How Flash is Changing our Lives

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November 12th, 2013

SanDisk®

Forward-Looking Statements

During our meeting today we may make forward-looking statements.

Any statement that refers to expectations, projections or other characterizations of future events or circumstances is a forward-looking statement, including those relating to market position, market growth, product sales, industry trends, supply chain, future memory technology, production capacity, production costs, technology transitions and future products. This presentation contains information from third parties, which reflect their projections as of the date of issuance.

Actual results may differ materially from those expressed in these forward-looking statements due to factors detailed under the caption “Risk Factors” and elsewhere in the documents we file from time to time with the SEC, including our annual and quarterly reports.

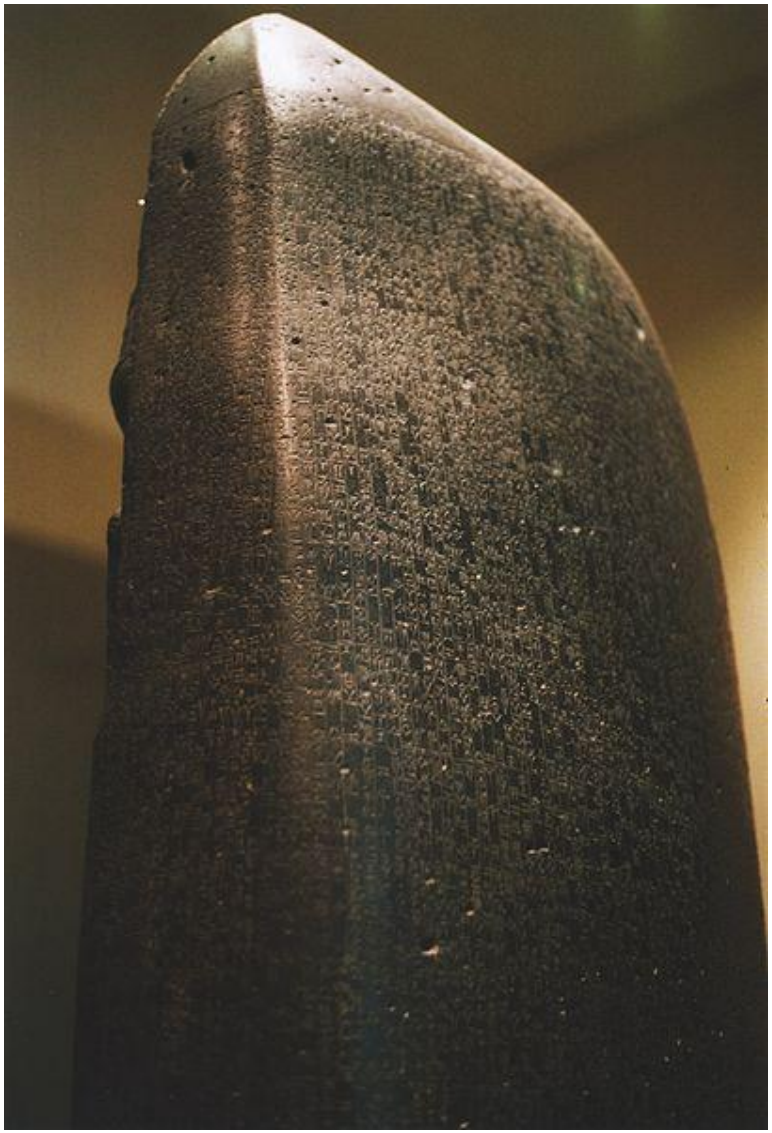
We undertake no obligation to update these forward-looking statements, which speak only as of the date hereof.

Agenda

- History of flash memory
- Where are we now
- What's next
- Scaling challenges

Early Tablets

Hammurabi's Code



Circa 1770 BC

Early Proliferation of media storage

Johannes Gutenberg

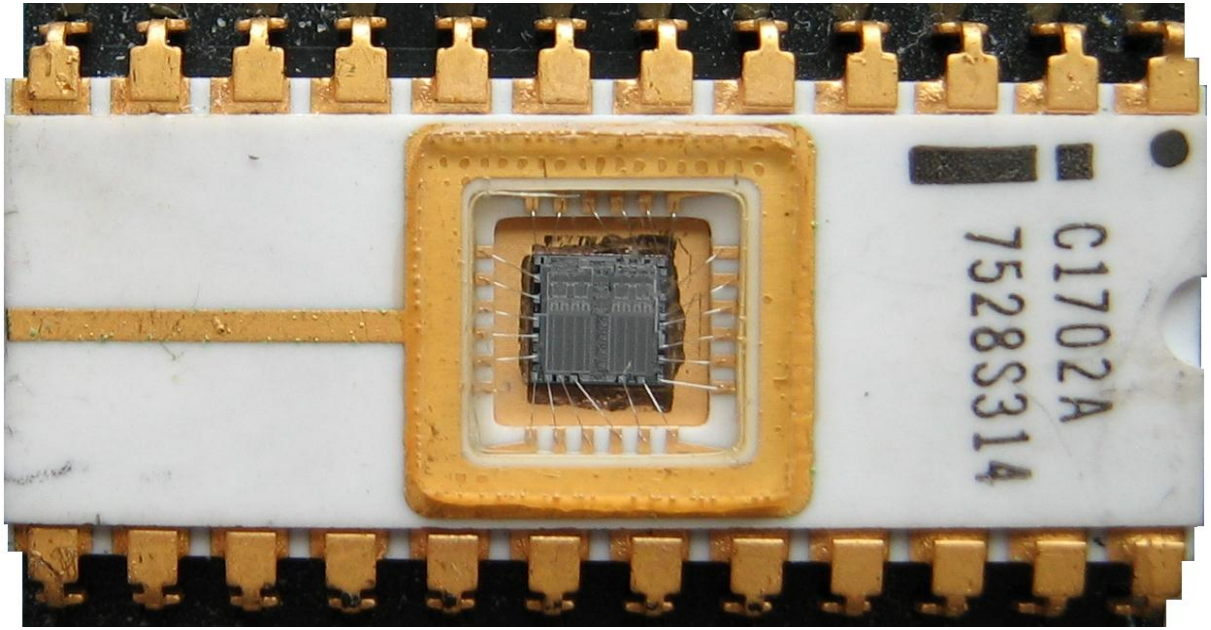
Circa 1450

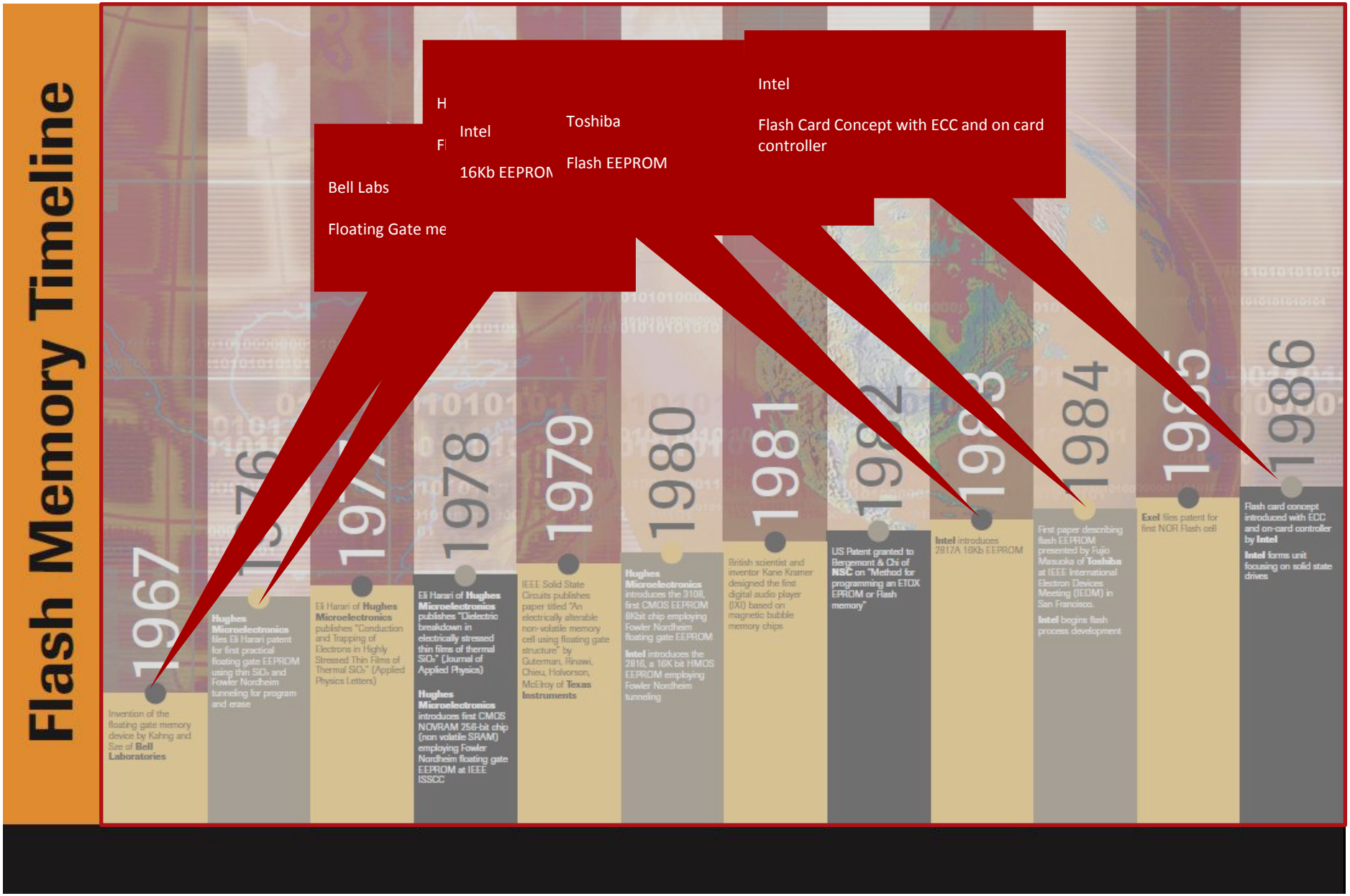
EPROM (Intel ~1970)

