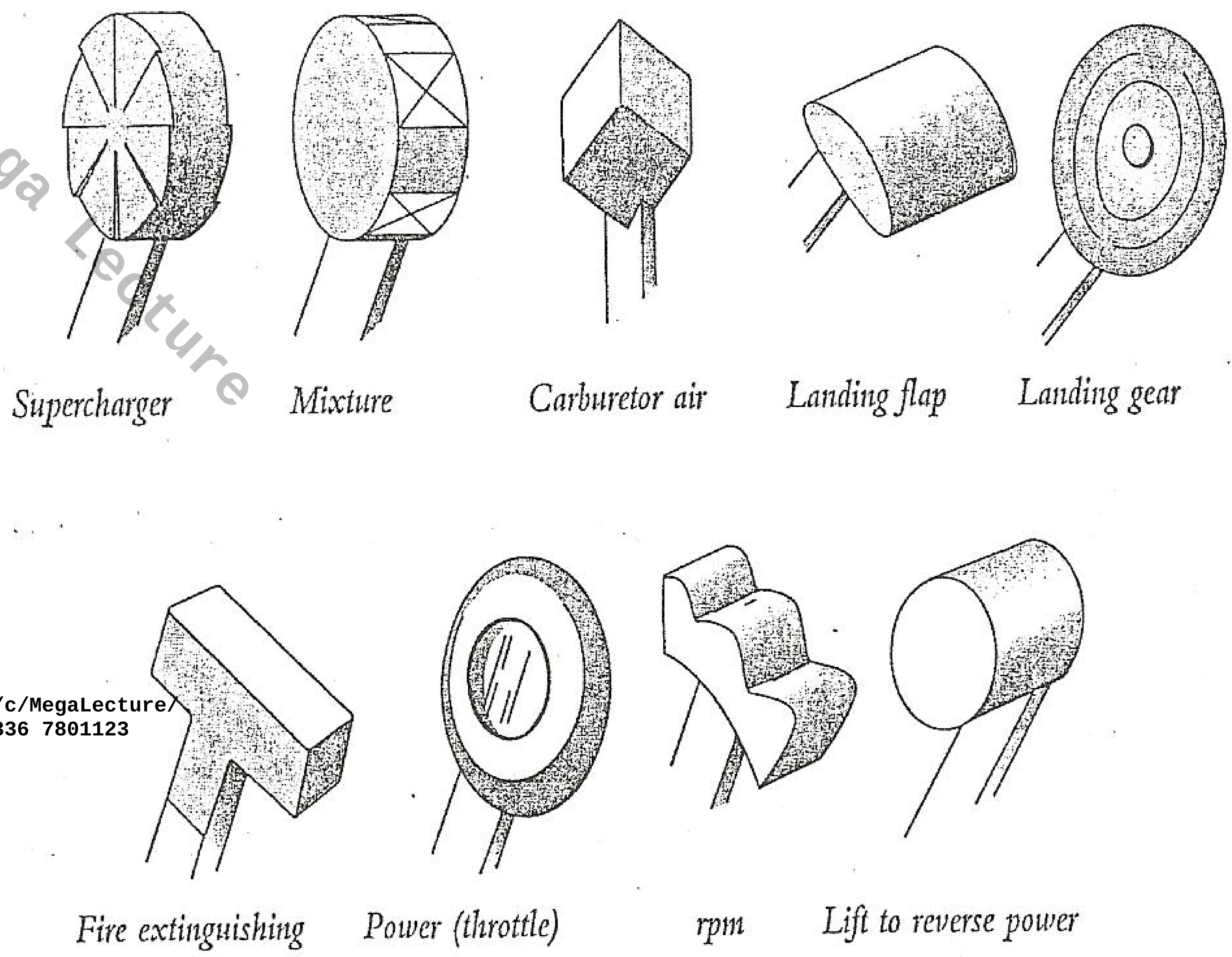


FIGURE 15.2

Tactile-coded Controls: Standardized Shape-coded Knobs for U. S. Air Force Aircraft
Source: United States Air Force. (1980). *Air force system command design handbook 1–3*. Human Factors Engineering.

make use of the computer more efficient and user-friendly, such as using certain coded keys instead of typing an entire command, or using text keys for editing procedures: removing or replacing a single character, an entire word, or a string of characters. Another innovation was the touch screen control, which enabled the user simply to touch some portion of the screen to activate computer functions. Finally, there is the ever-present computer mouse, in its various forms. Early research found that the mouse was the fastest type of general computer control with the lowest rate of errors (Card, English, & Burr, 1978). This is one of the reasons that mouse-type and trackball controls have become the standard.

