Understanding the fundamentals of the technical components of information systems is an essential first step in understanding the strategic role of information systems in modern organizations. An obvious technical component is the physical computing machinery, known as hardware. In this chapter we will see that hardware is more than just the computer itself—it includes a variety of related technologies involved with getting data into and out of the computer. The information in this chapter not only will provide a foundation for understanding the rest of the text, but it also will help you make informed decisions about personal and professional computing technology.

CHAPTER OUTLINE
3.1 The Significance of Hardware
3.2 The Central Processing Unit
3.3 Computer Memory
3.4 Computer Hierarchy
3.5 Input Technologies
3.6 Output Technologies
3.7 Strategic Hardware Issues

LEARNING OBJECTIVES
1. Identify the major hardware components of a computer system.
2. Describe the design and functioning of the central processing unit.
3. Discuss the relationships between microprocessor component designs and performance.
4. Describe the main types of primary and secondary storage.
5. Distinguish between primary and secondary storage along the dimensions of speed, cost, and capacity.
6. Define enterprise storage and describe the various types of enterprise storage.
7. Describe the hierarchy of computers according to power and their respective roles.
8. Differentiate the various types of input and output technologies and their uses.
9. Describe what multimedia systems are and what technologies they use.
10. Discuss strategic issues that link hardware design and innovation to competitive business strategy.
COMBINING MAINFRAMES AND E-COMMERCE

The Business Problem

ABF Freight System, Inc.® (ABF) is a less-than-truckload (LTL) transportation company in Fort Smith, Arkansas. LTL carriers such as ABF® and competitor Roadway Express fill the niche between parcel carriers like Federal Express and full-truckload carriers like JB Hunt that specialize in huge shipments. Competition also comes from virtual companies, such as Freightquote.com and Transportation.com.

LTL carriers ship general commodities. Their core customers are businesses, not consumers. These carriers calculate prices for each shipment using variables such as weight, volume, distance, and the number of boxes. LTL carriers typically offer discounts on most shipments, often making custom quotes to win jobs. ABF® wanted to leverage the Internet to be able to keep up with rapidly changing business conditions and to offer an accurate price to customers without reinventing mainframe applications.

The IT Solution

ABF Freight System, Inc.® (ABF) built an e-commerce infrastructure that runs on its IBM S/390 mainframe. The same mainframe applications that ABF® had used to calculate pricing, trace shipments, schedule routes, and review freight bills are now accessible via the e-commerce Web site, the intranet, devices enabled by Wireless Application Protocol (WAP), imaging software, and an interactive voice response (IVR) system.

At ABF®’s self-service Web site, dubbed eCenter®, customers map routes, trace shipments, schedule a pickup, and create a bill of lading (the formal document required for shipments). ABF® customers generate price quotes that include discounts, view images of shipment documents, and review damage claim status. The eCenter® also provides predictive e-mail alerts that offer progress reports of a shipment in transit and alert the customer if the shipment will be late.

eCenter® has several innovative features. The Shipment Planner™ displays pending shipments in a calendar format. A feature called Transparent Links lets ABF® customers incorporate shipping data from ABF®’s mainframe into their own systems via XML. ABF® Anywhere lets users communicate with ABF with a Palm handheld device or mobile phone equipped with Internet access. Dynamic Rerouting lets customers change the destination of an in-transit shipment or recall a shipment by accessing ABF®’s Web site. ABF® then e-mails a confirmation of the new destination and revised charges.

Drivers en route check in at ABF service stations in 311 locations until they arrive at the destination terminal, where the shipment is scheduled for delivery to the consignee’s address. At each checkpoint, drivers submit documents (each with a bar code), such as the bill of lading, for scanning. The scanned images are uploaded via FTP over the wide area network (WAN) to a database on the mainframe located at company headquarters. This process creates a visual record.

The Results

ABF®’s e-commerce infrastructure has more than 23,000 registered users from more than 17,000 ABF customers. These customers generate more than 70 percent of ABF®’s annual revenue and shipment volume. ABF®’s new e-commerce infrastructure enhances customer service, and has created a new business line and opened new markets for the company. The infrastructure also has revamped virtually everyone’s job at ABF, from how a regional vice president builds customer loyalty to how a customer service representative spends the day.

Source: Network World (February 26, 2001); abfs.com.
Selecting the right IT infrastructure for any business is a complex decision. Such a decision often entails “out of the box” thinking—that is, imagining how business processes could be ideally configured and supported—rather than incremental improvement of an outdated process. Indeed, A B F®’s e-commerce infrastructure is an outstanding example of old-to-new economy transformation. The company had a tremendous amount riding on its IT decision. In the LTL industry, superior system performance translates very quickly into customer satisfaction.

The same basic issues confront all organizations that use computing technology. Such decisions about information technology usually focus on three interrelated factors: capability (power and appropriateness for the task), speed, and cost. A computer’s hardware design drives all three factors, and all three factors are interrelated and are much more complex than you might imagine.

The incredible rate of innovation in the computer industry further complicates IT decisions. The A B F® executives in this case had a difficult decision to make, because A B F® was already a going concern with an information technology already in place. Computer technologies can become obsolete much more quickly than other organizational technologies. Yet, regardless of industry, computer hardware is essential to survival, and the most modern hardware may be essential to sustaining advantage over competitors. Evaluating new hardware options and figuring out how to integrate them with existing (legacy) systems is an ongoing responsibility in most organizations.

Finally, almost any time an organization makes major changes in its computer infrastructure, much of its software needs to be rewritten to run on the hardware’s new operating system. In some cases, all the data that a company has accumulated may have to be put into a different format. Personnel may have to be retrained on the new computers. These are very lengthy and expensive undertakings, often dwarfing basic hardware acquisition costs by tenfold. Therefore, computer hardware choices are generally made only after careful study. Many of the issues in such decision making involve employees from all functional areas and are the topics of this chapter.

What We Learned from This Case

Selecting the right IT infrastructure for any business is a complex decision. Such a decision often entails “out of the box” thinking—that is, imagining how business processes could be ideally configured and supported—rather than incremental improvement of an outdated process. Indeed, A B F®’s e-commerce infrastructure is an outstanding example of old-to-new economy transformation. The company had a tremendous amount riding on its IT decision. In the LTL industry, superior system performance translates very quickly into customer satisfaction.

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3.1 THE SIGNIFICANCE OF HARDWARE

Most businesspeople rightly suspect that knowing how to use computer technology is more important to their personal productivity and their firm’s competitive advantage than knowing the technical details of how the technology functions. But some basic understanding of computer hardware design and function is essential because organizations frequently must assess their competitive advantage in terms of computing capability. Important decisions about computing capability have to be made, and to a large degree these decisions turn on an understanding of hardware design. In this chapter you will learn the basics of hardware design and understand the sources of this capability.

Our objective is to demonstrate how computers input, process, output, and store information. We will also look at the hierarchy of computer hardware, from the super computer down to the handheld microcomputer and even some smaller technologies. Finally we will consider the dynamics of computer hardware innovation and the effects it has on organizational decision making.

An important benefit from reading this chapter will be that not only will you better understand the computer hardware decisions in your organization, but also your personal computing decisions will be much better informed. Many of the design
principles presented here apply to any size computer, as do the dynamics of innovation and cost that affect personal as well as corporate hardware decisions.

As we noted in Chapter 1, computer-based information systems (CBISs) are composed of hardware, software, databases, telecommunications, procedures, and people. The components are organized to input, process, and output data and information. Chapter 3 focuses on the hardware component of the CBIS. Hardware refers to the physical equipment used for the input, processing, output, and storage activities of a computer system. It consists of the following:

- Central processing unit (CPU)
- Memory (primary and secondary storage)
- Input technologies
- Output technologies
- Communication technologies

The first four of these components are discussed in the following sections. Communication technologies is the subject of Chapter 7.

### 3.2 THE CENTRAL PROCESSING UNIT

The **central processing unit (CPU)** performs the actual computation or “number crunching” inside any computer. The CPU is a **microprocessor** (for example, a Pentium 4 by Intel) made up of millions of microscopic transistors embedded in a circuit on a silicon wafer or chip. (Hence, microprocessors are commonly referred to as chips.) Examples of specific microprocessors are listed in Table 3.1.

As shown in Figure 3.1 (on page 58), the microprocessor has different parts, which perform different functions. The **control unit** sequentially accesses program instructions, decodes them, and controls the flow of data to and from the ALU, the registers, the caches, primary storage, secondary storage, and various output devices. The **arithmetic-logic unit (ALU)** performs the mathematic calculations and makes logical comparisons. The **registers** are high-speed storage areas that store very small amounts of data and instructions for short periods of time. (For a more technical overview of the components of modern chips, see Modern Chip Components on the Web site.)

**How the CPU Works**

The CPU, on a basic level, operates like a tiny factory. Inputs come in and are stored until needed, at which point they are retrieved and processed and the output is

<table>
<thead>
<tr>
<th>Name</th>
<th>Manufacturer</th>
<th>Word Length</th>
<th>Clock Speed (MHz)</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pentium III</td>
<td>Intel</td>
<td>32</td>
<td>1000+</td>
<td>PCs and workstations</td>
</tr>
<tr>
<td>Pentium 4</td>
<td>Intel</td>
<td>64</td>
<td>2000+</td>
<td>PCs and workstations</td>
</tr>
<tr>
<td>PowerPC</td>
<td>Motorola, IBM, Apple</td>
<td>32</td>
<td>1000+</td>
<td>High-end PCs and workstations</td>
</tr>
<tr>
<td>Alpha</td>
<td>Compaq</td>
<td>64</td>
<td>1500+</td>
<td>PCs and workstations</td>
</tr>
<tr>
<td>Athlon</td>
<td>Advanced Micro Devices</td>
<td>32</td>
<td>1000+</td>
<td>PCs and workstations</td>
</tr>
</tbody>
</table>
stored and then delivered somewhere. Figure 3.2 illustrates this process, which works as follows:

- The inputs are data and brief instructions about what to do with the data. These instructions come from software in other parts of the computer. Data might be entered by the user through the keyboard, for example, or read from a data file in another part of the computer. The inputs are stored in registers until they are sent to the next step in the processing.

- Data and instructions travel in the chip via electrical pathways called buses. The size of the bus—analogous to the width of a highway—determines how much information can flow at any time.

- The control unit directs the flow of data and instructions within the chip.

- The arithmetic-logic unit (A L U) receives the data and instructions from the registers and makes the desired computation. These data and instructions have been translated into binary form, that is, only 0s and 1s. The CPU can process only binary data.

- The data in their original form and the instructions are sent to storage registers and then are sent back to a storage place outside the chip, such as the computer’s hard
Meanwhile, the transformed data go to another register and then on to other parts of the computer (to the monitor for display, or to be stored, for example).

(For a more technical overview of CPU operations, see CPU Operations on the Web site.)