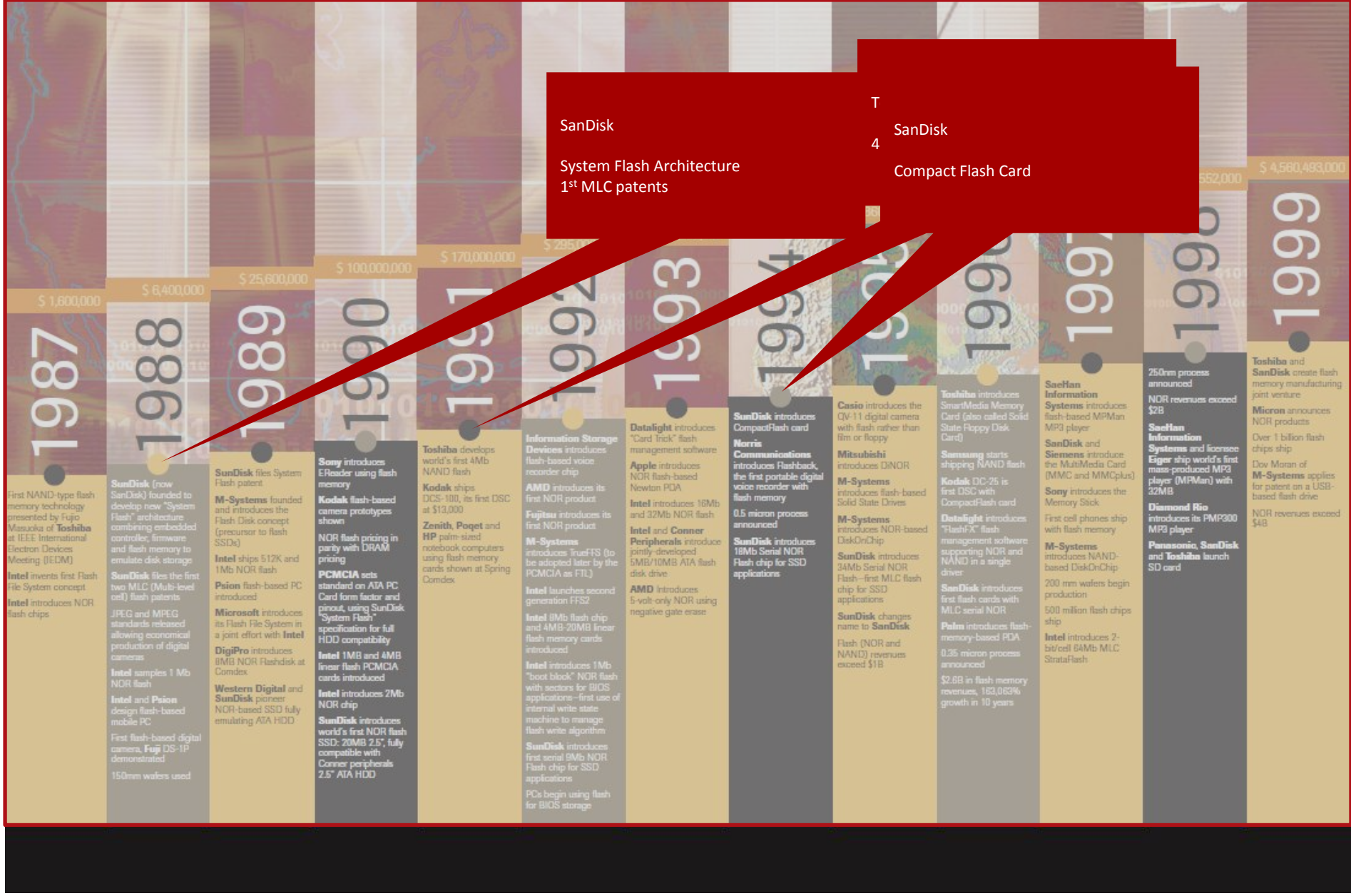
Enabling Microprocessor Revolution

Microcode store

UV chip erase




Flash Memory Timeline
1967
Invention of the floating gate memory device by Kahng and Sze of Bell Laboratories
1976
Hughes Microelectronics files Eli Harari patent for first practical floating gate EEPROM using thin SiO2 and Fowler Nordheim tunneling for program and erase
1977
Eli Harari of Hughes Microelectronics publishes "Conduction and Trapping of Electrons in Highly Stressed Thin Films of Thermal SiO2" (Applied Physics Letters)
1978
Eli Harari of Hughes Microelectronics publishes "Dielectric breakdown in electrically stressed thin films of thermal SiO2" (Journal of Applied Physics)
Hughes Microelectronics introduces first CMOS NOVRAM 256-bit chip (non volatile SRAM) employing Fowler Nordheim floating gate EEPROM at IEEE ISSDC
1979
IEEE Solid State Circuits publishes paper titled "An electrically alterable non-volatile memory cell using floating gate structure" by Guterman, Rinawi, Chieu, Holvorson, McElroy of Texas Instruments
1980
Hughes Microelectronics introduces the 3108, first CMOS EEPROM 8Kbit chip employing Fowler Nordheim floating gate EEPROM
Intel introduces the 2816, a 16K bit HMOS EEPROM employing Fowler Nordheim tunneling
1981
British scientist and inventor Kane Kramer designed the first digital audio player (DXI) based on magnetic bubble memory chips
1982
US Patent granted to Bergemont & Chi of NSC on "Method for programming an ETOX EPROM or Flash memory"
1983
Intel introduces 2817A 16Kb EEPROM
1984
First paper describing flash EEPROM presented by Fujio Masuoka of Toshiba at IEEE International Electron Devices Meeting (IEDM) in San Francisco.
Intel begins flash process development
1985
Exel files patent for first NOR Flash cell
1986
Flash card concept introduced with ECC and on-card controller by Intel
Intel forms unit focusing on solid state drives
Bell Labs
Floating Gate me
Intel
16Kb EEPROM
Toshiba
Flash EEPROM
Intel
Flash Card Concept with ECC and on card controller


