The Big Dig

Fed up with notoriously bad traffic and the pollution and noise that go with it, Boston is hiding its highways underground—but what will it take to keep subterranean travelers safe?

BY SIMSON L. GARFINKEL

WHEN PRESIDENT DWIGHT D. Eisenhower signed the Federal Highway System legislation in 1956, he couldn't possibly have envisioned the behemoth construction project that is now being undertaken in Boston to complete the system. Government officials call it the Central Artery/Tunnel (CA/T) Project; locals just say "the Big Dig." By the time it's finished in 2004, this roadway will boast a segment eight lanes wide, 3.5 miles long, completely buried beneath the bustling financial district of one of the nation's oldest cities. The new tunnel will replace Boston's much-maligned Central Artery—a dilapidated steel viaduct that cuts between downtown high-rises—with a stretch of the world's largest underground highway. An underwater tunnel (completed in 1995) will feed traffic from the airport into the artery, all for the unprecedented cost of more than $10 billion.

Although burying the highway promises to leave an improved environment for Boston's surface dwellers—cleaner, quieter, more open—it raises the stakes for subterranean travelers. Traffic jams and flat tires, merely annoying above ground, can turn deadly below if motorists are trapped in a haze of toxic exhaust fumes. Add to the mix a car fire or an oil tanker explosion and the situation could become dire. So Big Dig engineers are pioneering new technologies in construction, traffic management, and fire control, all designed to keep life flowing smoothly and safely through the artery.

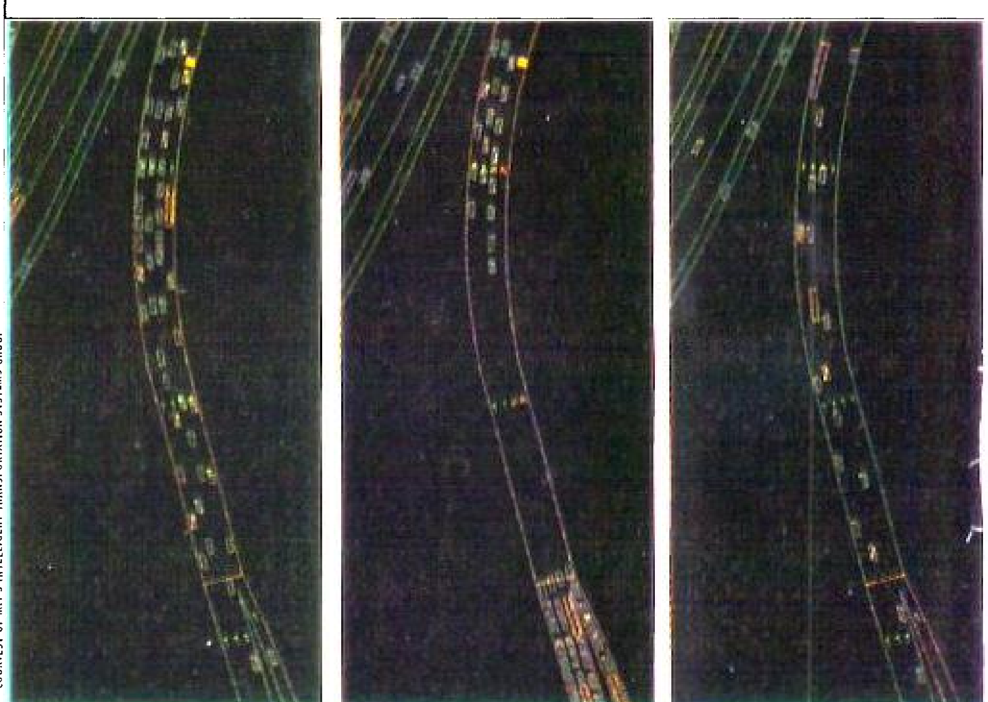
The Brains behind the Operation

BEYOND LAYING STEEL AND POURING CONCRETE, Big Dig crews are deploying hundreds of closed-circuit television cameras, infrared sensors, and variable message signs throughout the system, wiring it together with a computer system that can withstand a terrorist attack, and building a command center so filled with screens, keyboards, and projection devices that it would make Darth Vader green with envy. It's all part of the Central Artery/Tunnel "Smart Highway," or Intelligent Transportation System.

