

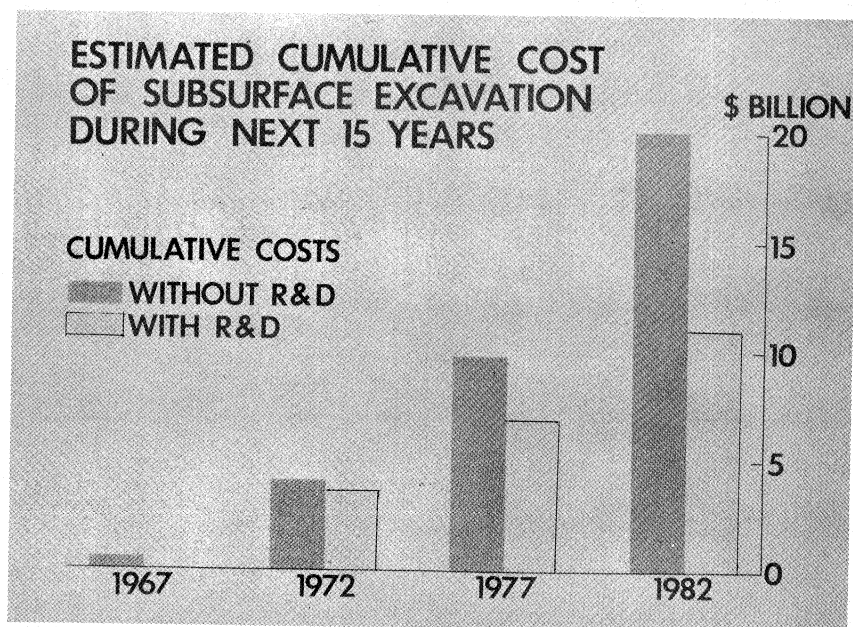


FIGURE 6

The United States is fortunate in having available today resources which, if brought to bear properly, can produce the advanced rapid-excavation technology required to meet this need. Mining research done by the Bureau of Mines and at a few of the universities is developing basic scientific knowledge, experimental procedures, and engineering techniques that will provide the springboard for accelerated progress. The strong national scientific and engineering community developed since World War II as a result of research in atomic energy, aerospace, and defense, can make major contributions to advancing excavation technology, a field to which its talents have not yet been applied. The long experience and the engineering and production know-how of the mining, construction, and equipment industries form the final element in a capability for advancement of tunneling technology far beyond anything that has ever before been available.

Among the most important of the advanced techniques available to us now, as a result of the rapid progress in science and engineering during the past 20 years, is the systems approach developed by the military to produce advanced weapons systems quickly. This approach is based on the simple and rather obvious truth that the quickest way to improve any technologic system designed to accomplish a specific task is to work toward improving all of the elements of the system simultaneously. In practice, this is not quite so simple as it sounds. The elements, or series of acts, that make up a system are usually interrelated and interdependent. Any change in one element usually affects the performance of one or more other elements of the system. The systems approach only became feasible, therefore, with the development of the high-speed digital computer, which makes possible the rapid evaluation of alternative hypothetical solutions to the problems involved in the many elements of a complex system.

The success of this approach has been amply demonstrated in the weapons systems and the aerospace technology that we now take for granted. It can do as much for us in excavation technology.

The tunneling technology we have today has evolved slowly, one step at a time, in the normal evolutionary manner. Some brilliant man with a mineral deposit to mine or a tunnel to drive had an idea that he thought would save him some effort or make him some money, and so he built a new machine. If it proved successful, others adopted it and improved it until it became a standard item of the technology. Then some later genius recognized another opportunity, perhaps made possible or even necessary by the earlier innovation, and he built