Make A Right Choice
-NAND Flash As Cache And Beyond

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Where can we use NAND Flash?

Everywhere in Computing

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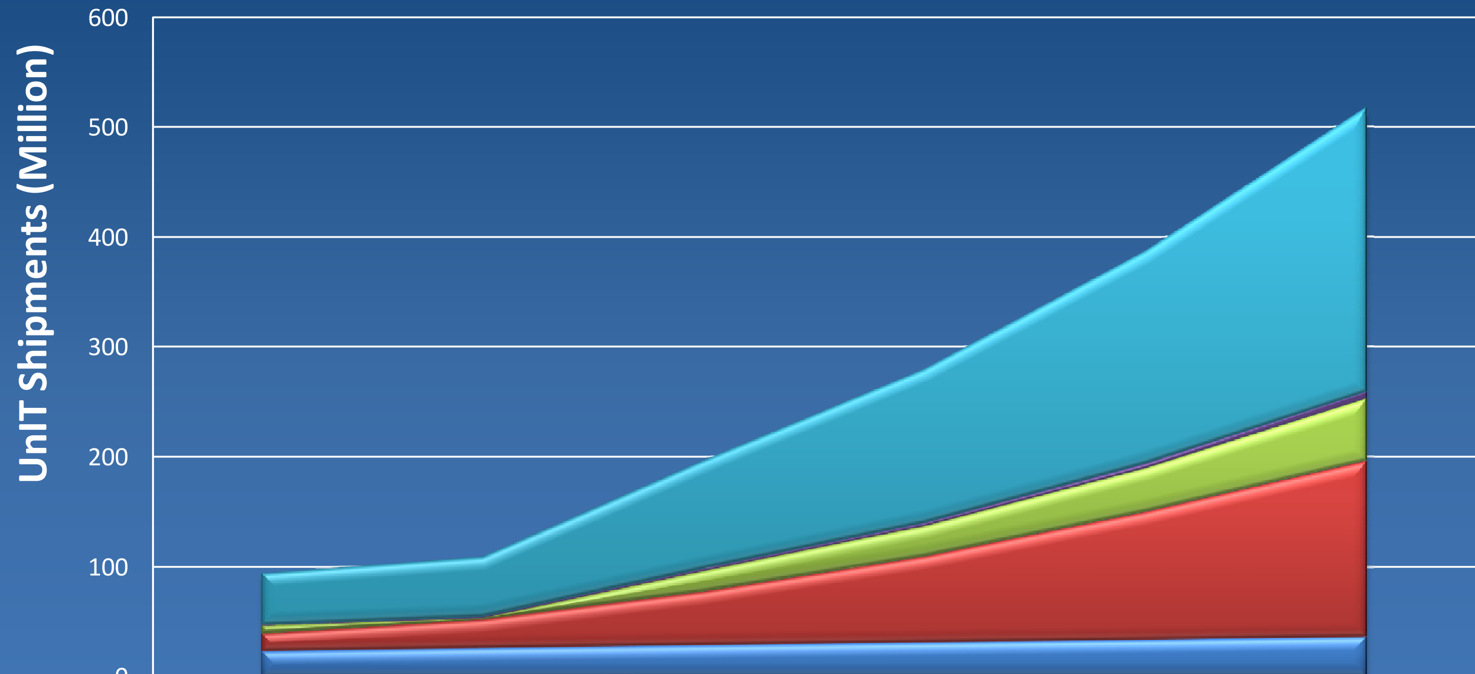
SSD Unit Shipment Forecast

Worldwide SSD Unit Sales



	2011	2012	2013	2014	2015	2016
Total	46.9	54.4	98.1	139.6	193.2	258.5
Embedded	0.5	1.1	2	2.9	4.1	6.1
Client Dual	7.7	1.5	19.1	27.8	39.7	56.6
Client Single	15.9	26.1	48.7	78.2	116.3	160
Enterprise	22.8	25.7	28.3	30.7	33.1	35.8

Source: Objective Analysis Data, 2012

What is Cache ?