Working in the "Star Wars" control center, the CA/T's half-dozen human operators will strive to maximize traffic flow and minimize motorists' exposure to carbon monoxide. The tools at their disposal will include traffic lights, speed limit signs, lane closure signals, AM and FM radio transmitters, ventilation equipment, even sewage pumps.

The CA/T's computers will constantly monitor the flow of traffic through the system. If there is a sudden interruption—say the traffic in a lane drops from 60 to 5 mph—the computer will automatically swing a camera to point at the area in question. The computer can calculate the severity of the incident, designate an appropriate human operator to handle it (based on his or her training and current

UNDER CONTROL: A computer simulation can model common traffic situations. In the first panel, a car has just broken down in the tunnel (indicated by a red square in the top center). In the second, operators respond by closing lanes (yellow Xs) and the entrance to the tunnel (red line). The CA/T managers' goal is to have the incident cleared and traffic flow restored in a mere 15 minutes (last panel).



COURTESY OF MIT'S INTELLIGENT TRANSPORTATION SYSTEMS GROUP

PHOTOGRAPHS BY ANDY RYAN

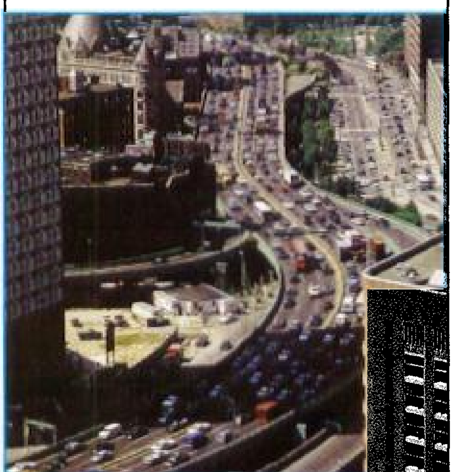
COMPOUND EYE: Operators in the "Star Wars" control center (above) can see every inch of the CA/T system. Along the highway 500 cameras feed images to a wall of monitors; when the computer detects a problem, it switches the video image to an operator's desktop monitor. The operator can alert drivers to lane closings and speed limit changes using variable message signs (below).

assignments), and make the video imag appear at the operator's console. The the computer will recommend a strate gy for handling the situation, but leav the final decision to the human, who ca change lights, adjust ventilation equip ment, or send messages to drivers, all t prevent a minor fender-bender fro becoming a major catastrophe.

But what should an operator actu ally do in an emergency? Close lane Slow traffic? Divert traffic? And how lon should lanes stay closed? To answer the questions, the Massachusetts Highwa Department contracted with MIT Intelligent Transportation Systems grou (http://its.mit.edu/) to build a advanced computer simulation th models up to 10,000 vehicles movin through ramps and tunnels.

"We simulate the drivers' decision such as acceleration, deceleration, lan changing, merging, and yielding," say professor Moshe Ben-Akiva, who direc the MIT group. "We can simulate inc dents by blocking lanes for a certain duration. We can simulate changes in visibility conditions." The system can even determine the effect of closing exits or adding new ones.

Along with the traffic simulator, the MIT group has built a second simulator that models the CA/T's human operators and traffic management system. This lets the researchers see the effect that different traffic management strategies will have on the ebb and flow of traffic inside the tunnel. When there is an accident inside the tunnel, for example, the portal lights on the freeway immediately turn from green to red to prevent more cars from entering. Using the simulator, the researchers calculated how long the operators should wait after the accident is cleared before the portal lights are turned from red back to green. "The original plans to change the portal lights to green immediately was not a good idea," says Ben-Akiva. "You should delay the change until you let the traffic inside clear out. Otherwise, you generate shock waves of traffic inside the tunnel."