This cycle of processing, known as a **machine instruction cycle**, occurs millions of times per second or more. It is faster or slower, depending on the following four factors of chip design:

1. **The preset speed of the clock** that times all chip activities, measured in megahertz (MHz), millions of cycles per second, and gigahertz (GHz), billions of cycles per second. The faster the **clock speed**, the faster the chip. (For example, all other factors being equal, a 1.0 GHz chip is twice as fast as a 500 MHz chip.)

2. **The word length**, which is the number of bits (0s and 1s) that can be processed by the CPU at any one time. The majority of current chips handle 32-bit word lengths, and the Pentium 4 is designed to handle 64-bit word lengths. Therefore, the Pentium 4 chip will process 64 bits of data in one machine cycle. The larger the word length, the faster the chip.

3. **The bus width**. The wider the bus (the physical paths down which the data and instructions travel as electrical impulses), the more data can be moved and the faster the processing. A processor's bus bandwidth is the product of the width of its bus (measured in bits) times the frequency at which the bus transfers data (measured in megahertz). For example, Intel's Pentium 4 processor uses a 64-bit bus that runs at 400 MHz. That gives it a peak bandwidth of 3.2 gigabits per second.

4. **The physical design** of the chip. Back to our “tiny factory” analogy, if the “factory” is very compact and efficiently laid out, then “materials” (data and instructions) do not have far to travel while being stored or processed. We also want to pack as many “machines” (transistors) into the factory as possible. The distance between transistors is known as **line width**. Historically, line width has been expressed in microns (millionths of a meter), but as technology has advanced, it has become more convenient to express line width in nanometers (billionths of a meter). Currently, most CPUs are designed with 180-nanometer technology (0.18 microns), but chip manufacturers are moving to 130-nanometer technology (0.13 microns). The smaller the line width, the more transistors can be packed onto a chip, and the faster the chip.

These four factors make it difficult to compare the speeds of different processors. As a result, Intel and other chip manufacturers have developed a number of benchmarks to compare processor speeds. (For a discussion of these benchmarks, see the section on Processor Benchmarks on the Web site.)

**Advances in Microprocessor Design**

Innovations in chip designs are coming at a faster and faster rate, as described by **Moore's Law**. Gordon Moore, an Intel Corporation co-founder, predicted in 1965 that microprocessor complexity would double approximately every two years. As shown in Figure 3.3 (on page 60), his prediction was amazingly accurate.

The advances predicted from Moore’s Law come mainly from the following changes:

- Increasing miniaturization of transistors.
- Making the physical layout of the chip’s components as compact and efficient as possible (decreasing line width).
Figure 3.3 Moore’s Law as it relates to transistor counts in Intel microprocessors.

Figure 3.4 The lineage of Intel microprocessors. [Diagram and content displayed from 1974–1993 reprinted from PC Magazine (April 27, 1993), with permission. Copyright © 1993, ZD, Inc. All rights reserved. Diagram and content displayed for dates beyond 1993 based on data from Intel, added by the authors to show Intel microprocessing trends through 2001.]
• Using materials for the chip that improve the conductivity (flow) of electricity. The traditional silicon is a semiconductor of electricity—electrons can flow through it at a certain rate. New materials such as gallium arsenide and silicon germanium allow even faster electron travel and some additional benefits, although they are more expensive to manufacture than silicon chips.

• Targeting the amount of basic instructions programmed into the chip. There are four broad categories of microprocessor architecture: complex instruction set computing (CISC), reduced instruction set computing (RISC), very long instruction word (VLIW), and the newest category, explicitly parallel instruction computing (EPIC). Most chips are designated as CISC and have very comprehensive instructions, directing every aspect of chip functioning. RISC chips eliminate rarely used instructions. Computers that use RISC chips (for example, a workstation devoted to high-speed mathematical computation) rely on their software to contain the special instructions. VLIW architectures reduce the number of instructions on a chip by lengthening each instruction. With EPIC architectures, the processor can execute certain program instructions in parallel. Intel’s Pentium 4 is the first implementation of EPIC architecture. (For a more technical discussion of these architectures, see Microprocessor Architecture on the Web site.)

In addition to increased speeds and performance, Moore’s Law has had an impact on costs. For example, in 1998, a personal computer with a 16 MHz Intel 80386 chip, one megabyte of RAM (discussed later in this chapter), a 40-megabyte hard disk (discussed later in this chapter), and a DOS 3.31 operating system (discussed in Chapter 4), cost $5,200. In 2002, a personal computer with a 2 GHz Intel Pentium 4 chip, 512 megabytes of RAM, an 80-gigabyte hard disk, and the Windows XP operating system, cost less than $1,000 (without the monitor).

Although organizations certainly benefit from microprocessors that are faster, they also benefit from chips that are less powerful but can be made very small and inexpensive. Microcontrollers are chips that are embedded in countless products and technologies, from cellular telephones to toys to automobile sensors. Microprocessors and microcontrollers are similar except that microcontrollers usually cost less and
work in less-demanding applications. Thus, the scientific advances in CPU design affect many organizations on the product and service side, not just on the internal CBIS side.

Figure 3.4 (on pages 60–61) illustrates the historical advancement of Intel microprocessors. New types of chips continue to be produced. (For a discussion of advanced chip technologies, see Advanced Chip Technologies on the Web site.)

Before you go on . . .

1. Briefly describe how a microprocessor functions.
2. What factors determine the speed of the microprocessor?
3. How are microprocessor designs advancing?

3.3 COMPUTER MEMORY

The amount and type of memory that a computer possesses has a great deal to do with its general utility, often affecting the type of program it can run and the work it can do, its speed, and both the cost of the machine and the cost of processing data. There are two basic categories of computer memory. The first is primary storage, so named because small amounts of data and information that will be immediately used by the CPU are stored there. The second is secondary storage, where much larger amounts of data and information (an entire software program, for example) are stored for extended periods of time.

Memory Capacity

As already noted, CPUs process only 0s and 1s. All data are translated through computer languages (covered in the next chapter) into series of these binary digits, or bits. A particular combination of bits represents a certain alphanumeric character or simple mathematical operation. Eight bits are needed to represent any one of these characters. This 8-bit string is known as a byte. The storage capacity of a computer is measured in bytes. (Bits are used as units of measure typically only for telecommunications capacity, as in how many million bits per second can be sent through a particular medium.) The hierarchy of byte memory capacity is as follows:

- **Kilobyte.** Kilo means one thousand, so a kilobyte (KB) is approximately one thousand bytes. Actually, a kilobyte is 1,024 bytes ($2^{10}$ bytes).
- **Megabyte.** Mega means one million, so a megabyte (MB) is approximately one million bytes (1,048,576 bytes, or $1,024 \times 1,024$, to be exact). Most personal computers have hundreds of megabytes of RAM memory (a type of primary storage, discussed in a later section).
- **Gigabyte.** Giga means one billion; a gigabyte (GB) is actually 1,073,741,824 bytes ($1,024 \times 1,024 \times 1,024$ bytes). The storage capacity of a hard drive (a type of secondary storage, discussed shortly) in modern personal computers is often many gigabytes.
- **Terabyte.** One trillion bytes (actually, 1,078,036,791,296 bytes) is a terabyte.

To get a feel for these amounts, consider the following examples. If your computer has 256 MB of RAM (a type of primary storage), it can store 268,435,456 bytes...
of data. A written word might, on average, contain 6 bytes, so this translates to approximately 44.8 million words. If your computer has 20 GB of storage capacity on the hard drive (a type of secondary storage) and the average page of text has about 2,000 bytes, your hard drive could store some 10 million pages of text.

**Primary Storage**

Primary storage, or main memory, as it is sometimes called, stores for very brief periods of time three types of information: data to be processed by the CPU, instructions for the CPU as to how to process the data, and operating system programs that manage various aspects of the computer’s operation. Primary storage takes place in chips mounted on the computer’s main circuit board (the motherboard), located as close as physically possible to the CPU chip. (See Figure 3.5.) As with the CPU, all the data and instructions in primary storage have been translated into binary code.

There are four main types of primary storage: (1) register, (2) random access memory (RAM), (3) cache memory, and (4) read-only memory (ROM). To understand their purpose, consider the following analogy: You keep a Swiss Army knife handy in your pocket for minor repairs around the house. You have a toolbox with an assortment of tools in the kitchen cabinet for bigger jobs. Finally, in the garage you have your large collection of tools. The amount and type of tools you need, how often you need them, and whether you will use them immediately determines how and where you store them. In addition, one type of storage area—like a fireproof wall safe—must be completely safe, so that its contents cannot be lost. The logic of primary storage in the computer is just like the logic of storing things in your house. That which will be used immediately gets stored in very small amounts as close to the CPU as possible. Remember, as with CPU chip design, the shorter the distance the electrical impulses (data) have to travel, the faster they can be transported and processed. That which requires special protection will be stored in an exceptionally secure manner. The four types of primary storage, which follow this logic, are described next.

**Registers.** As indicated earlier in the chapter, registers are part of the CPU. They have the least capacity, storing extremely limited amounts of instructions and data only immediately before and after processing. This is analogous to your pocket in the Swiss Army knife example.

**Random access memory.** Random access memory (RAM) is analogous to the kitchen toolbox. It stores more information than the registers (your pocket) and is farther away from the CPU, but it stores less than secondary storage (the garage) and is much closer to the CPU than is secondary storage. When you start most software programs on your computer, the entire program is brought from secondary storage into RAM. As you use the program, small parts of the program’s instructions and data are sent into the registers and then to the CPU. Again, getting the data and instructions as close to the CPU as possible is key to the computer’s speed, as is the fact that the RAM is a type of microprocessor chip. As we shall discuss later, the chip is much faster (and more costly) than are secondary storage devices.

RAM is temporary and volatile; that is, RAM chips lose their contents if the current is lost or turned off (as in a power surge, brownout, or electrical noise generated by lightning or nearby machines). RAM chips are located directly on the computer’s main circuit board or in other chips located on peripheral cards that plug into the main circuit board.
The two main types of RAM are dynamic RAM (DRAM) and static RAM (SRAM). DRAM memory chips offer the greatest capacities and the lowest cost per bit, but are relatively slow. SRAM costs more than DRAM but has a higher level of performance, making SRAM the preferred choice for performance-sensitive applications, including the external L2 and L3 caches (discussed next) that speed up microprocessor performance.

**Cache memory.** Cache memory is a type of high-speed memory that a processor can access more rapidly than main memory (RAM). It augments RAM in the following way: Many modern computer applications (Microsoft XP, for example) are very complex and have huge numbers of instructions. It takes considerable RAM capacity (usually a minimum of 128 megabytes) to store the entire instruction set. Or you may be using an application that exceeds your RAM. In either case, your processor must go to secondary storage (similar to a lengthy trip to the garage) to retrieve the necessary instructions. To alleviate this problem, software is often written in smaller blocks of instructions. As needed, these blocks can be brought from secondary storage into RAM. This process is still slow, however.