- A cache is simply a copy of a small data segment residing in the main memory
- Fast but small extra memory
- Hold identical copies of main memory
- Lower latency
- Higher bandwidth
- Usually several levels (1, 2 and 3)

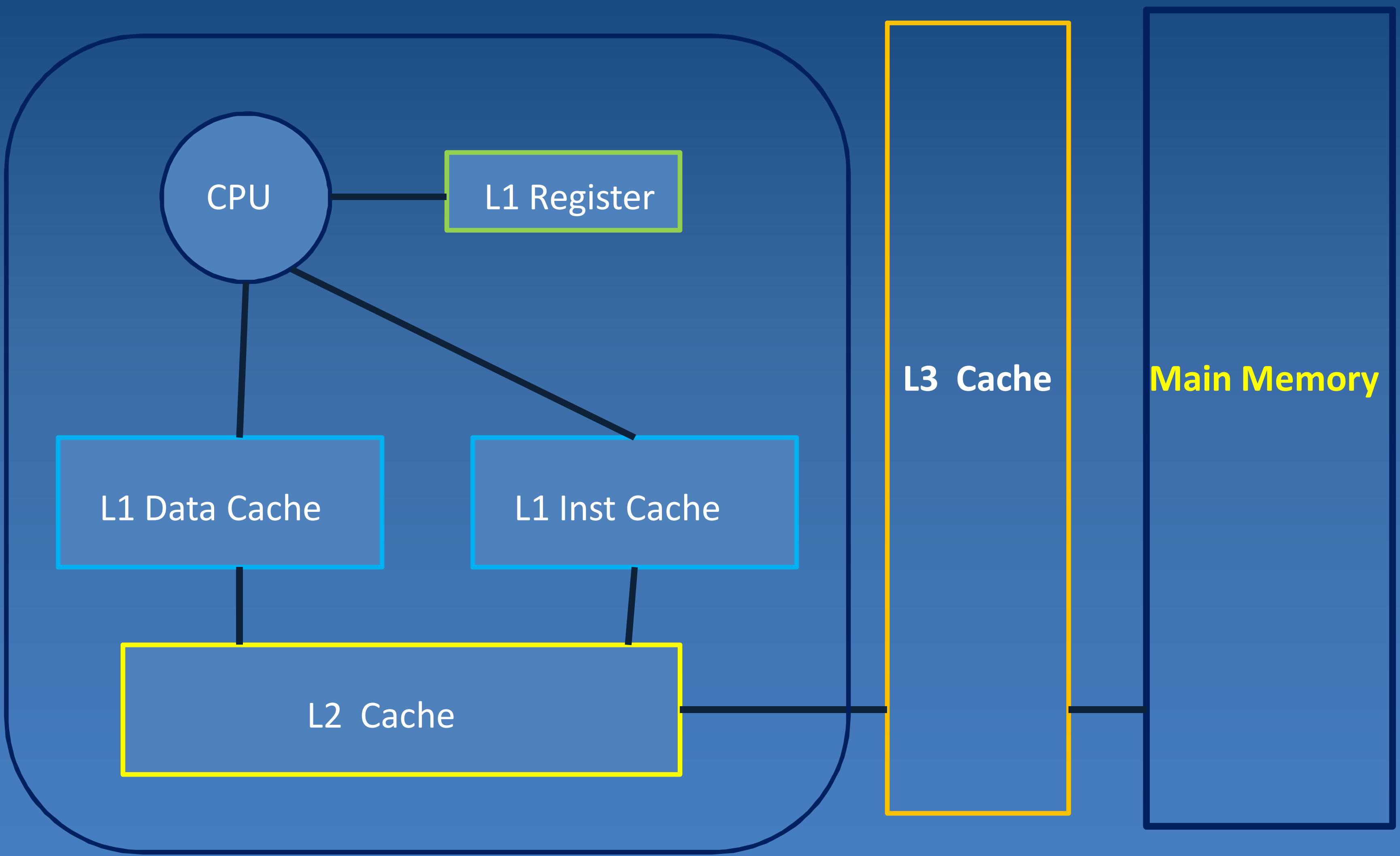
Why cache is so important?

- Old days: CPUs clock frequency was the primary performance indicator.
- Microprocessor execution speeds are improving at a rate of 50%-80% per year while DRAM access times are improving at only 5%-10% per year.
- If the same microprocessor operating at the same frequency, system performance will then be a function of memory and I/O to satisfy the data requirements of the CPU.

Types of Cache and Its Architecture:

- There are **three types** of cache that are now being used:
  - One on-chip with the processor, referred to as the "Level-1" cache (**L1**) or primary cache
  - Another is on-die cache in the SRAM is the "Level 2" cache (**L2**) or secondary cache.
  - **L3** Cache
- PCs and Servers, Workstations each use different cache architectures:
  - PCs use an **asynchronous cache**
  - Servers and workstations rely on **synchronous cache**
  - Super workstations rely on pipelined **caching architectures.**

Typical Cache Configuration



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How Cache is Used?