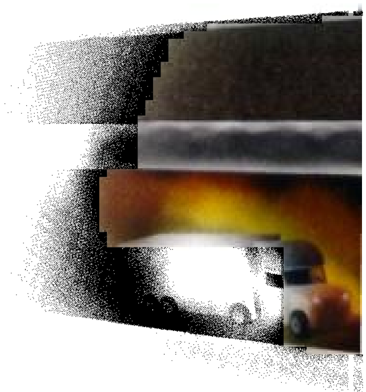
ARTERIAL BYPASS: Big Dig contractors are tearing down the elevated artery (above) and tearing up the urban landscape (below) to make way the new tunnel.

Fire in the Mountains

IF CA/T DESIGNERS AND OPERATORS GOT some surprises when they began simulating traffic flow, they got even bigger shocks when they began to look into another problem: how to protect a tunnel and its occupants from the ravages of fire. It wasn't just the threat of direct burns that they were worried about. In fact, "Smoke and heat are the real killers in a fire," says Richard W. Drake, operations manager for the Central Artery/Tunnel Project.

For years, explains Drake, engineers around the world have been building automobile tunnels with ventilation equipment large enough to handle the smoke from the biggest fire conceivable. But they had no way of knowing how their conceptions of fire would match a real blaze. Though tunnel fires—such as the one that broke out in 1996 in the Channel Tunnel that connects the U.K. and France—capture international media attention, none has burned under the watchful eye of high-speed scientific instruments. So engineers have always based their fireproofing designs on theoretical models, not hard data.

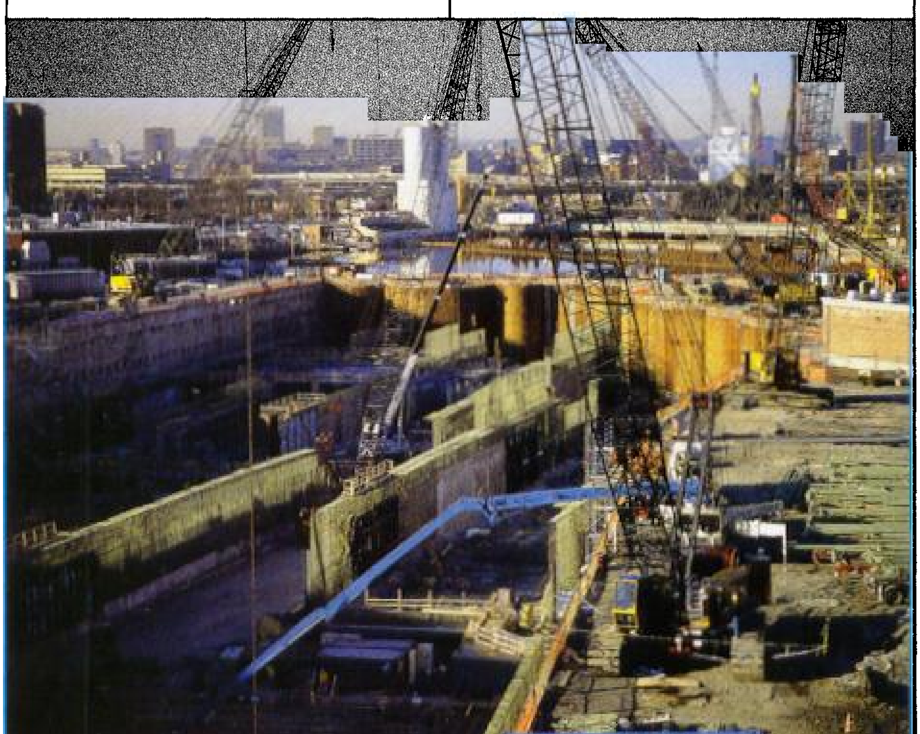
FANNING THE FLAMES: Should fire break out underground, motorists' lives will depend upon seven mammoth ventilation buildings perched above the tunnel. Each structure will house 18-foot fans that draw fresh air in through the louvered sides of the building and pull smoke and fumes out of the tunnel. A series of experimental fires in an abandoned tunnel in West Virginia taught Big Dig engineers how best to operate fans during a blaze, allowing occupants to breathe without feeding the flames.

