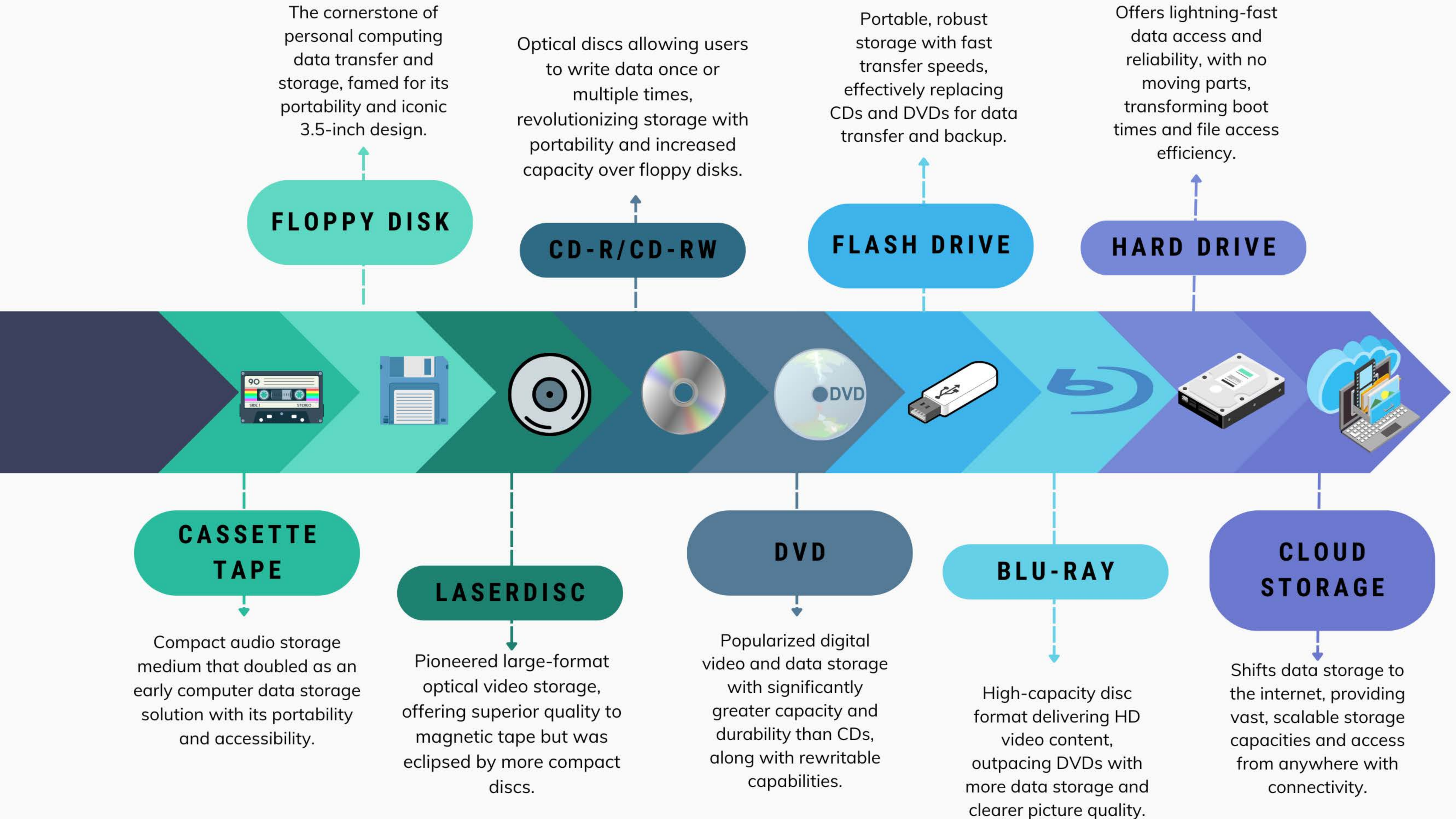


# THE EVOLUTION OF DATA STORAGE MEDIUMS





## BENCHMARKS

# Comparison

	Floppy	CD-R	DVD	Blu-Ray	HDD	SSD
Read Speed	0.06 MB/s	7.8 MB/s	22.16 MB/s	54 MB/s	130 MB/s	7500 MB/s
Write Speed	0.06 MB/s	7.2 MB/s	22.16 MB/s	72 MB/s	130 MB/s	6900 MB/s
Access Time	100 - 300 ms	80 - 150 ms	90 - 160 ms	180 - 300 ms	5 - 10 ms	0.1 - 0.5 ms
Maximum Capacity	1.44 MB	700 MB	8.5 GB	100 GB	32 TB	100+ TB