SanDisk
System Flash Architecture
1st MLC patents
T
4
SanDisk
Compact Flash Card
$ 1,600,000
1987
First NAND-type flash memory technology presented by Fujio Masuoka of Toshiba at IEEE International Electron Devices Meeting (IEDM)
Intel invents first Flash File System concept
Intel introduces NOR flash chips
$ 6,400,000
1988
SunDisk (now SanDisk) founded to develop new "System Flash" architecture combining embedded controller, firmware and flash memory to emulate disk storage
SunDisk files the first two MLC (Multi-level cell) flash patents
JPEG and MPEG standards released allowing economical production of digital cameras
Intel samples 1 Mb NOR flash
Intel and Psion design flash-based mobile PC
First flash-based digital camera, Fuji DS-1P demonstrated
150mm wafers used
$ 25,600,000
1989
SunDisk files System Flash patent
M-Systems founded and introduces the Flash Disk concept (precursor to flash SSDs)
Intel ships 512K and 1Mb NOR flash
Psion flash-based PC introduced
Microsoft introduces its Flash File System in a joint effort with Intel
DigiPro introduces 8MB NOR Flashdisk at Comdex
Western Digital and SunDisk pioneer NOR-based SSD fully emulating ATA HDD
$ 100,000,000
1990
Sony introduces EReader using flash memory
Kodak flash-based camera prototypes shown
NOR flash pricing in parity with DRAM pricing
PCMCIA sets standard on ATA PC Card form factor and pinout, using SunDisk "System Flash" specification for full HDD compatibility
Intel 1MB and 4MB linear flash PCMCIA cards introduced
Intel introduces 2Mb NOR chip
SunDisk introduces world's first NOR flash SSD: 20MB 2.5", fully compatible with Conner peripherals 2.5" ATA HDD
$ 170,000,000
1991
Toshiba develops world's first 4Mb NAND flash
Kodak ships DCS-100, its first DSC at $13,000
Zenith, Poget and HP palm-sized notebook computers using flash memory cards shown at Spring Comdex
$ 295
1992
Information Storage Devices introduces flash-based voice recorder chip
AMD introduces its first NOR product
Fujitsu introduces its first NOR product
M-Systems introduces TrueFFS (to be adopted later by the PCMCIA as FTL)
Intel launches second generation FFS2
Intel 8Mb flash chip and 4MB-20MB linear flash memory cards introduced
Intel introduces 1Mb "boot block" NOR flash with sectors for BIOS applications—first use of internal write state machine to manage flash write algorithm
SunDisk introduces first serial 8Mb NOR Flash chip for SSD applications
PCs begin using flash for BIOS storage
1993
Datalight introduces "Card Trick" flash management software
Apple introduces NOR flash-based Newton PDA
Intel introduces 16Mb and 32Mb NOR flash
Intel and Conner Peripherals introduce jointly-developed 5MB/10MB ATA flash disk drive
AMD introduces 5-volt-only NOR using negative gate erase
1994
SunDisk introduces CompactFlash card
Norris Communications introduces Flashback, the first portable digital voice recorder with flash memory
0.5 micron process announced
SunDisk introduces 18Mb Serial NOR Flash chip for SSD applications
19
Casio introduces the QV-11 digital camera with flash rather than film or floppy
Mitsubishi introduces DINOR
M-Systems introduces flash-based Solid State Drives
M-Systems introduces NOR-based DiskOnChip
SunDisk introduces 34Mb Serial NOR Flash—first MLC flash chip for SSD applications
SunDisk changes name to SanDisk
Flash (NOR and NAND) revenues exceed $1B
1996
Toshiba introduces SmartMedia Memory Card (also called Solid State Floppy Disk Card)
Samsung starts shipping NAND flash
Kodak DC-25 is first DSC with CompactFlash card
Datalight introduces "FlashFX" flash management software supporting NOR and NAND in a single driver
SunDisk introduces first flash cards with MLC serial NOR
Palm introduces flash-memory-based PDA
0.35 micron process announced
$2.6B in flash memory revenues, 163,063% growth in 10 years
1997
SaeHan Information Systems introduces flash-based MPMan MP3 player
SunDisk and Siemens introduce the MultiMedia Card (MMC and MMCplus)
Sony introduces the Memory Stick
First cell phones ship with flash memory
M-Systems introduces NAND-based DiskOnChip
200 mm wafers begin production
500 million flash chips ship
Intel introduces 2-bit/cell 64Mb MLC StrataFlash
552,000
1998
250nm process announced
NOR revenues exceed $2B
SaeHan Information Systems and licensee Eiger ship world's first mass-produced MP3 player (MPMan) with 32MB
Diamond Rio introduces its PMP300 MP3 player
Panasonic, SunDisk and Toshiba launch SD card
$ 4,560,493,000
1999
Toshiba and SunDisk create flash memory manufacturing joint venture
Micron announces NOR products
Over 1 billion flash chips ship
Dov Moran of M-Systems applies for patent on a USB-based flash drive
NOR revenues exceed $4B


SanDisk and Toshiba
1Gb MLC NAND
Apple
1st NAND Flash based products
Fusion IO
640GB MLC NAND PCIe drive
Toshiba
MLC SATA SSD
2000
2001
2002
2003
2007
$ 10,637,231,000
$ 7594,502,000
$ 7,766,797,000
$ 11,738,282,00
$ 22,182,405
$ 28,123,615,000
$ 24,000,000,000
M-Systems (working with IBM) and Trek Technology introduce USB flash drives
Intel ships its one billionth flash unit
160nm process announced
Flash (NOR and NAND) revenues exceed $10B
Toshiba and SanDisk announce 1Gb MLC NAND
SanDisk introduces first NAND System Flash product
Hitachi introduces AG-AND
Samsung begins mass production of 512Mb flash memory device
NAND revenues exceed $1B
Olympus and FujiFilm introduce xD-Picture Card
MMCmobile card introduced by MMCA (MultiMediaCard Association)
Sony and SanDisk jointly introduce the Memory Stick PRO and half-size Memory Stick PRO Duo cards
AMD introduces MirrorBit charge trap flash
130nm process announced
SanDisk introduces miniSD card
Sony and SanDisk jointly introduce the Memory Stick PRO Micro
Spansion spins out of AMD and Fujitsu
NAND revenues exceed $5B
U3 software system for USB flash drives introduced by SanDisk and M-Systems
NAND prices drop below DRAM prices
SanDisk and Motorola introduce the TransFlash card, now the microSD card
Datalight introduces multi-threaded "FlashFX Pro" management software to support multimedia NAND devices
Spansion announces MirrorBit Quad 4-bit NOR
90nm process announced
Hynix and ST Micro form flash joint venture
Hynix NAND product introduced
Infineon NAND product introduced based on Saifun Charge Trap Flash
Panasonic and Sanyo introduce the first flash-based camcorders
SanDisk introduces Flash Sansa MP3 players
Apple introduces its first two flash-based iPods, the iPod shuffle and the iPod nano
Microsoft introduces Hybrid Hard Disk Drive concept
MMCmicro card introduced by the MMCA
70nm process announced
Micron introduces NAND product
Over 3 billion flash chips ship
NAND GB shipments overtake those of DRAM
NAND revenues exceed $10B
Intel introduces Robson Cache Memory (now called Turbo Memory)
Microsoft introduces ReadyBoost
SanDisk announces 3-bit MLC NAND technology
M-Systems announces 4-bit MLC technology
SanDisk announces the microSDHC card
SanDisk acquires Matrix Semiconductor
SanDisk acquires M-Systems
Samsung and Seagate demonstrate first Hybrid Hard Disk Drives
IMFT formed by Intel and Micron to manufacture NAND flash
STEC acquires Gnutech
Spansion introduces ORNAND flash
65nm process announced
300 mm wafers begin production
Flash revenues exceed $20B
First Flash Memory Summit held in San Jose
Toshiba introduces eMMC NAND
IMFT begins to ship 50 nm NAND flash
Toshiba introduces first MLC SATA-based SSD
Apple introduces the iPhone
Fusion-io announces 640 GB ioDrive MLC NAND-based PCIe XA board
BiTMICRO launches 3.5" SSD with capacity of 1.6 TB (for military applications)
Spansion acquires Saifun
Several laptop MLC SSDs introduced with up to 128 GB storage
Dell introduces SSD option for laptop models
Sub-$200 netbook computers introduced with flash memory storage
Microsoft introduces flash-based Zune Player
NAND revenues exceed $14.5B
Flash revenues exceed $22B, almost 9 times 1997 revenues
Seagate announces the Hybrid Storage Alliance
Seagate introduces the first hybrid HDD, the Momentus PSD
SanDisk introduces ABL to enable high speed MLC, TLC and XA NAND
34nm process announced by Intel and Micron
Toshiba introduces first 512GB MLC SATA-based SSD
Intel and STMicro spin off Numonyx
IBM demos first "Million IOPS" array
EMC announces use of flash-based SSDs for enterprise SAN applications
Apple introduces MacBook Air
Micron, Samsung and Sun Microsystems announce high-endurance flash memory
Violin introduces first fully flash-based storage appliance
Samsung announces 160GB 2.5" MLC SSD with SATA II interface
Several companies announce MLC flash SSDs with up to 256GB for notebook apps
Micron introduces first serial NAND flash
Toshiba develops 3D NAND structure, BiCS
Apple sells 1M flash-based iPhones in 3 days
Intel, Micron introduce 34nm NAND
Samsung introduces the first full HD camcorder with a 64 GB SSD
Seagate enters SSD market
SandForce introduces first compression-based SSD controller
Virident and Schooner introduce first flash-based application appliances for the data center
Pillar Data converts Axiom SANs to SSD
Pliant introduces first SAS SSD
SanDisk and Toshiba present 4-bit/cell flash at ISSCC
WD acquires SiliconSystems and gets into SSD business
NVELO introduces first PC flash caching software "Dataplex"
SanDisk introduces 100-year flash storage vault
Intel, Micron introduce 25nm TLC and MLC NAND
Numonyx acquired by Micron
Microchip acquires SST
Samsung Electronics begins producing 64 Gb, 3-bit NAND
Samsung Electronics introduces high-speed 512 GB SSD utilizing toggle-mode DDR NAND memory
Seagate announces first self-managed hybrid HDD, the Momentus XT, with 4 GB of NAND flash and 500 GB HDD storage
Pliant
IMFT introduces 20nm NAND flash
Intel announces Smart Response SSD caching for PCs
Seagate announces second generation Momentus XT hybrid HDD with 8 GB of NAND flash and 750 GB HDD storage
Ultrabook begins to ship with Smart Response SSD cache
Macronix and Winbond enter NAND flash business
NAND
CELEBRATING
25
YEARS
FLASH

Putting it all together

- Thin Si Oxide and using FN mechanism to W/E cell
- NAND gate architecture which is cost effective and scalable
- Multi bit per cell technology
- Sophisticated memory management algorithms

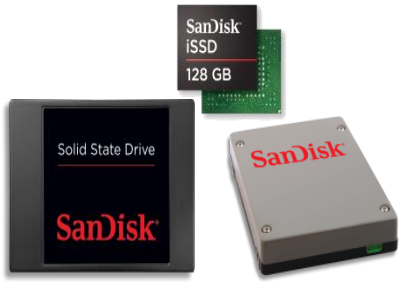
Flash Memory's History of Disruption

Digital Imaging

USB Flash Drives

Digital Music

Mobile Phones



SSDs: Notebooks, Tablets & Data Centers

more than

40,000,000

pictures

EVERY DAY

Source: Instagram™ Press Center


Insta
WORD
FOTO
3.85mm 1:2.8
qik

Smartphone MegaPixels Grew 4X!