- Cache contains copies of some of Main Memory
  - those storage locations recently used
    - when Main Memory address A is referenced in CPU
    - cache checked for a copy of contents of A
  - if found, cache hit
    - copy used
    - no need to access Main Memory
  - if not found, cache miss
    - Main Memory accessed to get contents of A
    - copy of contents also loaded into cache

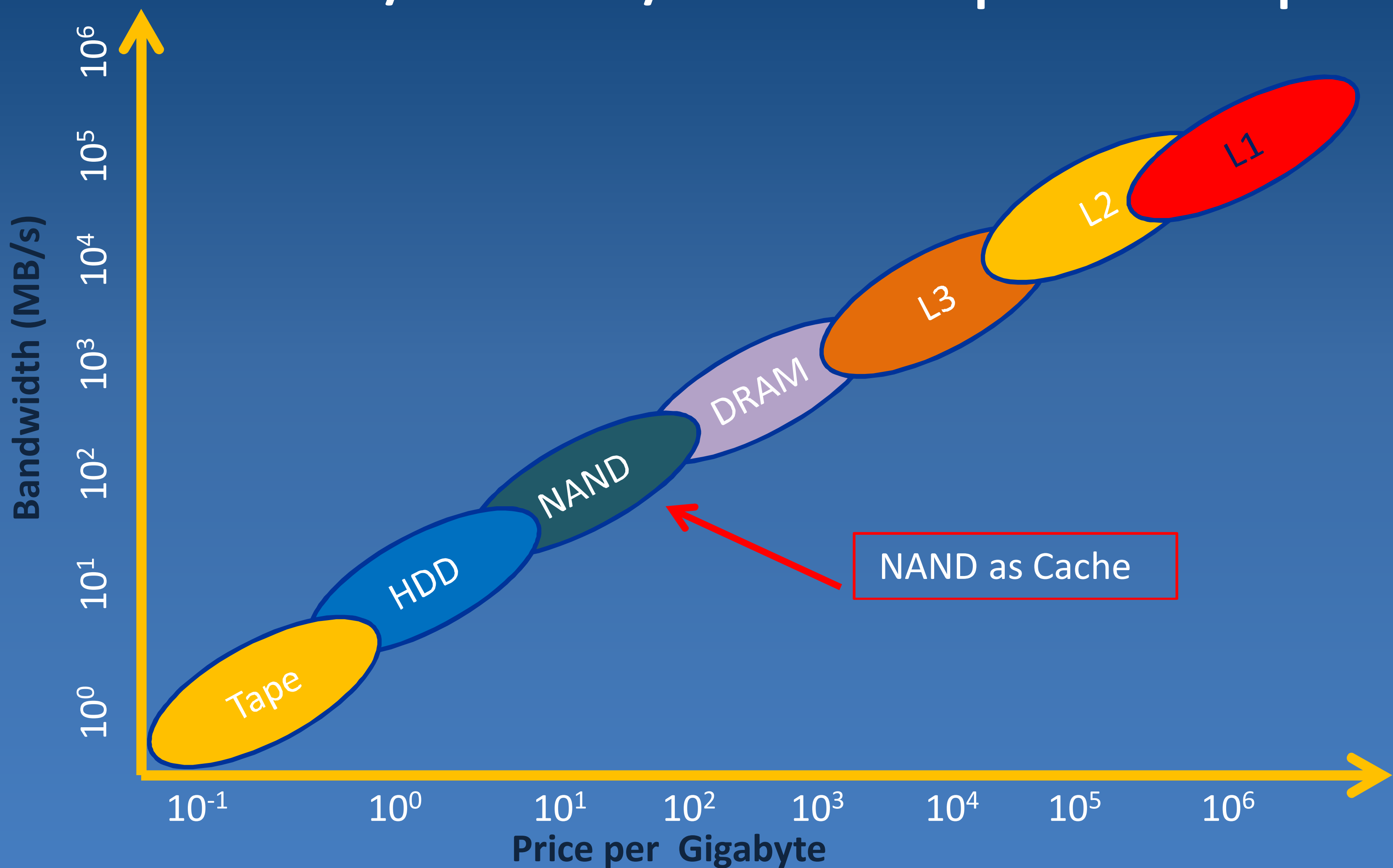
Why needs Cache ?

- Due to increasing gap between CPU and main Memory, small SRAM memory called L1 cache inserted.
- L1 caches can be accessed almost as fast as the registers, typically in 1 or 2 clock cycle
- Due to even more increasing gap between CPU and main memory, Additional cache: L2 cache inserted between L1 cache and main memory : accessed in fewer clock cycles.

Why needs Cache (continue) ?

