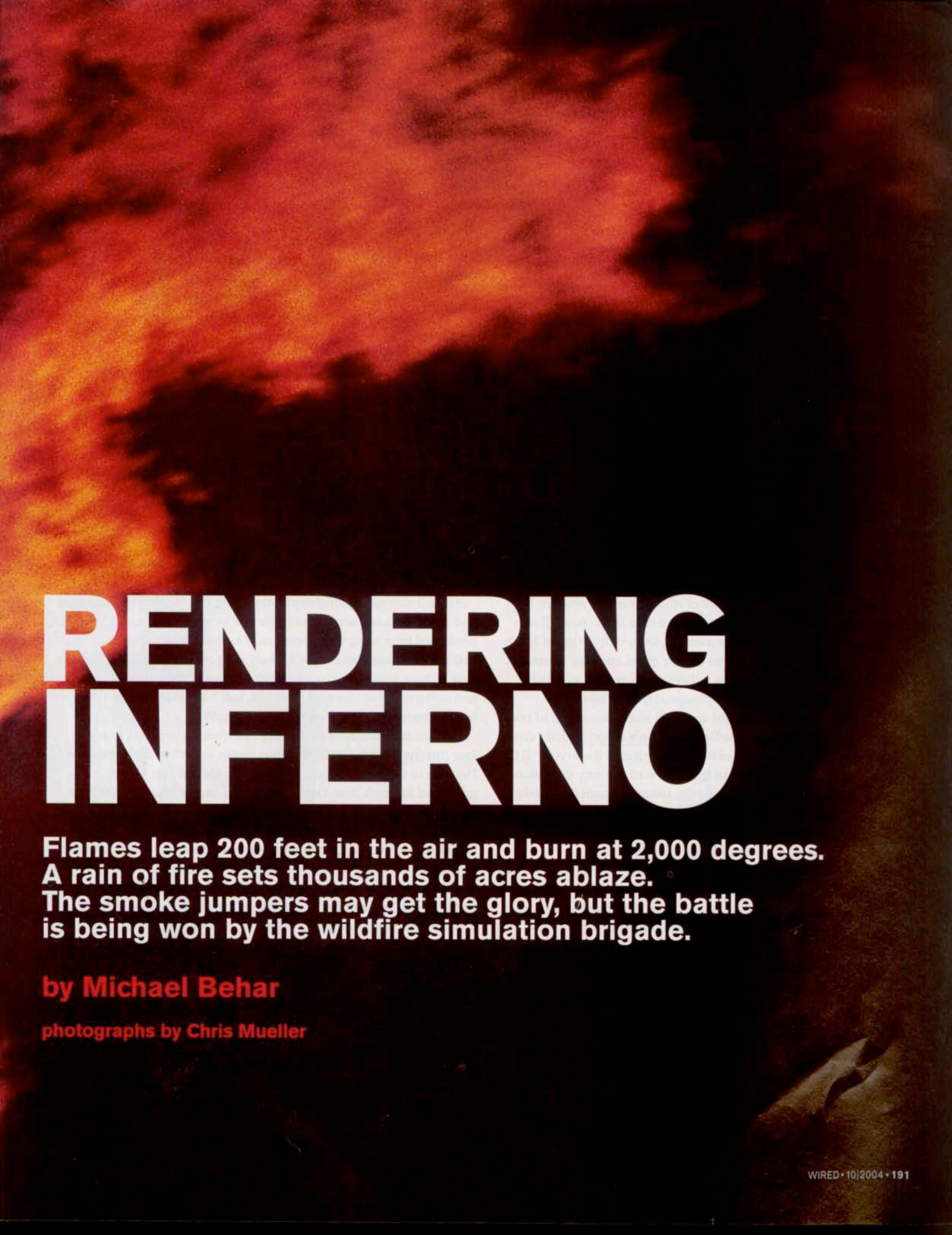
