

another new machine. And so it went, as shown in figure 7 until our present bag of tools evolved.

The change in rate of improvement that can be expected with the systems approach is illustrated by the slope of the curve at the right side of figure 5. The current average rate of tunneling with mechanical boring machines is 375 feet per week. With an intensive research and development program, it is expected that the rate could be increased to 1500 feet per week in ten years. In 15 years the projected rate is 1750 feet per week. Without an accelerated research and development program, i.e. at the current low effort, the tunneling rate as shown in figure 5 is expected to be only about 800 feet per week in 15 years.

Any excavation system, whether for construction of a subway or for mining coal, involves a complex series of actions which can be grouped, according to their purposes, into four principal sub-systems—rock disintegration, materials handling, ground control and support, and environmental control. First, the rock, soil, or mineral must be broken, i.e., it must be separated from its original place in the crust of the earth. Second, it must be loaded and transported to some other location. Third, the ground around the opening must be stabilized, or supported, to prevent or control its movement. And fourth, the environment must be controlled, i.e., the influx of water and noxious or explosive gas must be prevented, and a safe livable atmosphere maintained for the workmen.

Therefore, a logical approach to the effective advancement of tunneling technology would be to conduct research on each of the subsystems according to the needs of the total system. Because of this logic, the Bureau of Mines has established its excavation research organization on a subsystem basis. During the past few years, the Bureau has been developing an in-house capability for each subsystem. It is, in fact, the only research organization in the United States that encompasses all functions of the excavation process. The professional staff comprises a diversity of disciplines including mining, civil, mechanical, electrical, electronic, hydraulic, and general engineers, physicists, geophysicists, geologists, chemists, mathematicians, computer programmers, metallurgists, and statistical theorists. These professionals, numbering approximately 300, are located at four research centers: in Denver, Colorado, Spokane, Washington, Minneapolis, Minnesota, and Pittsburgh, Pennsylvania. Their objective is to improve present technology and to provide new technology through scientific and engineering research. It was because of this capability that the Department of the Interior was selected by President Johnson to coordinate a government-wide subsurface excavation research and development that would benefit, not only mining, but any activity involving subsurface excavation.

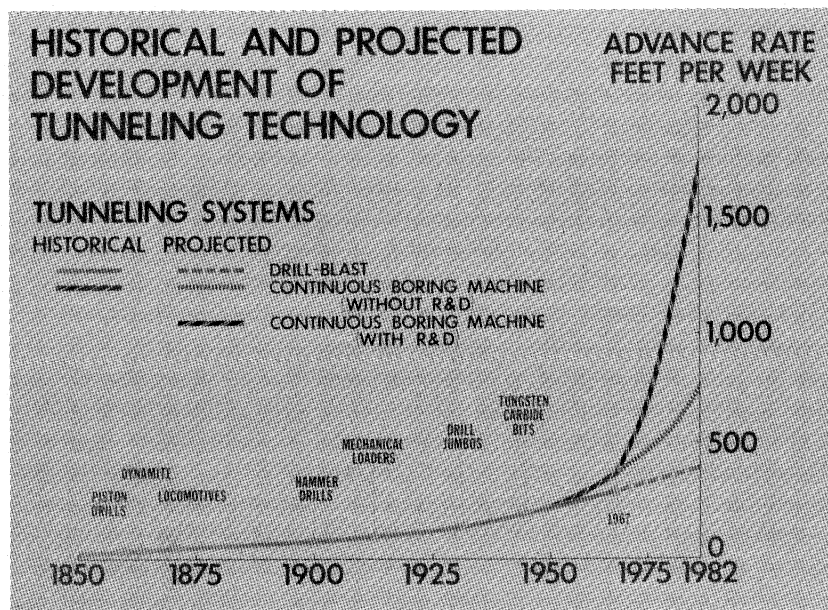


FIGURE 7