Cache memory is a place closer to the CPU where the computer can temporarily store those blocks of instructions used most often. Blocks used less often remain in RAM until they are transferred to cache; blocks used infrequently stay stored in secondary storage. Cache memory is faster than RAM because the instructions travel a shorter distance to the CPU. In our tool analogy, cache memory might represent an additional box with a selected set of needed tools from the kitchen toolbox and the garage.

There are two types of cache memory in the majority of computer systems—Level 1 (L1) cache is located in the processor, and Level 2 (L2) cache is located on the motherboard but not actually in the processor. L1 cache is smaller and faster than L2 cache. Chip manufacturers are now designing chips with L1 cache and L2 cache in the processor and Level 3 (L3) cache on the motherboard.

**Read-only memory.** In our previous example, we alluded to the need for greater security when storing certain types of critical data or instructions. (This was represented by the wall safe.) Most people who use computers have lost precious data at one time or another due to a computer “crash” or a power failure. What is usually lost is whatever is in RAM, cache, or the registers at the time. This loss occurs because these types of memory are volatile. Whatever information they may contain is lost when there is no electricity flowing through them. The cautious computer user frequently saves his or her data to nonvolatile memory (secondary storage). In addition, most modern software applications have autosave functions. Programs stored in secondary storage, even though they are temporarily copied into RAM when used, remain intact because only the copy is lost and not the original.

**Read-only memory (ROM)** is the place (a type of chip) where certain critical instructions are safeguarded. ROM is nonvolatile and retains these instructions when the power to the computer is turned off. The read-only designation means that these instructions can be read only by the computer and cannot be changed by the user. An example of ROM instructions are those needed to start or “boot” the computer once it has been shut off. There are variants of ROM chips that can be programmed (PROM), and some that can be erased and rewritten (EPROM). These are relatively rare in mainstream organizational computing, but are often incorporated into other specialized technologies such as video games (PROM) or robotic manufacturing (EPROM).
A another form of rewritable ROM storage is called flash memory. This technology can be built into a system or installed on a personal computer card (known as a flash card). These cards, though they have limited capacity, are compact, portable, and require little energy to read and write. Flash memory via flash cards is very popular for small portable technologies such as cellular telephones, digital cameras, handheld computers, and other consumer products.

**Secondary Storage**

Secondary storage is designed to store very large amounts of data for extended periods of time. Secondary storage can have memory capacity of several terabytes or more and only small portions of that data are placed in primary storage at any one time. Secondary storage has the following characteristics:

- It is nonvolatile.
- It takes much more time to retrieve data from secondary storage than it does from RAM because of the electromechanical nature of secondary storage devices.
- It is much more cost effective than primary storage (see Figure 3.6).
- It can take place on a variety of media, each with its own technology, as discussed next.
- The overall trends in secondary storage are toward more direct-access methods, higher capacity with lower costs, and increased portability.

**Magnetic media.** Magnetic tape is kept on a large open reel or in a smaller cartridge or cassette. Although this is an old technology, it remains popular because it is the cheapest storage medium and can handle enormous amounts of data. The downside is that it is the slowest for retrieval of data, because all the data are placed on the tape sequentially. Sequential access means that the system might have to run through the majority of the tape, for example, before it comes to the desired piece of data. Magnetic media store information by giving tiny particles of iron oxide embedded on the tape a positive or negative polarization. Recall that all data that a computer understands are binary. The positive or negative polarization of the particles corresponds to a 0 or a 1.

Magnetic tape storage often is used for information that an organization must maintain, but uses rarely or does not need immediate access to. Industries with huge numbers of files (e.g., insurance companies), use magnetic tape systems. Modern versions of magnetic tape systems use cartridges and often a robotic system that selects and loads the appropriate cartridge automatically. There are also some tape systems,
like digital audio tapes (DAT), for smaller applications such as storing copies of all the contents of a personal computer’s secondary storage (“backing up” the storage).

**Magnetic disks** come in a variety of styles and are popular because they allow much more rapid access to the data than does magnetic tape. Magnetic disks, called hard disks or fixed disk drives, are the most commonly used mass storage devices because of their low cost, high speed, and large storage capacity. Fixed disk drives read from, and write to, stacks of rotating magnetic disk platters mounted in rigid enclosures and sealed against environmental or atmospheric contamination. These disks are permanently mounted in a unit that may be internal or external to the computer.

All disk drives (including removable disk modules, floppy disk drives, and optical drives) are called **hard drives** and store data on platters divided into concentric tracks. Each track is divided further into segments called sectors. To access a given sector, a read/write head pivots across the rotating disks to locate the right track, calculated from an index table, and the head then waits as the disk rotates until the right sector is underneath it. (For a more technical discussion of hard disk drives, see Hard Disk Drives on the Web site.)

Every piece of data has an address attached to it, corresponding to a particular track and sector. Any piece of desired data can be retrieved in a nonsequential manner, by **direct access** (which is why hard disk drives are sometimes called direct access storage devices). The read/write heads use the data’s address to quickly find and read the data. (See Figure 3.7.) Unlike magnetic tape, the system does not have to read through all the data to find what it wants.

The read/write heads are attached to arms that hover over the disks, moving in and out (see Figure 3.8). They read the data when positioned over the correct track and when the correct sector spins by. Because the head floats just above the surface of the disk (less than 25 microns), any bit of dust or contamination can disrupt the device. When this happens, it is called a disk crash and usually results in catastrophic loss of data. For this reason, hard drives are hermetically sealed when manufactured.

A modern personal computer typically has many gigabytes (some more than 100 gigabytes) of storage capacity in its internal hard drive. Data access is very fast, measured in milliseconds. For these reasons, hard disk drives are popular and common. Because they are somewhat susceptible to mechanical failure, and because users may need to take all their hard drive’s contents to another location, many users like to back up their hard drive’s contents with a portable hard disk drive system, such as Iomega’s Jaz.

**Disk drive interfaces.** To take advantage of the new, faster technologies, disk drive interfaces must also be faster. Most PCs and workstations use one of two
high-performance disk interface standards: **Enhanced Integrated Drive Electronics (EIDE)** or **Small Computer Systems Interface (SCSI)**. EIDE offers good performance, is inexpensive, and supports up to four disks, tapes, or CD-ROM drives. SCSI drives are more expensive than EIDE drives, but they offer a faster interface and support more devices. SCSI interfaces are therefore used for graphics workstations, server-based storage, and large databases. (For discussions of other interfaces, including fibre channel, firewire, Infiniband, and the universal serial bus, see Other Interfaces on the Web site.)

**Magnetic diskettes.** Magnetic diskettes, or floppy disks as they are commonly called, function similarly to hard drives, but with some key differences. The most obvious is that they are not rigid, but are made out of flexible Mylar. They are much slower than hard drives. They have much less capacity, ranging from 1.44 megabytes for a standard high-density disk to 250 megabytes for a disk formatted for a Zip drive (on which the data are compressed). Further, although they are individually inexpensive, floppy disks are less cost-efficient than hard drive storage. However, the big advantage of floppy disks has been that they are portable. Hard disk drives are usually permanently installed in a computer, but the small, removable diskette (installed in its thin plastic housing) can fit into a shirt pocket and can be easily mailed.

**Optical storage devices.** Unlike magnetic media, optical storage devices do not store data via magnetism. As shown in Figure 3.9, to record information on these devices, a pinpoint laser beam is used to burn tiny holes into the surface of a reflective plastic platter (such as a compact disk). When the information is read, another laser, installed in the optical disk drive of the computer (such as a compact disk drive), shines on the surface of the disk. If light is reflected, that corresponds to one binary state. If the light shines on one of the holes burned by the recording laser, there is no reflection...
and the other binary state is read. Compared to magnetic media, optical disk drives are slower than magnetic hard drives. On the other hand, they are much less susceptible to damage from contamination and are also less fragile.

In addition, optical disks can store much more information, both on a routine basis and also when combined into storage systems. Optical disk storage systems can be used for large-capacity data storage. These technologies, known as **optical jukeboxes**, store many disks and operate much like the automated phonograph record changers for which they are named.

Types of optical disks include compact disk read-only memory (**CD-ROM**), digital video disk (**DVD**), and fluorescent multilayer disk (**FMD-ROM**).

**Compact disk, read-only memory (**CD-ROM**)** storage devices feature high capacity, low cost, and high durability. However, because it is a read-only medium, the **CD-ROM** can be only read and not written on. Compact disk, rewritable (**CD-RW**) adds rewritability to the recordable compact disk market, which previously had offered only write-once **CD-ROM** technology.

The **digital video disk (**DVD**)** is a five-inch disk with the capacity to store about 135 minutes of digital video. **DVD** provides sharp detail, true color, no flicker, and no snow. Sound is recorded in digital Dolby, creating clear “surround-sound” effects. **DVDs** have advantages over videocassettes, including better quality, smaller size (meaning they occupy less shelf space), and lower duplicating costs. **DVDs** can also perform as computer storage disks, providing storage capabilities of 17 gigabytes. **DVD** players can read current **CD-ROMs**, but current **CD-ROM** players cannot read **DVDs**. The access speed of a **DVD** drive is faster than a typical **CD-ROM** drive.

A new optical storage technology called **fluorescent multilayer disk (**FMD-ROM**)** greatly increases storage capacity. The idea of using multiple layers on an optical disk is not new, as **DVDs** currently support two layers. However, by using a new fluorescent-based optical system, **FMDs** can support 20 layers or more. **FMDs** are clear disks; in the layers are fluorescent materials that give off light. The presence or absence of these materials tells the drive whether there is information there or not. All layers of an **FMD** can be read in parallel, thereby increasing the data transfer rate.

**Memory cards.** **PC memory cards** are credit-card-size devices that can be installed in an adapter or slot in many personal computers. The **PC memory card** functions as if it were a fixed hard disk drive. The cost per megabyte of storage is greater than for traditional hard disk storage, but the cards do have advantages. They are less failure-prone than hard disks, are portable, and are relatively easy to use. Software manufacturers often store the instructions for their programs on a memory card for use with laptop computers. The **Personal Computer Memory Card International Association (**PCMCIA**) is a group of computer manufacturers who are creating standards for these memory cards.

**Expandable storage.** **Expandable storage devices** are removable disk cartridges. The storage capacity ranges from 100 megabytes to several gigabytes per cartridge, and the access speed is similar to that of an internal hard drive. Although more expensive than internal hard drives, expandable storage devices combine hard disk storage capacity and diskette portability. **Expandable storage devices** are ideal for backup of the internal hard drive, as they can hold more than 80 times as much data and operate five times faster than existing floppy diskette drives.

**Advanced storage technologies.** (For an overview of advanced storage technologies, see the section on Advanced Storage Technologies on the Web site.)
**Enterprise Storage Systems**

The amount of digital information is doubling every two years. As a result, many companies are employing enterprise storage systems.

