Emanuel & Matt (JUST INTRODUCE OURESELVES)

Emanuel: Hi I'm Emanuel Onofre

Matt: Hi I'm Matt

CSC137 - Technical Presentation

Crash Course: Solid State Drives

By: Emanuel Onofre and Matthew Mendoza

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Intel Has A New Logo for The First Time Since 2006.

Although known as Processor Manufacturing company and being a PC-centric to now a Data-centric company.

Intel is stretching its resources to develop on and invest in new and existing platforms and markets.

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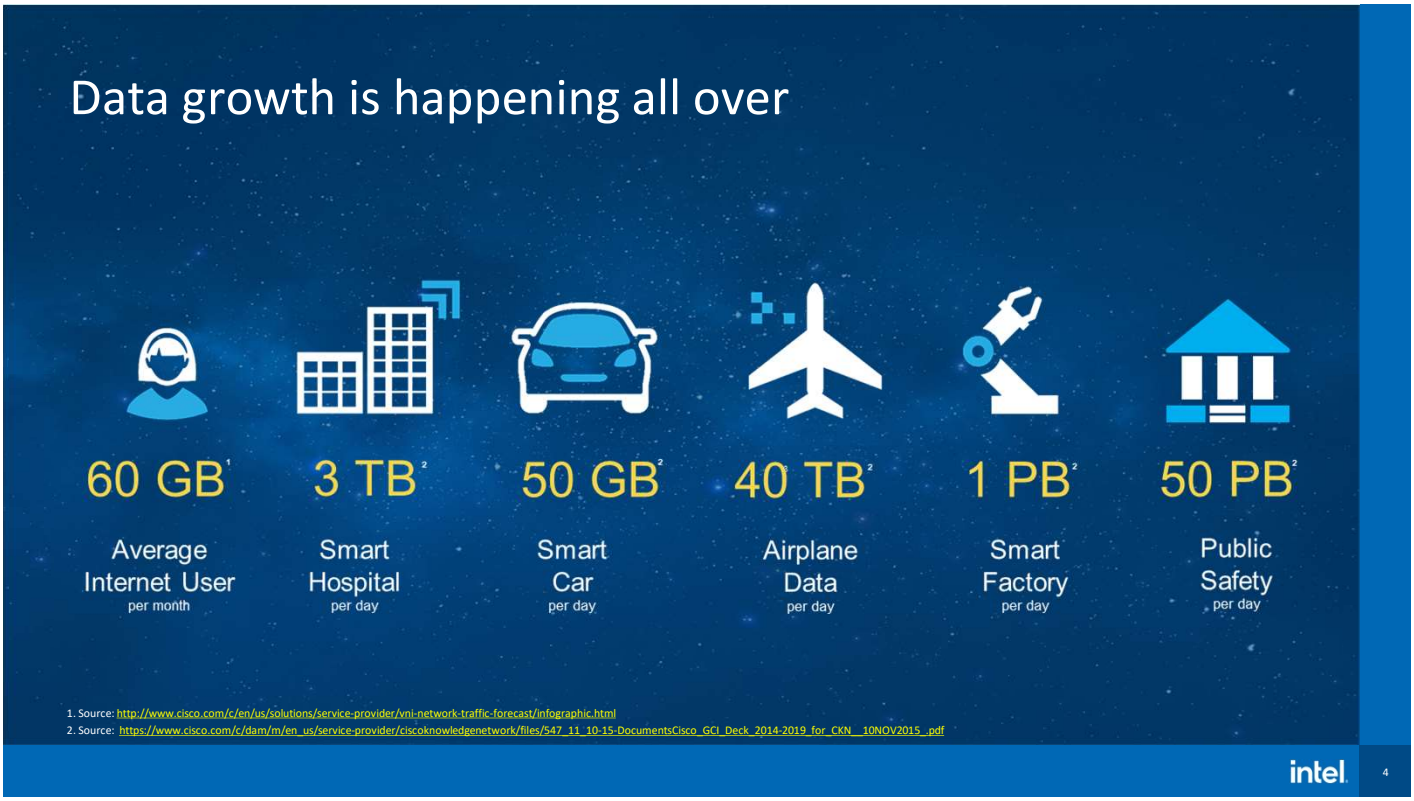
Often, we like to think processing power and how small we can get the manufacturing process of the semiconductors,
But that is to ignore other elements of the computers and systems.

So we need to remind ourselves what is a computer. In basic form it's just inputs, processing, and outputs.
But how are those inputs and outputs stored, so that you can do processing is an area that we often take for grated



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As you can see here, we produce a lot more digital files than we do physical.
The order of scale is dramatic across industries, infer structures, and with time.

Today we would like to take a deeper dive into storage by providing you a 101-crash course on SSDs.

Emanual may you start us off with the basics?

Learning Objectives

- Kinds of memory devices
  - Primary vs Secondary
- Introduction to SSDs
  - HDD vs SSD
  - SATA vs NVME
- Anatomy of an SSD
  - Components of an SSD
  - NAND
  - 3D NAND vs 3D XPoint – Intel
- Software Components

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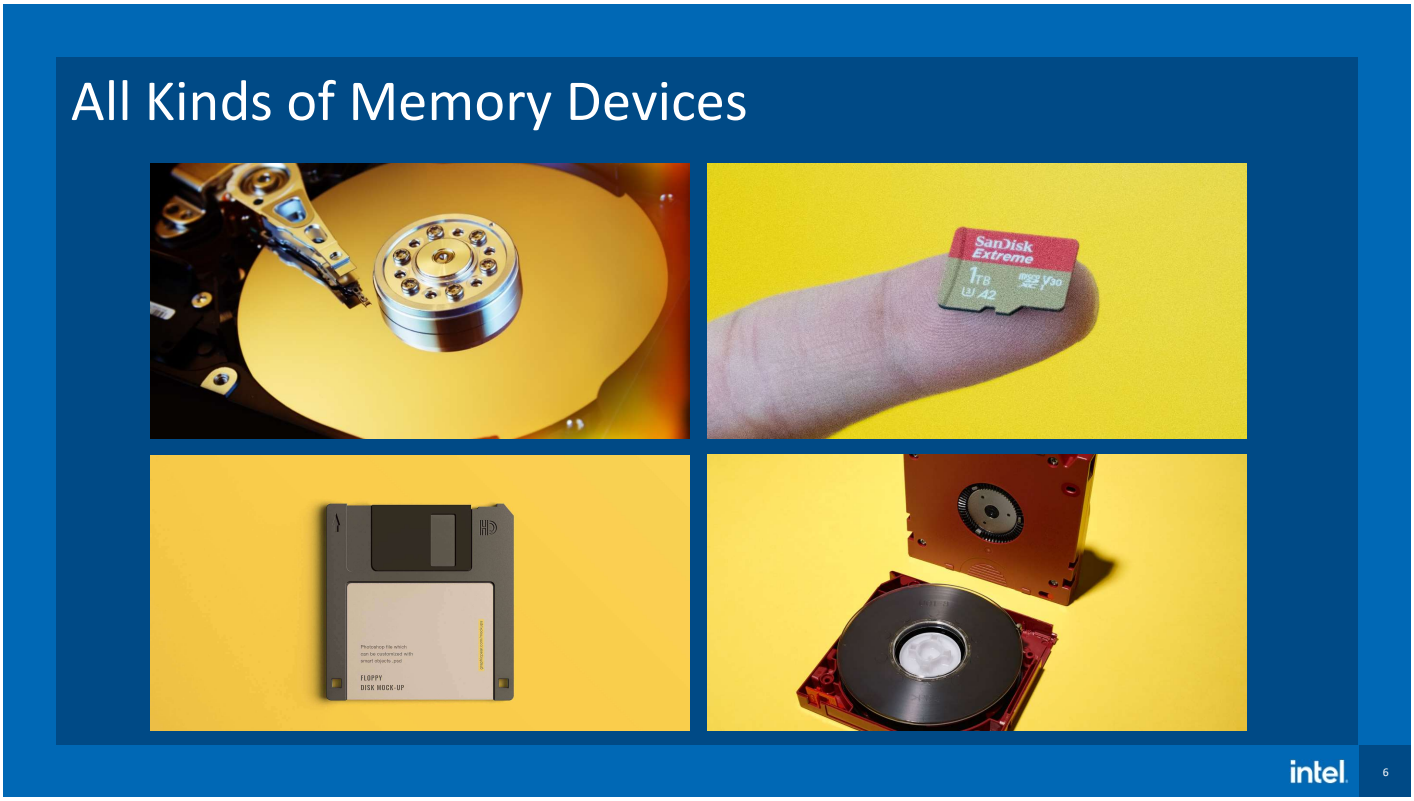
- SATA vs NVME

