The first approach tried by IBM's engineers was to deliver pressurized air to the heads, but this was too expensive because it required a bank of compressors. Eventually, they found out that the head could fly barely above the surface of the disk if it was built to glide above the airflow produced by the spinning disk. The airhead could fly directly to the correct track, and since the disks were spinning constantly, the access time was dramatically lower than for a stop-and-go unit.

In order to get a flat surface, the disks were coated with a magnetic paint poured on the disk when it was spinning. The paint was an iron oxide suspension (the same as that used to paint the Golden Gate Bridge in San Francisco) with good magnetic properties. The final unit was expensive by current standards: The 305 RAMAC cost U.S.$35,000 a year to lease, or U.S.$7000 per megabyte per year.

Many other storage technology breakthroughs were also invented later at IBM's San Jose plant. These include the removable disk pack (1961), **floppy disk** drive (1971), and Winchester hard disk (1973). An entire industry was spawned by RAMAC: The hard disk sector today is a U.S.$50 billion business served by more than 100 companies.

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—Frank Darius

RAM and ROM

The acronyms RAM and ROM stand for *random access memory* and *read-only memory*, respectively. RAM is used to store the programs being executed, the user data, the **operating system**, and any other software needed by the computer when running. RAM chips are volatile—that is, they lose the information stored in them when the power is turned off. ROM chips store those parts of the **software** used to bootstrap the computer and low-level routines accessed at power-up. Software can be stored permanently in ROM chips and does not get lost when the computer is turned off. Fonts for a **printer** can also be stored in ROM chips, since they will not be modified during the lifetime of the device.

RAM chips received this name because the information stored in them can be accessed directly. The capacity of RAM chips is measured in bits, and a 4-kilobit RAM chip is one capable of holding 4096 single bits. The bits are numbered from 0 to 4095, and when an address is set at the address pins of the chip, the corresponding bit can immediately be read or overwritten. Therefore, to read a bit at address 100, for example, it is not necessary to read the previous 99 bits, as in the case of a magnetic tape in which all information is stored sequentially and the reading head has to pass through all the data. Thus we speak of "random access" to the bits stored in a RAM chip.

There are several types of RAM: *dynamic* and *static memory* chips. The first kind of memory elements is built out of **flip-flops**, circuits in which each stored bit is being recirculated permanently in order to keep it in store. Static memory chips operate using small capacitors in which a small charge can be deposited. The absence of charge represents a 0; a charge represents a 1. Since the charge tends to leak, static memory chips have to be refreshed periodically by reading all the bits stored in them and recharging those capacitors in which a 1 has been found. The refreshing is done by the processor or by special on-chip refreshing hardware.

Information can be stored in a ROM chip by melting fuses arranged in an array. A melted fuse represents a 0 and an intact fuse a 1, because it allows a small current to be transported to the chip's output line. A ROM chip is written only once, to be read many times. The **BIOS** (Basic Input/Output System) routines of an IBM **personal computer** (PC) or compatible machine are stored in ROM chips. PROMs (programmable ROMs) are special chips that can be loaded with information, but which can also be reloaded several times using a special procedure.

CD-ROMs are just another technology for the permanent storage of information. In the case of CD-ROMs, the information is burned on a plastic material by using a laser that modifies its chemical properties at a small spot. These modification can be measured later using another laser.

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—Raúl Rojas

RealAudio

RealAudio was the first successful streaming audio format for use on the **World Wide Web**, originally developed by Progressive Networks (later to become Real Networks) in 1995. As such, RealAudio is one of the oldest multimedia facilities on the Web. The major innovation of streaming audio is that it can start playing before the entire audio file has been received. This contrasts with audio formats such as WAV, AIF, and Sun AU format, where the entire file must be downloaded before the audio is played on the user's computer.

In addition to the advantage of streaming, the RealAudio format provided a significant improvement in the compression of audio data compared to previous formats. The RealAudio format allowed a file to be a tenth the size of the equivalent WAV format audio file. Thus digital audio could be downloaded over a telephone modem and played in real time at reasonable quality. RealAudio allowed AM radio quality to be achieved at approximately 1 kilobyte per second, as available on a 14.4 kilobaud (bits per second) modem. Subsequent improvements in modem speeds, computer speeds, and data compression techniques have allowed even better results to be attained. For example, **RealVideo**, also from Real Networks, allowed low-quality video to be transmitted on a telephone line.

Data compression techniques have improved as faster computers have allowed decoding of better compression in real time. In addition, Real Networks has studied how people hear sounds. Psychoacoustical research has demonstrated that some frequencies of sound can be eliminated without greatly affecting understanding. Thus, Real Networks has different methods for encoding voice alone, voice with music, and music only. Frequencies important for voice understanding can be preserved while the rest are highly compressed or eliminated.

The RealAudio format has had a number of competitors. Apple's **QuickTime** format includes streaming audio as well as allowing video and **virtual reality**. Macromedia has also made use of the wide distribution of their Shockwave Web **browser** "plug-in" to introduce streaming audio. Neither of these formats requires a special server, whereas RealAudio has traditionally done so. RealAudio (and RealVideo) can be encoded so that they can be streamed from a normal Web server without requiring a separate Real server. Microsoft introduced Active Streaming Format (ASF), which runs from **Windows NT** servers. The **MP3** format has proved very popular for digital music encoding on the **Internet**, and many portable MP3 players are available.

As well as Real server software, Real Networks has produced various pieces of software for handling RealAudio on personal computers; RealPlayer plays audio and video, RealJukebox stores, organizes, and plays digital music, and RealDownload aids in downloading files.

RealAudio, together with RealVideo, is part of the Synchronized Multimedia Integration Language (SMIL), a World Wide Web standard for multimedia presentations, which helps to promote its continued use. RealAudio has been an important milestone in the use of audio for multimedia on the World Wide Web, although the use of streaming and dramatically improved compression, both of which made continuous digital audio via the Internet over a telephone a practical reality.

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—Jonathan Bowen

Real-Time Systems

Real-time systems are usually **fault-tolerant**, often **embedded**, computer systems that are controlling