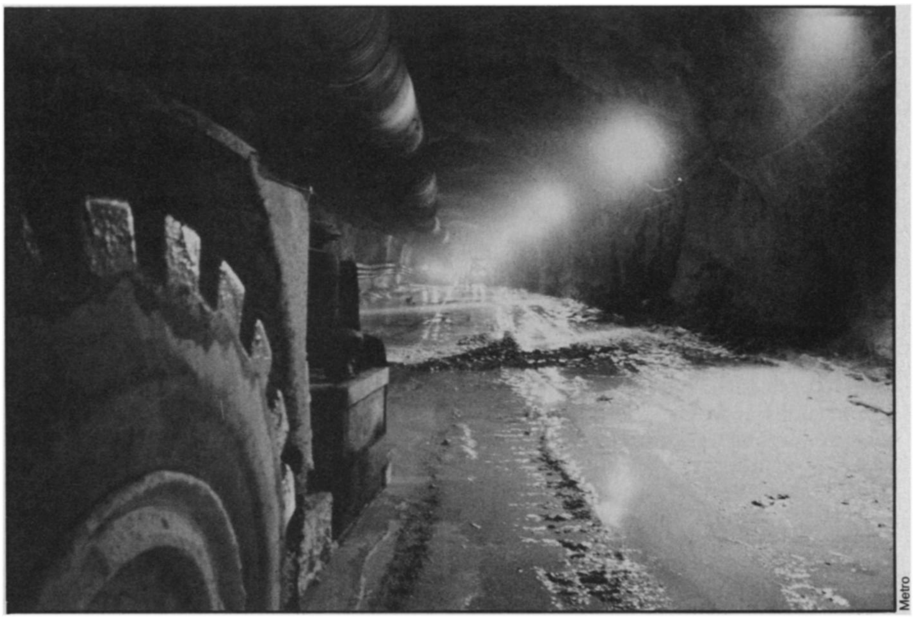
METRO: MIRACLE IN THE MUD



Even as trains begin to run, Metro construction continues—a tale of mud and rock.

Washington's new subway features everything from laser-guided excavation machines to computerized schedules for plainclothesmen

BY JOHN H. DOUGLAS

"It would not be a difficult proposition to build a subway here," said the Treasury Department's supervising architect about Washington, D.C., in 1909. "In fact, I can think of no place where it would be easier or less expensive." Hardly. Now into its seventh year of construction, using the latest modern equipment, Washington's Metro has only just opened its first 4.6-mile line (SN: 4/3/76, p. 214), out of a projected 99.8-mile system to be completed in the early 1980s. Metro is the largest urban transit system ever built under one plan at one time. At the peak, 7,300 construction workers and 2,000 planners and engineers were employed on the project. It is now expected to cost $4.67 billion, nearly double earlier estimates.

Storms, strikes, inflation and politics aside, the task has been anything but the technically easy project forecast in 1909. As congested surface traffic has tried to negotiate torn-up streets, construction workers down below have had to work their way through the sewery remains of Tiber Creek—the stream that in the early days could isolate the Capitol from the White House at high water. Further downtown, an expensive piece of earth-drilling equipment had to be abandoned when it became wedged in an unexpected outcropping of rock. And "Foggy Bottom" Metro station will memorialize the swamp whose muck still underlies a large portion of the capital, making excavation difficult.

Construction on such a grand scale is still a grimy, dangerous business despite some amazing new mechanical aids. While sweating men strain to remove the rubble, a giant tunnel-boring machine called a "mole" follows a laser beam as it grinds through solid rock. A rotating 19-foot-diameter cutting head mounted with 45 grinding disks (weighing 300 pounds each) tears away at the rock face, reducing it to small chips. When outside interruptions could be kept to a minimum, the mole and its human support crew could average 90 to 100 feet a day for months at a time through the solid foundation that underlies much of Northwest Washington, in the well-named Rock Creek area.

Closer to the Potomac River, the going gets tougher, as workmen must shore up crumbly earthen tunnel walls and constantly pump mud and water from the old swamp bed. Here a machine affectionately called the "cookie cutter" represents the latest technological method of the tunnel-shield method of drilling. As the name implies, a circular cutting edge is jacked into the soil ahead of the machine, much as a kitchen cookie cutter pushes through dough. Metal shields are then installed to prevent collapse. Progress is usually limited to about 50 feet a day, and if an unexpected outcropping of bedrock is encountered, the cutting rim can become wedged so tightly it must be abandoned, as happened recently under Lafayette Square.