STOP AND REVIEW

List, in order, the steps (inputs, outputs, etc.) in an operator-machine system.

Finally, there are very advanced control systems developed by human factors specialists. Two special and very sophisticated machine control systems are teleoperators and speech-activated controls. These advanced controls are currently in limited operation in certain work situations, but as their technology improves, they may become more widespread. **Teleoperators** are sophisticated control systems that act as an extension of the human operator. Usually teleoperators are used in environments that would be dangerous for humans, such as underwater, in outer space, or in radioactive environments. A common teleoperator system consists of the mechanical arms used for delicate handling of radioactive material. The operator sits in one room, separated by a safety shield from the mechanical arm and radioactive materials in the adjacent room. The operator places his or her hands in a complicated

teleoperators
sophisticated control systems that act as an extension of the human operator

APPLYING I/O PSYCHOLOGY

Early Video Games: Problems in the Design of Machine Controls

In the late 1970s, the country was swept by a video game craze. Advances in computerization led to the development of these new entertainment devices. Although the early video games were fairly sophisticated in technical design, they often lacked human factors sophistication, particularly in their controls. These video game "antiques" can thus be analyzed from the standpoint of a human factors psychologist in an effort to spot weaknesses in their operator-machine system design and suggest means of improvement.

One of the very first video arcade games was called Pong. It consisted of two vertical bars of light, which represented the two players' paddles, and a bouncing ball. The object of the game, a video version of Ping Pong, was for the players to hit the ball with the paddles to keep it in play. If one player missed hitting the ball, the opponent received a point. The problem with Pong was that the players' control knobs did not match the functions that they performed. The video paddles were controlled by knobs that were twisted. A clockwise twist made the paddle go up, whereas a counterclockwise twist made it go down (see Figure 15.3). It took players quite a while to learn to control the paddles because the knobs violated the principle that a control should imitate the movement it produces. If the Pong paddle controls had been slide switches mounted so that an upward movement on the switch produced an upward movement in the paddle and a downward slide caused a downward movement, there would have been much less operator error.

Asteroids was another early video game. It consisted of a video spaceship (a triangle) that could be rotated to fire at and destroy asteroids before they collided with the ship. Again there was a problem in the control design. The ship was rotated by pressing one of two buttons. Pressing the button on the left caused

