delivering the exceptional performance which RING customers have been accustomed to, showing 10x improvement when compared with other object storage solutions. Also, with this release, Scality provides the S3 Server Open Source version through the Amazon AWS Marketplace.

People in the News:

Primary Data Press Release (1/20/16)
Industry veteran Robert Wilson has joined Primary Data to scale out its sales team and Channel growth as the company's new Head of Sales. Formerly the

Vice President of Global Sales at EMC ScaleIO, and Vice President of Hyperscale Sales at Fusion-io, Wilson brings years of expertise in leading sales teams to help innovative customers adopt advanced storage solutions to support business growth.

NVM Express Organization Elects Facebook and Toshiba to Board (Press Release, 1/24/17)
NVM Express, Inc., the organization that developed the NVM Express specification for accessing SSDs on a PCIe bus, announced the results of its recent board elections.

Elected to promoter positions were Facebook, Micron, Microsoft, Samsung, Seagate, Toshiba, and Western Digital. Facebook and Toshiba are new to the promoter level, and the others are incumbents. The election winners join existing promoters Cisco, Dell EMC, Intel, Microsemi, NetApp and Oracle, whose current terms expire at the end of 2017.

Representatives from the 13 promoter companies form the NVM Express, Inc. board of directors, which governs the organization, including setting strategic direction. All contributor and promoter member companies are eligible to run for promoter positions, where there are elections each year for roughly half the positions.

Mark W. Adams Appointed to Seagate Board of Directors (Press Release, 1/19/17)
Mark W. Adams was appointed to the Company's Board of Directors. Mr. Adams was appointed at Seagate's Board of Directors meeting held on January 19, 2017.

Qumulo Appoints Former EMC Executive Bill Richter as CEO (Company Press Release, 1/29/16)
Qumulo announced the appointment of EMC Isilon veteran Bill Richter as chief executive officer. Richter has 20 years of leadership experience in the technology industry. Prior to joining Qumulo, Richter served as a partner at Madrona Venture Group, where he helped identify new investments and provided strategic and operational advice to portfolio companies. Prior to that, he was president of the Isilon Storage Division of EMC, where he grew the business to $1.5 billion in annual sales in 2014. Richter also served as COO of EMC's $4 billion Midrange Storage business. He was Isilon's public company CFO from 2007 through the $2.5 billion sale to EMC in 2010. Earlier in his career, Richter held management and leadership roles at Amazon and PwC.

NVMdurance announces appointment of Kevin Kilbuck as Chief Marketing Officer (Company Press Release, 1/9/17)
NVMdurance, announced that Kevin Kilbuck has been appointed as Chief Marketing Officer. Kevin spent almost 15 years in a number of memory and

storage marketing roles in Micron, most recently as Director of NAND Flash Marketing, before joining NVMdurance. In Micron, Kevin developed segment, customer and product strategies that resulted in Micron securing the number one market share position in the NAND enterprise segment. Kevin was responsible for all marketing functions related to NAND components, managed NAND solutions and solid state drives (SSDs) including strategic, technical and product marketing as well as business development and applications engineering. Prior to Micron, Kevin spent 12 years at Toshiba America in various marketing, engineering and sales positions, including director of the Memory Business Unit, covering all memory products, including NOR and NAND flash, DRAM and SRAM.

Upcoming Events

- **Storage Valley Supper Clubs, March 9, 2017 starting at 6 PM, Milpitas, CA,** http://www.SVSC.eventbrite.com
- **Creative Storage Conference, May 24, 2017,** www.creativestorage.org
- **Flash Memory Summit, August 8-10, 2017,** http://www.flashmemorysummit.com
- **Storage Visions Conference, October 16, 2017,** www.storagevisions.com
- **TechTarget Conferences:** http://events.techtarget.com/html/index.html

QUARTERLY HDD NUMBERS UPDATE

Total HDD shipments in CQ3 2016 were down 1.7% compared with CQ3 2016 (M 111.5 M units in Q4 2016 versus 113.5 M units in Q3 2016). This is after a 15.2% increase for CQ3 2016 from CQ2 2016, 2.1% decline for CQ2 2016 from CQ1 2016, 12.3% decline for CQ1 2016 from CQ4 2015 and a 3.6% decline for CQ4 2015 from CQ3 2015. Notebook HDD shipments declined by 19.9% while desktop HDD shipments declined 18.6% Q2Q. CE HDD shipments were up 20.8% while branded shipments were down 7.9% Q2Q. High performance enterprise HDDs were down 11.3% while near line enterprise HDDs were up 1.5% Q2Q. 3.5-inch HDDs declined by 11.0% Q2Q. 2.5-inch HDDs increased by about 7.9% Q2Q.