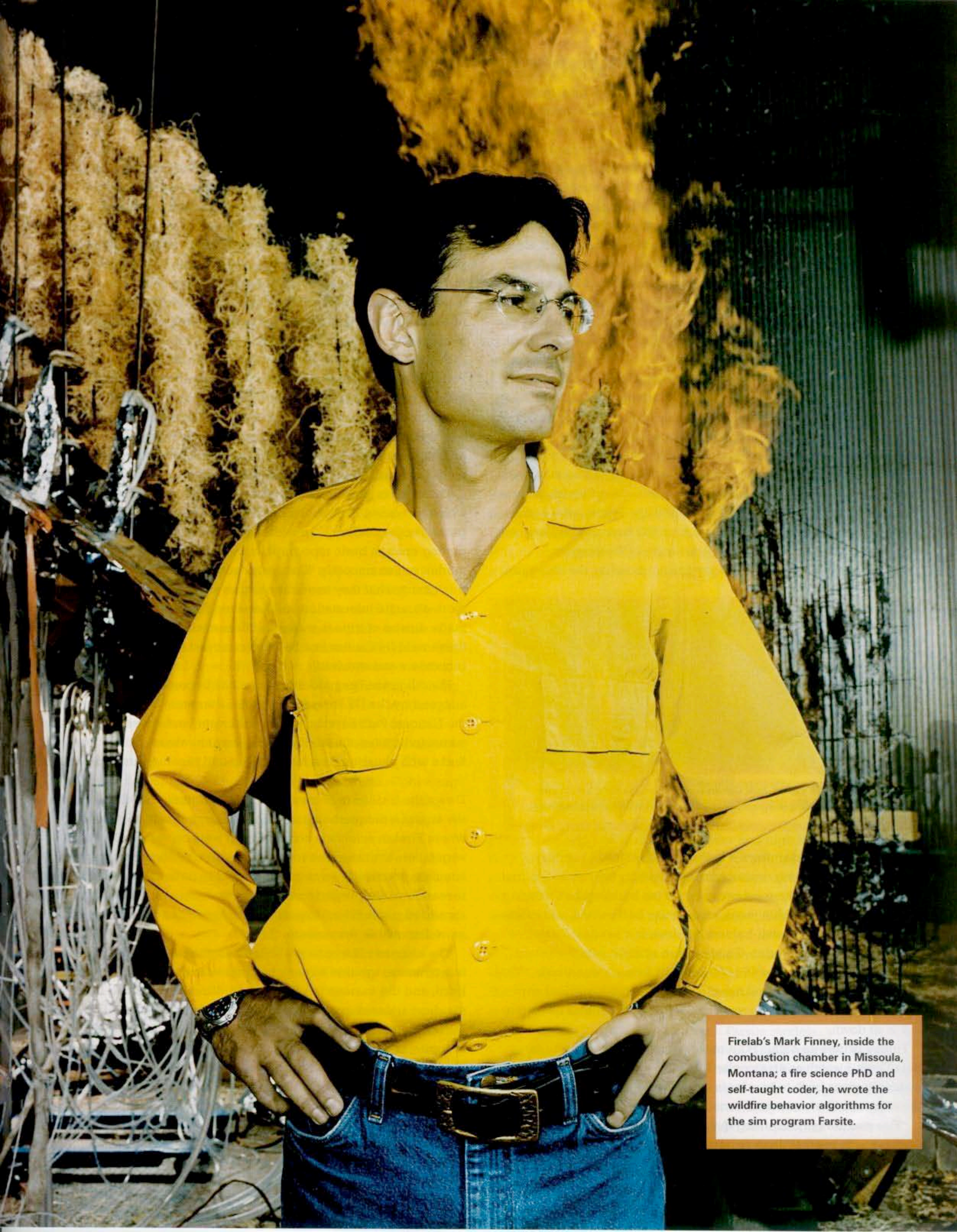