**Read Speed:** Refers to how quickly data can be read from the device once it has been located and accessed

**Write Speed:** Refers to how fast a file can be written and stored

**Access Time:** The delay it takes for the device to locate and begin retrieving requested data



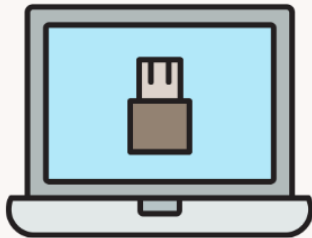
# | FLASH DRIVE

**MSYSTEM****IBM**

The USB flash drive was invented in 1999 by the Israeli company M-Systems led by engineer Dov Moran led by engineer Dov Moran, with IBM filing the first patent in 1999

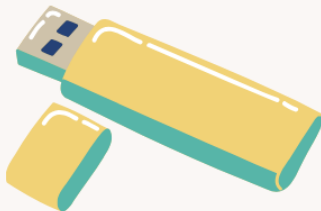


USB flash drives have seen a dramatic increase in storage capacity over time, ranging from initial sizes of 8 MB to modern drives that can hold up to 2 TB. This is equivalent to storing hundreds of thousands of documents, thousands of songs, or hundreds of high-definition movies.



Read and write speeds vary depending on the device and technology used, with typical speeds ranging from 10 MB/s to over 400 MB/s for USB 3.0 and higher devices.

Flash drives are typically about 2 to 3 inches (5 to 7.6 cm) long, 0.5 to 1 inch (1.3 to 2.5 cm) wide, and 0.2 to 0.4 inches (0.5 to 1 cm) thick.



Flash drives were a major innovation due to their compact size, durability, and lack of moving parts compared to earlier storage media like floppy disks and CD-ROMs. They offer plug-and-play convenience and compatibility with a wide range of devices.



USB flash drives are still relevant today, although their popularity has been somewhat eclipsed by cloud storage services for certain applications.

Flash drives continue to evolve with faster data transfer speeds, higher storage capacities, and new form factors like USB-C. They are also used as promotional items, with customized branding.





# The Cassette Tape

One of the Oldest forms of Data Storage



## Invention Year and Inventor

Invented by Lou Ottens and his team at the Dutch company Philips the cassette tape was released in August 1963.



## Storage Capability

A standard cassette tape used for data storage (such as the C64 datasette) had a capacity of about 660 KB per side, totaling around 1.32 MB for a 90-minute tape. (~1 iPhone Screenshot)



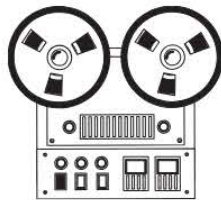
## What was it used for?

Cassette tapes were primarily used for listening to music, but they were also used for recording speeches, lectures, and even early computer data storage.



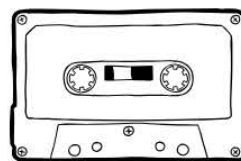
## Benchmarks

The data transfer rate for a typical computer data cassette was around 2,000 bits per second (bps), which is exponentially slower than modern storage devices.



## Innovation and Improvements

Cassette tapes revolutionized data storage with their portability, affordability, and ease of use compared to predecessors like punched cards, magnetic drums, and reel-to-reel tapes. Their compact design and low cost made computing more accessible, bridging the gap between cumbersome, expensive storage media and the user-friendly, cost-effective solutions that followed.



## Sizing

A standard cassette tape measures approximately 4 inches (10.2 cm) wide, 2.5 inches (6.35 cm) high, and 0.5 inches (1.27 cm) thick.

## Relevancy



Cassette tapes for data storage started to become obsolete in the mid-1980s with the rise of more reliable and higher-capacity storage media like floppy disks.

# OPTICAL STORAGE

## DIGITAL VERSATILE DISC (DVD)

12cm diameter

### Storage & Speeds

- Typically **4.7 GB** for single-layer discs and **8.5 GB** for dual-layer discs. Extended capacities with later versions.
- **1x speed equals 1.385 MB/s** for single-speed DVD.