In **Table 1** we see a 0.87% increase in ASPs in CQ4 2016 compared to CQ3 2016. There was a 1.92% increase in ASPs in CQ3 compared to CQ2 2016, an 8.82% increase in ASPs in CQ2 compared to CQ1 2016, a 0.85% decline in ASPs in CQ1 2016 compared to CQ4 2015 and a 1.7% increase in CQ4 compared to CQ3 2015. This quarter continued the increase in ASPs we saw in the prior two quarters.

We can see the multiyear trends in ASPs as shown in **Figure 1**.

TABLE 1. AVERAGE DISK DRIVE SALES PRICES (ASP) AND UNIT VOLUMES (MILLIONS/$ PER UNIT)

	Q4 15 Units/$	**Q1 16 Units/$**	**Q2 16 Units/$**	**Q3 16 Units/$**	**Q4 16 Units/$**
Seagate	45.9/$59.00	39.2/$59.00	36.8/$66.70	38.9/$66.60	40.0/$66.40
WD	49.7/$61.00	43.1/$60.00	40.1/$63.00	47.5/$61.00	4.8/$62.00

Table 2 gives CQ4 2016 drive numbers by company and application.

Table 3 shows CQ4 2016 drive numbers by company and form factor.

Figure 2 shows the unit shipment market share of the three HDD producers for calendar 2016.

FIGURE 1. AVERAGE DRIVE PRICE TREND FOR SEAGATE, WESTERN DIGITAL AND HGST (Q4 '98 TO Q4 '16)

TABLE 2. CALENDAR Q4 2016 DISK DRIVE SHIPMENTS BY APPLICATION (UNITS IN MILLIONS)

Company	Mobile	CE	Branded	Desktop	Near Line	Enterprise	Total Q4
Seagate	8.6	8.1	6.3	8.9	4.8	3.3	40.0
WD	14.7	8.2	5.5	9.92	4.6	1.7	44.8
Toshiba	11.52	4.35	3.01	5.4	1.0	1.5	26.7
Total	**34.8**	**20.7**	**14.8**	**24.2**	**10.4**	**6.5**	**111.5**

TABLE 3. CALENDAR Q4 2016 DISK DRIVE FORM FACTOR SHIPMENTS (UNITS IN MILLIONS, ESTIMATED)

Company	2.5 inch	3.5 inch	Total Q4
Seagate	17.8	22.2	40.0
WD	22.6	22.1	44.8
Toshiba	19.4	7.3	26.7

Total	**59.8**	**51.7**	**111.5**

FIGURE 2. CALENDAAR 2016 MARKET SHARE

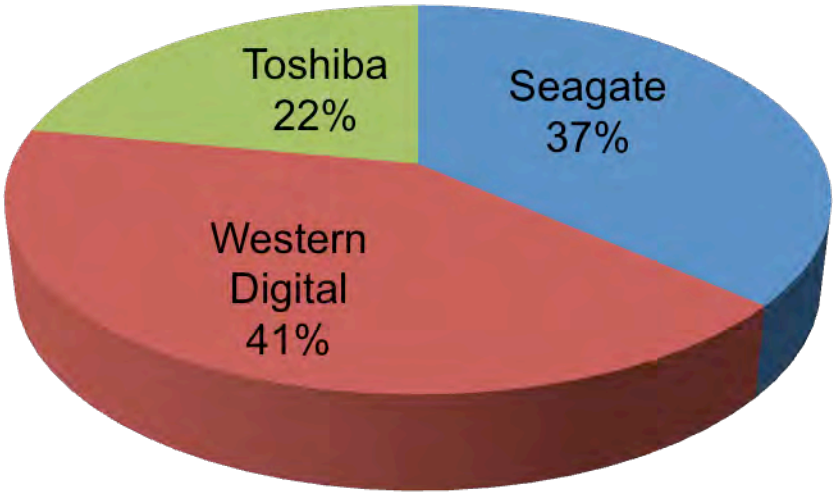


Figure 3 shows high, median and low estimate of total drive unit volume estimates out to 2021 based upon these assumptions.

Figure 4 gives our estimates for HDDs, magnetic media (disks) and heads production out to 2021 based upon the median estimate for HDDs in Figure 3. Slower growth in HDD areal density and the growth of capacity oriented SATA drives for enterprise and hyperscale applications will result in more components per drive by 2021. This gives a lower decline in the shipments in components even with HDD shipments eroding in the near term.