Anatomy of an SSD
- Components of an SSD
- NAND
- 3D NAND vs 3D XPoint – Intel

Software Components



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All Kinds of Memory Devices

Types of Memory

Memory comes in two flavors

The Difference	
Primary Memory • Volatile • Smaller storage capacity, but provides faster access to data and files	Secondary Memory • Non-Volatile • Slower, but holds a large amount of media, software, and files

Primary Memory - RAM

Secondary Memory - HDD

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Memory comes in two flavors: Primary Memory and Secondary Memory

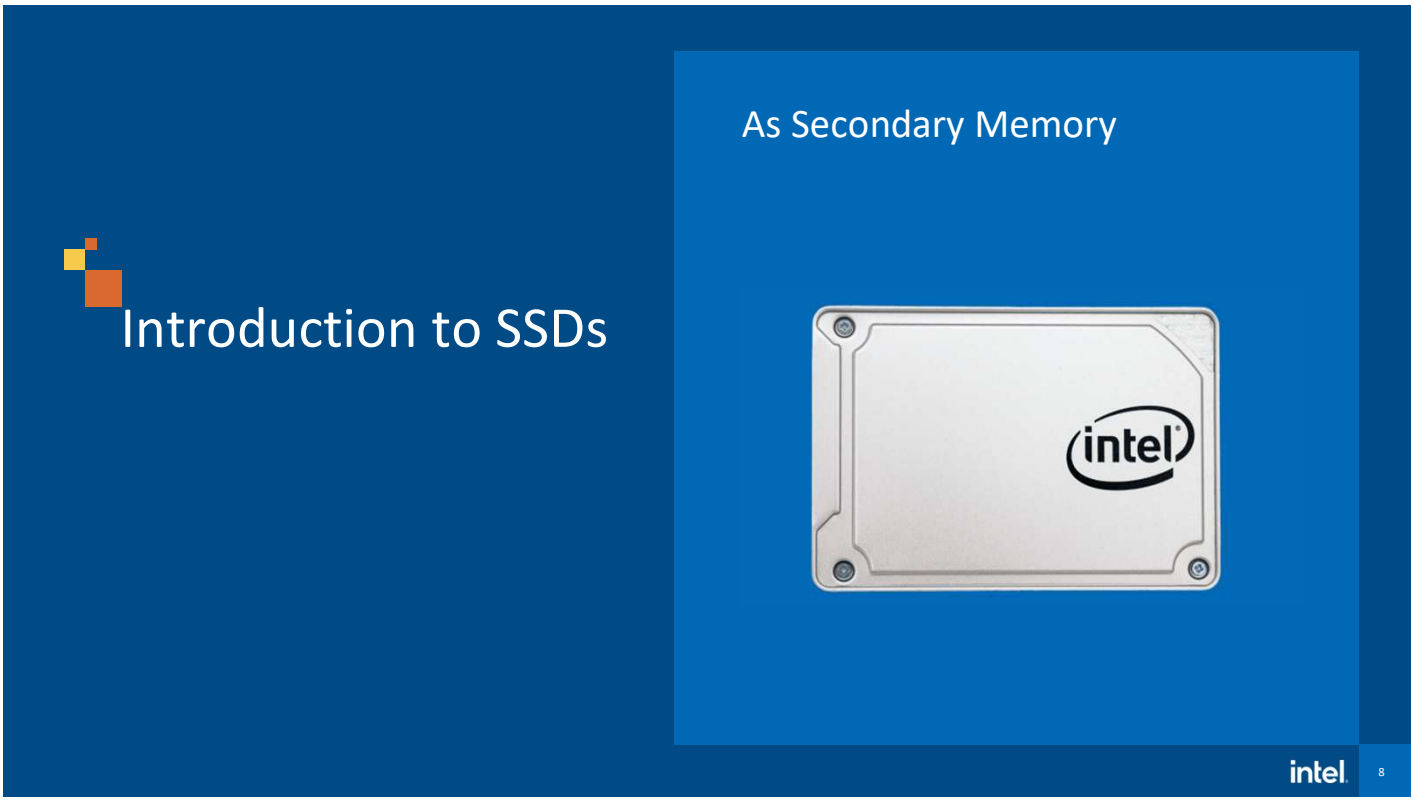
Primary Memory

- Is volatile
- Has a smaller storage capacity, but provides faster access to data and files

Secondary Memory

- Is non-volatile
- Slower, but holds a large amount of data and are best suited to hold your videos, music, software, and other files

Volatile means that when power is cut (turn off) the data on memory is lost and unrecoverable. The data relies on a continuous power source



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Introduction to SSDs
As Secondary Memory

Introduction to SSDs

HDD vs SSD

Hard Disk Drives

- Non-volatile Memory
  - Magnetic-Based Storage
- Moving parts
- Lower cost per gigabyte

Solid Disk Drives

- Non-volatile Memory
  - NAND Flash Storage
  - 3D XPoint (Intel and Micron)
- No moving parts
- Better Performance
- Higher cost per gigabyte