An **enterprise storage system** is an independent, external system with intelligence that includes two or more storage devices. These systems are an alternative to allowing each host or server to manage its own storage devices directly. Enterprise storage systems provide large amounts of storage, high-performance data transfer, a high degree of availability, protection against data loss, and sophisticated management tools. (For a technical discussion of enterprise storage systems, see the section on Enterprise Storage Systems on the Web site.)

There are three major types of enterprise storage subsystems: redundant arrays of independent disks (RAIDs), storage area networks (SANs), and network-attached storage (NAS).

**Redundant array of independent disks.** Hard drives in all computer systems are susceptible to failures caused by temperature variations, head crashes, motor failure, controller failure, and changing voltage conditions. To improve reliability and protect the data in their enterprise storage systems, many computer systems use **redundant arrays of independent disks (RAID)** storage products.

RAID links groups of standard hard drives to a specialized microcontroller. The microcontroller coordinates the drives so they appear as a single logical drive, but they take advantage of the multiple physical drives by storing data redundantly, thus protecting against data loss due to the failure of any single drive.

**Storage area network.** A **storage area network (SAN)** is an architecture for building special, dedicated networks that allow rapid and reliable access to storage devices by multiple servers. **Storage over IP**, sometimes called IP over SCSI or iSCSI, is a technology that uses the Internet Protocol to transport stored data between devices within a SAN. **Storage visualization software** is used with SANs to graphically plot an entire network and allow storage administrators to view the properties of, and monitor, all devices from a single console.

**Network-attached storage.** A **network-attached storage (NAS)** device is a special-purpose server that provides file storage to users who access the device over a network. The NAS server is simple to install (i.e., plug-and-play), and works exactly like a general-purpose file server, so no user retraining or special software is needed.

Table 3.2 (on page 70) compares the advantages and disadvantages of the various secondary storage media.

**Storage Service Providers**

**Storage service providers (SSPs)**, also called storage-on-demand or storage utilities, provide customers with the storage capacity they require as well as professional services including assessment, design, operations, and management. Services offered by SSPs include primary online data storage, backup and restorability, availability, and accessibility.

SSPs offer the advantages of implementing storage solutions quickly and managing storage around-the-clock, even if the storage devices are located at the customer’s data center. However, there is some increased security risk associated with moving an enterprise’s data off-site.
### Table 3.2 Secondary Storage

<table>
<thead>
<tr>
<th>Type</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Magnetic storage devices:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnetic tape</td>
<td>Lowest cost per unit stored</td>
<td>Sequential access means slow retrieval speeds</td>
<td>Corporate data archiving</td>
</tr>
<tr>
<td>Hard drive</td>
<td>Relatively high capacity and fast retrieval speed</td>
<td>Fragile; high cost per unit stored</td>
<td>Personal computers through mainframes</td>
</tr>
<tr>
<td>RAID</td>
<td>High capacity; designed for fault tolerance and reduced risk of data loss; low cost per unit stored</td>
<td>Expensive, semipermanent installation</td>
<td>Corporate data storage that requires frequent, rapid access</td>
</tr>
<tr>
<td>SAN</td>
<td>High capacity; designed for large amounts of enterprise data</td>
<td>Expensive</td>
<td>Corporate data storage that requires frequent, rapid access</td>
</tr>
<tr>
<td>NAS</td>
<td>High capacity; designed for large amounts of enterprise data</td>
<td>Expensive</td>
<td>Corporate data storage that requires frequent, rapid access</td>
</tr>
<tr>
<td>Magnetic diskettes</td>
<td>Low cost per diskette, portability</td>
<td>Low capacity; very high cost per unit stored; fragile</td>
<td>Personal computers</td>
</tr>
<tr>
<td>Memory cards</td>
<td>Portable; easy to use; less failure prone than hard drives</td>
<td>Expensive</td>
<td>Personal and laptop computers</td>
</tr>
<tr>
<td>Expandable storage</td>
<td>Portable; high capacity</td>
<td>More expensive than hard drives</td>
<td>Backup of internal hard drive</td>
</tr>
<tr>
<td><strong>Optical storage devices:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CD-ROM</td>
<td>High capacity; moderate cost per unit stored; high durability</td>
<td>Slower retrieval speeds than hard drives; only certain types can be rewritten</td>
<td>Personal computers through corporate data storage</td>
</tr>
<tr>
<td>DVD</td>
<td>High capacity; moderate cost per unit stored</td>
<td>Slower retrieval speeds than hard drives</td>
<td>Personal computers through corporate data storage</td>
</tr>
<tr>
<td>FMD-ROM</td>
<td>Very high capacity; moderate cost per unit stored</td>
<td>Faster retrieval speeds than DVD or CD-ROM; slower retrieval speeds than hard drives</td>
<td>Personal computers through corporate data storage</td>
</tr>
</tbody>
</table>

**Before you go on . . .**

1. Describe the four main types of primary storage.
2. Describe different types of secondary storage.
3. How does primary storage differ from secondary storage in terms of speed, cost, and capacity?
4. Describe the three types of enterprise storage systems.
The traditional way of comparing classes of computers is by their processing power. Analysts typically divide computers (called the platform in the computer industry) into six categories: supercomputers, mainframes, midrange computers (minicomputers and servers), workstations, notebooks and desktop computers, and appliances. Recently, the lines between these categories have blurred. This section presents each class of computer, beginning with the most powerful and ending with the least powerful. We describe the computers and their respective roles in modern organizations. IT’s About Business Box 3.1 gives an example of several different types of computers used in Formula One auto racing.

Supercomputers

The term supercomputer does not refer to a specific technology, but to the fastest computing engines available at any given time. Supercomputers generally address computationally demanding tasks on very large data sets. Rather than transaction processing and business applications—the forte of mainframes and other multiprocessor platforms—supercomputers typically run military and scientific applications, although their use for commercial applications, such as data mining, has been increasing. Supercomputers generally operate at 4 to 10 times faster than the next most powerful computer class, the mainframe.

Box 3.1: Where the computers meet the road

Formula One racing is big business. Each racing team has a multimillion-dollar budget each season. The cars are high-tech, but the real high-tech machines are the computers and other information technologies that go into designing—and increasingly, controlling—the race cars. Formula One racing is perhaps the most technologically advanced sport in the world.

In 1991, the Williams British racing team introduced a revolutionary car combining a computer-controlled, semiautomatic gearbox with electronic traction control. That computerized car won the 1992 world championship.

For today’s top Formula One racing teams, engineers draft car designs on numerous Sun workstations running computer-aided design software (discussed in Chapter 4). The car models are run through virtual wind tunnels simulated on a high-end Sun server.

On race day, roughly 120 sensors in the car monitor everything from engine temperature to the position of each wheel. The data from the sensors are relayed by microwave radio to servers that each team keeps trackside; about 1.2 gigabytes of information are recorded on each lap. Engineers study the data and make instant decisions about when to bring the car in for a pit stop and what adjustments to make. The crew and the engineers can relay advice to the driver. Formula One teams have installed controls on the steering wheel that let the driver make mid-race changes to the car’s transmission and power train.

The race data from the trackside servers is sent via high-speed Internet or satellite links to team headquarters. At the headquarters lab, laps are recorded and later replayed on a mainframe computer—or with a real car mounted on a chassis dynamics rig—to fine-tune the car’s engineering. During races, the lab can send tips for tweaking a car’s configuration to crews at the track.

Source: Business 2.0 (October 2001).

Questions

1. Identify the different types of computers used by Formula One racing teams.
2. Does what is learned in Formula One racing transfer to regular automobiles? Give examples.
a more technical overview of supercomputers, see the section on Supercomputers on the Web site.)

**EXAMPLE**

**Supercomputers help analyze the Earth’s crust.** Scientists know that the Earth’s continental plates are constantly moving at a glacial pace over the planet’s surface, but the complicated internal dynamics that cause this movement are unresolved. The Earth rids itself of the intense heat within its core through a massive circulation system of molten earth and solidified crust, powering the movement of the continental plates. Earlier computer models viewed the process in two dimensions—depth and horizontal extension—which is not a full 3-D representation of the Earth.

The scale is so huge that, until recently, scientists could not assemble computers powerful enough to process the immense amount of data necessary to realistically simulate the movement of the plates. Now, using a massively parallel supercomputer (4 gigaflops—4 billion floating point operations per second—of processing power) and specially designed modeling software, researchers at Princeton University in New Jersey have been moving toward the answer. They are working to understand the cycle of convection occurring deep inside the planet. The researchers’ work could someday help scientists accurately predict earthquakes and volcanic eruptions. ●

**Mainframe Computers**

Although mainframe computers are increasingly viewed as just another type of server, albeit at the high end of the performance and reliability scales, they remain a distinct class of systems differentiated by hardware and software features. Mainframes remain popular in large enterprises for extensive computing applications that are accessed by thousands of users. Examples of mainframe applications include airline reservation systems, corporate payroll, and student grade calculation and reporting. Analysts predict that Internet-based computing will lead to continued growth in the mainframe market.

Mainframes are less powerful and generally less expensive than supercomputers. In 2000, mainframe capacity was priced at approximately $2,260 per MIP (millions of instructions per second), down significantly from $9,410 in 1997. Prices are expected to fall to $490 per MIP by 2004. This pricing pressure has forced two vendors of mainframe systems, Amdahl and Hitachi, out of the mainframe market, leaving only IBM as a vendor of traditional mainframe systems. IBM calls its mainframe computer series the eServer zSeries.

A mainframe system may have up to several gigabytes of primary storage. Online and offline secondary storage (see the discussion of Enterprise Storage Systems on page 69) may use high-capacity magnetic and optical storage media with capacities in
the terabyte range. Typically, several hundreds or thousands of online computers can be linked to a mainframe. Today’s most advanced mainframes perform at more than 2,500 MIPs and can handle up to one billion transactions per day.

Some large organizations that began moving away from mainframes toward distributed systems now are moving back toward mainframes because of their centralized administration, high reliability, and increasing flexibility. This process is called recentralization. The reasons for the shift include supporting the high transaction levels associated with e-commerce, reducing the total cost of ownership of distributed systems, simplifying administration, reducing support-personnel requirements, and improving system performance. In addition, host computing provides a secure, robust computing environment in which to run strategic, mission-critical applications. (Distributed computing and related topics are discussed in detail in Chapter 6.) (For a more technical discussion of mainframes, see the section on Mainframes on the Web site.)

**EXAMPLE**

Merrill Lynch’s online information and customer service. Merrill Lynch, with total client assets of more than $1.5 trillion, has a long history of mainframe computing for providing innovative client services. A new mainframe system plays a key role in delivering information via the company Web site, satisfying nearly 750,000 requests daily. To run its Web presence and to provide support for online Internet trading, Merrill Lynch uses an IBM mainframe with 8 gigabytes of random access memory. The mainframe also supports market data capture, feedback pages from customers, and secure portfolio downloads. Mainframe workloads at Merrill Lynch have increased 30 percent over the last few years. Internet activity, extended trading hours, and moving to stock-pricing decimalization are expected to further increase workloads.