Figure 5 shows an updated areal density growth chart including developments through Q4 2016. Laboratory demonstrations and product announcement maximum areal densities are shown.

Figure 6 shows the product announcement maximum areal density per quarter compared to lines representing areal density growth. We saw announced product areal density in crease in the last quarter.

Figure 7 gives our projections for drives by market niche out to 2021. **Figure 8** does the same for drive form factor. Note the expected reversal of storage in small form factors going into the future.

FIGURE 3. BANDED HARD DRIVE VOLUME PROJECTIONS

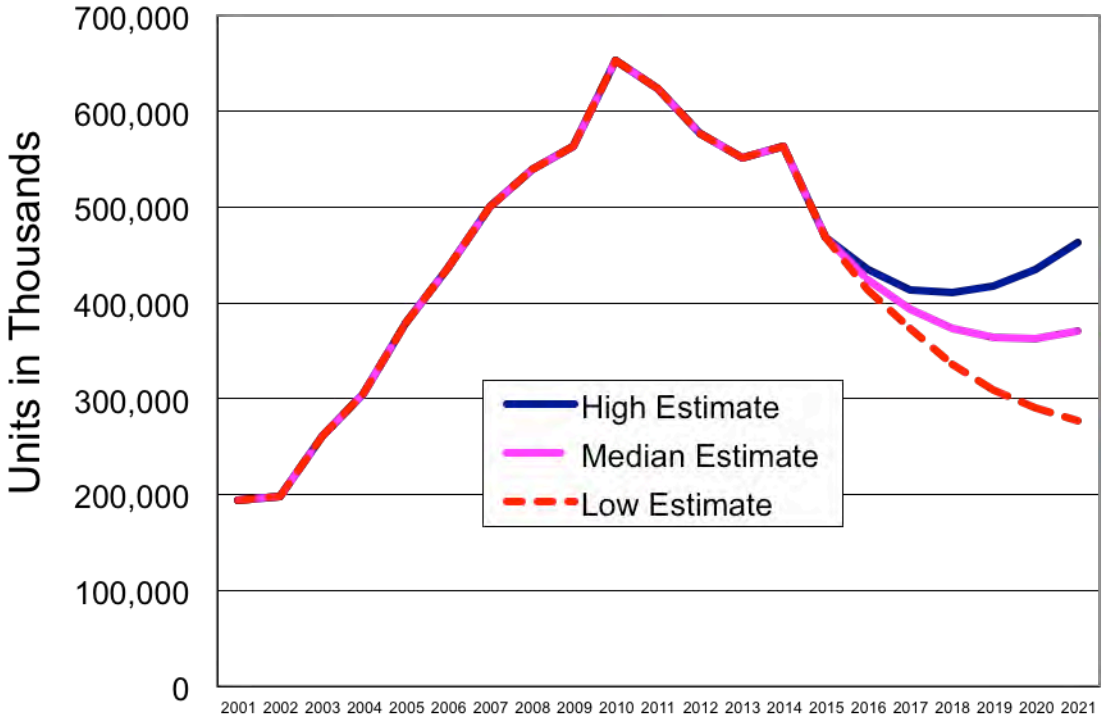
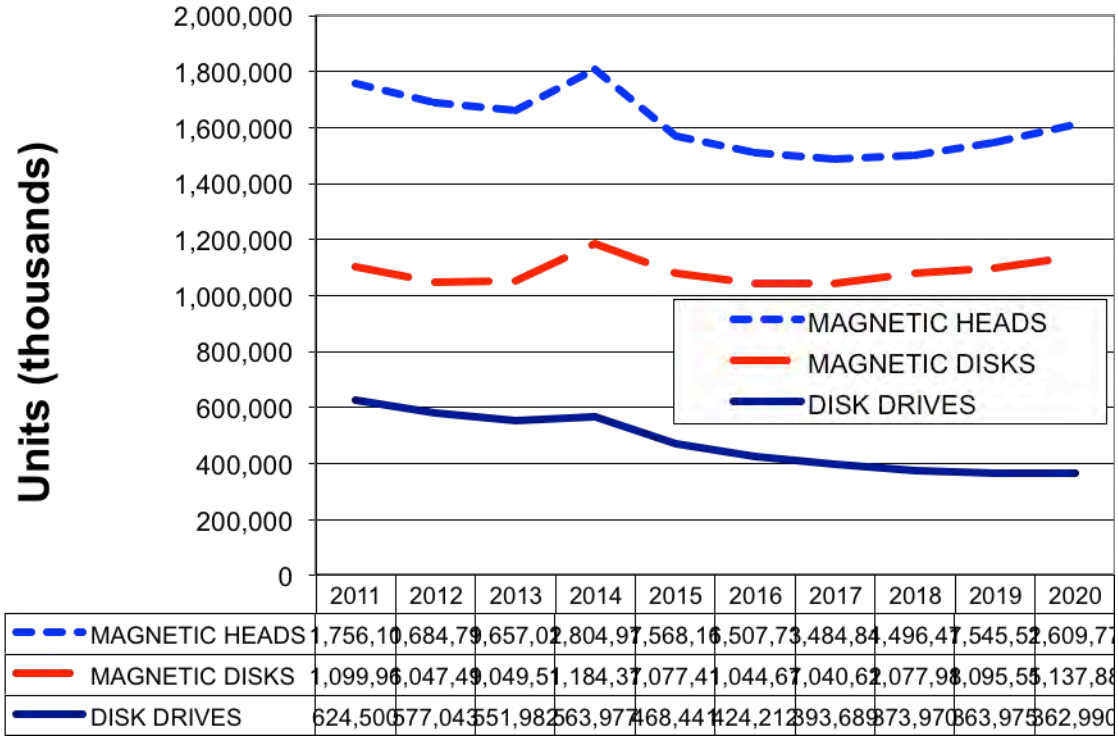