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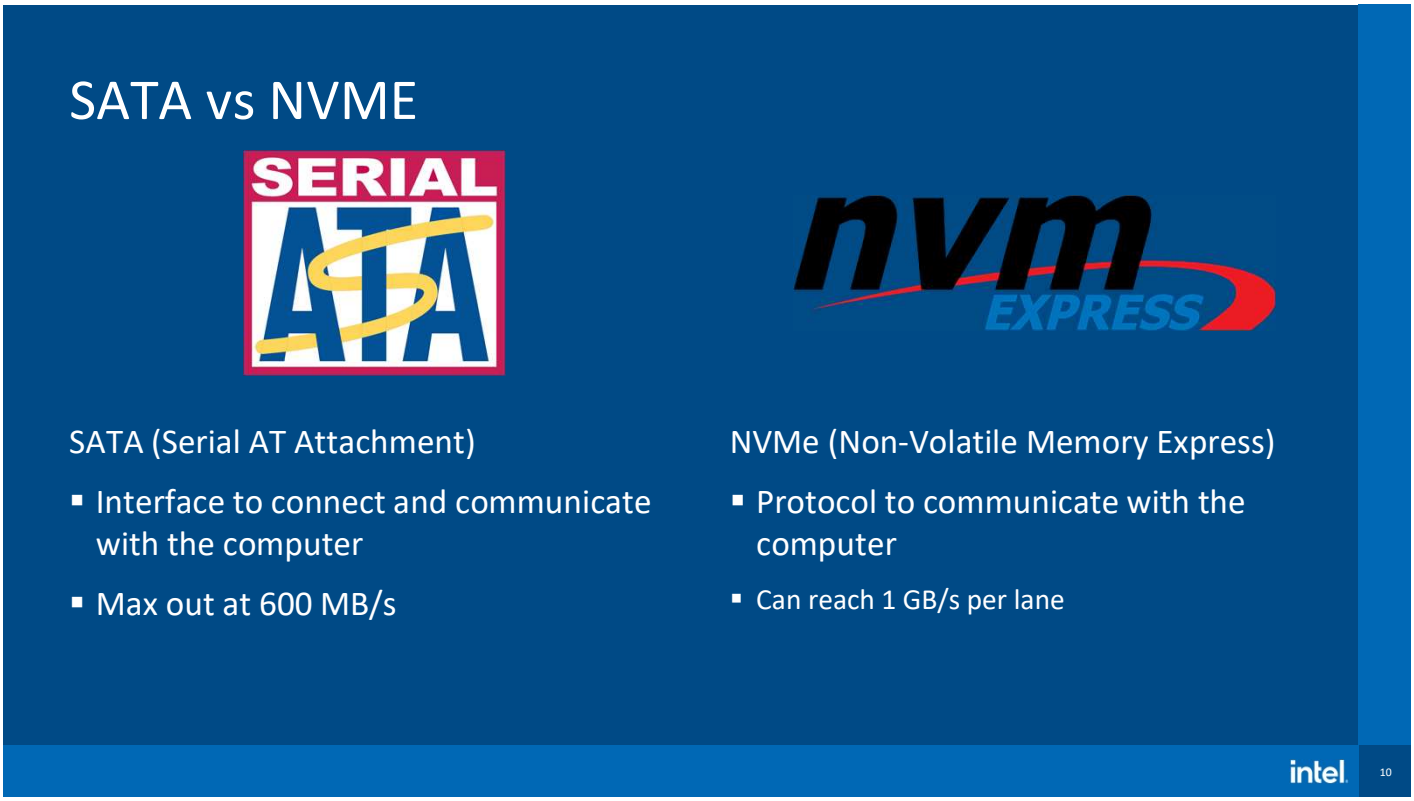
Both non-volatile meaning that data does not rely on a continuous power source.

Hard Drives has been the industry standard for about 50 years
They implement a non-volatile memory that is magnetic based where the read/write head changes the polarity of magnetic charge on the rotating magnetic platters rotating 1000 of times a second beneath the arm of the read/write head.
These moving parts are prone to error, wear and tear, higher power draw, and generates heat.

Solid Disk Drives on the other hand have no moving parts; as a result, making them more reliable, consume less power, and durable.



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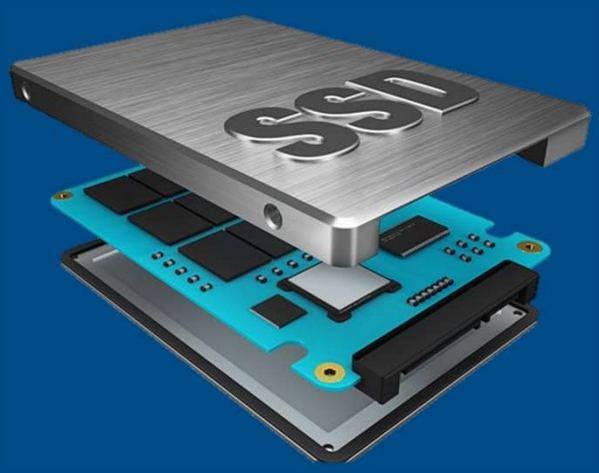
SATA has been the standard since 2000 for Hard Disk Drives and early Solid-State Drives with the goal to increase the bandwidth of data.
After three releases of the standard SATA would max out at 600 Megabyte per second (MB/s) for SSDs
As NAND technologies advanced SATA bottlenecked.

NVMe was developed to correct this issue.
They can reach to one Gigabyte per second (GB/s) per lane and is designed with the interface of PCIe which is the BUS that handles the connection.
Most SSDs have four lanes allowing the four Gigabytes through-put speeds to and from the storage device. This is six times faster than SATA.

Anatomy of an SSD



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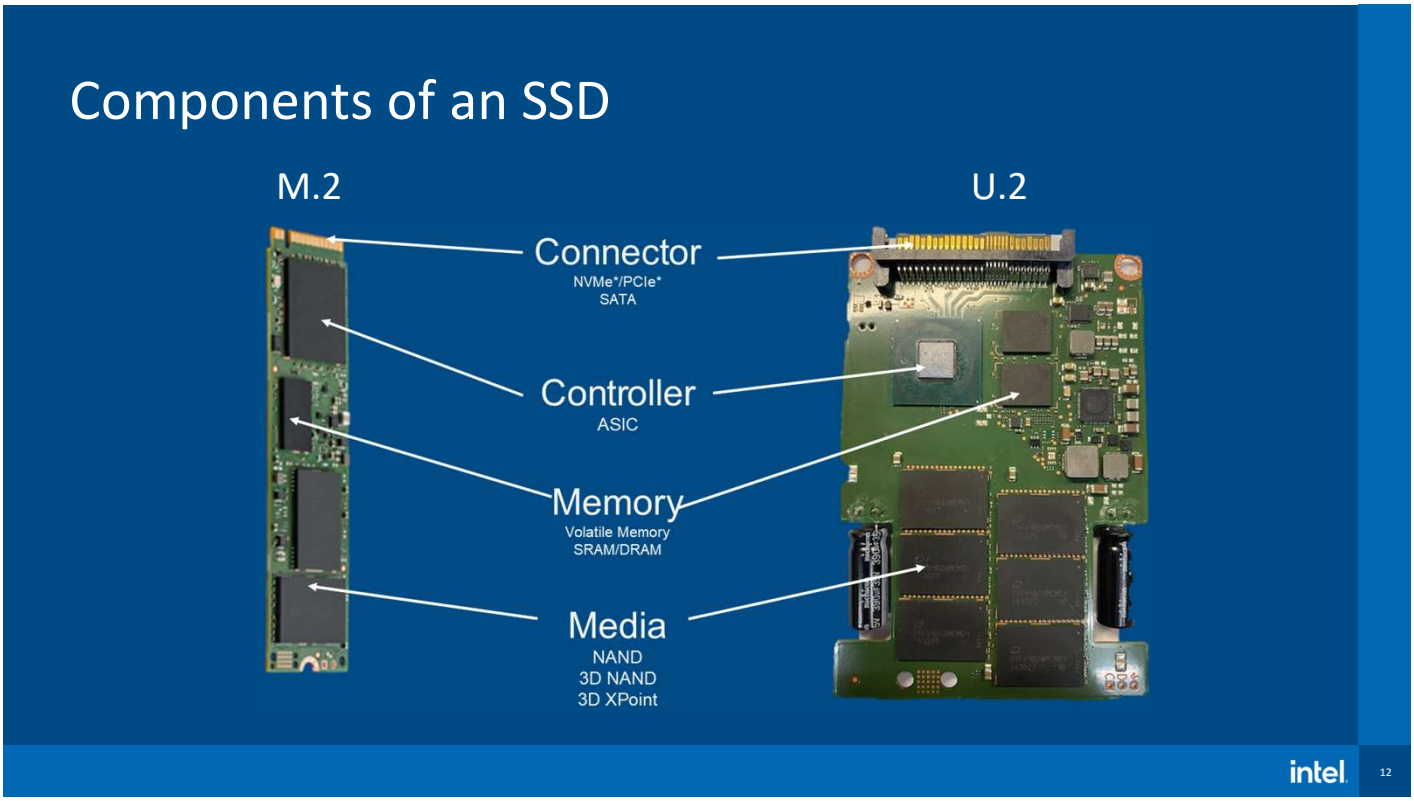
Anatomy of an SSD