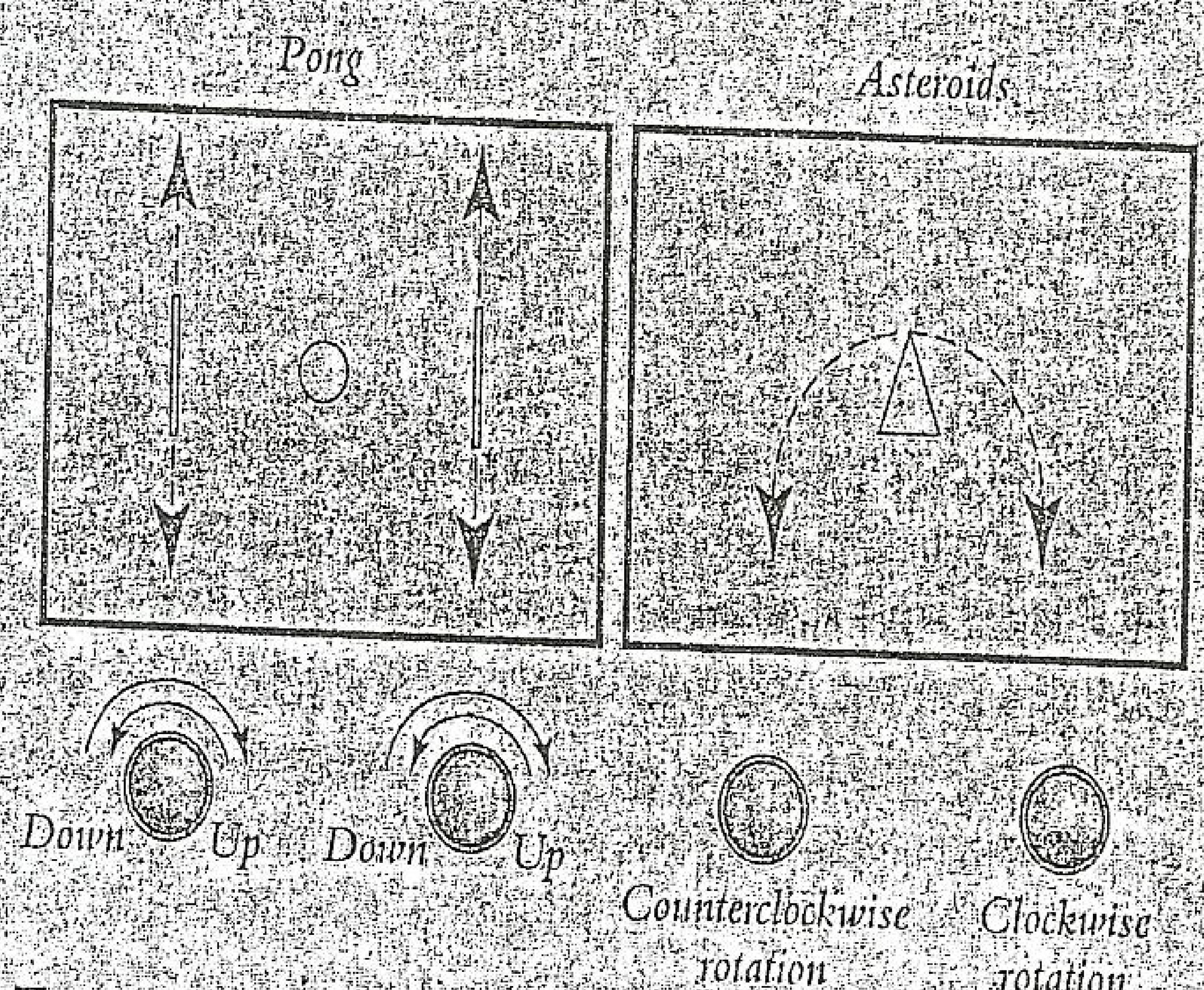
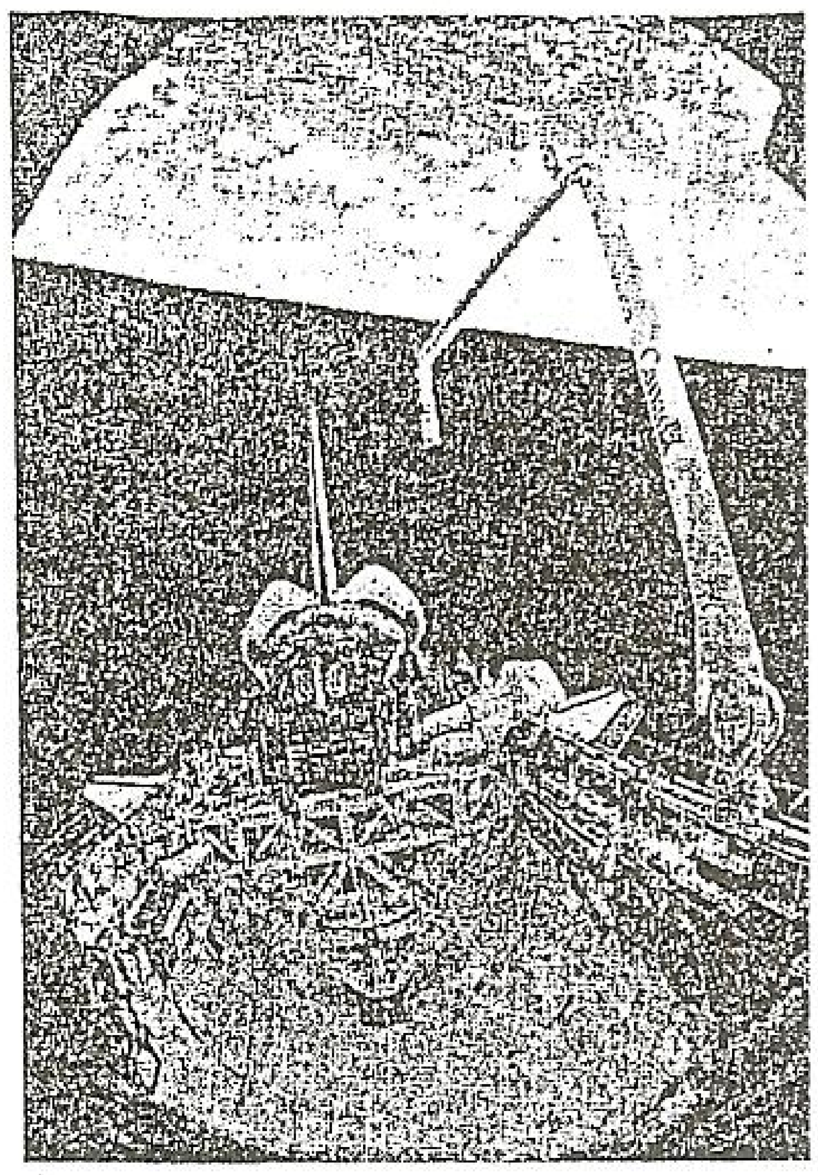