FIGURE 4. PROJECTED DEMAND FOR HDD HEADS AND DISKS



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
MAGNETIC HEADS	1,756,10	0,684,79	9,657,02	2,804,97	7,568,16	6,507,73	3,484,84	4,496,47	7,545,52	2,609,77
MAGNETIC DISKS	1,099,96	6,047,49	9,049,51	1,184,37	7,077,41	1,044,67	7,040,62	2,077,98	8,095,55	5,137,88
DISK DRIVES	624,500	577,043	551,982	563,977	468,441	424,212	393,689	373,970	363,975	362,990

FIGURE 5. AREAL DENSITY ANNOUNCEMENT DEVELOPMENTS

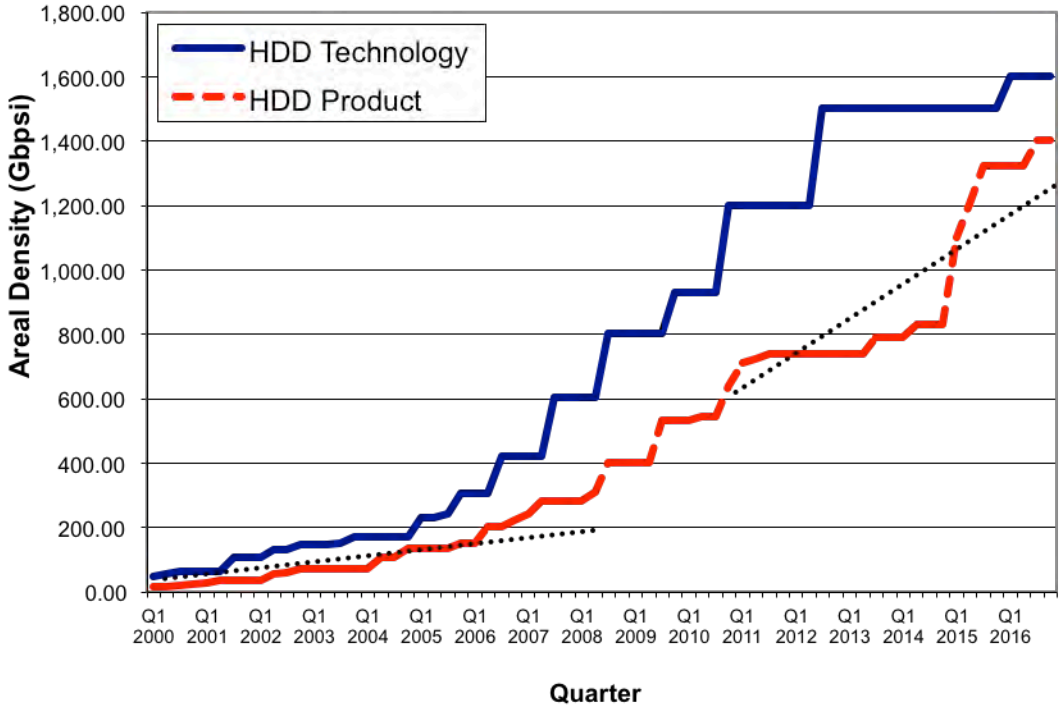


FIGURE 6. AREAL DENSITY PRODUCT ANNOUNCEMENTS VS. CAGR

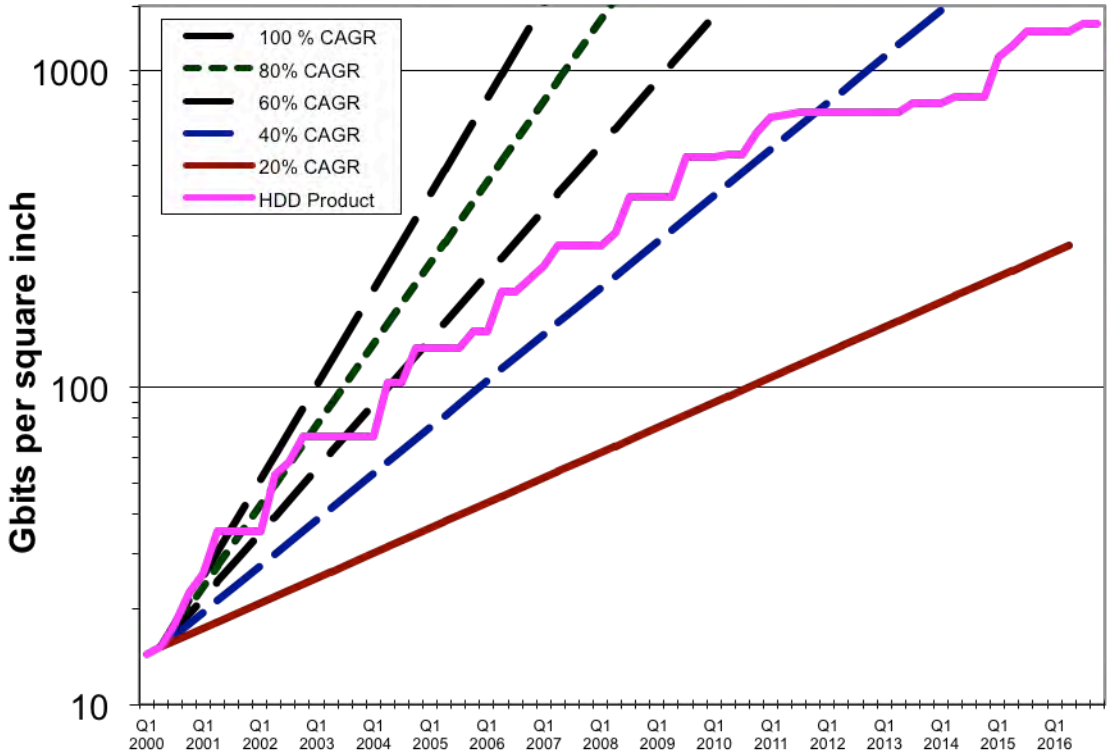


FIGURE 7. PROJECTION OF DRIVES BY MARKET NICHES (1,000'S UNITS)