- L2 cache attached to the memory bus or to its own cache bus
- Some high performance systems also include additional L3 cache which sits between L2 and main memory . It has different arrangement but principle same.
- The cache is placed both physically closer and logically closer to the CPU than the main memory.

The HDD/NAND/DRAM Speed Gap



Source: OBJECTIVE ANALYSIS

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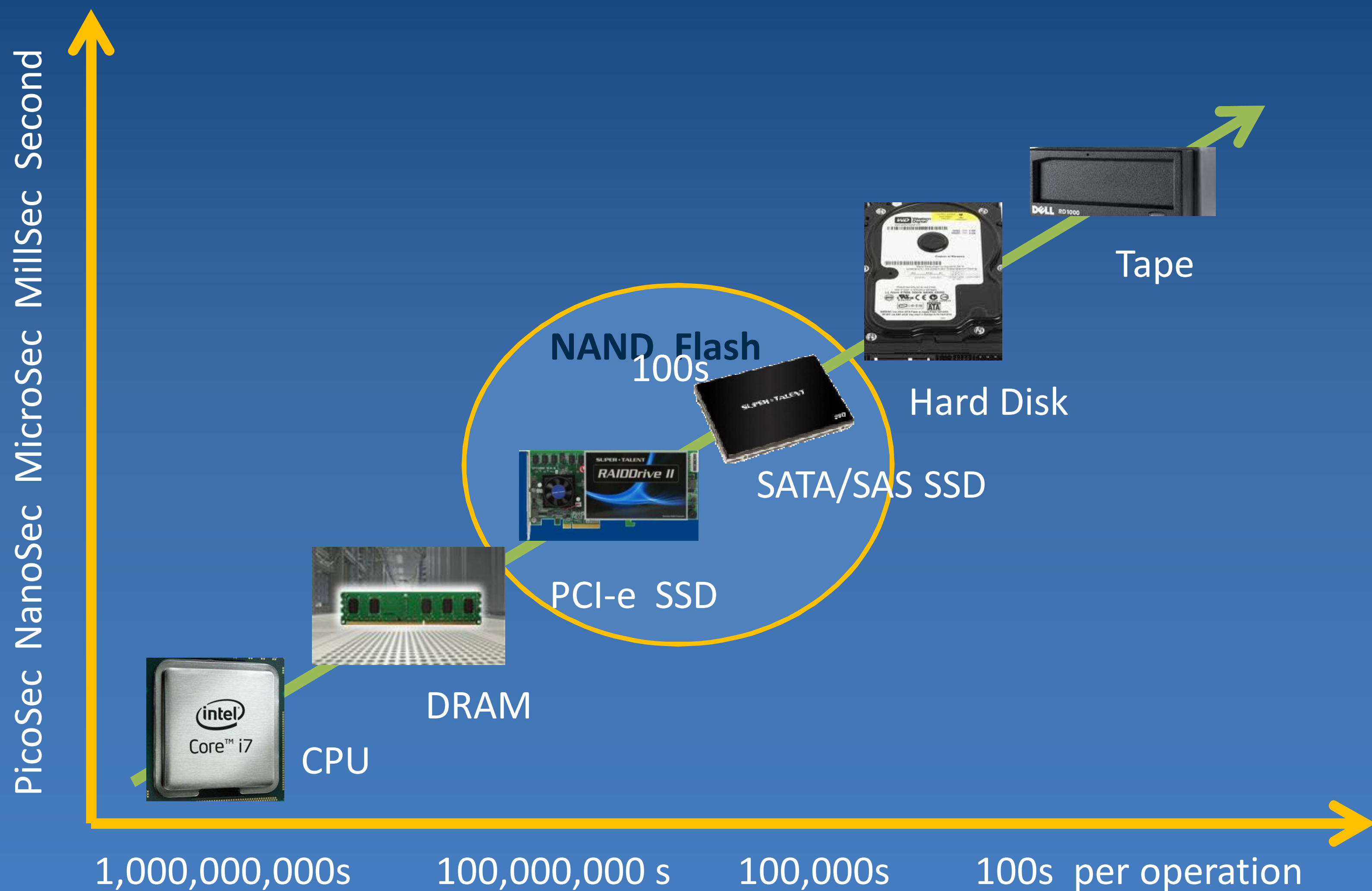
CPU/Memory/NAND/HDD evolution