### Innovation & Common Use

- Increased storage capacity, supporting **high-definition video** and audio. Utilized a **blue-violet laser** for data reading.
- **High-definition home video entertainment, gaming, and data storage.**
- Still in use, especially for high-definition video, but **faces competition from online streaming services.**

### Invention

- Developed by the **Blu-ray Disc Association (BDA)**, including companies like Sony, Philips, and Panasonic. Released in **2006**.

### Invention

- Developed collaboratively by **Philips, Sony, Toshiba, and Panasonic** in the early **1990s**.

### Innovation & Common Use

- **Significantly increased storage capacity**, allowing for **higher-quality** video and audio. Also introduced various formats like DVD-ROM for data storage.
- **Home video entertainment, software distribution, and data storage.**
- Still widely used, but **faced competition from Blu-ray** and **online streaming** in the **2010s**.

# OPTICAL STORAGE

## BLU-RAY DISC

12cm diameter

### Storage & Speeds

- Typically **25 GB** for single-layer discs and **50 GB** for dual-layer discs. Higher capacities available with newer versions.
- **1x speed equals 36 Mbps (4.5 MB/s).**



# OPTICAL STORAGE LASERDISC (LD)

30cm diameter

## Storage & Speeds

- Typically stored up to **60 minutes** per side (single layer), later extended to 120 minutes using double-sided discs.
- Variable speed, typically **570 revolutions per minute (RPM)**.

## Invention

- Invented in **1978** by **David Paul Gregg**.

## Innovation & Common Use

- Introduced **digital audio**, providing high-quality sound with no degradation over time. Also used for data storage.
- **Mainstream audio playback, software distribution, and data storage.**
- Still in use, especially for audio, but largely replaced by DVDs and later formats for data storage. **Declined significantly in the 2010s.**

## Invention

- Invented in **1982** by **James T. Russell**.

## Other Info

- LaserDiscs were known for their analog video and audio, and their large, cumbersome size compared to later optical disc formats.

## Innovation & Common Use

- LaserDisc was the **first optical disc storage medium**, offering better video and audio quality compared to VHS tapes.
- Popular for **home video playback and educational purposes**, but eventually overshadowed by VHS due to shorter playback times and higher costs.
- Declined in popularity during the 1990s with the rise of DVDs. Became largely **obsolete by the early 2000s**.

# OPTICAL STORAGE COMPACT DISC (CD)

12cm diameter

## Storage & Speeds

- Initially designed for **74 minutes** of audio, later extended to **80 minutes**. Data CDs could hold around **650-700 MB**.
- **1x speed** equals **150 KB/s** for audio CDs. Data CDs varied in speed, with 1x being equivalent to 150 KB/s.

# CLOUD STORAGE

Data to be accessed anytime, anywhere

## Storage Capability

Unlimited storage potential; can host millions of HD videos and billions of documents

## Innovation

Shift from physical to virtual; no physical device needed for storage, enabling real-time access and sharing across the globe

## Current Use-Cases

Online backup, collaborative work environments, streaming services, and hosting applications

## Speed

Typically bottlenecked by your internet connection; top speeds depend on host's infrastructure

## Physical Size

Data centers can span thousands of square feet and are strategically spread out around the world to minimize latency

## Reliability

Major cloud service providers implement extensive redundancy to stored data to minimize data loss

## History and Invention

Conceptualized in the 1960s with the development of the internet; commercially viable services emerged in the 2000s by companies like Amazon (AWS in 2006) and Google (Google Drive in 2012)



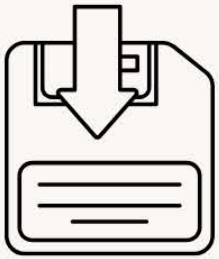


# FLOPPY DISK



The 8-inch floppy disk was invented by International Business Machines Corporation (IBM) in 1971, with the 5.25-inch and 3.5-inch versions introduced in the mid-1970s and early 1980s.

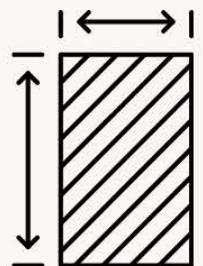
1970



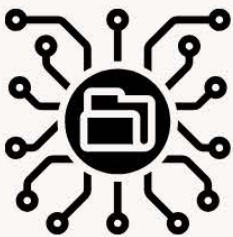
The most common floppy disks measured 3.5 inches (8.9 cm) square and about 0.1 inches (2.5 mm) thick.

The data transfer rate for floppy disks was relatively slow, typically around 250-500 kilobits per second (kbps).