FIGURE 15.3

Two Early Video Games, Pong and Asteroids

APPLYING I/O PSYCHOLOGY *(continued)*

the spaceship to rotate counterclockwise; pressing the button on the right created a clockwise rotation (see Figure 15.3). Novice operators had trouble pushing the correct button and releasing it at the appropriate time to be able to hit the approaching asteroid targets. Imagine a redesign with a knob (like the ones controlling the paddles on Pong) that when twisted to the right creates a clockwise rotation and when twisted to the left causes the spaceship to rotate counterclockwise. The game would be made more efficient from the operator's perspective because the control actions would more closely resemble the movements they produced. (Of course if these video games had been made more efficiently, it might have taken the challenge out of them.) Today's video games have more sophisticated controls that produce more complex actions. For the most part, video game controls have been improved following the human factors guidelines for control design. However, it is still possible to find inefficient mismatches between the controls in certain video games and the specific actions they cause. (Interestingly, some of these "antique" video games are back. For example, many personal computers come with a version of Asteroids—including the same poor control functions!)



In dangerous environments, such as outer space, teleoperators allow humans to control the work from a safe distance.

control apparatus while the mechanical arms, with fingerlike prongs, imitate each of the movements of the operator, whose own arms and fingers are harnessed in the control devices. If the operator's left hand makes a pinching motion, the mechanical arm will make a similar motion to grip an object. The operator can watch the process of the mechanical arm either directly through a window or on a television screen.

An even more advanced control system is **voice control**. In sophisticated voice control systems, such as speech-recognition computer systems, the verbal commands of the operator substitute for the keyboard to enter data directly into the system. Although these controls permit the quick entry of information and free the operator's hands for other activities, the current state of speech-activated technology is such that there are some limitations. For instance, each word or command must be programmed into the system, which means that words must be uttered clearly and consistently. To cut down on errors, the operator must learn to use the same speech patterns, pitch, and voice inflections each time a word or command is uttered. Also, extraneous sounds such as coughing, clearing the throat, or stammering will not be recognized and may produce errors in the system operation. Voice control systems need further development before they can be put into everyday work use (it will probably be some time before you and I can actually "speak" to our computers). Currently, however, they are successfully used with certain tasks, such as simple data recording in situations in which the operator's hands are occupied by other activities, such as postal workers who sort packages and enter destinations vocally. Voice controls are also being used more and more to replace

voice control
machine controls that respond to the spoken words of humans

- evaluation

UP CLOSE

Accidents Lead to Increased Attention to Human Factors in Industry

In earlier times, a worker who made a mistake might spoil a piece of work, waste some time, or in extreme cases, cause an accident that could injure or kill several workers. Today, however, a worker mistake can lead to dire consequences. Consider, for example, the disasters in the nuclear energy industry—Three Mile Island (TMI) and Chernobyl—or Union Carbide's chemical accident in Bhopal, India. In each of these cases, errors in operator-machine systems led to devastating consequences not only for the workers themselves but also for people in the surrounding communities. Specifically, in each case, operators were unaware of the seriousness of the system malfunctions because warning displays were poorly designed or located, and operators had not been sufficiently trained in dealing with these emergency situations. The Chernobyl nuclear disaster caused many deaths and exposed thousands to deadly radiation. The Bhopal tragedy—the worst industrial crisis in history—resulted in thousands of deaths and injuries to over a quarter of a million people living around the chemical plant (Morehouse & Subramaniam, 1986). While the TMI incident is classified as a "near disaster," without any direct deaths or injuries, the toll in terms of stress to the nearby residents was considerable (Hartsough & Savitsky, 1984).

The near nuclear meltdown at TMI in March of 1979 has received one of the most extensive investigations into the safety of operations of an industrial plant (Sills, Wolf, & Shelanski, 1982). All of the evidence points to serious human factors flaws in the design and operation of the plant. For example, control panels presented operators with an overwhelming amount of complex information—more than 1,600 gauges and windows that had to be scanned to find where a malfunction was occurring! Moreover, many warning devices were slow to display emergency information and difficult for operators to read (a problem not limited to TMI).

