At Manchester University, Freddie Williams and Tom Kilburn develop the Williams-Kilburn tube. The tube, tested in 1947, was the first high-speed, entirely electronic memory. It used a cathode ray tube (similar to an analog TV picture tube) to store bits as dots on the screen's surface. Each dot lasted a fraction of a second before fading so the information was constantly refreshed. Information was read by a metal pickup plate that would detect a change in electrical charge.

Maurice Wilkes and his team at the University of Cambri construct the Electronic Delay Storage Automatic Calculator (EDSAC). EDSAC, a stored program computer, used delay line memory. Wilkes had attended the University of Pennsylvania's Moore School of Engineering summer sessions about the ENIAC in 1946 and shortly thereafter began work on the EDSAC.

Magnetic drum memory
While working on the Whirlwind project at MIT, Jay Forrester writes a notebook entry on June 13 that describes his early thoughts on the “coincident current” technique for a magnetic core memory system. This system was the first reliable high-speed random access memory for computers. Magnetic core memory was widely used as the main memory technology for computers well into the 1970s.

Eager to enhance America’s codebreaking capabilities, the US Navy contracts with Engineering Research Associates (ERA) for a stored program computer. The result was Atlas, completed in 1950. Atlas used magnetic drum memory, which stored information on the outside of a rotating cylinder coated with ferromagnetic material and circled by read/write heads in fixed positions. ERA successfully sold a commercial version of the Atlas, the ERA 1103.

UNIVAC UNISERVO tape drive

UNIVAC introduces the “UNISERVO” tape drive for the UNIVAC I computer. It was the first tape storage device for a commercial computer, and the relative low cost, portability and unlimited offline capacity of magnetic tape made it very popular. UNIVAC tapes were ½" wide, 0.0015" thick, up to 1,500’ long, and made of phosphor-bronze with a metallic coating. Weighing about three pounds, each reel could hold 1,440,000 decimal digits and could be read at 100 inches/sec.

While working on the Whirlwind project at MIT, Jay Forrester holds an early core memory plane.

IBM 726 Magnetic tape

Magnetic tape allows for inexpensive mass storage of information and is a key part of the computer revolution. IBM 726 was an early and important practical high-speed magnetic tape system for electronic computers. Announced on May 21, 1952, the system used a unique ‘vacuum chamber’ design for the tape drive.
method of keeping a loop of tape circulating between two points, allowing the tape drive to start and stop the tape in split-second. The Model 726 was initially sold in 1953 with IBM’s first electronic digital computer, the Model 701, and could store 2 million digits per tape—an enormous amount at the time. The 726 rented for $850 a month.

In 1953, MIT’s Whirlwind becomes the first computer to use magnetic core memory. Core memory is made up of tiny “donuts” made of magnetic material strung on wires into a grid. Each core stored a bit, magnetized one way for a “zero,” and the other way for a “one.” The wires could both detect and change the state of a bit. Though several inventors were involved, it was MIT’s Jay Forrester who perfected the technology. In 1971, the introduction of the Intel 1103 DRAM integrated circuit signaled the beginning of the end for magnetic core memory in computers.

The era of magnetic disk storage dawns with IBM’s shipment of a RAMAC 305 computer system to Zellerbach Paper in San Francisco. The computer was based on the new technology of the hard disk drive — the world’s first. The RAMAC disk drive consisted of 50 magnetically coated platters capable of storing about 5 million characters of data. RAMAC allowed real-time random access to large amounts of data, unlike magnetic tape or punched cards. A working RAMAC hard disk assembly is demonstrated regularly at Computer History Museum.

Bryant Chucking Grinder Company magnetic disk drive

Bryant Chucking Grinder Company, a computer drum manufacturer, explores new storage ideas. They began

RAMAC

Magnetostrictive delay lines
developing a disk drive in 1959—made up of a horizontal shaft with eight or more 39-inch magnesium disks. Few sold.