Camera resolutions in high end smartphones
Source: IDC, Worldwide Mobile Phone Camera 2012-2016 Forecast, doc # 234534 May 2012

20

MEGAPIXELS IN 2016

Source: SanDisk estimates

7MB
20 MP

1MB
3 MP

What's Happening In

Video?

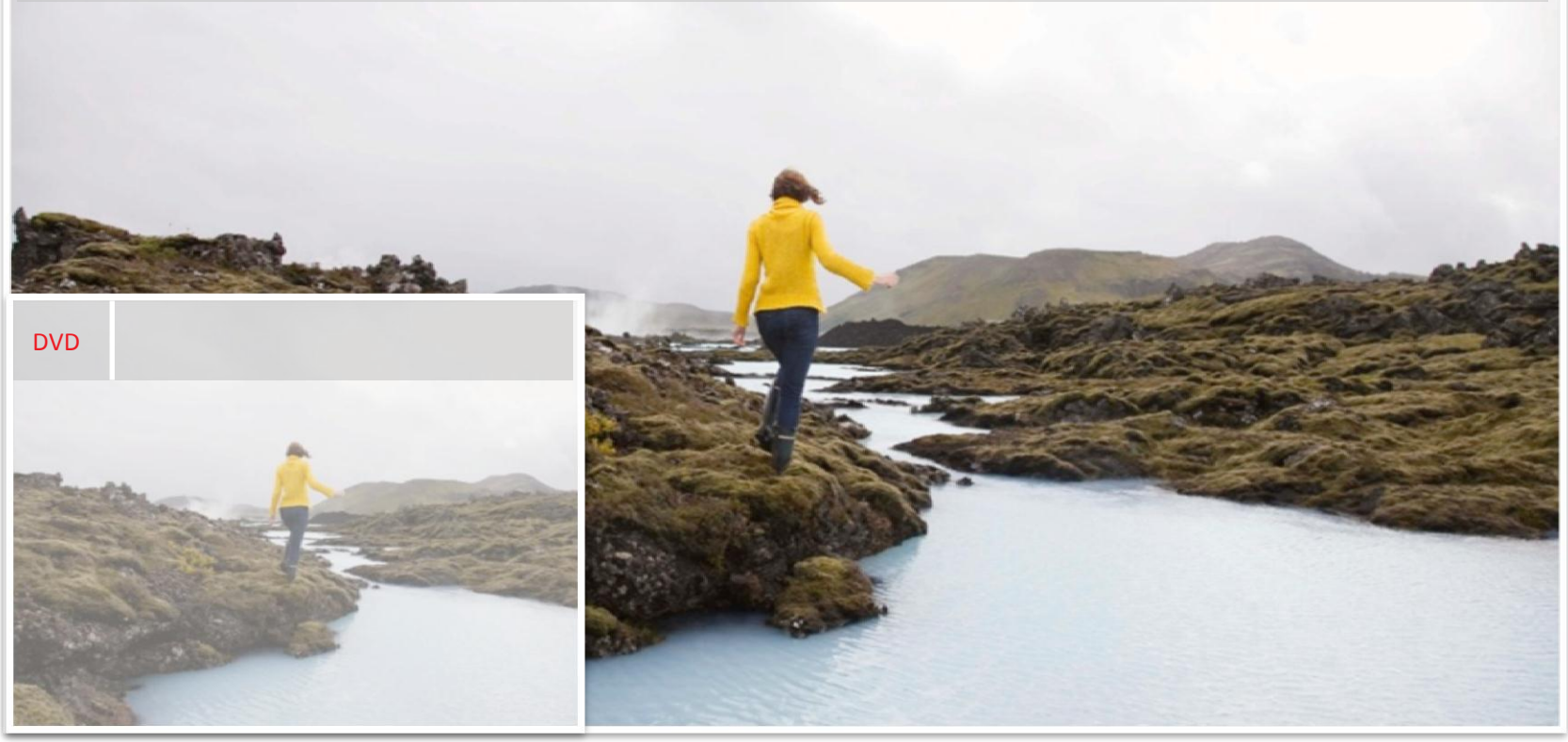
DVD

4.7GB for 2 Hour Movie

Source: SanDisk estimates

1080p HDTV

25GB for 2 Hour Movie



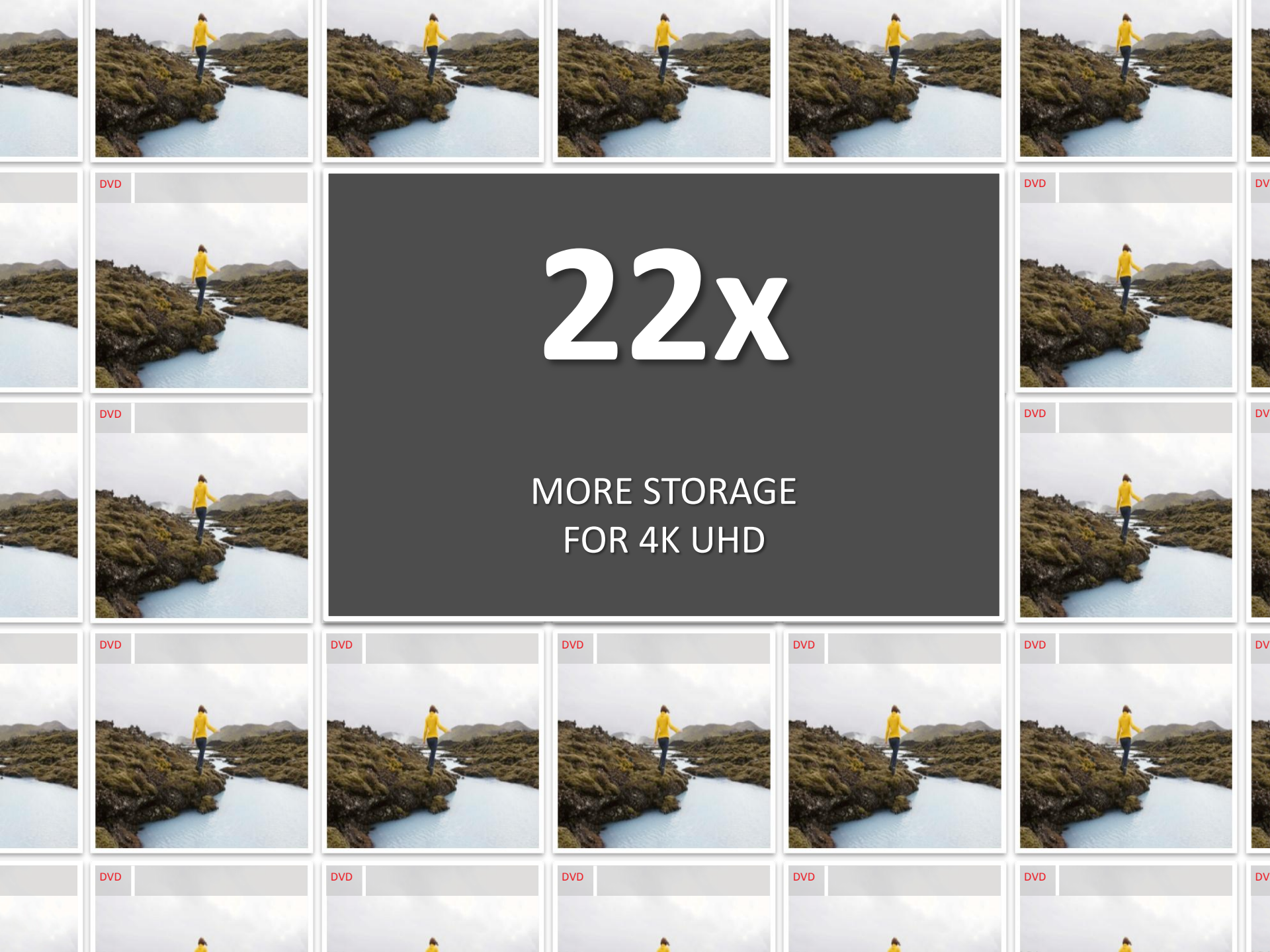
DVD

Source: SanDisk estimates

4K Ultra HD

100GB for 2 Hour Movie

Source: SanDisk estimates

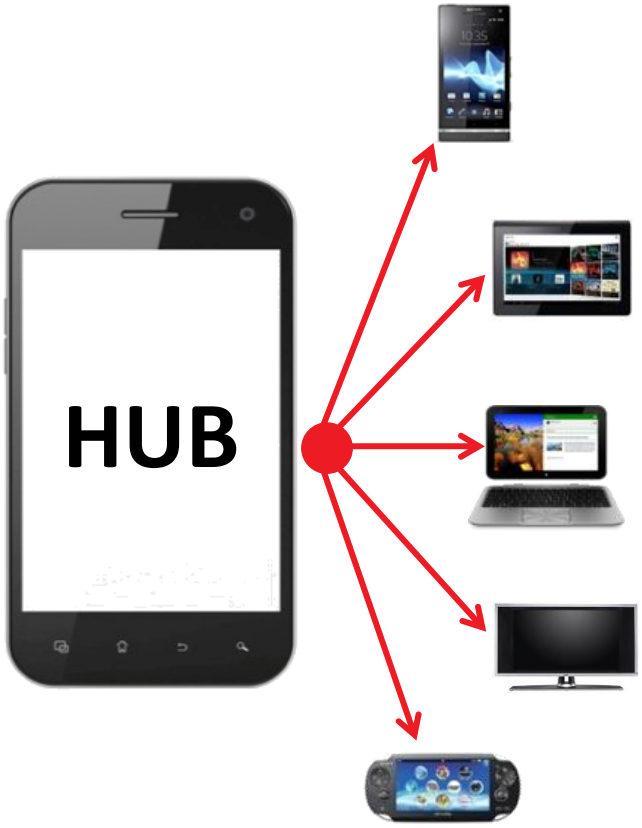

22x
MORE STORAGE
FOR 4K UHD

Mobile Devices Becoming Media Hubs

Fast Connectivity

Security

Proximity – Wifi Miracast™



Connected Home $2.1B in 2016

Smart TVs

CONNECTED STBs