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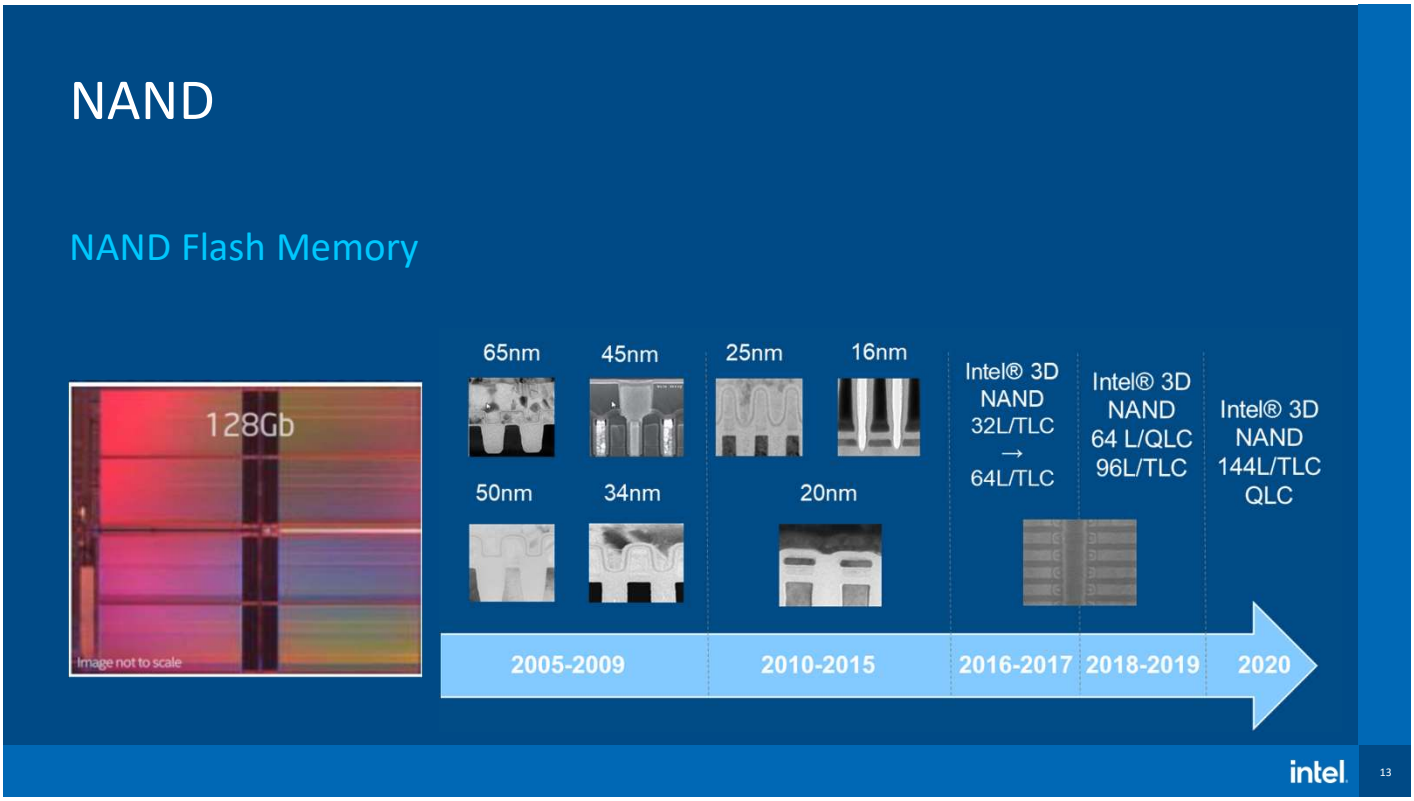
Here are two types of SSDs a M.2 on the left and U.2 on the right later we'll talk about form factors.
For now we'll talk about the components that sit on the Printed Circuit Board.

Working our way top-down we have the

1. **Connector:** The physical connection point to interface with the drives.
2. **Controller:** Which works as a "minicomputer" for the SSD
3. **Memory:** Which works as the cache for the Controller
   And at the bottom we have
4. **Media**: Which is often NAND and both 3D NAND and 3D Cross-point are of both Intel and Micron technologies



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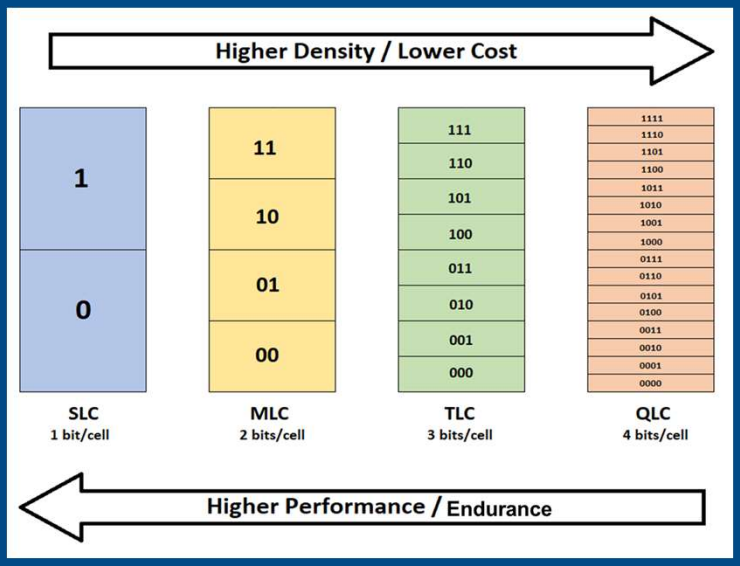
NAND: Also known as 2D NAND or Planar NAND
It has been around since the 90s, but Intel started using the technology for their SSD in the mid-2000s
It is a type of flash memory. Its writes, erases are faster, stores more data, and is more efficient than Hard Disk Drive technologies.
It is important to know that NAND does not have bit control.

NAND can be configured in multiple ways

I will now hand it off to Matt to pick it up from here

Cell Layers



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The different configurations of individual cells of NAND flash are based on their Cell Layers.