The Ferranti Sirius is announced. The Sirius was a small cost business computer using a simple programming language. Its main memory was a magnetostrictive delay. The medium here was a thin strip of special metal rolled coil, with transducers at either end. Like all delay lines, input was fed into one end, detected at the other, and continued recirculated. Although this type of delay line was considered to be somewhat slow, its low cost made it attractive to computer designers.

The concept of virtual memory emerges from a team under the direction of Tom Kilburn at the University of Manchester on its Atlas computer. Virtual memory permitted a computer to use its storage capacity to switch rapidly among multiple programs or users and was a key requirement for timesharing.

DECtape is introduced. It was a modification of DEC's earlier LINCtape, and as a reliable and inexpensive storage medium was used in several generations of DEC minicomputers. ¾-inch tape was widely thought to be an improvement over paper tape and part of its reliability stemmed from the fact it was laminated and the magnetic part of the tape was sandwiched between two layers of mylar. DECtape was also used as a form of personal data storage, as the small reels could be easily hand-carried.
Card Random Access Memory (CRAM) is introduced. The NCR 315 and several later NCR mainframes used this mechanically complex magnetic CRAM for secondary storage. The mylar cards were suspended from rods that selected and dropped one at a time for processing. Each CRAM deck of 256 cards recorded about 5.5 MB.

IBM 1311 Disk Storage Drive

IBM 1311 Disk Storage Drive is announced. Announced on October 11, 1962, the IBM 1311 was the first disk drive IBM made with a removable disk pack. Each pack weighed about ten pounds, held six disks, and had a capacity of 2 million characters. The disks rotated at 1,500 RPM and were accessed by a hydraulic actuator with one head per disk. The 1311 offered some of the advantages of both tapes and disks.

Thin-film memory

Thin-film memory is introduced. Sperry Rand developed this faster variation on core memory. Small glass plates held tiny dots of magnetic metal film interconnected with printed drive and sense wires. Used in the UNIVAC 1107 for high-speed registers, it proved too expensive for general use. However, it did find a larger market in military computers and higher end projects where speed was a premium. Several other manufacturers, such as RCA, also developed thin-film memory.

IBM 2315 disk cartridge

IBM's 2315 disk cartridge is announced. This 1MB disk cartridge was used with the IBM 1800 and 1130 computer and it provided easily transported “personal storage” for those small computers. Each 2315 consisted of a magnetically coated, direct access disk encased in a plastic cartridge that easily fit into built-in disk drives. When it was inserted into the disk drive, a power drive engaged the disk and spun it at 1,500 revolutions per minute. Simultaneously, an arm extended to perform read and write functions on the disk’s magnetic surfaces.

IBM 2321 Data Cell Drive

Seven years in the making, IBM's 2321 Data Cell Drive stores up to 400 MB. The Data Cell Drive was announced with the System/360 mainframe computer. Wide magnetic strips were plucked from bins and wrapped around a rotating cylinder reading and writing. Reliability problems plagued the initial models, but after improvements were made it became
IBM 2314 direct access storage facility

The IBM 2314 direct access storage facility is introduced. It was an improvement over the 2311 disk storage drive and provided higher data storage density. Eight drives (plus a spare) with removable 29 MB disk packs shared one control unit. The extra drive was a spare for the user or could be worked on by a field engineer while the other eight were in use by the customer. Attached to a System/360 computer, it supported applications like online banking, ATMs, and just-in-time manufacturing.

Victor 3900 desktop calculator

Victor Comptometer Corporation produces the Victor 3900 desktop calculator. Six 100-bit MOS shift registers built by General Microelectronics provided memory for the calculator, which was the first to use MOS for both logic and memory. The calculator could perform multiple functions and had a small, integrated CRT display. However, the immature MOS technology made it relatively reliable and sold until 1976.

Transmitter Read Only Storage (TROS)

IBM introduces Transformer Read Only Storage (TROS) in 1965. TROS modules preceded solid state ROM chips, and each bit of this read-only memory was stored in a little magnetic transformer. Punches in mylar strips controlled whether current flowed through the transformer or around it, representing a binary zero or one.