DVRs

Flash Usage	Media	Applications	Time Shifting

Source: SanDisk estimates

Increasing Product Requirements

Faster Application Execution

Faster Web Browsing

Smoother Multi-tasking

Computational Photography

Longer Battery Life, Power Savings

Sharing, Connectivity

Higher Resolution Video

Four Unique Opportunities Emerging for Personal Computing Devices

SSD for Ultrathin

Thinnest form factor

SSD for Performance

Superior performance for business/gaming

SSD for Caching

Improved user experience at low cost

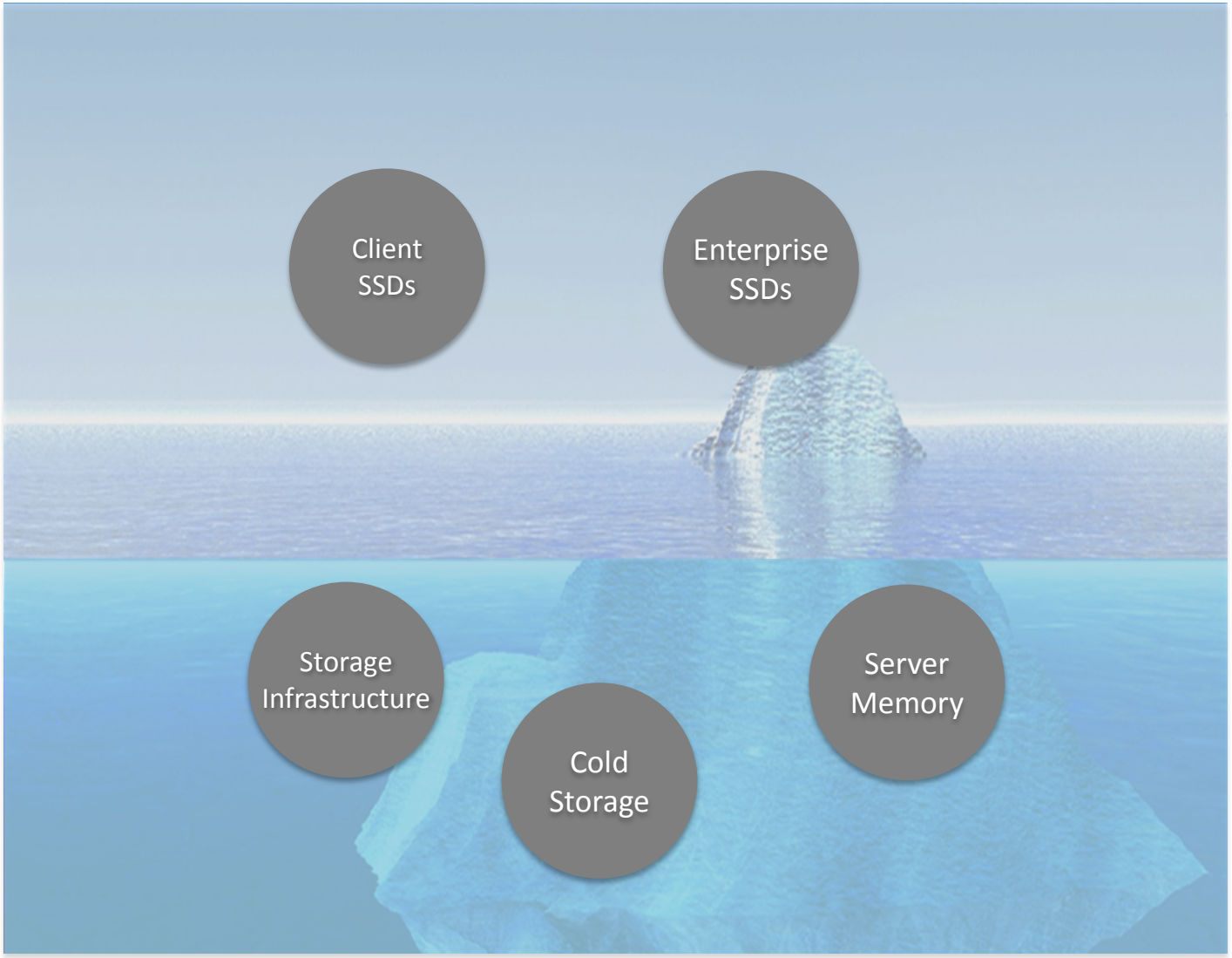
Flash for Hybrid Drives

More storage with a built-in flash cache

Penetration rate* of NAND Flash in all personal computers grows from 8% in 2012 to 52% in 2016