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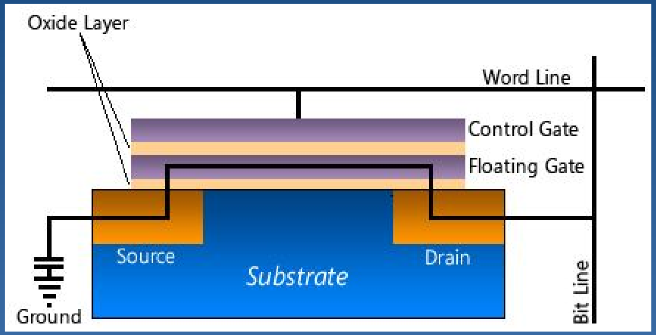
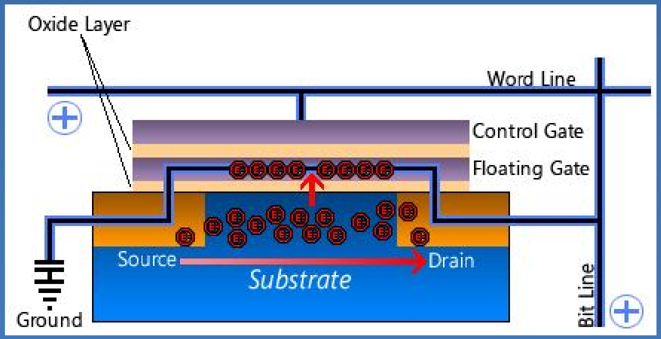
Keys to Consider using NAND

- Performance
- Capacity
- Bits per Cell
- Number of Write/Erase Cycles (Endurance)
- Data Retention
- Cost
- Cell Size/Lithography





Why NAND flash as cache so important?

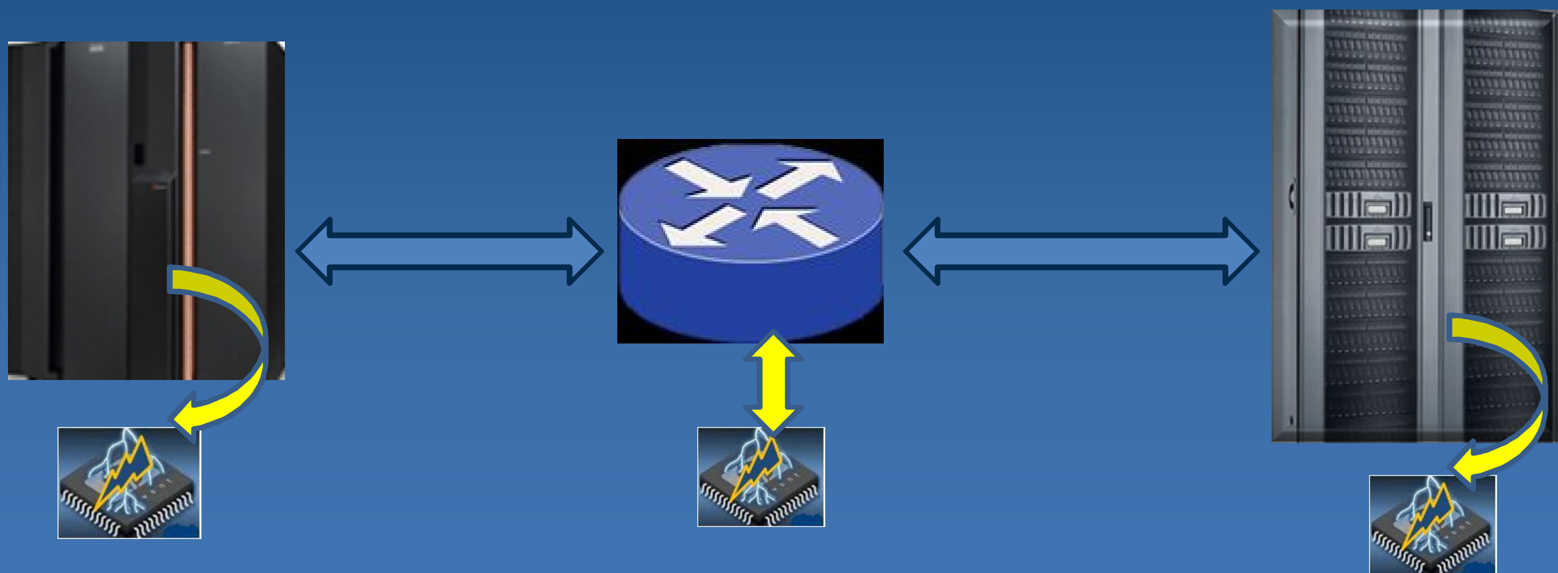
- Increasing IOPS up to 20% to 30%
- Improving average response time up to 20%
- Less power up to 30% to 40%
- Lower storage cost up to 45% per TB