Signetics 8-bit RAM

The April 4, 1966 issue of Electronics magazine features an 8-bit RAM designed by Signetics for the SDS Sigma 7 mainframe computer. The article was titled, "Integrated scratch pads sire new generation of computers." This 8-bit RAM was one of the earliest uses of dedicated semiconductors in memory devices in computer systems.
The manufacturing process made the parts unreliable, limiting sales.

IBM 1360 Photo-Digital Storage System

The IBM 1360 Photo-Digital Storage System is installed at Lawrence Livermore National Laboratory. The system could read and write up to a trillion bits of information—the first system in the world. The 1360 used thin strips of film on which were written data created by an electron beam and wet photographic development process. The system used sophisticated error correction and a pneumatic robot to move the film strips to and from a storage unit. Only five were built.

IBM “Minnow” floppy disk drive

At IBM, development begins on the Minnow, a read-only floppy disk drive designed to load microcode into the controller for the "Merlin" (IBM 3330) Direct Access Storage Facility. The outcome of the work was a read-only, 8-inch, 80 kilobyte floppy disk and disk drive—the world’s first. Released as the IBM 23FD in 1971, it was used with the System 370 among other computers. Unlike hard drives, a user could easily transfer a floppy in its protective jacket from one drive to another. It was not until 1973 that IBM released a read/write floppy disk drive. Soon after, it became an industry standard.

First IBM computer to use semiconductor memory

Apollo Guidance Computer read-only rope memory
Apollo Guidance Computer read-only rope memory is launched into space aboard the Apollo 11 mission, which carried American astronauts to the Moon and back. This memory was made by hand, and was equivalent to 72 KB storage. Manufacturing rope memory was laborious and it could take months to weave a program into the rope memory. If a wire went through one of the circular cores it represented a binary one, and those that went around a core represented a binary zero.

In a departure from using magnetic core memory technology, IBM introduces the System 370 Model 145 mainframe computer, the company's first all-semiconductor memory computer. The Model 145 could store an equivalent amount of data in half the space, compared to a computer using core memory.

The ILLIAC IV supercomputer is delivered to NASA Ames Research Center at Moffett Field, California. One Fairchild-built Processing Element Memory (PEM), which stores 16,834 bytes, was in each of ILLIAC IV’s 64 processors. The 131,072-bit PEM was built by Fairchild using their new 256-bit bipolar SRAM chips. This was the first commercial use of commodity semiconductor memory in a large computer system.

IBM's 3340 data module is introduced. It was based on “Winchester” technology that put the read/write heads, platters and access mechanism in a sealed removable unit. Low-mass heads landed safely on the lubricated platter surface when the power was off. Most hard disks do that but are no longer removable. Winchester technology drive arrays were IBM’s last storage system with large removable disk packs. Strings of two to eight 3340 drives could be attached to an IBM mainframe computer, providing a storage capacity of up to 280 million bytes per string.
The introduction of the 1 KB Intel 1103 memory chip marks the beginning of the end for magnetic core memory and ushers in the era of dynamic random-access memory (DRAM) integrated circuits for main memory in computers. The 1103 sold slowly at first, but this likely helped the development team at Intel, which was still ironing out details about the chip's specifications after its initial release. However, at a price of 1¢ per bit and with a speed compatible with existing logic circuits, sales skyrocketed after several design revisions.

IBM 3850 mass storage system

The IBM 3850 mass storage system is introduced. The largest 3850 storage system held 4,720 cartridges, stored GB, and was 20 feet long. IBM claimed online magnetic storage was ten times more costly than the 3850. Released as an alternative to a manual tape reel library, the system used 4-inch long cylinders of magnetic tape that were retrieved and replaced by a robotic arm. Those cylinders stored in hexagonal, “honeycomb” bins to reduce space.

DEC RL01

The DEC RL01 is introduced as a successor to DEC’s RK05 drives. It was an attempt to lower maintenance costs while bolstering disk drive reliability. It was initially released with a 5 MB capacity, and two years later a 10 MB version was put on the market. Also, head alignment tools were removed, as maintenance on these parts was costly and time-consuming. Future disk drives largely adopted this feature.