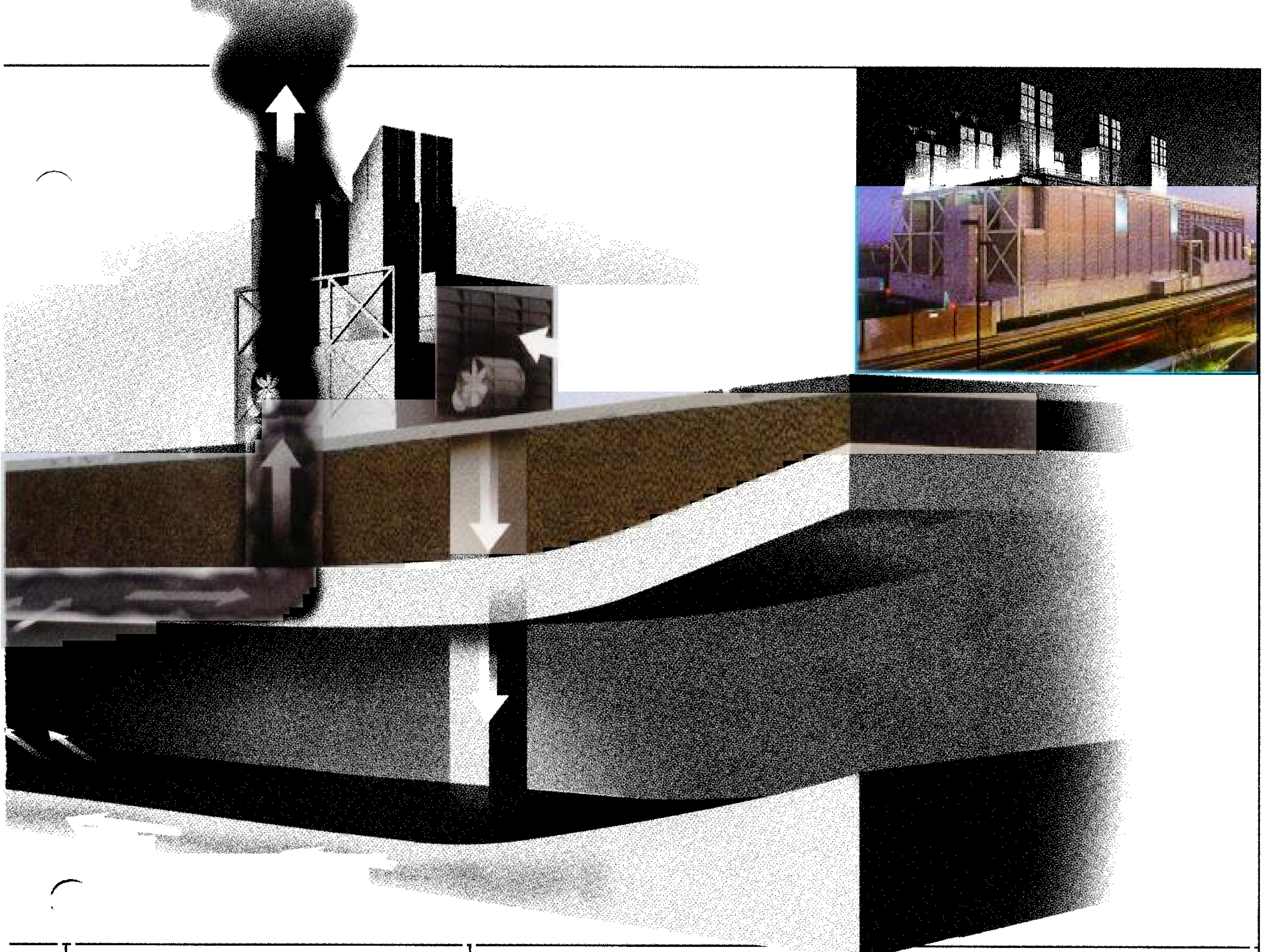


Uncomfortable with this uncertainty, engineers have for decades over-built their projects, adding more ventilation equipment, insulation, and structural support than they thought necessary—just in case their models underestimated the heat and smoke a tunnel fire could produce.

What engineers needed was a test bed—an experimental system for tunnel fires. And in the early 1980s, the Federal Highway Administration (FHA) came up with one, re-routing a section of I74 in a way that left an empty 1.1-mile tunnel in the hills of West Virginia. There the FHA teamed up with Parsons Brinckerhoff, one of Big Dig's primary contractors, to perform a series of full-scale burns that would finally put the theories about tunnel fires to the test.

The team spent $10 million renovating the abandoned tunnel with a state-of-the-art ventilation system and another $10





million installing sophisticated monitoring instruments. "We outfitted the tunnel on a grid system so you could collect data on temperature, air flow, and carbon monoxide throughout the tunnel," says Drake, who supervised the project.

In the middle of the abandoned tunnel the engineers built large steel pans measuring more than 10 feet on a side. They filled the pans with 6 inches of water (to protect the steel from the heat) and then an inch of fuel oil. A remote-controlled propane burner ignited the fuel.

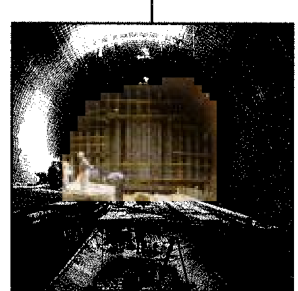
Ultimately, Drake supervised 101 burns. The smallest was 10 megawatts (MW), simulating a small car bursting into flames. The largest was 100 MW—approximately the power released when a small gasoline tanker has a head-on collision with a truck.

"If you want to see what Hell looks like, we'll show you a picture of a 100-megawatt fire," says Drake. "It is absolutely astounding to see tiles blown off the wall. The asphalt and tar expansion joints bubble."