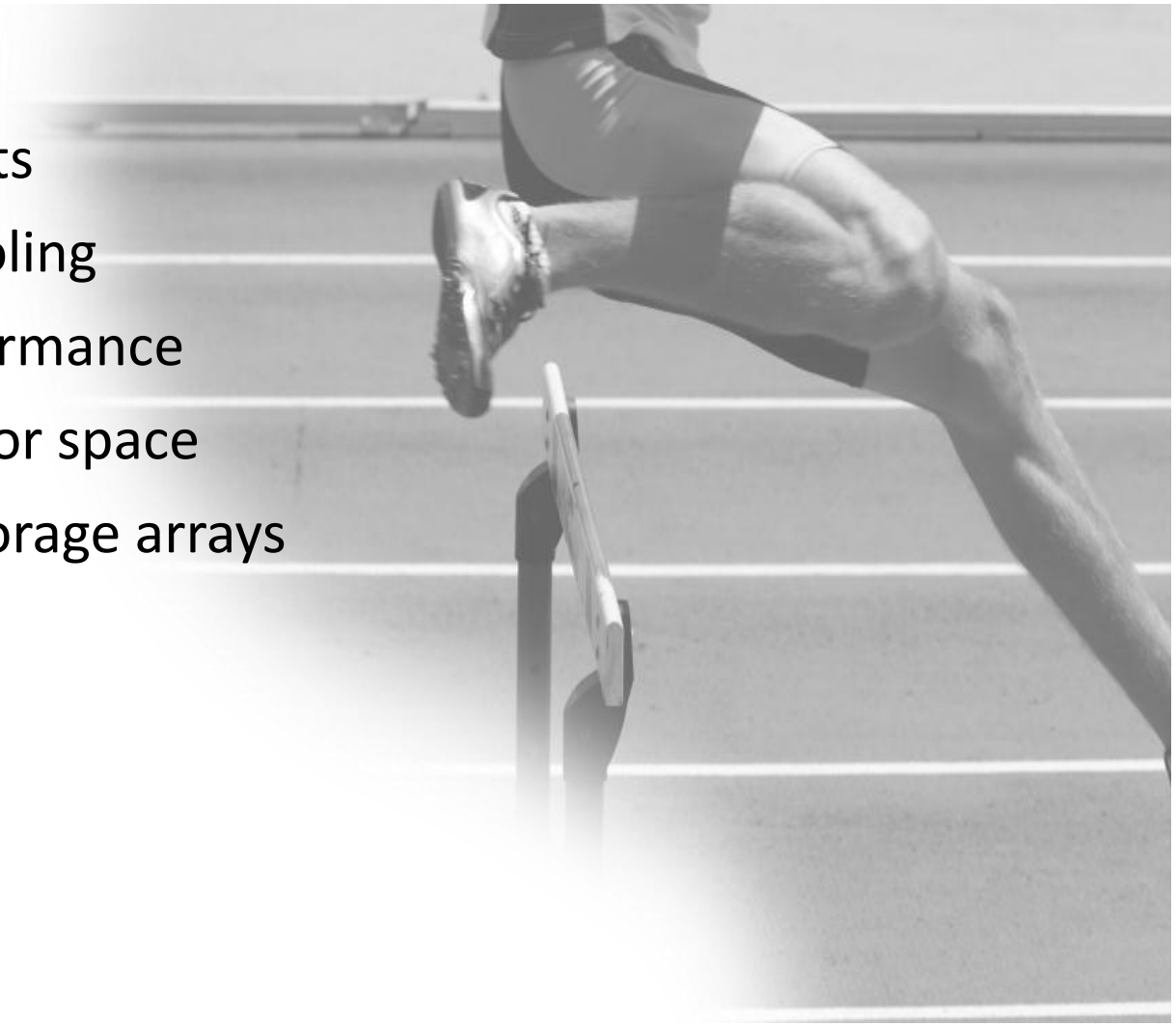
*SanDisk estimates

Enterprise SSDs



Focusing on the Needs of the Modern Data Center

- Instant access
- Reduced support costs
- Lower power and cooling
- Memory speed performance
- Reduced rack and floor space
- Fewer servers and storage arrays



Forces Driving the Transformation

- Virtualization
  - Fundamental challenges for shared storage infrastructure
  - Server-tier agility demands storage-tier capability
- Scale-out, In-Memory Computing
  - Requires large-scale memory pools
- Cloud – Public & Private
  - Storage capacity available for subscription: TB/month
  - Storage policy can evolve faster than previous in-house tech
- New math: $/GB replaced by $/IOPS
  - (Nearly) infinite capacity is taken as given
  - Key challenge is *delivery* of large volumes of data

Hard Disk Drive Storage Challenge

HDDs throttle the performance of processor and memory

Power / Cost

>2 Gigawatts to power hard drives in 2016*

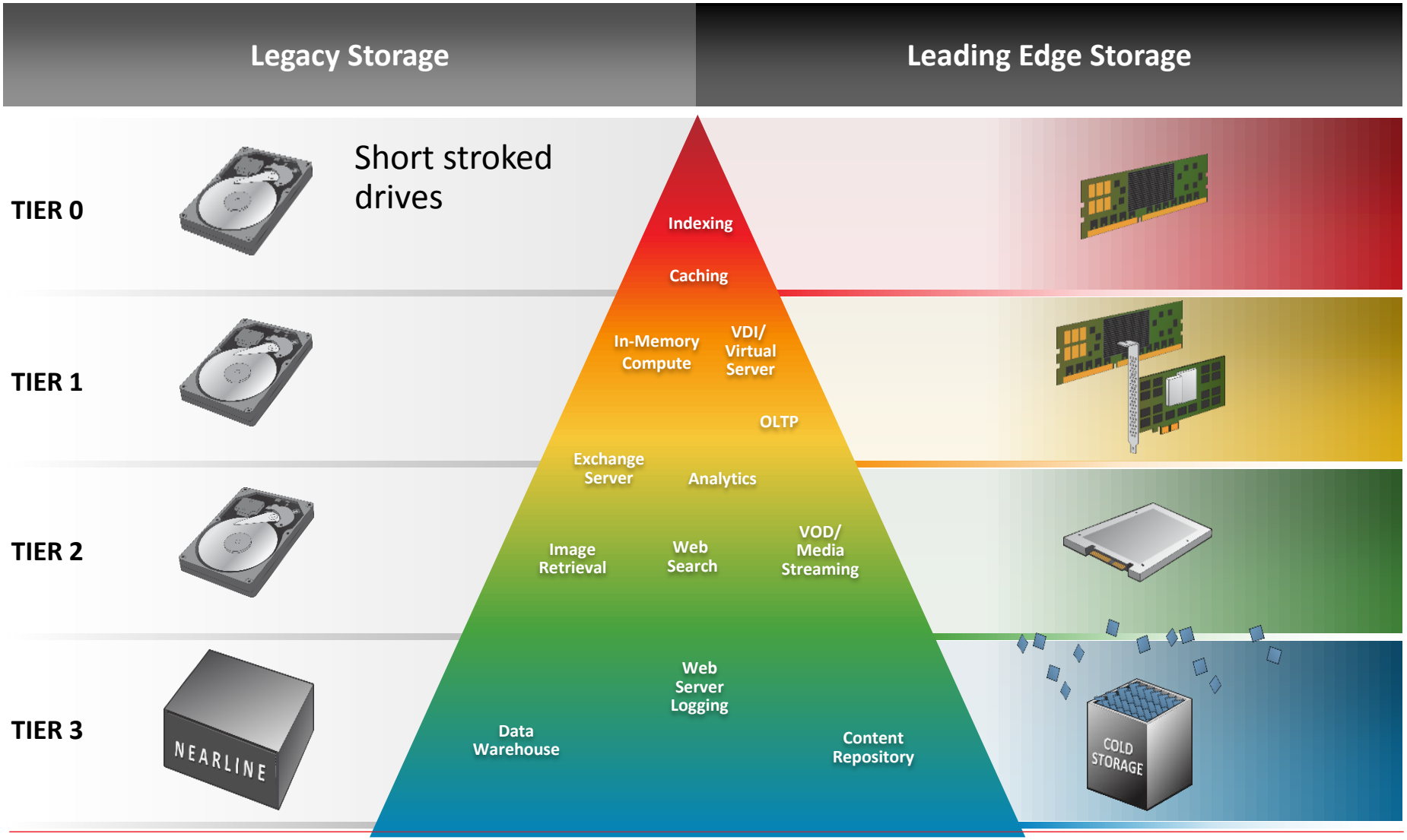
Maintenance Predictability

100s of drive failures per minute worldwide by 2016*

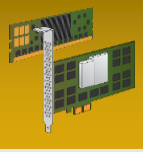
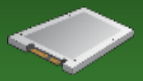
HDDs are challenged to scale economically for long-term storage

*Source: “Forecast: Hard-Disk Drives, Worldwide,” 2010-2017, 1Q13 Update, SanDisk estimates

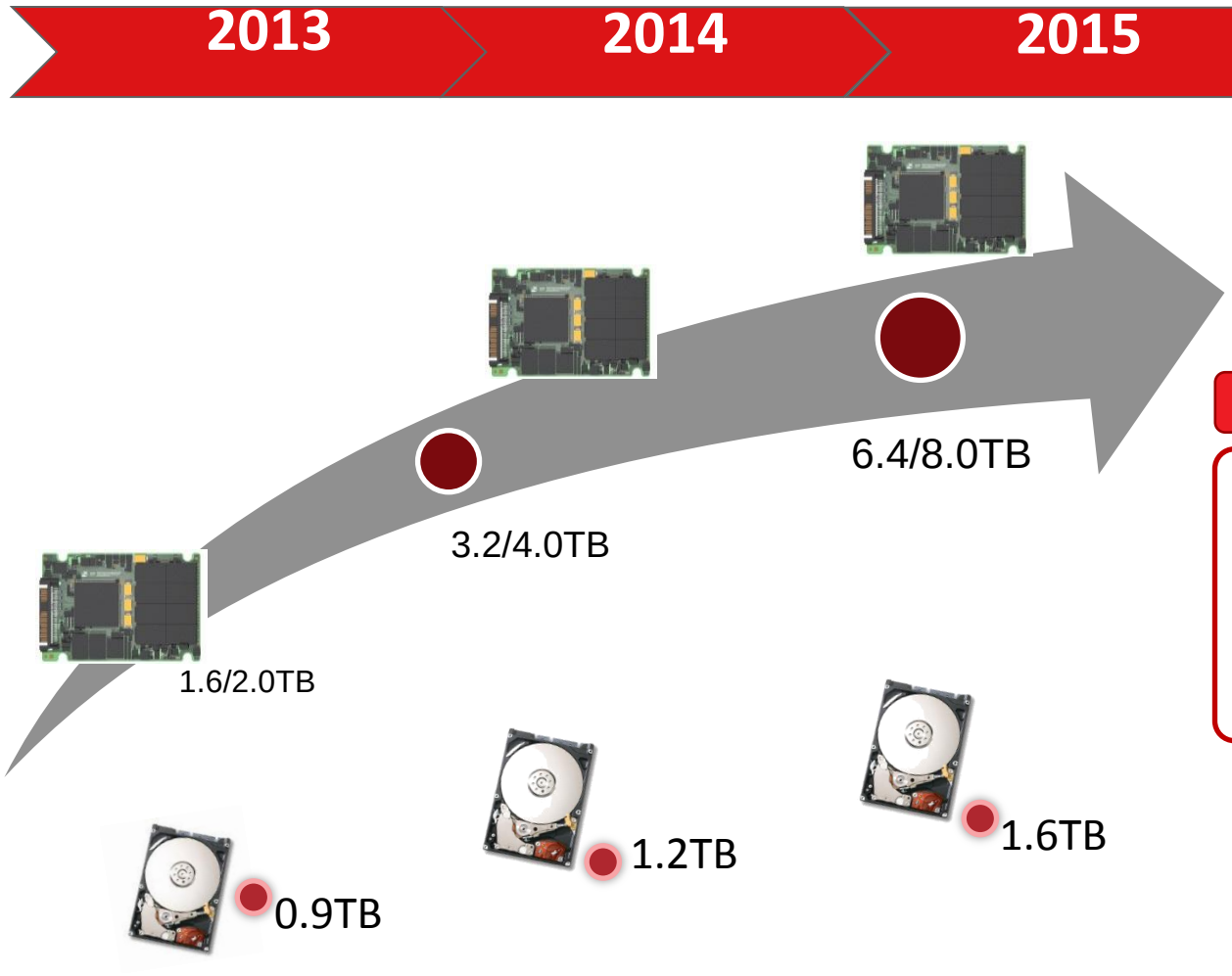
Driving the Next Wave of All Flash Adoption