Japanese manufactured dynamic random-access memory (DRAM)

The Japanese Trade Ministry sees a chance to make Japan leader in the dynamic random-access memory (DRAM) industry, as sales soared when DRAMs entered commercial production in the early 1970s. With customer demand in millions, DRAMs became the first “mass market” chips, sparking fierce international competition. In 1976, the Japanese Trade Ministry funded Fujitsu, Hitachi, Mitsubishi, NEC, and Toshiba to develop 64K DRAMs. The consortium triumphed, decimating American memory suppliers and provoking the U.S. government to threaten trade sanctions.

Commodore 1530 Datasette

The Commodore 1530 Datasette was introduced in 1976. It was a portable tape drive that allowed users to save and load programs and data onto magnetic tape. The Datasette was compatible with the Commodore PET and was a popular accessory for the system.
Although tensions eased between Japanese and American manufacturers, Korea soon overtook them both.

**The built-in Commodore 1530 Datasette (data+cassette) is the primary storage device for the newly released Commodore PET. The device converted digital information from the computer into analog sound signals which were stored on compact cassettes. The method was cost-effective and reliable, but also very slow.**

**ROM chips**

The Atari Video Computer System (VCS) video game console is introduced. It was one of the first successful consoles that used interchangeable cartridges with factory programmed ROM chips to store the software. At first, designers planned to use an internal ROM chip that contained several pre-programmed games. This method was used in many predecessor consoles, but Atari’s choice on using cartridges in part led the VCS to becoming one of the most popular video gaming systems of all time.

**LaserDisc**

The LaserDisc is introduced as “Discovision” by MCA and Philips. The first LaserDisc sold in North America was the Jaws. It offered better audio and video quality than its competitors, but LaserDisc players were prohibitively expensive for many consumers. That fact, in conjunction the availability of only a limited LaserDisc library, helped gain significant popularity only in parts of Asia. Now obs it was the direct forerunner of the CD and DVD.

**Shugart 5 ¼-inch flexible disk drive**

The 5 ¼-inch flexible disk drive and diskette are introduced by Wang Laboratories to produce a disk drive small enough to use with a desktop computer, since 8-inch floppy drives were considered too large for that purpose. By 1978, more than a dozen manufacturers were producing 5 ¼-inch floppy drives.
Intel introduces its 4 Mbit bubble memory array. A few magnetic bubble memories reached the market in the 1970s and 1980s and were used in niche markets like video games and machine tool controllers. The introduction of cheaper, faster and higher density memory solutions rendered bubble memory obsolete. Each silver square, or "bubble," on this board stored 1 Mbit.

Seagate Technology creates the first hard disk drive for microcomputers, the ST506. The disk held 5 megabytes data, five times as much as a standard floppy disk, and fit the space of a floppy disk drive. The hard disk drive itself a rigid metallic platter coated on both sides with a thin layer magnetic material that stores digital data.

Seagate Technology grew out of a 1979 conversation between Alan Shugart and Finis Conner, who had worked together at Memorex. The two men decided to found the company after developing the idea of scaling down a hard disk drive to the same size as the then-standard 5 ¼-inch floppy. Upon releasing its first product, Seagate quickly drew such big-name customers as Apple Computer and Within a few years, it sold 4 million units.

Sony introduces the first 3 ½-inch floppy drives and diskettes in 1981. The first significant company to adopt the 3 ½-inch floppy for general use was Hewlett-Packard in 1982, an event which was critical in establishing momentum for the format and which helped it prevail over the other contenders for the microfloppy standard, including 3-inch, 3 ¼-inch, and 3.9-inch formats.
The Bernoulli Box is released. Using a special cartridge-based system that used hard disk technology, the Bernoulli Box was a type of removable storage that allowed people to move large files between computers when few alternatives (such as a network) existed. Allowing for many times the amount of storage afforded by a regular floppy disk, the cartridges came in capacities ranging from 5MB to 230MB.