Current generation of SSD uses NAND Flash storage the building blocks of which is a memory cell.

These are the base units to where data are written in an SSD.

Each memory cell accepts a certain amount of bits which are registered on the storage device as a one or a zero.

Cells can be programed to fit multiple cells. **The image represents a cell split in four different ways.**

As you split a cell you gain greater density and reduce cost of production; however, this in turn decreases performance and endurance of the cell.

The most common type of Cell Layered SSD on market you can find is TLC.

Single layer Cell **(SLC)**

Multi Layer Cell **(MLC)**

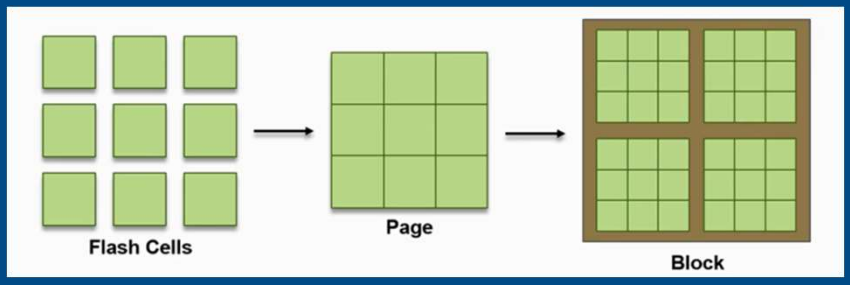
Triple-Layer Cell **(TLC)**

Quad Layer Cell **(QLC)**

NAND Structure

A Closer look at SSD

- Bits → Cells → Pages → Blocks
- SDDs write in Pages
- SSDs erase in Blocks



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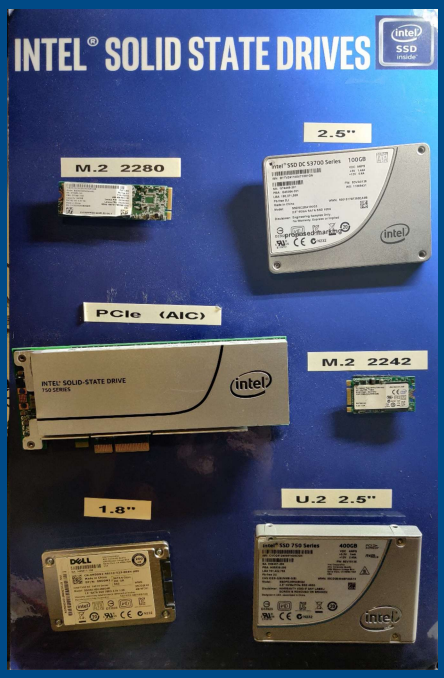
NAND Flash Storage is organized into Blocks
Where Blocks carry Pages, Pages carry Cells, and Cells carry Bits.

A NAND Cell cannot be individually be erased. Many Cells form a Page, and the Page is the smallest unit you're able to write to. Multiple Pages are put into a Block is the smallest unit the NAND can be erased from.

In short, an SSD writes data into pages until the Block is full and when you erase data from an SSD it will be erased in Blocks.

Form Factors

	2.5”	M.2	AIC (Add in card)	EDSFF “Ruler”
NVME				
SATA				



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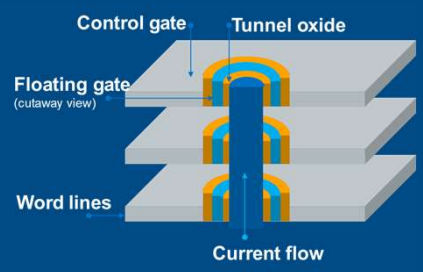
Here we have various forms factors of an SSD.

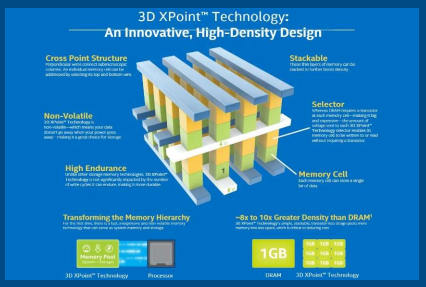
On the SATA side we have 2.5-inch drive and a M.2 (AKA a “Gum Stick”)

On the NVMe Side we have 2.5-inch, a Gum Stick, AIC (add in card), EDSFF “Ruler”

New Media Technologies - Intel

3D NAND vs 3D XPoint





1. **Physics** of controlling electrons through tunnel oxide **deeply understood**
2. **Discrete cell isolation** minimizes risk of cross-cell interference
3. **~6x more electrons** in vertical cell increases control

1. **Cross Point Structure**: Selectors allow dense packing and individual access to bits leading to Scalability where Memory layers can be stacked in a 3D manner
2. **Breakthrough Material Advances** leads to Higher Performance

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3D NAND and 3D Cross-point are two types of media Intel produce their SSDs.

3D NAND is an evolution of 2D NAND.

Intel 3D NAND is built on a proven technology to address the cell reliability challenges. It accomplish this in three ways

1. **Controlling electrons through tunnel oxide**
   - Physics and materials science has been deeply understood for 3+ decades
   - Deep knowledge enables Intel to maintain precise placement and sensing necessary with shrinking tolerances

2. **Cell isolation**

- Charge storage nodes are isolated.

- This is a unique approach providing strong protection from charge loss and cell to cell interference

1. **More electrons**

- Vertical gate-all-around structure provides almost 6 times more electrons per cell than planar floating gate
- More electrons mean greater control in hitting smaller tolerances
- More electrons also means the cells are less susceptible to voltage changes from leakage of a small amount of electrons

As a result 3D NAND technology increases storage density and lowers cost per Gigabyte