To the team's amazement, the tunnel and the ventilation equipment held up far better through these holocausts than the models had predicted. "Nobody thought we would ever get this number of fires off. They thought the tunnel would collapse long before we were done with it," says Drake.

The resilience of the tunnel in West Virginia pointed toward a staggering conclusion: Worldwide, billions of dollars had been wasted making tunnels more fire resistant than was ever needed.

Although the results came too late to allow for a complete Big Dig redesign, Drake has still been able to save tens of millions of dollars in concrete and excavation costs by shrinking some ventilation shafts and eliminating others. "We saved about $25 million on this project in insulation costs alone," says Drake. "We are very confident that we can show you $45 million in savings overall."



More important, the tests have taught engineers how to "tune" the CA/T's ventilation system. In the event of a fire, says Drake, conventional wisdom had always held that fans supplying fresh air to tunnel regions adjacent to the flames should be set at roughly 50 percent of capacity. It was an attempt to strike a delicate balance: "You don't want to feed fresh air" to the fire, explains Drake, but you don't want people trapped in their cars to suffocate either.

Again, conventional wisdom was wrong. The West Virginia experiments showed that it is better to turn the nearby supply fans way down during a fire—to just 10 percent or 20 percent of capacity. At these reduced settings, the tests prove, the ventilation system will still provide enough fresh air for trapped motorists, and it won't fan the flames as high. It's a strategic adjustment that might seem minor, but with a quarter of a million vehicles expected to negotiate the tunnel each day by 2010, its impact could prove enormous. TR

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