CD-ROM

Able to hold 550 megabytes of pre-recorded data, CD-ROMs grow out of music Compact Disks (CDs). The CD was developed by Sony and Philips in 1982 for distributing music. The first general-interest CD-ROM product released after Philips and Sony announced the CD-ROM format in 1984 was Grolier’s Electronic Encyclopedia, which came out in 1987. The 9 million words in the encyclopedia only took up 12 percent of the available space. The same year, computer electronics companies worked together to set a standard so any computer would be able to access the information.

Flash memory

Fujio Masuoka invents flash memory in 1984 while working for Toshiba. Capable of being erased and re-programmed multiple times, flash memory quickly gained a loyal following in the computer memory industry. Although Masuoka’s idea won praise, he was unhappy with what he saw as Toshiba’s failure to reward his work, and Masuoka quit to become a professor at Tohoku University. Bucking Japan’s culture of company loyalty, he sued his former employer demanding

CompacTape

CompacTape is introduced. Originally developed by Digital Equipment Corporation for its VAX family of computers, the drive wrote 22 data tracks back and forth on ½-inch wide tape and originally held 92 MB of data. It replaced the 1960s-era DECTape, and its usage grew rapidly in the mid-1990s. It evolved into Digital Linear Tape (DLT), and was widely used in medium and large-sized Local Area Networks. The DLT technology was purchased by Quantum in 1994, and nearly 20 years after its introduction, “SuperDLT” could hold up to 800 GB of data.

CD-ROM
DEC ships the HSC50 controller for its first intelligent disk subsystem.

The HSC50 contains local intelligence capable of managing the physical activity of the drives, optimizing subsystem throughput, detecting and correcting physical errors, and performing local functions such as diagnostic execution without host intervention.

**IBM 3480 cartridge tape system**

Announced in March 1984, IBM’s new 3480 cartridge tape system sought to replace the traditional reels of magnetic tape in the computer center with a 4-inch by 5-inch cartridge that held more information (200MB) and offered faster access to it. IBM withdrew the system in 1989 but the new format caught on with other computer makers who began making 3480-compatible storage systems for several years after that, offering increased storage capacity in the same physical format.

**Conner CP340A hard disk drive (HDD)**

The Conner CP340A hard disk drive (HDD) is introduced. It established the 3½-inch HDD form factor as the standard of the time. The CP340A was controlled by a microprocessor.

**SCSI-1 standard**

The SCSI-1 standard is adopted, and formalizes the interface that had its roots in SASI, which was introduced by Shug Associates several years earlier. Before SCSI, external devices such as hard drives had specific and non-standardized interfaces for connecting to computers. SCSI introduced a common, single adapter for all of these devices. Commonly used in tape drives and hard disks, the SCSI interface allowed for multi-tasking when processing commands at a high speed.
used embedded servo positioning, and had self-testing functionality. It gained a huge market share very quickly due to an agreement with Compaq to use the product in their computers. Due to the customer-investor relationship with Compaq, Conner Peripherals became one of the fastest growing US companies at that time.

**1990**

**IBM 9345 hard disk drive**

IBM's 9345 hard disk drive is introduced. Codenamed "Sawmill," it was the first hard disk drive to use magneto-resistive heads. Magneto-resistive heads gave the 9345 advantage over its competitors, as the bits could be stored more densely. The first model of this 5 ¼-inch disk drive had two 1 GB hard disk assemblies (HDAs) and the second model had two 1.5 GB HDAs.

**Magneto-Optical Discs**

Magneto-Optical Discs are introduced. Housed in cartridges, they are a combination of magnetic and optical storage, as their name suggests. They could be rewritten up to one million times. Faster than CD/RWs and DVD-RAMs, M-O discs used lasers that heated up the bits on the disc, after

**1992**

**SSD module**

A prototype solid state disk (SSD) module is made for evaluation by IBM. SanDisk, which at time was known as SunDisk, manufactured the module which used non-volatile memory chips to replace the spinning disks of a hard disk drive. SanDisk recognized that handheld devices and computers were becoming lighter and smaller, and that flash memory, as was used in the SSD module, offered powerful advantages over hard disks.

**Storage Tek 4400 ACS tape library**

Storage Tek announces upgrades to its 4400 ACS tape library. This tape robot was used in a variety of installations, and one was used at the Stanford Linear Accelerator Center.
which a magnet would change the bit’s polarity according to what was being written, thereby storing the information.