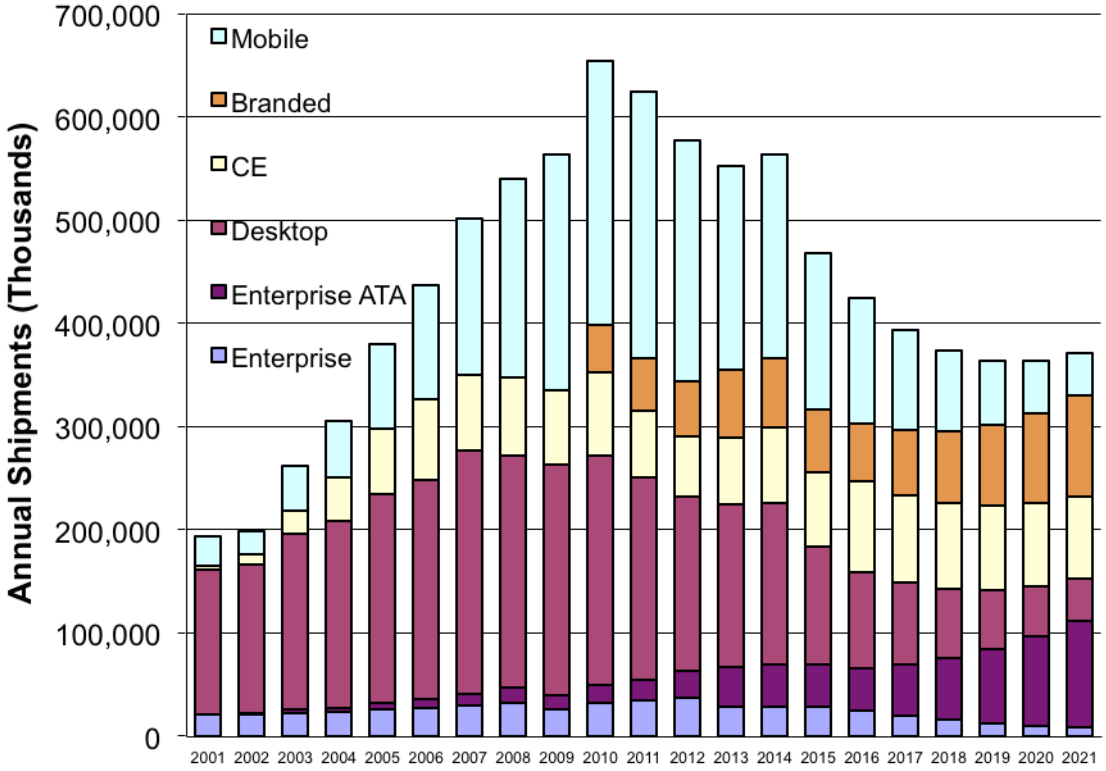
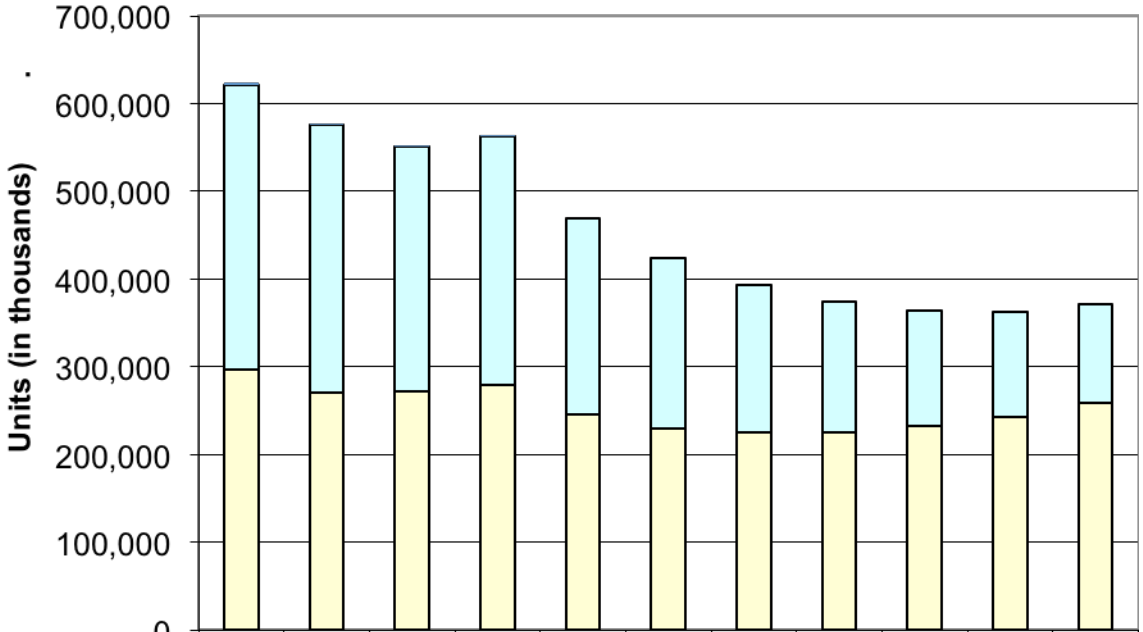


FIGURE 8. PROJECTION OF DISK DRIVES BY FORM FACTOR (1,000'S UNITS)



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1.8 inch	3,800	1,921	716	636	0	0	0	0	0	0	0
2.5 inch	324,000	304,176	278,748	284,348	223,094	194,241	168,463	148,398	131,951	120,348	112,300
3.5 inch	296,700	270,946	272,518	278,992	245,347	229,971	225,226	225,572	232,024	242,641	258,326

Figure 9 projects total shipments of HDD storage capacity on an annual basis to 2021. **Figure 10** shows the average $/GB for HDDs. **Figure 11** shows total projected shipments for Tape (LTO), SSDs and HDDs.