NAND flash Caching Architectures

Server

Network

Storage



Flash On Server
Closest to CPU
Lowest latency

Good for Cluster Severs

Flash on Storage
Controller

Google Data Center

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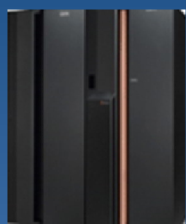
NAND flash as Cache In Data Center

Server Level

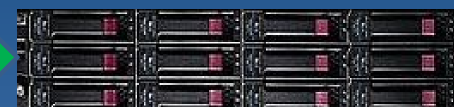


*PCI-e SSD on the Host
*SAS/SATA SSD on the Host

Controller Level

* Flash Cache

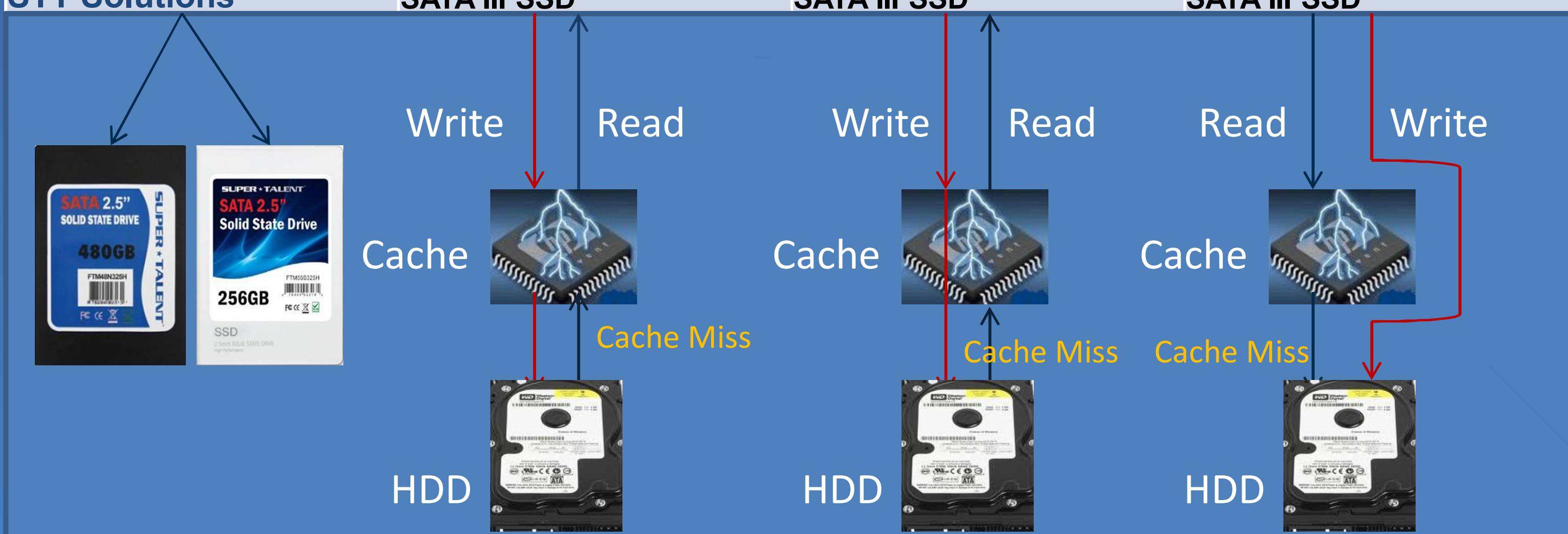
Disk Array Level



*Flash Array Pool
*Flash as Cache

Cache Write Policy

Policy	Write Back	Write Through	Write Around/ Read only
Store operation	Write to SSD 1st then copy to HDD	Write to SSD and HDD at the same time	No write to SSD
Data protection	Data loss risk if write to SSD failure	Yes	Yes
Performance	Middle	Low	High if Read Intensive
Application	Data Mining Searching	OLPT	Database/Wed Searching
STT Solutions	TeraDrive/SuperNova SATA III SSD	TeraDrive/SuperNova SATA III SSD	TeraDrive/SuperNova SATA III SSD