**Midrange Computers**

There are two types of midrange computers, minicomputers and servers. **Minicomputers** are relatively small, inexpensive, and compact computers that perform the same functions as mainframe computers, but to a more limited extent. These computers are designed to accomplish specific tasks such as process control, scientific research, and engineering applications. Larger companies gain greater corporate flexibility by distributing data processing with minicomputers in organizational units instead of centralizing computing at one location. Minicomputers meet the needs of smaller organizations that would rather not utilize scarce corporate resources by purchasing larger, less scalable computer systems. IBM is the market leader in minicomputers with its eServer iSeries (formerly the AS/400).

**EXAMPLE**

Automated Training Systems moves to the Internet. Automated Training Systems (ATS) produces training products for midrange computer users, which consist of audioscassette media and workbooks. ATS packages, developed for in-house training, allow learning when convenient for students, and they virtually eliminate many of the problems normally associated with training new users (time away from the job, scheduling, and travel). ATS uses an IBM iSeries minicomputer to run its Web site. The company modified its order-entry application with a browser interface to provide its customers with information and the ability to place orders over the Internet. Since the implementation of its Internet project, ATS is receiving orders and inquiries from all
over the world. In response to demand, ATS is currently working to translate its courses into Japanese and Chinese. ATS has significantly improved its customer service and support while reducing its overall costs. The company’s president notes that ATS received enough orders in one day over the Internet to recover its entire investment in hardware.

Smaller types of midrange computers, called servers, typically support computer networks, enabling users to share files, software, peripheral devices, and other network resources. Servers have large amounts of primary and secondary storage and powerful CPUs.

Servers provide the hardware for e-commerce. They deliver Web pages and process purchase and sales transactions. Organizations with heavy e-commerce requirements and very large Web sites are running their Web and e-commerce applications on multiple servers in server farms. Server farms are large groups of servers maintained by an organization or by a commercial vendor and made available to customers.

As companies pack greater numbers of servers in their server farms, they are using pizza-box-size servers called rack servers that can be stacked in racks. These computers run cooler, and therefore can be packed more closely, requiring less space. To further increase density, companies are using a server design called a blade. A blade is a card about the size of a paperback book on which memory, processor, and hard drives are mounted.

**EXAMPLE**

**Immunet: Using the Web to combat AIDS.** Immunet uses the Web to help fight HIV and AIDS. Because HIV and AIDS research evolves so rapidly, medical personnel must rely on accredited Continuing Medical Education (CME) courses to keep on top of the latest developments, medications, and treatment protocols. Immunet offers accredited CME courses online.

In addition, while AIDS treatment is covered by health plans, many of these do not specify which doctors specialize in AIDS. Patients are often required to seek referrals from multiple doctors before finding the right one. In some cases, these issues must first be discussed with human resources personnel who administer health benefit plans—an uncomfortable option for many seeking help. Immunet provides automated searches and matches between patients and doctors.

Having acquired two new domain names, aids.edu and aids.org, Immunet chose IBM Netfinity servers because they provided reliability and availability to enable the company to manage its Web sites. Immunet now has a comprehensive Web site that monthly serves more than 80,000 visitors from more than 155 countries.

**Workstations**

Computer vendors originally developed desktop engineering workstations, or workstations for short, to provide the high levels of performance demanded by engineers. That is, workstations run computationally intensive scientific, engineering, and financial applications. **Workstations** are typically based on RISC (reduced instruction set computing) architecture and provide both very high-speed calculations and high-resolution graphic displays. These computers have found widespread acceptance within the scientific community and, more recently, within the business community. Workstation applications include electronic and mechanical design, medical imaging,
scientific visualization, 3-D animation, and video editing. By the second half of the 1990s, many workstation features were commonplace in PCs, blurring the distinction between workstations and personal computers.

**Microcomputers**

Microcomputers (also called micros, personal computers, or PCs) are the smallest and least expensive category of general-purpose computers. They can be subdivided into four classifications based on their size: desktops, thin clients, notebooks and laptops, and mobile devices.

**Desktop PCs.** The desktop personal computer has become the dominant method of accessing workgroup and enterprisewide applications. It is the typical, familiar microcomputer system that has become a standard tool for business, and, increasingly, the home. It is usually modular in design, with separate but connected monitor, keyboard, and CPU. In general, modern microcomputers have between 64 megabytes and 512 megabytes of primary storage, one 3.5-inch floppy drive, a CD-ROM (or DVD) drive, and up to 100 gigabytes or more of secondary storage.

Most desktop systems currently use Intel 32-bit technology (but are moving to 64-bit technology), running some version of Windows. The exception is the Apple Macintosh, which runs Mac OS (operating system) on a PowerPC processor. Apple offers two desktop Macintosh systems, the high-performance Power Mac G4 series and the entry-level iMac series.

**Thin-client systems.** Thin-client systems are desktop computer systems that do not offer the full functionality of a PC. Compared to a PC, thin clients are less complex, particularly because they lack locally installed software, and thus are easier and less expensive to operate and support than PCs. The benefits of thin clients include fast application deployment, centralized management, lower cost of ownership, and easier installation, management, maintenance, and support. Disadvantages include user resistance and the need to upgrade servers and buy additional server applications and licenses. One type of thin client is the terminal, allowing the user to only access an application running on a server.

A another type of thin client is a network computer, which is a system that provides access to Internet-based applications via a Web browser and can download software, usually in the form of Java applets. With PC vendors lowering their systems costs and simplifying maintenance, NCs remain niche products. However, vendors continue to manufacture thin-client systems for use at retail stations, kiosks, and other sites that require access to corporate repositories but little desktop functionality. Industry experts predicted that the PC would give way to network computers, but as IT’s About Business Box 3.2 (on page 76) shows, that has not been the case. Table 3.3 (on page 76) compares the classes of computers discussed so far.

**Laptop and notebook computers.** As computers become much smaller and vastly more powerful, they become portable, and new ways of using them open up. Laptop and notebook computers are small, easily transportable, lightweight microcomputers that fit easily into a briefcase. They are designed for maximum convenience and transportability, allowing access to processing power and data outside an office environment. Manager’s Checklist 3.1 (on page 77) compares the trade-offs between desktop and portable PCs.
Emerging platforms for computing and communications include such mobile devices as handheld computers, often called personal digital assistants (PDAs) or handheld personal computers, and mobile phone handsets with new wireless and Internet access capabilities formerly associated with PDAs. Other emerging platforms (game consoles and cable set-top boxes) are consumer electronics devices that are expanding into computing and telecommunications. Mobile devices are be-

### Box 3.2: Predictions of the death of PCs were exaggerated

Conventional wisdom says that the personal computer is a $1,000 commodity with too much processing power, too much memory, too much storage, and an unhealthy dependence on Windows and a Web browser. But in a survey, three-quarters of IT executives said that the PC will remain their main desktop computer for the next five years.

The GartnerGroup (a marketing research group that often studies IT trends) predicted that 20 percent of the desktop market would be thin clients by the end of 2002, a figure that in June 2001 actually was about 1 percent. Instead, the differences between PCs and thin clients are blurring. Analysts stated that thin clients could save up to 39 percent on PC total cost of ownership (TCO), but that has not happened. IT executives say they do not measure TCO simply as PC versus thin client. They note that the cost of thin clients is not so low that it is worth reengineering, retraining, and running a mixed environment. In fact, the executives said that TCO should stand for “thin clients are oversimplified.”

A nother problem is that if a company moves from PCs to thin clients, the new environment will require complex storage systems and higher-end servers. Also, if an application runs in only one place (i.e., the network), then the network must always be up and running. One executive said that his firm could just buy PCs, or it could spend twice as much on the communications network in order to keep the client thin.

**Questions**

1. What are the advantages and disadvantages of network PCs?
2. What is the biggest reason for staying with desktop PCs?

### Questions

**1.** What are the advantages and disadvantages of network PCs?

**2.** What is the biggest reason for staying with desktop PCs?

### Mobile Devices

Emerging platforms for computing and communications include such mobile devices as handheld computers, often called personal digital assistants (PDAs) or handheld personal computers, and mobile phone handsets with new wireless and Internet access capabilities formerly associated with PDAs. Other emerging platforms (game consoles and cable set-top boxes) are consumer electronics devices that are expanding into computing and telecommunications. Mobile devices are be-

### Table 3.3 Comparing Computers (Desktop and Larger)

<table>
<thead>
<tr>
<th>Type</th>
<th>Processor Speed</th>
<th>Amount of RAM</th>
<th>Physical Size</th>
<th>Common Role/Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supercomputer</td>
<td>60 billion to 3 trillion FLOPs</td>
<td>8,000 MB +</td>
<td>Like a small car</td>
<td>Scientific calculation, complex system modeling, and simulation</td>
</tr>
<tr>
<td>Mainframe</td>
<td>500–4,500 MIPS</td>
<td>256–4,096 MB</td>
<td>Like a refrigerator</td>
<td>Enterprisewide systems, corporate database management</td>
</tr>
<tr>
<td>Midrange Computers</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minicomputer</td>
<td>250–1,000 MIPS</td>
<td>256–2,048 MB</td>
<td>Like a file cabinet</td>
<td>Department-level or small company; dedicated to a particular system (e.g., e-mail)</td>
</tr>
<tr>
<td>Server</td>
<td>100–500 MIPS</td>
<td>256–1,024 MB</td>
<td>Fits on desktop</td>
<td>Supports computer networks; e-commerce</td>
</tr>
<tr>
<td>Workstation</td>
<td>50–250 MIPS</td>
<td>128–1,024 MB</td>
<td>Fits on desktop</td>
<td>Engineering/CA D software development</td>
</tr>
<tr>
<td>Microcomputer</td>
<td>10–100 MIPS</td>
<td>64–512 MB</td>
<td>Fits on desktop</td>
<td>Personal/workgroup productivity, communication</td>
</tr>
</tbody>
</table>
coming more popular and more capable of augmenting, or even substituting for, desktop and notebook computers.

Table 3.4 (on page 78) describes the various types of mobile devices. In general, mobile devices have the following characteristics:

- They cost much less than PCs.
- Their operating systems are simpler than those on a desktop PC.
- They provide good performance at specific tasks but do not replace the full functions of a PC.
- They provide both computer and/or communications features.
- They offer a Web portal that is viewable on a screen.

The following example describes an application of PDAs in the U.S. Navy.

---

**EXAMPLE**

**PDAs in the U.S. Navy.** The U.S. Navy recently realized that its aircraft carrier flight-grading system was not effective. Officers spent all day recording flight evaluations in spiral notebooks, then sat for up to two hours each night reentering that data into a computer.

Using application development software and Palm handheld devices, the Navy created a flight-recording program, PASS, for devices running the Palm operating system. The results were immediate. PASS is now in official use by more than 50 landing-signal officers—pilots who grade flight landings—on two of the Navy’s 12 aircraft carriers.