FIGURE 9. PROJECTION OF DISK DRIVE ANNUAL CAPACITY SHIPMENT

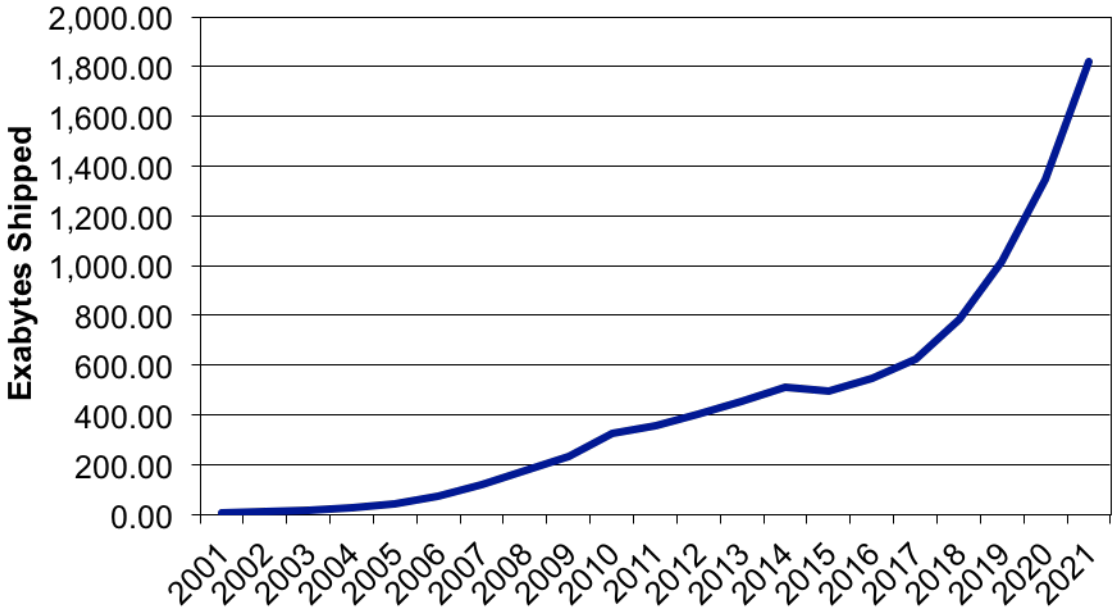


FIGURE 10. AVERAGE $/GB FOR HDDS

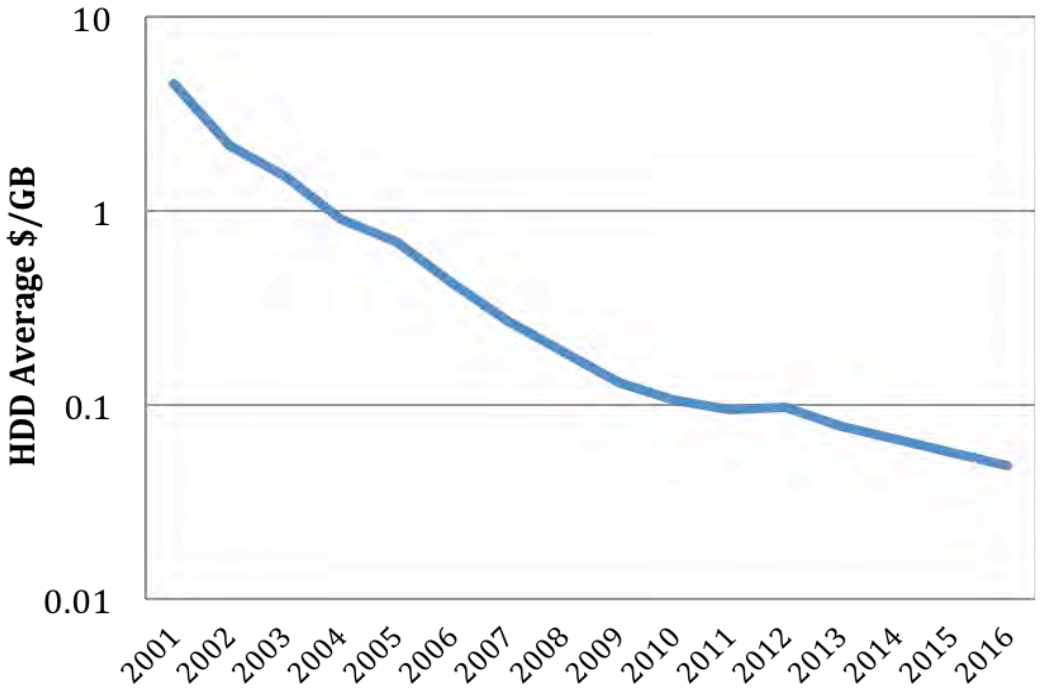
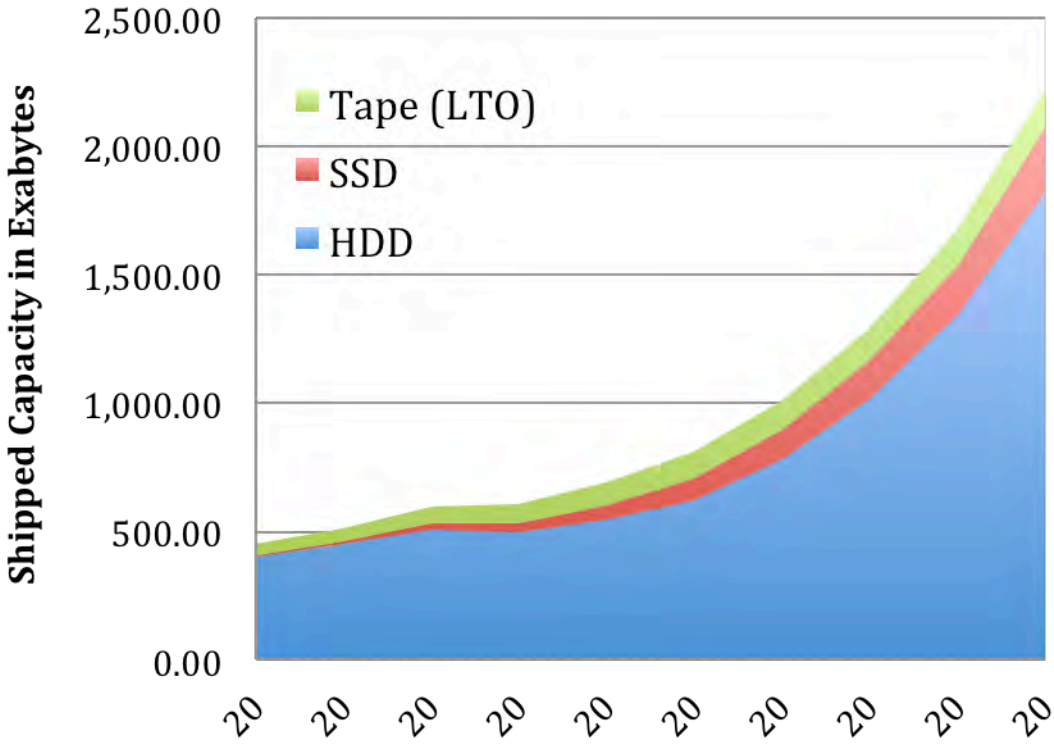


FIGURE 11. CAPACITY SHIPMENTS FOR LTO TAPE, SSDS AND HDDS



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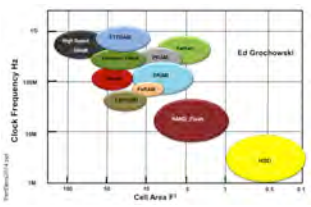

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About Tom Coughlin

Tom Coughlin, President, Coughlin Associates is a widely respected storage analyst and consultant. He has over 30 years in the data storage industry with multiple engineering and management positions at high profile companies.

Tom has many publications and six patents to his credit. Tom is also the author of Digital Storage in Consumer Electronics: The Essential Guide, which was published by Newnes Press in March 2008. Tom has also written Blogs on digital storage topics for GLG, POST Magazine and Forbes. Coughlin Associates provides market and technology analysis (including reports on several digital storage technologies and applications and a newsletter) as well as Data Storage Technical Consulting services.

Tom is active with SMPTE, IDEMA, SNIA, the IEEE Magnetics Society, IEEE Consumer Electronics Society, and other professional organizations. Tom is the founder and organizer of the Annual Storage Visions Conference (www.storagevisions.com), a partner to the annual Consumer Electronics Show as well as the Creative Storage Conference (for more information go to www.creativestorage.org). Tom is also the chairman of the annual Flash Memory Summit. He is a Leader in the Gerson Lehrman Group Councils of Advisors and a member of the Consultants Network of Silicon Valley (CNSV). For more information go to www.tomcoughlin.com.

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