Consider the following excerpt from a government investigation of the TMI incident:

> The lack of human factors considerations at the design stage was most evident in TMI's control room. It was poorly designed with problems including: controls located far from instrument displays that showed the condition of the system; cumbersome and inconsistent instruments that often looked identical and were placed side by side, but controlled widely different functions; instrument readings that were difficult to read, obscured by glare or poor lighting or actually hidden from the operators; contradictory systems of lights, levers, or knobs—a red light may mean a valve was open in one plant area and closed in another, or pulling one lever up may have closed a valve, while pulling another lever down may have closed another one. . . . (Comptroller General Report on the Congress of the United States, 1980).

The net result was the near avoidance of a potentially catastrophic nuclear accident. The Chernobyl nuclear accident, on the other hand, was primarily due to poor operator training.

UP CLOSE *(continued)*

Operators at Chernobyl were not informed that a meltdown could occur if plant power was reduced below 25 percent. Moreover, the operators were so poorly trained that their responses to the meltdown situation were too slow and often inappropriate.

It is unfortunate, but it took disasters such as these to force governments and organizations to consider human factors more fully in the design and operations of complex operator-machine systems. In fact, before the TMI accident, there were virtually no human factors psychologists on the staffs of the Nuclear Regulatory Commission (NRC) nor of the firms hired to design, build, and operate nuclear power plants (Cordes, 1983). Since then, considerable attention has been given to human factors issues in the design and operation of American nuclear power plants. The NRC now has dozens of human factors psychologists on staff. Unfortunately, despite these improvements, there is still not enough concern given to human factors in complex plant operations.

telephone operators (Brems, Rabin, & Waggett, 1995). Finally, voice controls are used on a limited basis primarily by individuals with disabilities who are unable to operate manual controls (Noyes, Haigh, & Starr, 1989).

WORKSPACE DESIGN

While much of human factors psychology involves the design and improvement of operator-machine systems, psychologists are also concerned with the design and improvement of the larger work environment. A great deal of attention has been given to **workspace design**, the physical layout of individual workstations, and the design and arrangement of space and equipment within factories and offices. Workspaces are designed with considerations of work performance efficiency, operator comfort and safety, operator abilities and limitations, and characteristics of the machines, tools, and products kept firmly in mind. Workspace design considers how individual workstations are designed, and how workstations are linked together to form entire work environments.

workspace design
the design and arrangement of equipment, space, and machinery within a work environment

Certain basic principles governing the location and arrangement of equipment, tools, and space should be followed whether designing an individual work station or an entire workspace, such as placing important displays, controls, and tools in a central location so that they can be easily accessed (McCormick & Sanders, 1993).

Human factors psychologists have also played an important role in the design of work tools and equipment. One area that has made many advancements in recent years is the human factors specialty of **engineering anthropometry**, which is the measurement of the physical characteristics of the human body and the development of equipment designed to fit the characteristics of the human user (Kroemer, 1983; Wickens et al., 1998). Because body measurements such as stature and arm reach can vary as a function of

engineering anthropometry
the measurement of physical characteristics of the human body and the development of equipment to fit those characteristics

Workspace design focuses on worker comfort and ease of use.

sex, age, and ethnic populations, certain work equipment, particularly work stations and seats, should be designed to fit the characteristics of the user. A tremendous amount of time and energy has gone into developing functional and comfortable seats for various workstations, including seats for working at computer terminals, and for automobiles and other vehicles. These seats are designed so that the operator is at the proper height and distance to operate the machine, displays are at eye level, and hand and foot controls can be easily reached. Seats are also fashioned so that operators who are seated for long periods do not experience back or leg strain.

Recent years have seen a great deal of interest in engineering anthropometry, not only in the workplace, but in homes and in schools. One interesting study looked at the effects of ergonomically designed school furniture on the comfort and attitudes of fourth graders. Although the students reported that the new furniture was more comfortable, they did not always sit in the redesigned seats properly—emphasizing the importance of combining appropriate design with instruction in how to use the equipment properly (Linton, Hellsing, Halme, & Akerstedt, 1994). Thus, not only should workspaces be designed for functional efficiency, but their characteristics must appeal psychologically to the worker (Donald, 1994). That is, the workspace should be reasonably pleasant and comfortable, with adequate space, lighting, and privacy.

Occupational Health Psychology

Industrial/organizational psychologists have long been concerned with the conditions under which people work, particularly the role that the physical work environment plays in affecting worker performance, satisfaction, and