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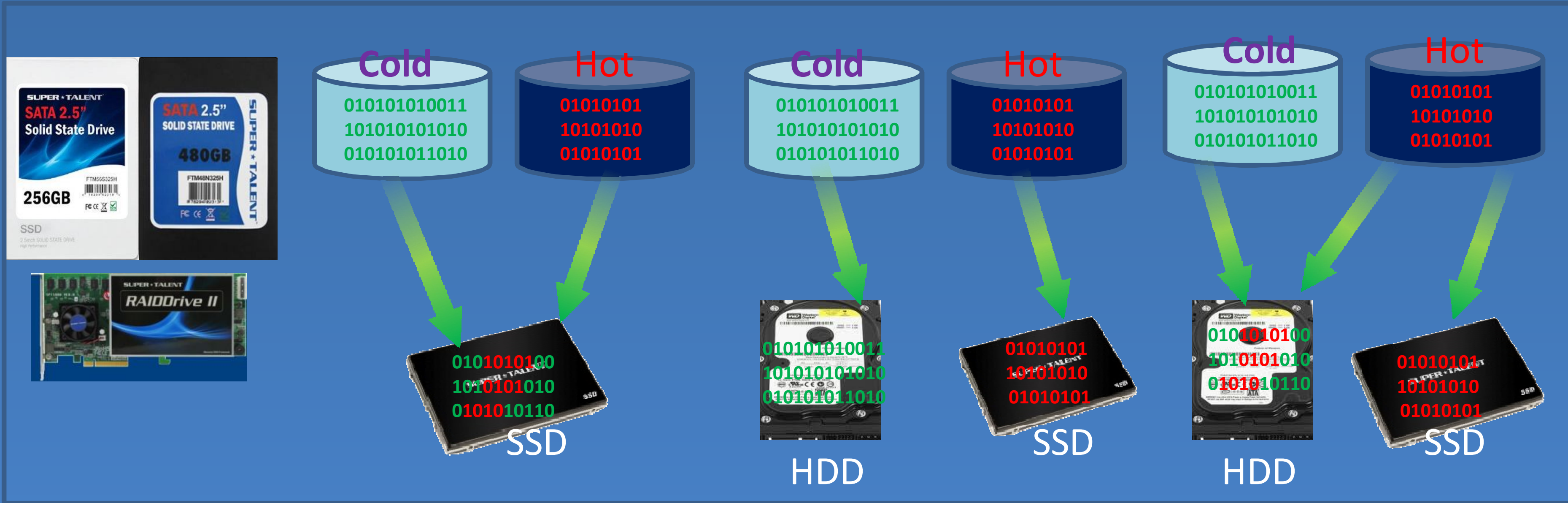
Data Placement Strategy

Strategy	Primary Storage	Tiering Storage	Caching
Capacity Usage	All	Frequently accessed Data	Copy of Freqently ace
Data Protection	SSD failure cause data loss	SSD failure cause data loss	SSD failure impact operation a little
Write Policy	Read/Write Intensive	Read Intenstive	Mixed Read/Write, Changing data access pattern
Application	Big data	Middle size data	A smaller chunk data
NAND Flash Type	SLC /eMLC/MLC	SLC/eMLC	SLC or eMLC
STT Solution	TeraDrive/SuperNova SATA III SSD	TeraDrive/SuperNova SATA III SSD/RAIDRIVE II	TeraDrive/SuperNova SATA III SSD/RAIDDRIVE II



NAND Flash Type Comparison

Type	P/E Cycle	Cost	Random Write Performance Comparing HDD
SLC	100k	High	5X
eSLC	50k	Middle High	3.75X
eMLC	30k	Middle	3X
MLC	10k	Low	2X
TLC	1K	Very Low	1X