Such techniques are becoming more commonplace in mining and construction, but a novel way of casting the graceful arches of Metro stations is so far unique. Each structure is cast in place using a steel form mounted on tracks, which expands to receive concrete for a narrow strip of the long arch, then retracts and moves forward after each strip has set. Bathtub-like indentations along the arches reduce the weight of the structure, increase its strength and improve the acoustics. The steel form allows a two-coffer-wide strip at a time to be cast. The final result—attractive, quiet stations with an open, airy quality—must be considered Metro's chief contribution to modern urban architecture.

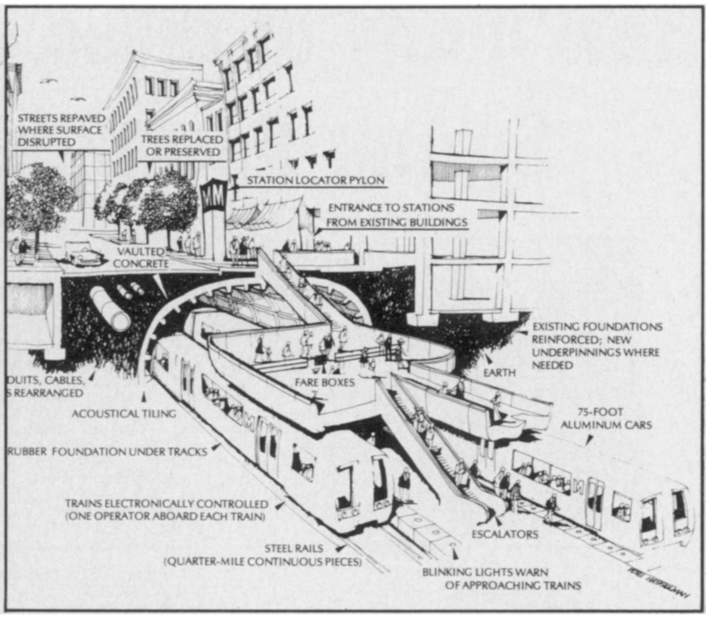
Aside from architecture, when urban planners discuss ways of improving city life, they talk perhaps most often of new ways to integrate communication and transportation (SN: 10/19/74, p. 246). One aspect of these discussions focuses on how inhabitants of the "wired city" will not have to travel as much because they can conduct their business by picture-phone and hard-copy transmission. The other aspect involves the use of communication and control—especially through computers—to make the transfer of passengers and goods more convenient (SN: 10/4/75, p. 220). Because it has been planned as a complete system, all at once, Metro represents a unique experiment in the marriage of transportation and communication.

Like BART in California, Metro trains are completely computer controlled. Boredom, in fact, may become a major problem for train operators. Nerve center for the complex system resides at Metro headquarters, in a room of subdued electronic frenzy. Here two digital computers are in contact with every train in the system at all times, and an Automatic Train Control System fulfills the three separate functions of train supervision, operation and protection.

First a supervisory plan is made and updated, scheduling the arrival, departure and running speeds of all trains. Next, the appropriate operating signals are transmitted to the control booth of each train, where an operator keeps an eye on things, more or less passively. Finally, as the orders are being carried out, a separate "protection" system independently monitors operations to make sure no accidents occur. This backup system supposedly assures that nothing—neither the computer-generated instructions, nor the operator on the train, nor the supervisor in the control room—can cause two trains to collide or make a train exceed its safe speed limit.

While the train operator sits and watches the lights blink and hopes people don't blame him for the doors not closing

Metro



Peter Hasselman for the Washington Post

Away from the city center (left), trains will meet suburban commuters; downtown, spacious, quiet stations await them.

Metro

Supervisors monitor systems operations.

(as they didn't at times on opening day), train control supervisors back at headquarters will have their hands full. Whenever anything goes wrong in the whole system—from a faulty fan in the Farragut North station to a robbery in progress at the Crystal City station, across the Potomac River in Virginia—an alarm will flash on one of eight CRT screens with a computerized message to the effect, "Here are your options, it's up to you now, fella."

Metro officials claim their communications and control system "set a new level of sophistication among train systems worldwide." When a supervisor decides what to do about the options presented to him in an emergency by the computer, for example, he maps out a strategy on the CRT screen, pushes a button marked EXECUTE, and waits. The computer sends its set of instructions to the train via a "leaky line" radio antenna system, using partially shielded cables that hold down outside interference while allowing a signal to "leak out" for reception by a radio receiver on a train.

Suppose now that something is broken on the train so that it cannot respond to the supervisor's command, interpreted by the computer. The supervisor can then talk directly with the train operator, announce to the passengers stuck in the tunnel that they will have to wait a bit, announce to the passengers waiting in the next station that they will also be delayed, and call emergency repair crews along the track to go to the stricken train. If, as a last resort, the passengers should have to be evacuated, he could also call security patrols, through their portable radios, to help out. (Metro will eventually have one of the world's largest private telephone exchanges, using a sophisticated technique called "line applique," which allows maintenance and security crews in tunnels to preempt communication lines for localized party use or emergency outside calls.)