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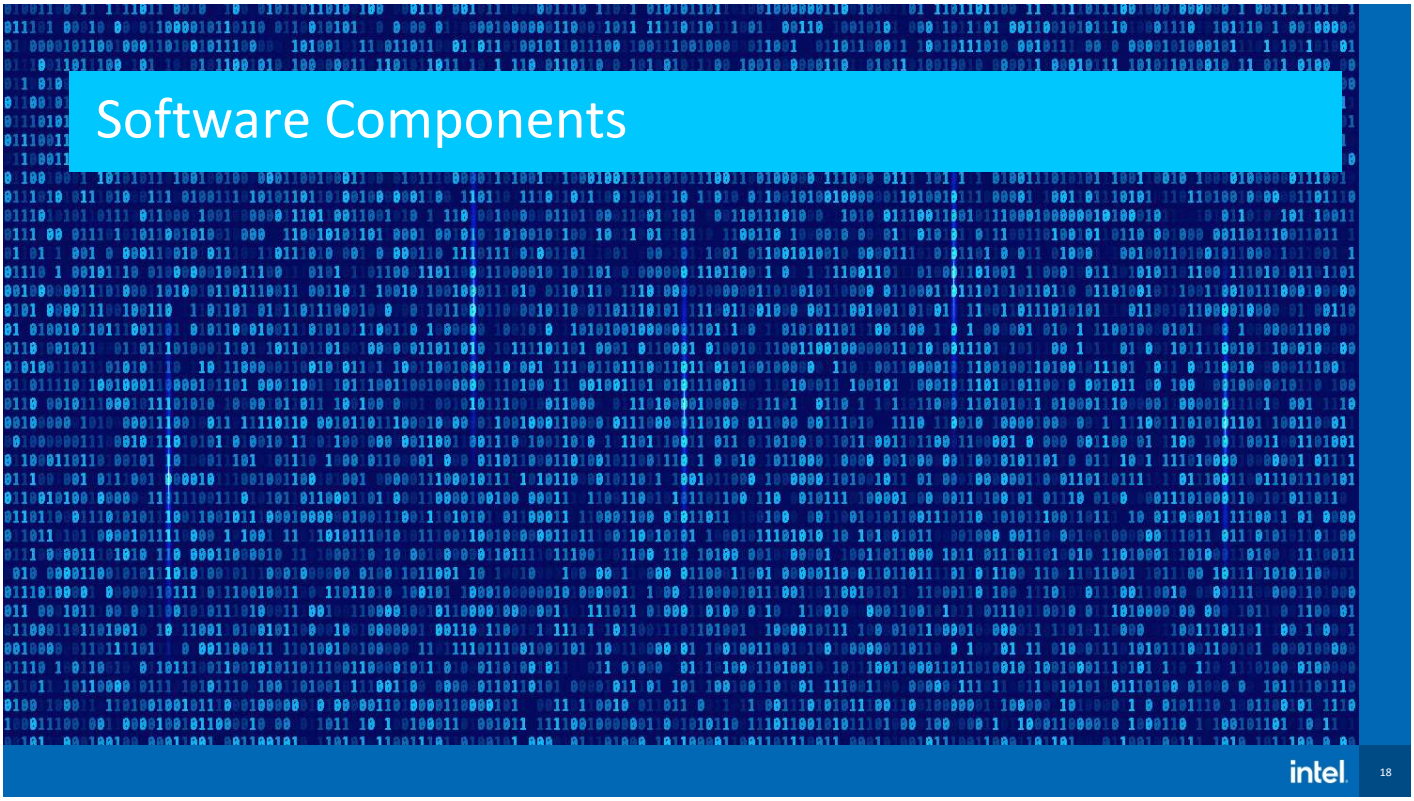
Codeveloped with Micron **3D Cross-point** is a phase change technology to bridge the growing gap between storage and memory.

This **Cross Point Structure:** allows dense packing and bit addressable where a memory cell can be individually addressed (unlike traditional NAND Flash where it needs to be written in pages).
The technology allows **Scalability** where Memory layers can be stacked in a 3D manner (hence why it is called 3D Cross-point).
3D Cross-point has **Breakthrough Material Advances** its compatible switch and memory cell materials leads to **High Performance**
Where its Cell and array architecture can switch states much faster than NAND

As a result it has lower latency and higher endurance.



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Software Components

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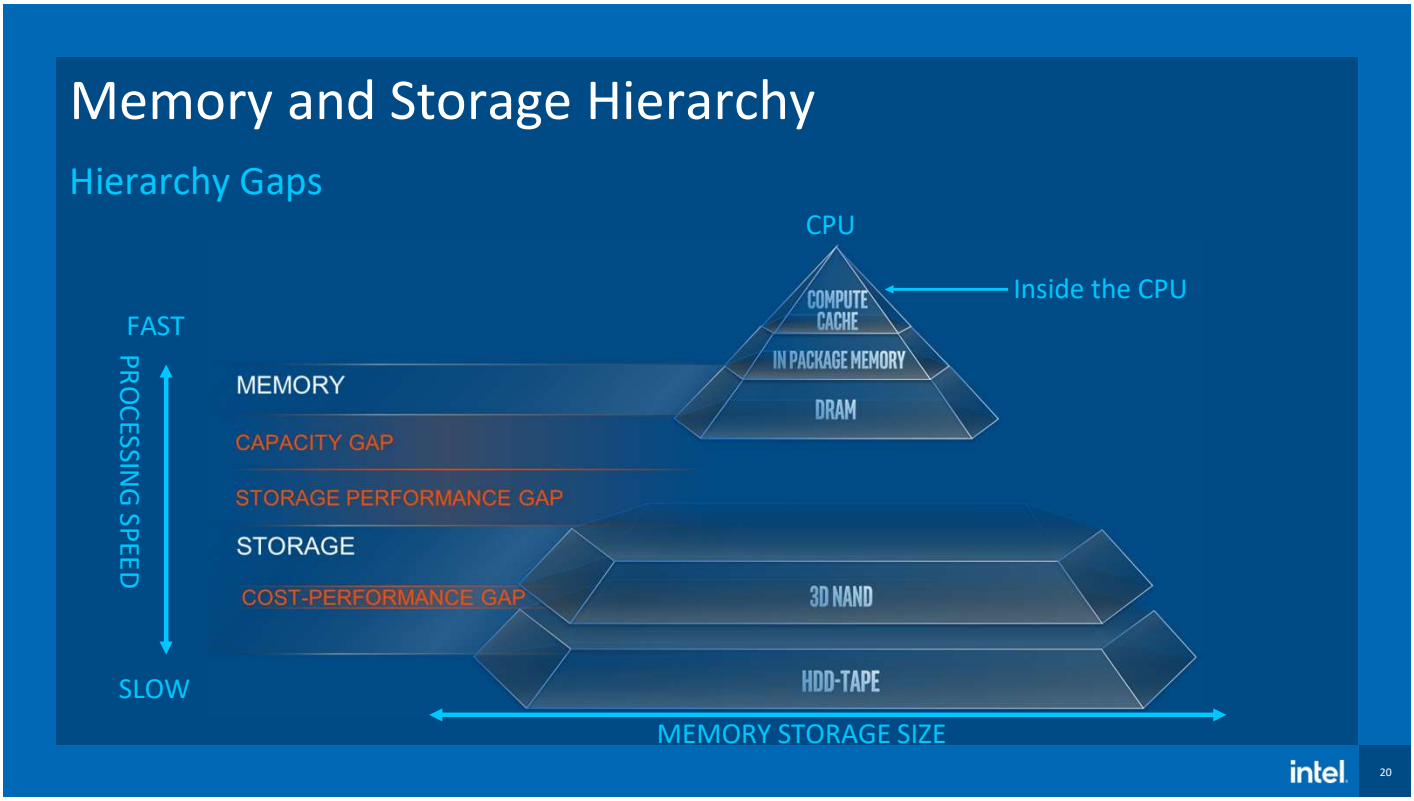
SSDs have a limited lifespan they can only be written to only a finite amount of time.

The following operations help the drive reallocate space making the drive most efficient and help maintain its fast speeds.

- **Wear Leveling –** Imagine the tiers of a car. To maximize the life of the tires you'd want to make sure that each tier is being worn out at the same rate. That way the tires can maximize their life cycle. Wear leveling to the blocks of an SSD evenly distributes writing data to all blocks versus just one or two.
- **Garbage Collection –** Recall that SSDs read and write data in Pages but erase data in Blocks.
  Garbage Collection optimizes space and improve efficiency of an SSD by making sure that there is as many Blocks as possible by a process called a "Trim Command"
- **A Trim Command –** It is the background process of the SSD's controller. This puts the erased blocks in a queue, so that they ready to used.
- **Over Provisioning –** It is the capacity that can only be accessed by the SSD's controller and not by the user. This extra space, usually seven percent, improves performance and lifetime of the SSD and is used for some of the background operations like Garbage Collection.