Flash Is Configurable for Every Workload in the Data Center

	Tier	Typical Workload	Key Operational Metric	Flash Type	Key Financial Metric
Primary & Compute Storage	Tier 0 	Indexes/Caching/ In-Memory Compute	Ultra Low Latency	Memory-Class (Flash on DIMM)	$/Response Time
	Tier 1 	Database Logs/ Transactions	Latency/IOPS	High Performance (Flash on DIMM or PCIe)	$/Transaction
	Tier 2 	Content Repository (Image Retrieval, VOD)	Mixed Use/ Read-Intensive Storage	High Capacity (SAS or SATA SSDs)	TCO
Nearline/ Archival Storage	Tier 3 	Nearline Backups/ Cool to Cold Archival Storage	High Capacity/ Low Power with Low Latency	Commodity (Commodity Appliance)	Response Time + TCO

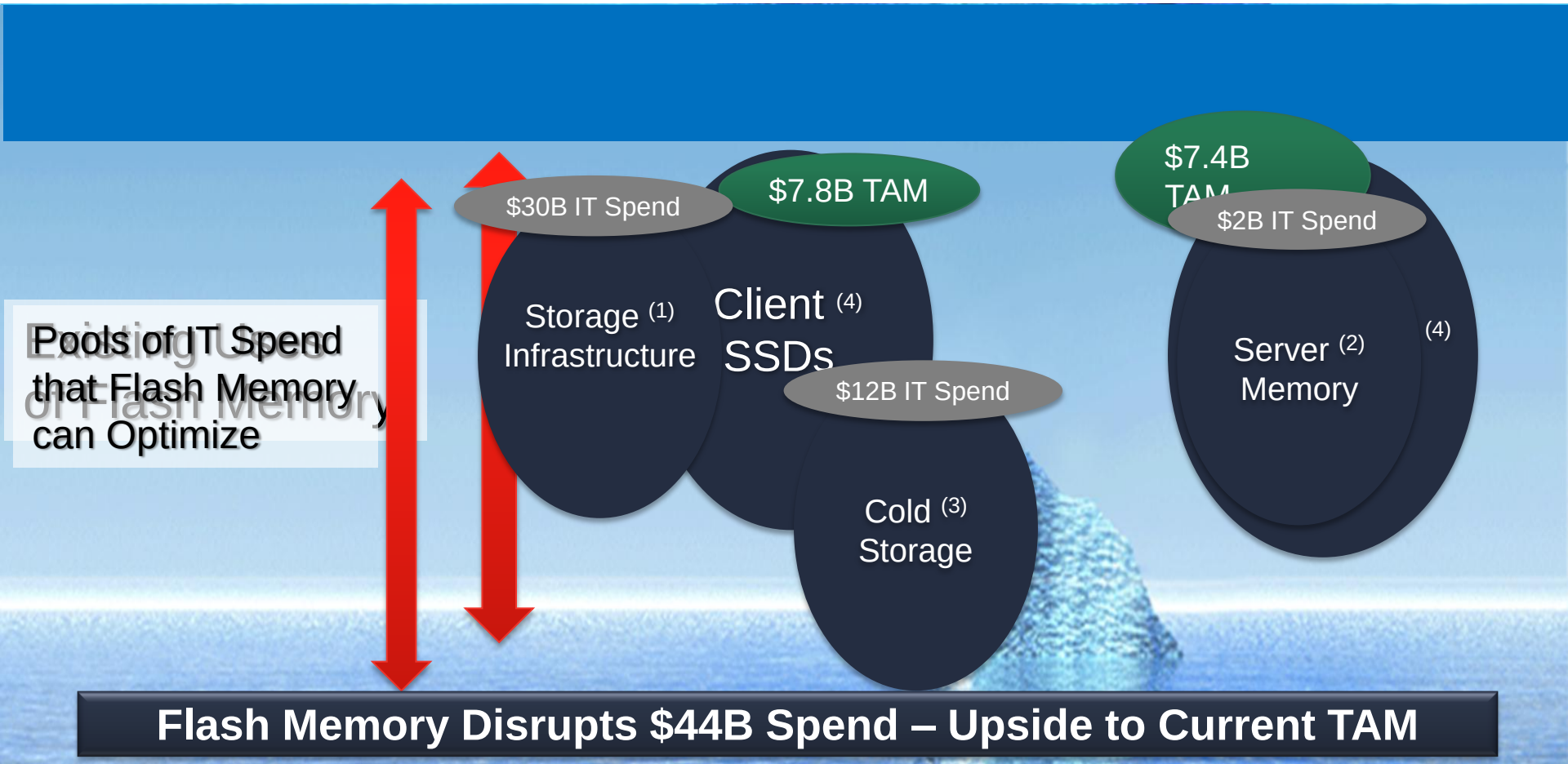
Enterprise SSDs to Outpace HDD Density & Performance



Market driver–"All flash arrays"

- $ per IOPS and latency
- Managed services and QoS
- $ per rack density
- $ per WATT
- Power utilization efficiency
- Competitive $ per GB to HDD

Existing and New Opportunities



Flash Memory Disrupts $44B Spend – Upside to Current TAM

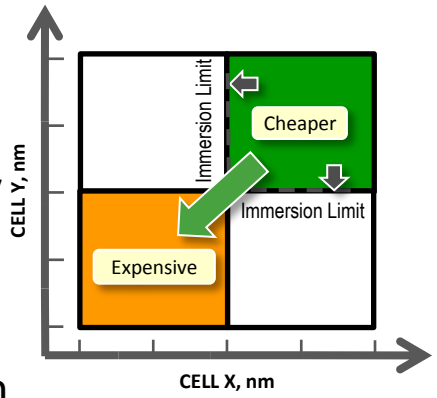
Sources: (1) "Forecast: External Controller-Based Disk Storage, Worldwide, All Countries," 2011-2017, 1Q13 Update, *Gartner*, March 2013, (2)"Semiconductor Forecast Database, Worldwide, 1Q13 Update," *Gartner*, March 2013, (3) "Forecast: Hard-Disk Drives, Worldwide, " 2010-2017, 1Q13 Update, (4) SanDisk estimates

NAND Scalability

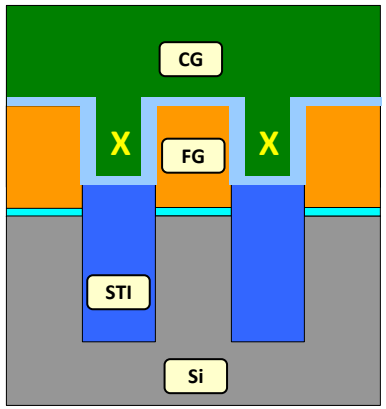
SanDisk®

NAND Scaling Considerations

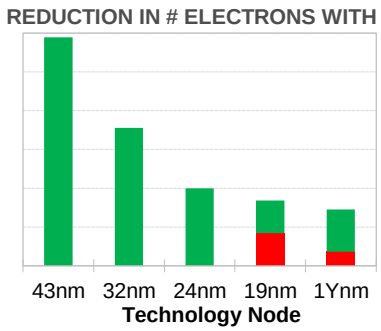
- **LITHOGRAPHY** (1)
  - Careful scaling required to extend mainstream Lithography and keep manufacturing costs low
- **PHYSICAL LIMIT** (2)
  - Process innovations required to keep cell to cell interaction in check without changing proven cell structure
- **ELECTRICAL LIMIT** (3)
  - Process innovations required to slow down reduction in # electrons in the cell and maintain reliability
- **BOTTOM LINE: BIGGER CHANGES**
  - Each NAND generation requiring significant cell changes to ensure good reliability and manufacturability
  - Solving above issues through innovations while keeping the cost low
  - Change cell structure as needed