The result of all this sophisticated equipment should be an unprecedented quality of integration of all Metro functions—scheduling normal service, providing maintenance, ensuring security. Computer coordination began even before the trains started running, in the design of escalators to handle crowds predicted for a decade in the future, one of the first times such modeling techniques have been used for planning a transit system. (In 1990, one million passengers a day are expected to ride Metro.) Next year, Metro will be integrated into an even more comprehensive transportation system as bus routes and schedules are coordinated with those of the trains.

Although the average passenger will, of course, miss out on all this behind-the scenes wizardry, one cannot fail to notice the quiet comfort and attractiveness of Metro's new cars—particularly if one is used to New York subway trains with their ear-piercing shriek on curves, seats created more for indestructibility than comfort, and spray-painted obscenities that chronicle the passage of succeeding generations of "artists." Whether Metro's electronic surveillance will forestall graffitti remains to be seen, but the cars appear at present to live up to the early claims that they would meet the "most stringent noise and vibration standards in the industry." At a cost of more than $400,000 apiece, they should. Rohr Industries made the 75-foot-long cars based on its aerospace experience, creating a shell that bears and distributes the weight like that of an airplane, rather than using a rigid frame like conventional railcars.

Each car has an operator's cubicle at one end and sets of two cars are joined together at the other end to form semipermanent "married pairs." These self-propelled pairs can reach speeds up to 75 miles per hour and it is hoped that average speeds, including stops, can top 35 miles per hour. For rush hours, several married pairs of cars will be strung together to form trains up to 600 feet long—the length of each station platform.

Car floors are carpeted; seats, heavily padded; and the whole car is suspended on air cushions. On sections of the line above ground, passengers will be able to watch the view through large tinted-glass windows. Each car will seat 81 persons, and hold 94 standing. Space between the cars and a station platform will be small enough to allow wheelchairs to pass easily, and stations will have elevators for use by the handicapped.

In any large city, security in a subway can be a major problem. Metro, at least, has the advantage of being able to design stations, trains and entrances with security in mind. In stations, an attendant in a glassed-in kiosk commands a view of the entire platform area by means of closed circuit television. The open-arch construction practically eliminates hiding places, and restrooms are for use only in an emergency. At present, all fares must

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safety and waste disposal, Teller says, and too many fears raised about them. He says there are at least four good ways of disposing of nuclear waste (burial in salt mines, storage in concrete bunkers, sinking in the ocean floor, or use for other purposes); we just have to pick one. He likens our trouble to that of Buridan's ass, which starved to death between two bales of hay because it couldn't decide which it wanted. "Only in this case there are four asses, NRC, ERDA, EPA and CEQ, and they must all go to one bundle."

Teller cares even less for more exotic energy suggestions. The use of thermal gradients in ocean water to generate energy, he feels, is not promising. The method is only about 7 percent efficient thermodynamically, and from an engineering standpoint only 3 percent efficient. Use of wind power might be practical in places where there are steady winds, such as Hawaii, where the trade winds blow. But Teller says that when he thought he was finally getting past the environmentalists by proposing windmills for Hawaii, "they started to talk about visual pollution."

Today's big problem is energy, Teller concludes, but that of the next few decades will be food. He sees the ocean as the main possible source of additional food. "The study and exploration of the oceans deserve great emphasis," he says, "but nothing can happen without science and technology."

—*Dietrick E. Thomsen*

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be paid in exact change (which can get confusing, for the amount varies depending on the time of day). Eventually, magnetic-strip fare cards will eliminate most of the need for carrying cash entirely.

Aboard trains, a two-way communication box linked to the operator replaces the conventional emergency pull-cord. Uniformed officers and plainclothesmen will patrol trains and stations in random patterns. To make sure their patrol patterns are not leaked to criminals or figured out by them, each officer will receive his personalized daily schedule directly from the computer. Should a mugging occur, communication with police on the surface would be almost instantaneous, and the robber could be slowed down by activation of a locking device on the exit turnstiles. Since no shops, concessions or other facilities will be allowed in stations, there will be almost no place to run to or loiter inconspicuously.

Modern as it is, there is some question as to whether Metro is the latest in a new breed of modern integrated transit systems to revitalize city life or the last of an expensive race of technological dinosaurs that will be replaced by some completely different concept of urban transportation. Its very grandness of scale should ensure its place as a crucial test case. □