The iconic "save" icon in many software applications is modeled after the 3.5-inch floppy disk, a testament to its lasting impact on computing culture



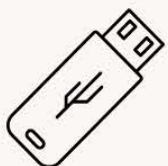
Early 5.25-inch floppy disks had a storage capacity of about 360 KB, while later 3.5-inch versions could hold up to 1.44 MB. This is roughly equivalent to a few text documents or a single low-resolution image.



Floppy disks were a significant innovation due to their portability, reusability, and ease of use compared to cassette tapes. They provided random access to data, allowing for faster retrieval compared to the sequential access of tapes.



Floppy disks began to decline in popularity in the late 1990s and early 2000s with the advent of higher-capacity storage media like CD-ROMs, USB flash drives, and cloud storage.







# THE MECHANICAL HARD DISK DRIVE



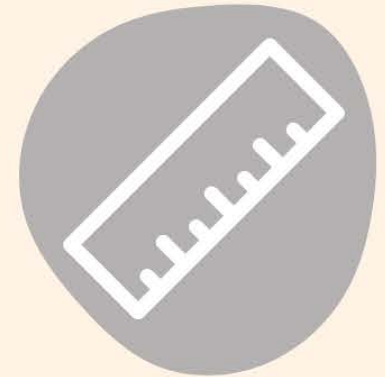
## Invention

The first HDD, the IBM 350 Disk Storage Unit, was introduced in 1956 as a part of the IBM 305 RAMAC computer system. It was invented by a team at IBM led by Reynold B. Johnson. HDDs are still widely used today.



## Speed

Typical read/write speeds of HDDs rarely vary, with modern consumer drives usually offering speeds of 100 MB/s to 160 MB/s. Enterprise-level drives might push this a little further, but HDDs greatly lag behind SSDs in terms of speed.



## Form Factors

Consumer HDDs usually come in either a 3.5-inch (5.75" x 4" x 1") or 2.5-inch form factor (4" x 2.75" x 0.5"). 3.5-inch HDDs are usually installed in desktops while 2.5-inch HDDs are used in laptops.



## Storage

Typical storage capacities for consumer-level HDDs are anywhere from 1TB to 8TB. Compared to SSDs, large capacity hard drives are much more cost-effective.



## Durability

Due to the mechanical nature of HDDs, they are much more prone to failure compared to SSDs. Many factors can influence the lifespan of an HDD such as extreme temperatures, humidity, shocks, and vibrations.





# SOLID STATE DRIVE

FAST, COMPACT, RELIABLE



## WHEN THEY WERE INVENTED

The journey of SSDs began in the 1950s with early concepts of solid-state storage. However, **the first commercially available flash-based SSD was introduced by SanDisk in 1991.**

This marked the transition towards the modern SSD, which gained popularity in the mid-2000s as technology advanced and costs decreased.



## TYPICAL STORAGE CAPACITY

SSDs offer a wide range of storage capacities, typically from **120GB to 4TB for consumer-level products**. Enterprise-grade SSDs, on the other hand, can reach upwards of 30TB (e.g. Samsung PM1643)!

Creatively put, a 1TB SSD can store over 200,000 5-minute MP3 songs or around 250 full-length HD movies.



## HOW FAST THEY CAN BE

SSDs are much faster than HDDs. SATA SSDs can reach **read/write speeds of up to 550 MB/s and 520 MB/s**, respectively.

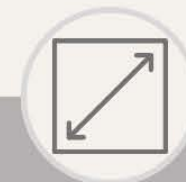
More advanced NVMe SSDs push this further, with speeds up to **7500 MB/s for reads and 6900 MB/s for writes**. Tasks such as video editing and software development can greatly benefit from these speeds.



## LIFESPAN AND DURABILITY

SSDs have no moving parts, making them **resistant to physical shock and vibrations**. The lifespan of an SSD depends on the type of NAND flash memory used and how many bits are stored per cell.

**Manufacturers measure SSD lifespan in Total Bytes Written (TBW)**, indicating how much data can be written to the drive before it wears out.



## AVAILABLE FORM FACTORS

The **2.5-inch SSD (100mm x 70mm x 7-15mm)** is common for laptops and desktops and is typically mounted on the computer chassis.

**M.2 SSDs (22mm wide and lengths from 30mm to 110mm)** are compact, ideal for thin laptops and small form factor PCs. These plug in directly to the motherboard (via an M.2 slot).