CompactFlash

When CompactFlash is introduced by SanDisk, it is quickly adopted and becomes the preferred memory storage option for many consumer as well as professional electronic devices. It was highly popular in digital still and video cameras, and although its dimensions were slightly larger than some other memory card formats, its ruggedness and high capacity made it a preferred choice. Although most CompactFlash units used flash memory, some actually relied on a hard disk.

Iomega Zip Disk

The Iomega Zip Disk is released. The initial Zip system allowed 100MB to be stored on a cartridge roughly the size of a 3 ½ inch floppy disk. Later versions increased the capacity of a single disk from 100MB to 2GB. Like hard disks but...
The Compact Disc-ReWritable (CD-RW) is introduced. This optical disc was used for data storage and in the backing up and transferring of files to various devices. It was less robust than some contemporary storage media, and could only be re-written roughly 1,000 times. However, this factor seldom encumbered users who rarely overwrote data that often on one disc. CD-RWs that were created on CD-RW drives were often unable to be read on CD-ROM drives. DVDs overtook much of the market share from CD-RWs.

IBM releases the Microdrive in 170 MB and 340 MB capacities. At the time of their introduction, they were the smallest hard drives in the world. Like all hard drives, Microdrives were mechanical and contained small, spinn disk platters, and were more prone to physical damage from temperature fluctuations and physical shock than other storage media. Hitachi purchased IBM's hard disk division in 2002, which included the Microdrive. For several years, Microdrives had more data capacity than CompactFlash cards, but were soon overtaken by the these and by USB flash drives. Many handheld, mobile devices contained embedded Microdrives for data storage.

USB Flash drives are introduced. Sometimes referred to as jump drives or memory sticks, these drives consisted of flash memory encased in a small form factor container with a USB interface. They could be used for data storage and in the backing up and transferring of files between various devices.
They were faster and had greater data capacity than earlier storage media. Also, they could not be scratched like optical discs and were resilient to magnetic erasure, unlike floppy disks. Drives for floppy disks and optical discs faded in popularity for desktop PCs and laptops in favor of USB ports after flash drives were introduced.

Amazon Web Services Launches Cloud-Based Services

Amazon Web Services is launched. It introduced a number of web services, including Amazon Elastic Cloud 2 (EC2) and Amazon Simple Storage Service (S3). EC2 allowed users to rent virtual time on the cloud to scale server capacity quickly and efficiently while only paying for what was used. Use of the cloud eliminates the need for a company to maintain a complex computing infrastructure on their own. Additionally, it saved space and hassle in the form of less onsite server room square footage. S3 was a cloud-based file hosting service that charged users monthly for the amount of data stored and for the bandwidth of transferring data. Similar services, like Google Drive, followed suit and created their own proprietary services.

Dropbox

Dropbox is founded by Arash Ferdowsi and Drew Houston. Dropbox was designed as a cloud-based service used for convenient storage and access to files. Users could upload files via the web to Dropbox’s vast server farms, and could instantly access them on any of their devices or compute that had the Dropbox client installed. The service also included sharing functionalities which allowed access to folders by multiple users. Dropbox’s “freemium” business model allowed limited, basic file management for free, but users requiring higher bandwidth, a fee was charged.
First 1 TB hard disk drive (HDD)

Hitachi Global Storage Technologies announces the first hard disk drive (HDD). The Hitachi Deskstar 7K1000 use 3.5-inch 200 GB platters and rotated at 7,200 RPM. By comparison, the world's first HDD, the IBM RAMAC 350, a storage capacity that was approximately 3.75 MB. As such the Deskstar had a greater storage capacity by a factor of 300,000 and was thousands of times smaller.

Cloud-based network-attached storage solutions

Vendors announce cloud-based network-attached storage solutions for online backup. They were designed for small and medium sized businesses in addition to general consumers. With these services, servers could automatically back up data to remote servers. They were designed for data protection, and along with backup capability it also provided a data recovery solution.