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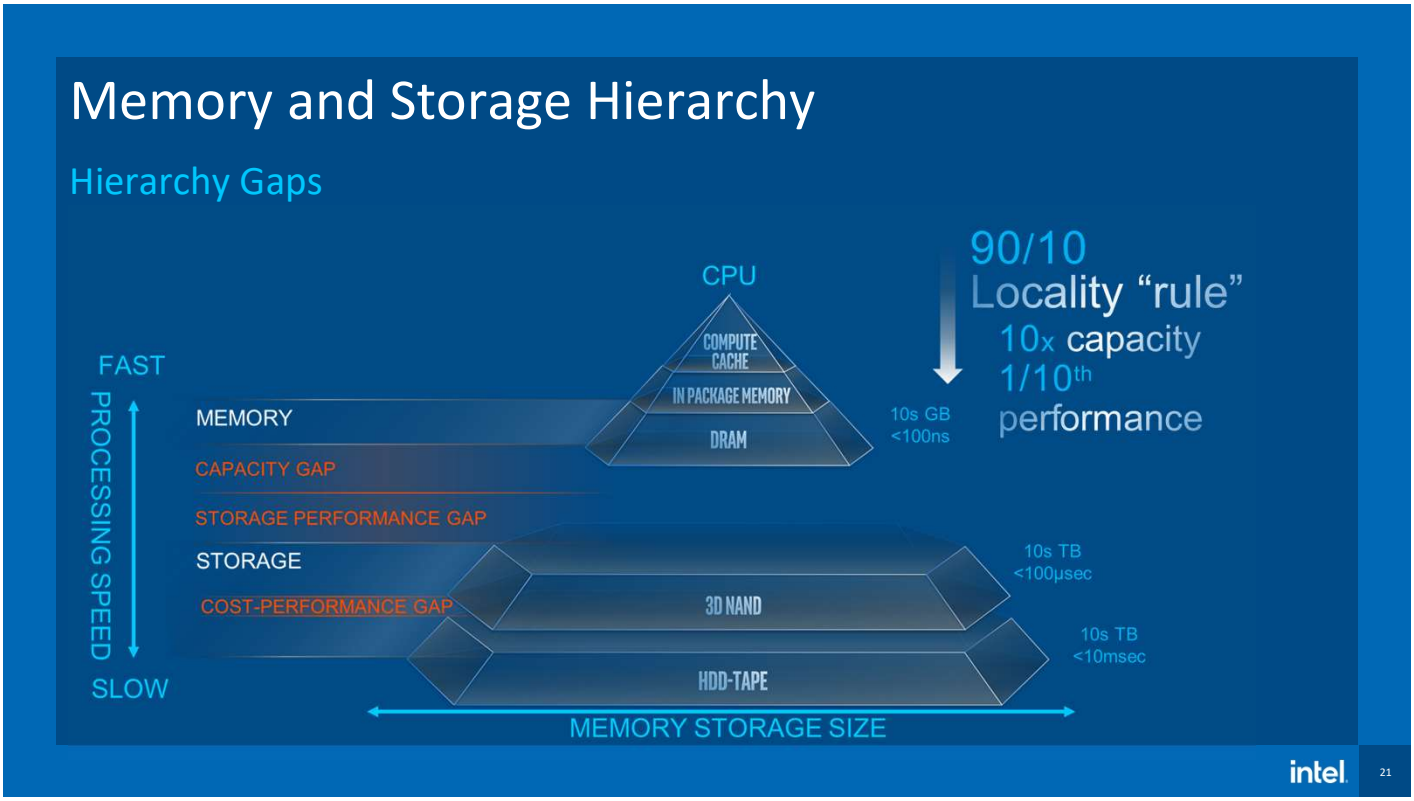
The gap between storage and memory.

As you can see there are lots of different types of memory inside any computer, but by comparing each of their relative storage size
And speeds, you end up with something like this pyramid.



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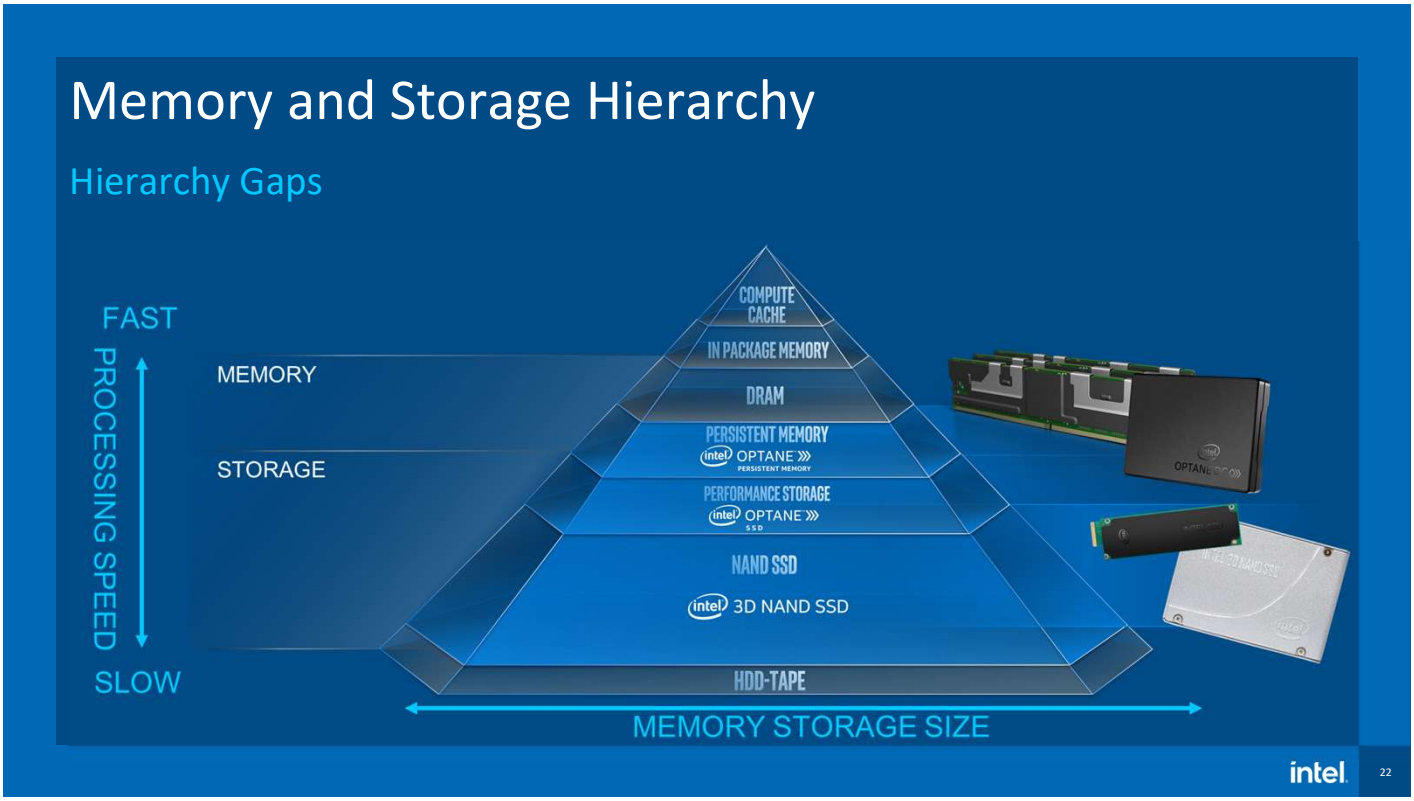
So we see this need in market to bridge these storage capacity and latency gaps