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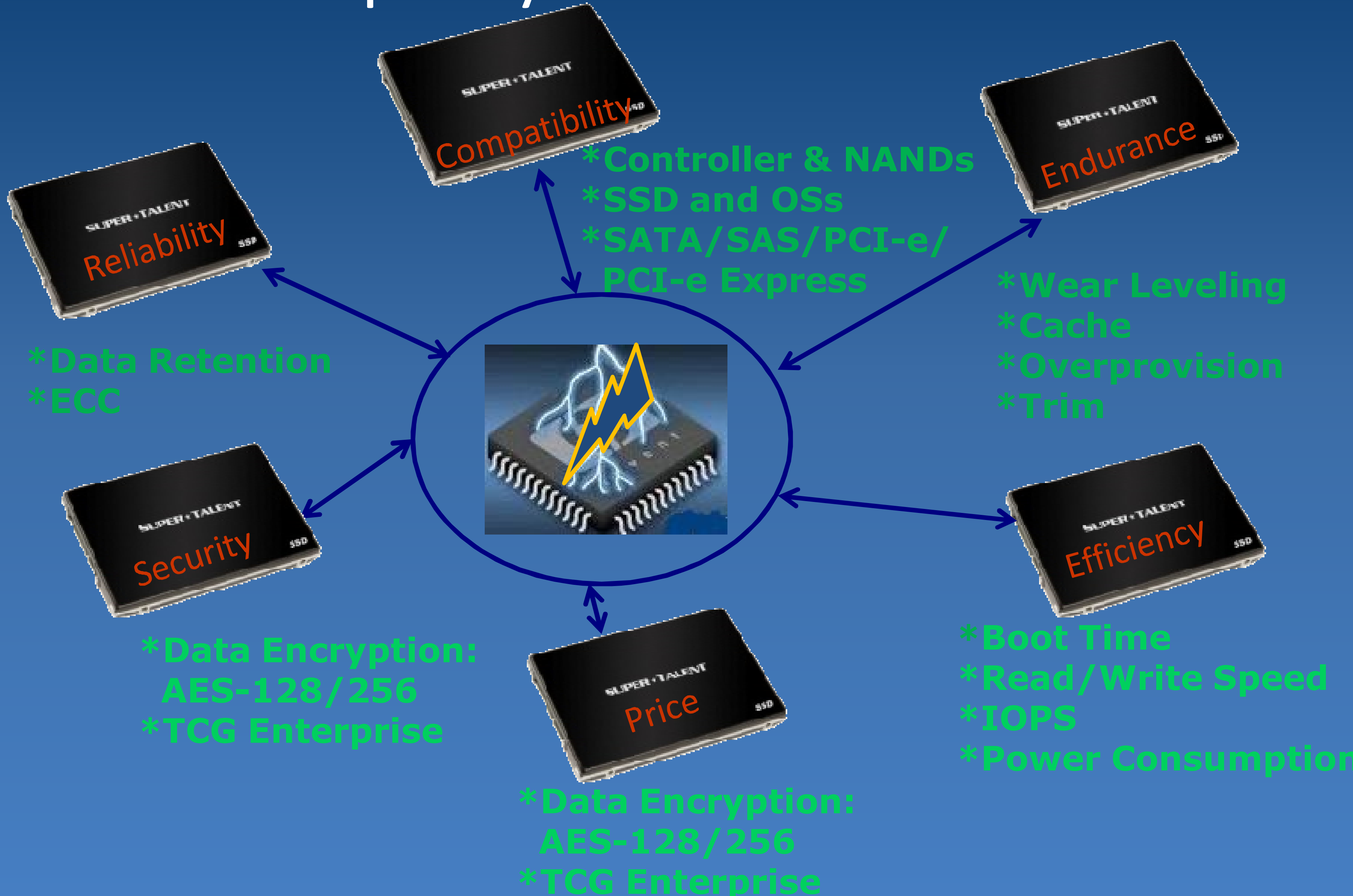
What to expect your NAND flash device?



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Performance Tier for Enterprise Storage Systems

Tier 0

- Financial Transactions
- E-commerce Applications

Tier 1

- Business Processing
- Data Analysis/Mining
- Cloud Computing
- Caching
- Data Centers

Tier 2

- E-mail
- File and Print

Tier 3

- Data Backup
- Archive

PCI-E SSD

100K+ IOPS

FC/SAS HDD/SATA III Extreme IOPS SSD

50K+ IOPS

SATA HDD/SSD

25K+ IOPS

TAPE/Offline

Ultra high performance Enterprise Storage Systems

High performance Enterprise Storage Systems

Low Cost HDD/SSD

Lowest Cost Storage Media

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NAND flash Solutions for Enterprise

- Server Based SSD has value for rapid boot
- PCIe has value for **caching** /storage memory
- Network Caching bring performance to legacy systems
- Storage Systems with integrated flash or flash only are compelling refreshes

Recap

- NAND Flash for Cache now is the critical part of the Server/Storage/Network
- Increase IOPS and lower IPOS/watt
- Cache Write policy and Data placement strategy impact IOPS and $ IPOS
- STT RAIDdrive , TeraNova and SuperNova are the right cache solution for Server/Storage/Network

Backup

Storage Technology Map

Architecture	System	Network	Technology	Component	Software
DAS	Disk	Switch	FC	RAID Controller	OS
SAN	Tape	Directors	SAS	JBOD	Security
NAS	High End FC Array	Gateway/Bridge	SCSI	HBA	Deduplication
Hybrid	Mid End FC Array	Appliances	SATA	NIC/TOE	Virtualization
	Unified Storage		iSCSI	NAS Head	Cloud Computing
	Libraries		InfiniBand	iSCSI Head	Snapshot
	Virtual Tape		GbE	CNA	Remote Duplication
			FCIP		Thin Provision
			IFCP		
			FCoE		

Thank you

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