1

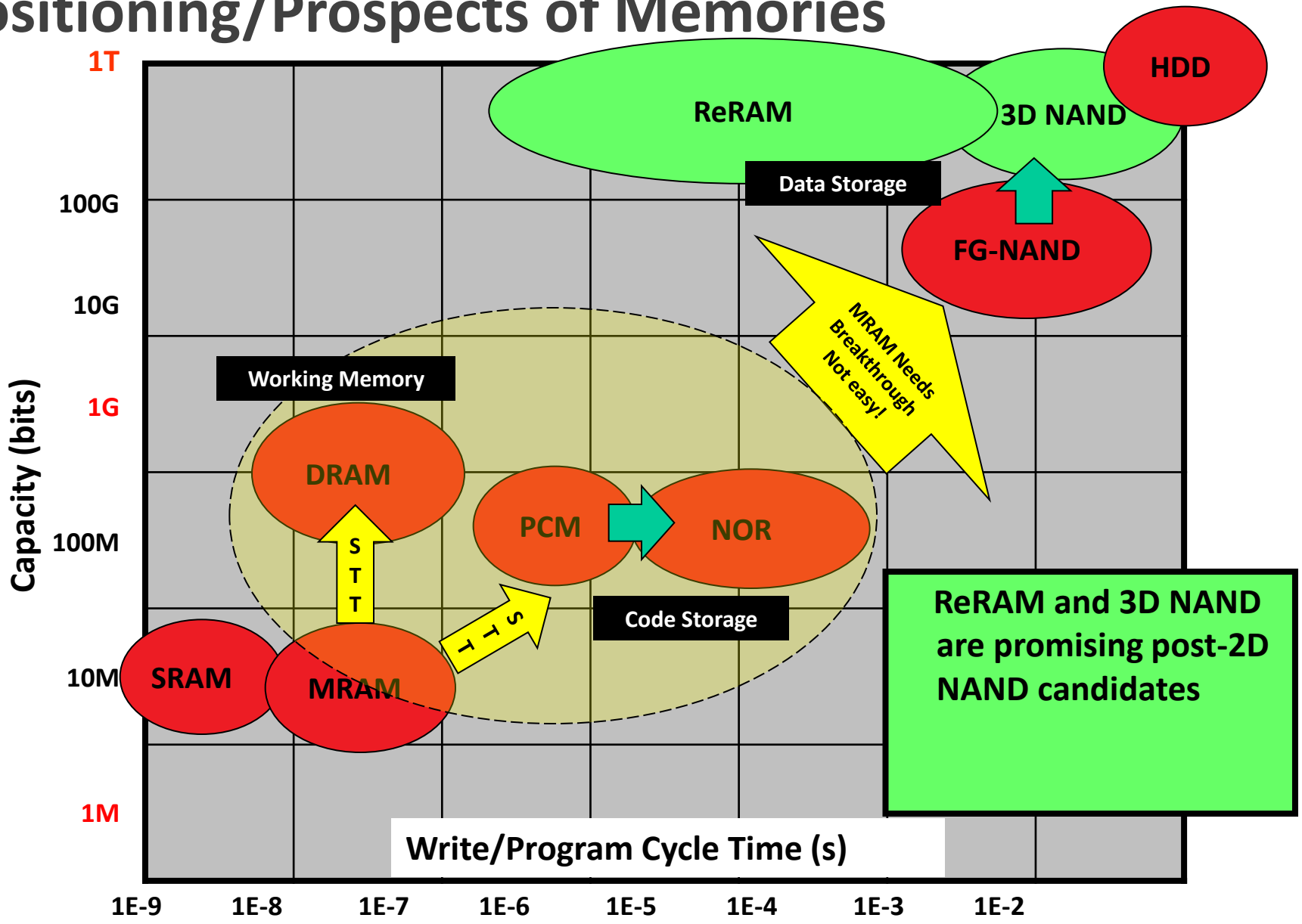


2



3

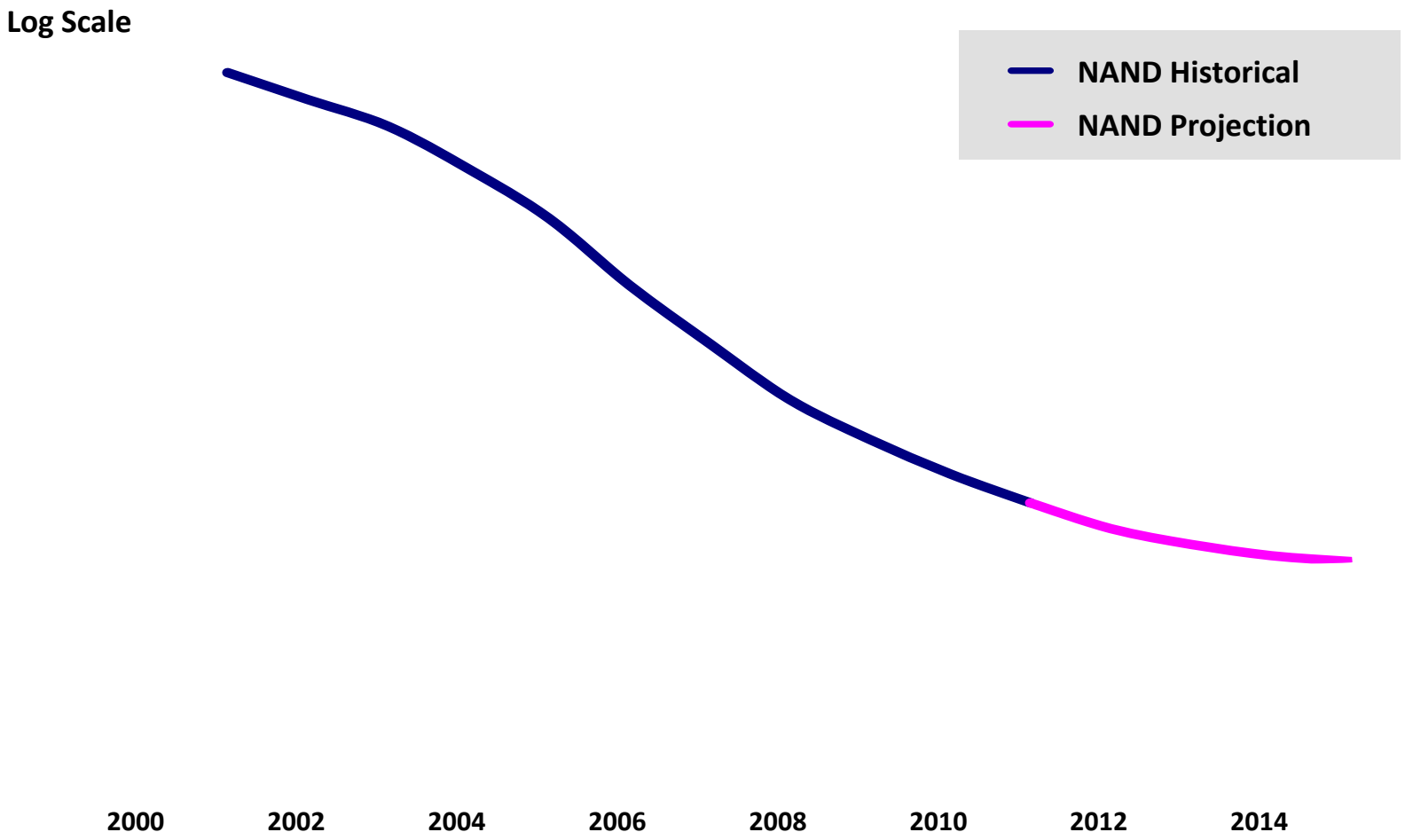
Positioning/Prospects of Memories



Beyond 2D NAND

- 2D-NAND Technology will continue to coexist with 3D technologies for the rest of the decade
  - Evaluating scaling below 1x nm node
  - Continued innovations in device physics, manufacturing, design, test, and system level solutions
- 3D-NAND
  - Capacity and die size primarily a function of number of layers and cell architecture, not lithography
  - Process challenges move from lithography to complex deposition/etch/device-formation
  - New 3D failure modes will require system solutions to meet product requirements
- Future non-volatile solutions for the future – Resistive RAM
  - Continued cost reduction and higher capacities beyond 3D-NAND
  - Device ultimately scalable to single digit nm (given EUV lithography is viable)
  - Understanding of new materials, physical mechanisms and devices

Extend NAND Scaling as Long as Possible



Key Technology Takeaways

- We see NAND scaling through 1x nm
- 3D-NAND will provide meaningful cost reduction versus 2D NAND
- 3-D ReRAM research ongoing. Potential scaling to sub-10nm. Successor to NAND into the next decade
- 2D-NAND and 3D technologies will coexist this decade

What's Next

Content

8ZB of Content
In 2015*

Mobility

More Powerful
Mobile Devices

Connectivity

More Responsive
Data Centers

Demand for Flash

Growth from Average
14GB per Device in 2014
to 29GB by 2016•

* IDC "THE DIGITAL UNIVERSE IN 2020: Big Data, Bigger Digital Shadows, and Biggest Growth in the Far East", Dec., '12.
• Based upon SanDisk projections of capacity growth in SanDisk's markets. Excludes SanDisk's capacity estimates for SSD overprovisioning.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