The application is simple to use. Using custom menus and the Palm’s built-in handwriting recognition software, officers input information on each flight, including the plane ID number, pilot name, which wire helped catch the plane, a grade for the
landing, and additional evaluation comments. After completing notes on a day’s worth of flights, the pilot synchronizes his PDA with a desktop computer. The PASS software flags any evaluations where data are missing or the comments do not mesh with the flight grade, then it enters the evaluations into the computer’s database. Data are backed up on Zip disks and periodically sent to the Pacific Fleet’s central data repository in San Diego.

The program has freed up more than 100 man-hours a month on each of the ships. Those extra hours are time the officers can spend doing more meaningful training. PASS has also increased the accuracy of flight evaluations. Thanks to the Palm’s ability to time-stamp records, landing-signal officers can precisely record landing intervals. (With flights coming in every 45 seconds at peak times, precision is crucial.) PASS’s shortcut keys for entering comments take the guesswork out of deciphering notebook scribbles.

### Computing Devices

As technology has improved, ever-smaller computing/communication devices have become possible. Technology such as wearable computing/communication devices (à la Star Trek)—which for generations seemed like science fiction—has now become reality. This section briefly looks at some of these new computing devices.

**Wearable computing.** Wearable computers are designed to be worn and used on the body. This new technology has so far been aimed primarily at niche markets in industry rather than at consumers. Industrial applications of wearable computing include systems for factory automation, warehouse management, and performance support, such as viewing technical manuals and diagrams while building or repairing something. The technology is already widely used in diverse industries such as freight deliv-

<table>
<thead>
<tr>
<th>Table 3.4 Mobile Devices and Their Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Device</strong></td>
</tr>
<tr>
<td><strong>Description and Use</strong></td>
</tr>
<tr>
<td>Handheld companions</td>
</tr>
<tr>
<td>Devices with a core functionality of accessing and managing data; designed as supplements to notebooks or PCs</td>
</tr>
<tr>
<td>PC companions</td>
</tr>
<tr>
<td>Devices primarily used for personal information management (PIM), e-mail, and light data-creation capabilities</td>
</tr>
<tr>
<td>Personal companions</td>
</tr>
<tr>
<td>Devices primarily used for PIM activities and data-viewing activities</td>
</tr>
<tr>
<td>Classic PDAs</td>
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<tr>
<td>Handheld units designed for PIM and vertical data collection.</td>
</tr>
<tr>
<td>Smart phones</td>
</tr>
<tr>
<td>Emerging mobile phones with added PDA, PIM, data, e-mail or messaging creation/service capabilities</td>
</tr>
<tr>
<td>Vertical application devices</td>
</tr>
<tr>
<td>Devices with a core functionality of data access, management, creation, and collection; designed for use in vertical markets*</td>
</tr>
<tr>
<td>Pen tablets</td>
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<tr>
<td>Business devices with pen input and tablet form for gathering data in the field or in a mobile situation</td>
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<tr>
<td>Pen notepads</td>
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<tr>
<td>Pen-based for vertical data collection applications</td>
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<tr>
<td>Keypad handhelds</td>
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<tr>
<td>Business devices with an alphanumeric keypad used in specialized data-collection applications</td>
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</table>

*Vertical markets refer to specific industries, such as manufacturing, finance, healthcare, etc.*
ery, aerospace, securities trading, and law enforcement. Governments have been examining such devices for military uses.

**Embedded computers** are placed inside other products to add features and capabilities. For example, the average mid-sized automobile has more than 3,000 embedded computers that monitor every function from braking to engine performance to seat controls with memory.

**Active badges** can be worn as ID cards by employees who wish to stay in touch at all times while moving around the corporate premises. The clip-on badge contains a microprocessor that transmits its (and its wearer’s) location to the building’s sensors, which send it to a computer. When someone wants to contact the badge wearer, the phone closest to the person is identified automatically. When badge wearers enter their offices, their badge identifies them and logs them on to their personal computers.

**Memory buttons** are nickel-sized devices that store a small database relating to whatever it is attached to. These devices are analogous to a bar code, but with far greater informational content and a content that is subject to change. The U.S. Postal Service is placing memory buttons in residential mailboxes to track and improve collection and delivery schedules.

An even smaller form of computer is the **smart card**. Similar in size and thickness to ordinary plastic credit cards, smart cards contain a small processor and memory that allow these “computers” to be used in everyday activities such as personal identification and banking.

Uses for smart cards are appearing rapidly. People are using them as checkbooks; a bank **ATM** (automated teller machine) can “deposit money” into the card’s memory for “withdrawal” at retail stores. Many states and private health maintenance organizations are issuing smart health cards that contain the owner’s complete health history, emergency data, and health insurance policy data. Smart cards are being used to transport data between computers, replacing floppy disks. Adding a small transmitter to a smart card can allow businesses to locate any employee and automatically route phone calls to the nearest telephone.

**Before you go on . . .**

1. Describe the computer hierarchy from the largest to the smallest computers.
2. What type of desktop PC has the least amount of processing power?
3. Give examples of the uses of supercomputers and handheld computers.

### 3.5 INPUT TECHNOLOGIES

Input technologies allow people and other technologies to put data into a computer. We begin with human data-entry devices.

**Human Data-Entry Devices**

Human data-entry devices allow people to communicate with the computer. Some of these devices are very common, such as the keyboard and the mouse. Others, such as the touch screen, stylus, trackball, joystick, and microphone, are used for somewhat more specialized purposes.
**Keyboards.** Keyboards are the most common input device. The keyboard is designed like a typewriter but with many additional function keys. Most computer users utilize keyboards regularly. However, excessive use of keyboards can lead to repetitive stress injuries like carpal tunnel syndrome. This type of injury is thought to be caused by improper placement of the hands and wrists when typing at the computer keyboard. As a result, a new generation of keyboards has been designed to encourage the proper hand and wrist positions by splitting and angling the keypad and by incorporating large wrist rests.

A more radical keyboard redesign is the DataHand keyboard from DataHand Systems of Phoenix, Arizona. The DataHand keyboard consists of two unattached pads, and rather than a conventional array of keys, the device has touch-sensitive receptacles (or finger wells) for the fingers and thumbs. Each finger well allows five different commands, which are actuated by touching one of the sides or the bottom of the finger wells. Complex commands can be programmed so that a single flick of the finger can be used to enter frequently used sequences of commands or chunks of data. The DataHand Web site has an excellent demonstration of the company’s ergonomic keyboard (see datahand.com).

**Mice and trackballs.** A mouse is a handheld device used to point a cursor at a desired place on the screen, such as an icon, a cell in a table, an item in a menu, or any other object. Once the arrow is placed on an object, the user clicks a button on the mouse, instructing the computer to take some action. The use of the mouse reduces the need to type in information or use one of the function keys.

A variant of the mouse is the trackball, which is often used in graphic design. The user holds an object much like a mouse, but rather than moving the entire device to move the cursor (as with a mouse), he or she rotates a ball that is built into the top of the device. Portable computers have some other mouselike technologies, such as the glide-and-tap pad, used in lieu of a mouse. Many portables also allow a conventional mouse to be plugged in when desired.

Another variant of the mouse, the optical mouse, replaces the ball, rollers, and wheels of the mechanical mouse with a light, lens, and a camera chip. It replicates the action of a ball and rollers by taking photographs of the surface it passes over, and comparing each successive image to determine where it is going.

The pen mouse resembles an automobile stick shift in a gear box. Moving the pen and pushing buttons on it perform the same functions of moving the cursor on the screen as a conventional pointing device. But the pen mouse base stays immobile on the desk. With a pen mouse, the forearm rests on the desk, saving wear and tension. Because the mouse is not lifted or moved, the fingers, not the arm, do the work.

**Other human data-entry devices.** Touch screens are a technology that divides a computer screen into different areas. Users simply touch the desired area (often buttons or squares) to trigger an action. These are common in computers built into self-service kiosks such as ATM machines and even bridal registries.

A stylus is a pen-style device that allows the user either to touch parts of a predetermined menu of options (as with a wearable computer, discussed above) or to hand-write information into the computer (as with some PDAs). (See the photo of the PDA and stylus on page 76.) The technology may respond to pressure of the stylus, or the stylus can be a type of light pen that emits light that is sensed by the computer.

A joy stick is used primarily at workstations that display dynamic graphics. It is also used to play video games. The joy stick moves and positions the cursor at the desired place on the screen.
A microphone is becoming a popular data-input device as voice-recognition software improves and people can use microphones to dictate to the computer. These are also critical technologies for people who are physically challenged and cannot use the more common input devices.

**Source Data Automation**

The object of source data automation is to input data with minimal human intervention. These technologies speed up data collection, reduce errors, and gather data at the source of a transaction or other event. Below are the common types.

**Cash-transaction devices.** Various input devices are common in association with cash transactions. The most common are ATMs and POS terminals.

A **automated teller machines (ATMs)** are interactive input/output devices that enable people to make bank transactions from remote locations. ATMs utilize touch screen input as well as magnetic card readers.

**Point-of-sale (POS) terminals** are computerized cash registers that also often incorporate touch screen technology and bar-code scanners (described below). These devices allow the input of numerous data such as item sold, price, method of payment, name or Zip code of the buyer, and so on. Some inputs are automated; others may be entered by the operator.

**Optical scanners.** Bar-code scanners, ubiquitous in retail stores, scan the black-and-white bar code lines typically printed on labels on merchandise. In addition, bar-code scanners are very popular for tracking inventory and shipping.

An **optical mark reader** is a special scanner for detecting the presence of pencil marks on a predetermined grid, such as multiple-choice test answer sheets. Similarly, **magnetic ink character readers (MICRs)** are used chiefly in the banking industry. Information is printed on checks in magnetic ink that can be read by the MICR technology, thus helping to automate and greatly increase the efficiency of the check-handling process.

**Optical character recognition (OCR) software** is used in conjunction with a scanner to convert text into digital form for input into the computer. Although the scanner can digitize any graphic, the OCR software can recognize the individual characters, so that they can be manipulated. As a practical example, the scanner by itself could “take a picture” of this page of text and convert it into digital information that the computer could store as a picture of the text. But you would not be able to decompose the “picture” file into individual words that could be further modified (manipulated by a word-processing program, for example). The OCR technology enables this last part. OCR-equipped scanning technologies are very useful when printed documents not only must be preserved but also would benefit from any manipulations or modifications. OCR technologies would enable you to scan data, process them with the OCR software, and then put them into a database, spreadsheet, or word-processing format.

As noted in the earlier section on handheld computers, OCR software is usually incorporated in stylus-input devices. Although quite sophisticated, OCR programs require training in order to be able to recognize handwriting. Even then, their accuracy in interpreting handwritten characters is less than when they are used to interpret typed text.