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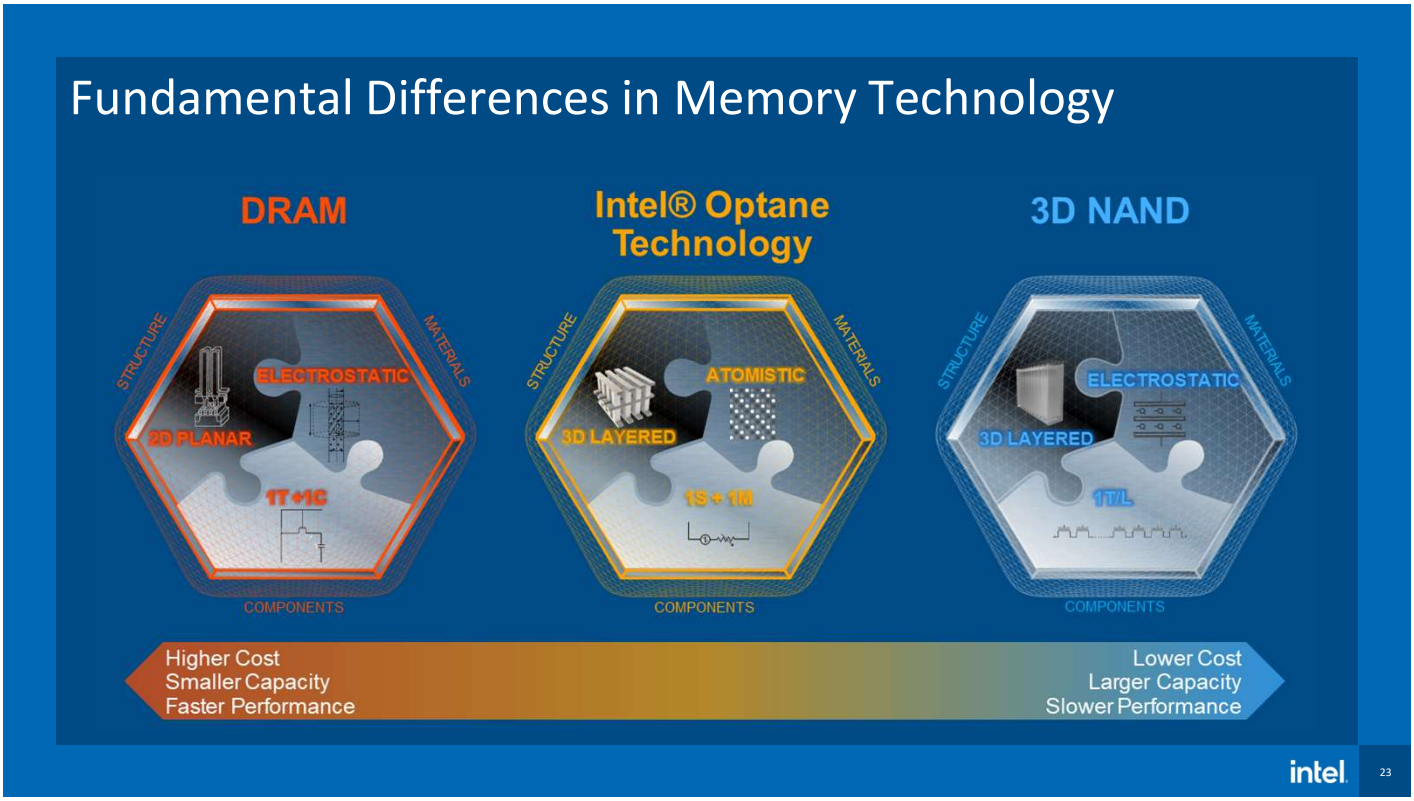
The goal for any data company is to make latency as low as possible without their hindering performance and proficiency;
as a result, this led to the development of Optane Memory, Optane SSDs, and 3D NAND.

Persistent Memory - **Optane Persistent Memory -** More data in memory
Performance Storage - **Optane SSD –** Data closer to the CPU
Capacity Storage - **3D NAND SSD –** More data into solid state storage



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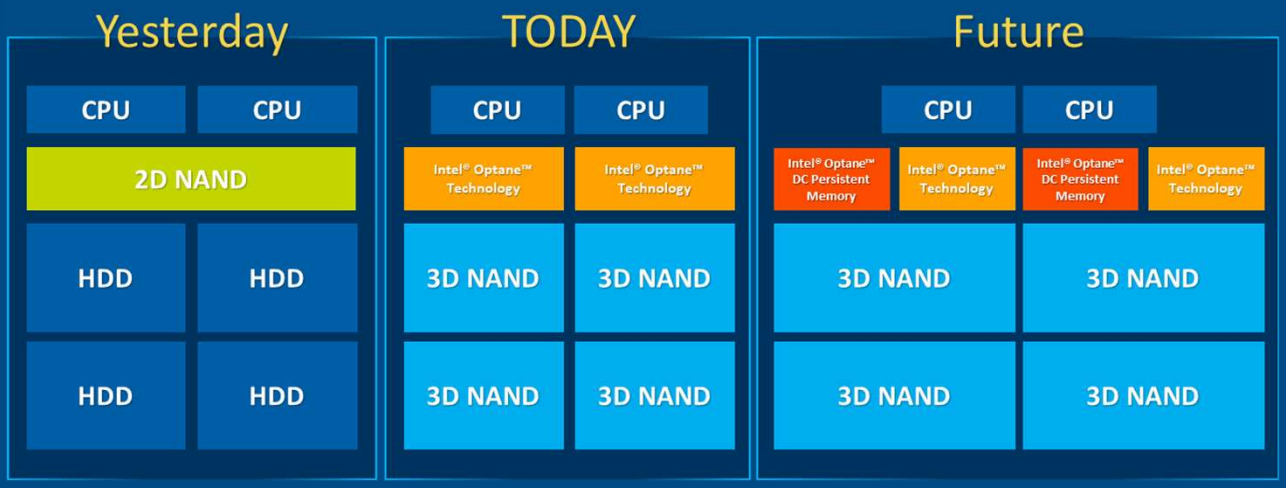
A portfolio of solution components



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Disciplined investment

Intel® Optane™ Technology

Intel Fab 11X: Rio Rancho, New Mexico

Intel® 3D NAND Technology

Intel Fab 68: China

Capacity for our Demand

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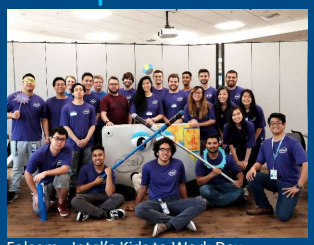
INTERNSHIPS

https://jobs.intel.com/page/show/internships

Santa Clara – Intel Campus

Folsom – Fall 2019 Rotation


Folsom - Intel's Kids to Work Day

Folsom – Intel Outreach (Sac State)


Folsom – Spring 2019 Rotation


Folsom – Networking and Friends


Folsom – Intel Outreach Intern Panel

Folsom – Engineers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