**Other source data automation devices.** Voice-recognition systems are used in conjunction with microphones to input speech to computers. Voice-recognition software (VRS) attempts to identify spoken words and translate them into digital text. Like
OCR software used for handwriting recognition, VRS requires training to become accustomed to the user’s voice and accent. These systems also leave much to be desired in terms of accuracy of word recognition, though the technology continues to improve.

Sensors are extremely common technologies embedded in other technologies. They collect data directly from the environment and input them into a computer system. Examples might include your car’s airbag activation sensor or fuel mixture/pollution control sensor, inventory control sensors in retail stores, and the myriad types of sensors built into a modern aircraft.

Cameras can now operate digitally, capturing images and converting them into digital files. There are digital still-image cameras, and there are now many types of digital motion-picture cameras. Many computer enthusiasts and practical business people find it useful to attach small digital cameras to their personal computers. When linked to the Internet, and using special software such as Microsoft’s NetMeeting, such a system can be used to conduct desktop videoconferencing.

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Before you go on . . .

1. Distinguish between human data input devices and source data automation.
2. Describe the relationship between OCR technology and scanner technology.

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3.6 OUTPUT TECHNOLOGIES

The output generated by a computer can be transmitted to the user via several devices and media. The presentation of information is extremely important in encouraging users to embrace computers. Below is a discussion of common types of output technologies.

**Monitors**

Monitors are the video screens used with most computers that display input as well as output. Like television sets, monitors come in a variety of sizes and color/resolution quality. And like television sets, the common desktop monitor uses cathode ray tube (CRT) technology to shoot beams of electrons to the screen. The electrons illuminate tiny points on the screen known as pixels. The more pixels on the screen, the better the resolution. That is, the less space between pixels—that is, the finer the dot pitch—the better the resolution. Here are some other useful facts about monitors:

- Portable computers use a flat screen that uses liquid crystal display (LCD) technology, not CRT.
- LCDs use less power than CRT monitors but cost six to eight times what an equivalent CRT does.
- LCD monitors may be passive matrix, which have somewhat less display speed and brightness compared to active matrix monitors, which function somewhat differently (and cost significantly more).

**Organic light-emitting diodes.** Organic light-emitting diodes (OLEDs) provide displays that are brighter, thinner, lighter, and faster than liquid crystal displays (LCDs).
LCDs, invented in 1963, have become the standard display for everything from watches to laptop computers. However, LCD screens are hard to make and expensive. Compared to LCDs, OLEDs take less power to run, offer higher contrast, look equally bright from all angles, handle video, and are cheaper to manufacture.

OLEDs do face technical obstacles with color. If you leave OLEDs on for a month or so, the color becomes very nonuniform. However, OLEDs are probably good enough right now for cell phones, which are typically used for 200 hours per year and would likely be replaced before the colors start to fade. But such performance is not adequate for handheld or laptop displays, for which several thousand hours of life are required.

**Retinal scanning displays.** As people increasingly use mobile devices, many are frustrated with the interfaces. The interfaces are too small, too slow, and too awkward to process information effectively. As a result, Web sites become unusable, e-mails are constrained, and graphics are eliminated. One solution does away with screens altogether. A firm named Microvision (mvis.com) projects an image, pixel by pixel, directly onto a viewer’s retina. This technology, called **retinal scanning displays (RSDs)**, is used in a variety of work situations, including medicine, air traffic control, and controls of industrial machines. RSDs can also be used in dangerous situations, for example, giving firefighters in a smoke-filled building a floor plan.

**Printers**

Printers come in a variety of styles for varying purposes. The three main types are impact printers, nonimpact printers, and plotters.

**Impact printers.** Impact printers work like typewriters, using some kind of striking action. A raised metal character strikes an inked ribbon that makes a printed impression of the character on the paper. These devices cannot produce high-resolution graphics, and they are relatively slow, noisy, and subject to mechanical failure. Although inexpensive, they are becoming less popular.

**Nonimpact printers.** Nonimpact printers come in two main styles. **Laser printers** are higher-speed, high-quality devices that use laser beams to write information on photosensitive drums, whole pages at a time; then the paper passes over the drum and picks up the image with toner (similar to ink). Laser printers produce very-high-resolution text and graphics, making them suitable for a broad range of printing needs from simple text to desktop publishing. **Inkjet printers** work differently, by shooting fine streams of colored ink onto the paper. These are less expensive than laser printers, but offer somewhat less resolution quality.

**Plotters.** Plotters are printing devices that use computer-directed pens for creating high-quality images. They are used in complex, low-volume situations, for example, creating maps and architectural drawings. Some plotters are quite large, suited for producing correspondingly large graphics.
**Voice Output**

*Voice output* is now possible via sophisticated synthesizer software that can be installed in most personal computers. A voice output system constructs the sonic equivalent of textual words, which can then be played through speakers. Other types of software can manage spoken communication in different ways. For example, one can purchase programs that integrate telephone voice mail with the computer, so that the computer can record and make limited responses to incoming calls.

**Multifunction Devices**

*Multifunction devices* combine a variety of technologies and are particularly appropriate for home offices. The technologies include fax, printer, scanner, copy machine, and answering machine. Depending on how much one wishes to invest and one's needs, any combination can be found in a single cost-effective machine.

**Multimedia**

*Multimedia output* is the computer-based integration of text, sound, still images, animation, and digitized motion video. It merges the capabilities of computers with televisions, VCRs, CD players, DVD players, video and audio recording equipment, and music and gaming technologies. Multimedia usually represents a collection of various input and output technologies, a system unto itself, as shown in Figure 3.10. Later in the book we will discuss the business uses of multimedia technology, but for the moment, consider these useful facts:

![Figure 3.10](image-url)

*Figure 3.10* Multimedia authoring system with a great variety of input sources and output displays. [Source: Based on illustration in Reseller Management (November 1993). From the 11/93 VAR Workbook Series by John McCormick and Tom Fare, Multimedia Today Supplement: VAR Workbook Series, pp. 4-5, 7.]
• High-quality multimedia processing requires the most powerful and sophisticated microprocessors available. Firms like Intel produce generations of chips especially designed for multimedia processing.

• Because of the variety of devices that can make up a multimedia system, standards such as the Multimedia Personal Computer (MPC) Council certification are important in ensuring that the devices are compliant and compatible.

• Extensive memory capacity—both primary and secondary storage—is essential for multimedia processing, particularly with video. Video typically requires using compression techniques to reduce the amount of storage needed. Even with compression techniques, those who work extensively with video processing often must augment their secondary storage with devices like writeable CD drives or external hard drives.

IT’s About Business Box 3.3 discusses a multimedia application.

Before you go on . . .

1. What are the differences between various types of monitors?
2. What are the main types of printers? How do they work?
3. Describe the concept of multimedia, and give an example of a multimedia system.

3.7 STRATEGIC HARDWARE ISSUES

The majority of this chapter has explained how hardware is designed and how it works. But it is what the hardware enables, how it is advancing, and how rapidly it is advancing that are the more complex and important issues for most businesspeople.
In many industries, exploiting computer hardware is a key to competitive advantage. Successful hardware exploitation comes from thoughtful consideration of the following issues.

**Productivity**

Hardware technology can affect both personal and organizational productivity. Businesses need to assess whether employees’ personal productivity is likely to increase as microprocessor power and speed increase. Perhaps your PC now takes 1/10th of a second to call up a program. If a new generation of chip can get your PC to call it up in 1/100th of a second, does your productivity increase by tenfold? If so, then an investment in a more powerful microprocessor might produce a competitive advantage.

Similarly, as primary storage capacity increases, what advantages come your way? A trend in software is to make each new version more complex. Consider, for example, the differences in Microsoft Office 2000. This software suite (discussed in Chapter 4) has so many more instructions that it cannot run well on machines with less than 128 MB RAM. To take advantage of the newer software, you need to upgrade machines. You also need to invest considerable time to understand whether the new innovations will help you, and then you must master them. The learning curve that comes with new machines and software typically comes with a cost to your productivity, at least in the short term. And perhaps by the time you master a new generation of technology, it will be obsolete. Multiply this decision by the number of employees who will use the new software, and you have an issue of organizational productivity to solve.

At the same time, the cost of computers is decreasing while the power is increasing. Is the workforce prepared to take advantage of these more powerful machines? How would your business measure the anticipated increases in productivity? You would need to be able to measure or somehow quantify the changes in organizational productivity in order to make a reasoned cost-benefit decision.

**Changing Work Styles**

Advances in miniaturization of microprocessors and memory devices are ushering in ever-smaller computing and communication devices that can assist employees in achieving a productive, nontraditional work style. This is particularly true for employees who work largely out of the office. Whether at home or on the road, employees can stay connected to the home office and keep their efforts coordinated with organizational goals via the cellular telephone, modem (discussed in Chapter 6), and portable computers of one style or another. All of these devices are enabled by advances in these technologies. The issue the organization must consider is whether these new work styles will benefit employees and the firm as a whole. In particular, does the firm know how to manage these new work styles?

**New Products and Services**

Because the cost of computing power continues to decline à la Moore’s Law, organizations may find that supercomputers are affordable and justifiable. With a supercomputer, business organizations can tackle increasingly sophisticated problems, from forecasting to product development to advanced market research. Similarly, advances in miniaturization of microcontrollers, microprocessors, and memory devices can also drive the development of new products and services for your firm. Is the organization ready and able to take advantage of these advances? What new products and services would advances in hardware make possible for the business?
Improved Communications

Multimedia is often thought of as the basis for an entertainment system, with limited use in the business world. This is short-sighted thinking. Increasingly, organizations recognize that multimedia capability is an important aspect of knowledge management and communication (as IT’s About Business Box 3.3 showed). When integrated with a firm’s network and/or the Internet, multimedia technology makes possible incredibly rich communication and knowledge sharing throughout the organization, as well as with the rest of the world. Many commercial Web sites feature multimedia, making video, audio, graphic, and textual information available to all who visit. Multimedia presentations are now the standard for excellence in the business world, and anyone who has to sell a product, service, or idea benefits from exploiting this technology. Is your organization ready to do so? What multimedia applications might provide a competitive advantage for your organization?

Before you go on . . .

1. How would you explain the role of various types of computer hardware in personal productivity? In organizational productivity?

2. What are the upsides and downsides that accompany advances in microprocessor design?

FOR ALL BUSINESS MAJORS AND NONBUSINESS MAJORS

There are practically no professional jobs in business today that do not require computer literacy and skills for personal productivity. And there are no industries that do not use computer technology for one form of competitive advantage or another.

Clearly, the design of computer hardware has profound impacts for businesspeople. It is also clear that personal and organizational success can an understanding of hardware design and a commitment to knowing where it is going and what opportunities and challenges innovations will bring. Because these innovations can occur so rapidly, hardware decisions at the individual level and at the organizational level are difficult.

At the individual level, most people who have a home or office computer system and want to upgrade it, or people contemplating their first computer purchase, are faced with the decision of when to buy as much as what to buy and at what cost.

At the organizational level, these same issues plague IS professionals, but they are more complex and more costly. Most organizations have many different computer systems in place at the same time. Innovations may come to different classes of computers at different times or rates, and managers must decide when old hardware legacy systems still have a productive role in the IS architecture, or when they should be replaced.

IS management at the corporate level is one of the most challenging careers today, due in no small part to the constant innovation in computer hardware. That may not be your career objective, but an appreciation of that area is beneficial. After all, the people who keep you equipped with the right computing hardware, as you can now see, are very important allies in your success.
Identify the major hardware components of a computer system.
Today’s computer systems have six major components: the central processing unit (CPU), primary storage, secondary storage, input technologies, output technologies, and communications technologies.

Describe the design and functioning of the central processing unit.
The CPU is made up of the arithmetic-logic unit that performs the calculations, the registers that store minute amounts of data and instructions immediately before and after processing, and the control unit that controls the flow of information on the microprocessor chip.

Discuss the relationships between microprocessor component designs and performance.
Microprocessor designs aim to increase processing speed by minimizing the physical distance that the data (as electrical impulses) must travel, and by increasing the bus width, clock speed, word length, and number of transistors on the chip.

Describe the main types of primary and secondary storage.
There are four types of primary storage: registers, random access memory (RAM), cache memory, and read-only memory (ROM). All are direct-access memory; only ROM is nonvolatile. Secondary storage includes magnetic media (tapes, hard drives, and diskettes) and optical media (CD-ROM, DVD, FMD-ROM, and optical jukeboxes).

Distinguish between primary and secondary storage along the dimensions of speed, cost, and capacity.
Primary storage has much less capacity than secondary storage, and is faster and more expensive per byte stored. Primary storage is located much closer to the CPU than is secondary storage. Sequential-access secondary storage media such as magnetic tape is much slower and less expensive than direct-access media (e.g., hard drives, optical media).

Define enterprise storage and describe the various types of enterprise storage.
An enterprise storage system is an independent, external system with intelligence that includes two or more storage devices. There are three major types of enterprise storage subsystems: redundant arrays of independent disks (RAIDs), storage area networks (SANs), and network-attached storage (NAS). RAID links groups of standard hard drives to a specialized microcontroller. SAN is an architecture for building special, dedicated networks that allow access to storage devices by multiple servers. A NAS device is a special-purpose server that provides file storage to users who access the device over a network.

Describe the hierarchy of computers according to power and their respective roles.
Supercomputers are the most powerful, designed to handle the maximum computational demands of science and the military. Mainframes are not as powerful as supercomputers, but are powerful enough for use by large organizations for centralized data processing and large databases. Minicomputers are smaller and less powerful versions of mainframes, often devoted to handling specific subsystems. Workstations are in between minicomputers and personal computers in speed, capacity, and graphics capability. Desktop personal computers (PCs) are the most common personal and business computers. Network computers have less computing power and storage, relying on connection to a network for communication, data, processing, and storage resources.

Laptop or notebook computers are small, easily transportable PCs. Palmtop computers are handheld microcomputers, usually configured for specific applica-
tions and limited in the number of ways they can accept user input and provide output. Wearable computers, worn on the user’s clothing, free their users’ movements. Embedded computers are placed inside other products to add features and capabilities. Employees may wear active badges as ID cards. Memory buttons are nickel-sized devices that store a small database relating to whatever it is attached to. Smart cards contain a small processor, memory, and an input/output device that allows them to be used in everyday activities such as personal identification and banking.

Differentiate the various types of input and output technologies and their uses.
Principal input technologies include the keyboard, mouse, trackball, touch screen, stylus, joystick, ATM, POS terminal, bar-code scanner, optical mark reader, optical character reader, handwriting and voice-recognition systems, sensor, microphone, and camera. Common output technologies include the monitor, impact and nonimpact printers, plotter, voice output, multifunction devices, and multimedia.

Describe what multimedia systems are and what technologies they use.
Multimedia computer systems integrate two or more types of media, such as text, graphics, sound, voice, full-motion video, images, and animation. They use a variety of input and output technologies, often including microphones, musical instruments, digitizers, CD-ROM, magnetic tape, and speakers. Multimedia systems typically require additional processing and storage capacity.

Discuss strategic issues that link hardware design and innovation to competitive business strategy.
According to Moore’s Law, microprocessor capability increases ever more rapidly. Miniaturization is also increasing. These advancements usher in new generations of faster, more powerful, and more compact computers, as well as new generations of microcontrollers. Organizations must continually appraise the issues of productivity work styles, new products and services, and improved communications against these new options. Adoption decisions are difficult because of heavy past, current, and future investment.

**INTERACTIVE LEARNING SESSION**
Go to the CD, access Chapter 3: Computer Hardware, and read the case presented. It will describe a business problem that will require you to make a decision on buying personal computers for your company. You will have to decide which variables are the most important (e.g., type of processor, processor speed, amount of RAM, hard drive capacity, etc.), and you must stay within your budget.

For additional resources, go to the book’s Web site for Chapter 3. There you will find Web resources for the chapter, including additional material about hardware technologies and systems; links to organizations, people, and technology; “IT’s About Business” company links; “What’s in IT for Me?” links; and a self-testing Web quiz for Chapter 3.

**DISCUSSION QUESTIONS**

1. What factors affect the speed of a microprocessor?
2. If you were the chief information officer (CIO) of a firm, what factors would you consider when selecting secondary storage media for your company’s records (files)?
3. What applications can you think of for voice-recognition systems?
4. Given that Moore’s Law has proven itself over the past two decades, speculate on what chip capabili-
ties will be 10 years in the future. What might your
desktop PC be able to do?

5. If you were the chief information officer (CIO) of a
firm, how would you explain the workings, benefits, and
limitations of a network computer-based system as opposed to using networked PCs (that is,
“thin” client vs. “fat” client)?

6. How would you justify to your employer the added
cost of a multimedia system over that of a nonmulti-
media-capable PC?

7. Give some examples of how wearable computers
might help your company.

8. What types of embedded computers can you think
of in your company? In your home?

**PROBLEM-SOLVING ACTIVITIES**

1. Obtain back issues of Computerworld or other in-
formation systems magazines. (Go back 5 or 10
years.) Note the cost and functionality (e.g., size of
RAM, hard drive capacity, chip speed) of computer
systems listed. Compare costs and functionality year
by year, and plot them on a graph.

2. Design multimedia systems for your personal use
and for your professional use. Give justifications of
the costs in terms of increased productivity and ca-
pability.

3. Describe what functions you would want in a PDA.
Give justifications of the cost in terms of increased
productivity and capability both for personal and
professional use.

4. What types of computing problems justify the invest-
ment in a supercomputer for a private-sector firm?

**INTERNET ACTIVITIES**

1. Access the Web sites of the major hardware manu-
facturers, for example, IBM (ibm.com), Sun
(sun.com), Apple (apple.com), Hewlett-Packard
(hp.com), and Silicon Graphics (sgi.com), and ob-
tain the latest information regarding hardware re-
leases for all platforms (supercomputer, mainframe,
workstation, personal computer, laptop). Prepare a
table comparing cost, speed, and capacity for each
product across manufacturers.

2. Access the Web sites of the major chip manufactur-
ers, for example, Intel (intel.com), Motorola (mo-
torola.com), and Advanced Micro Devices
(amd.com), and obtain the latest information re-
garding new and planned chips. Compare perfor-
mane and costs across vendors.

3. Access Intel’s Web site (intel.com) and visit its mu-
seum and the animated microprocessor page. Pre-
pare a presentation of each step in the machine
instruction cycle.

**TEAM ACTIVITIES AND ROLE PLAYING**

1. Visit your campus computer center. Note each dif-
ferent type of computer in use and find out what
types of applications are run on each type.

2. Interview your campus CIO and find out on what
basis he or she decides to upgrade particular sys-

**REAL-WORLD CASE** amica.com

**Insuring Growth at Amica**

**The Business Problem** Amica is a $3 billion insurance
company operating in 27 states. Facing increased com-
petition in the insurance industry, Amica wanted to
provide online services to its policyholders, giving them
improved access to the company without compromising
the company’s reputation for highly personalized cus-
tomer service.

Slowing market growth in the insurance industry
has led to aggressive price cutting, as insurers have
sought to increase their market share. With the con-
sumer market (the segment served by Amica) increas-
ingly willing to change providers for lower rates, the
need to increase customer loyalty has become more
acute.

Amica’s main strategy for growth has been geo-
graphic expansion as well as a major advertising cam-
paign designed to raise Amica’s profile outside the
Northeast. Amica recognized the need to expand its
range of channels, and embraced the Internet as a new distribution and communications channel.

The IT Solution  In response to business pressures, Amica developed a Web-based customer self-service solution that delivers rich content to policyholders as well as handles transactional services. Nonpolicyholders can visit the Web site to view information designed to support their insurance decisions as well as consumer safety information. Policyholders can access detailed billing and account history information, pay premiums, and report claims online. Policyholders can also obtain auto, homeowner, and liability insurance quotes online.

A mica’s e-business solution uses multiple Windows NT servers as its Web servers, linked to a number of databases that reside on Amica’s mainframe computer. The company feels that this IT infrastructure was essential for the success and smooth operation of its Web site. The mainframe provides security, reliability, and “24/7/365” availability. The Web servers provide flexibility, scalability, and rapid response time to users accessing the Web site.

The Results  Amica experienced a 170 percent increase in site requests and a 145 percent increase in site visits during the Web site’s first month of operation. In addition, through surveys, the company has discovered that the Web site has increased customer satisfaction. Amica has also increased new customer acquisition at lower cost via its Web site.

Source: amica.com.

Questions

1. Explain how the mainframe delivers its advantages and how the servers deliver their advantages.

2. Could Amica successfully get rid of its mainframe to save money? Why or why not?

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VIRTUAL COMPANY ASSIGNMENT

Extreme Descent Snowboards

Background  The phone rings as you are about to start your day. You answer the phone, and Jacob March, the vice president of information systems, asks if you can come to his office. You hang up the phone, grab your blazer, and head down the hall to Jacob’s office.

Jacob stands up and offers his hand as you walk into his spacious office. He offers you a seat in front of his large mahogany desk. After exchanging a few pleasantries and some small talk, he asks if you are ready for another assignment. You tell Jacob excitedly that you are ready to accept the challenge.

Jacob explains that some of the PCs in the office are aging. “We need some measurement that gives us a cost-benefit analysis for acquiring new PC hardware. One measurement is the total cost of ownership model that investigates the total cost of the computer equipment,” he says. You have recently studied in depth about hardware that is available. Your assignment will be to recommend a TCO model for evaluating hardware.

Assignment

1. Use a search engine to find information about TCO. What is a TCO model?

2. What are the disadvantages to the TCO model?

3. Describe how TCO could be used at EDS to determine its total computer related expenditures.