RENDERING INFERNO

Flames leap 200 feet in the air and burn at 2,000 degrees. A rain of fire sets thousands of acres ablaze. The smoke jumpers may get the glory, but the battle is being won by the wildfire simulation brigade.

by Michael Behar

photographs by Chris Mueller



Firelab's Mark Finney, inside the combustion chamber in Missoula, Montana; a fire science PhD and self-taught coder, he wrote the wildfire behavior algorithms for the sim program Farsite.

Wildfire experts mark the beginning of fire science with a single event: the Mann Gulch fire. It was spotted at 12:25 pm on August 5, 1949, in the Gates of the Mountains Wilderness about 20 miles north of Helena, Montana. Around 4 pm, 18 smoke jumpers were air-dropped just ahead of the flames. By 6 pm, 13 of them were dead. The death toll was unprecedented. Victims' families and the heads of federal and state forestry agencies demanded to know how an elite team could have been overrun so quickly by flames.

The controversy made its way to Congress, which allocated funds to establish the nation's first wildfire research center. In 1960, the Fire Sciences Lab, nicknamed Firelab, opened for business. A year later, Richard Rothermel, a weapons engineer for the Air Force and later a designer for Douglas Aircraft, came to the center and pioneered fire behavior research. "In the first 10 years, we were trying to learn everything from scratch," says Rothermel, now 75, who still lives in Missoula. "We spent a lot of time just figuring out how to conduct fire experiments and how we could use the data to construct models." In 1976, Firelab mathematician and mechanical engineer Frank Albini formulated graphical models, called nomograms, to determine a blaze's rate of spread and intensity.

Firelab, the world's largest institute dedicated to the study of wildfires, occupies a two-story building at the end of a service road behind the blink-and-you'll-miss-it Missoula airport. The lab is something of an MIT for pyros, staffed with PhDs like Finney, who earned his doctorate in wildland fire science from UC Berkeley and holds a master's in fire ecology from the University of Washington.

When I arrive one cool and soggy spring morning, the reception area is empty. I wander down a hallway clad in floor-to-ceiling wood paneling, passing researchers chitchatting over coffee, to find Finney at his desk. Like most everyone in the building, he's wearing a western-style shirt, blue jeans, an oversize belt buckle, and cross-trainers. Taped to the wall behind his desk is a Landsat 7 satellite snapshot of the epic Rodeo-Chediski fire of 2002, which torched more than 450 homes and 469,000 acres of Arizona woodlands. "That was a big-ass fire," he declares, clearing off a chair stacked with research reports and back issues of *Wildfire* magazine as he invites me to sit down.

Structure ignition expert Jack Cohen torches houses for a living; one result is his modeling program, SIAM, that helps flame-proof buildings.

Finney brings up on his PC a replay of a Farsite simulation for Beta-Doris. I watch as an amoeba-like blob engulfs the terrain, then suddenly gives birth to hundreds of flickering specks that zip across the reservoir like a swarm of crazed fireflies.

"Fire was always something that caught my eye," he says. "It was fascinating to me that there was so much unknown about it." Finney, a Colorado native who was born and raised in Golden, spent his summers hiking and camping throughout the Rockies. During college, he joined a firefighting team with the US Bureau of Land Management. The work was backbreaking and often totally ineffective. In 1988, after a fire in Yellowstone devastated 800,000 acres of the country's oldest national park, he says, "the Park Service was under criticism for not having any tool for making projections about where fires would go and what the consequences were of letting them burn."

From his experience in the field, Finney knew all too well the folly of trying to put out every blaze. When wildfires are continually suppressed, the undergrowth proliferates, leaving a tinderbox ecology that creates ideal conditions for hugely destructive infernos. "Fire is not a bad thing," says Finney. "It is a misunderstood phenomenon of our wildlands. Our ignorance is what leads to our inability to manage it."

In 1991, Finney took a job as a fire researcher for Sequoia National Park in California and began teaching himself computer programming in his spare time. Soon he was writing code to run fire behavior algorithms based on the models developed by Rothermel and Albini.

"I learned as I went," says Finney. "Computers were becoming faster and more available to fire managers. Spatial data and graphical information systems were becoming integrated into land management."

Three years later, Finney got the chance to test his new program, which he named Farsite, on fires in Yosemite and Glacier national parks. Farsite performed reasonably well. But there were problems getting enough basic topographic, weather, and fuel data to allow the models to run smoothly. "Data sets contain errors," he says. "And you don't know what they are until you start working with them." To gather more accurate information and fine-tune Farsite's algorithms, Finney made dozens of trips to major wildfires over the past 10 years. "Sometimes we'd fly the fire in a helicopter or just sit up on a rock with binoculars and watch it."

His diligence has paid off: Farsite has become indispensable, adopted by the US Forest Service, the Bureau of Land Management, the National Park Service, and several state land agencies. Visit the command center of a wildfire under way anywhere in the US and you'll find a tech plugging data into a laptop and running Farsite models.

Down the hall from Finney's office is a concrete-lined room about the size of a racquetball court. This is the combustion chamber, where Firelab scientists conduct burn tests on various kinds of vegetation, tweaking the room's humidity and temperature to simulate practically any scenario found in nature. When I stop by, researchers are preparing to ignite Ponderosa pine needles and shredded poplar in an experiment to learn why some trees are more flammable than others.

The chamber is where you'll find Jack Cohen. The former hotshot is a structure ignition expert; he studies how and why buildings burn, and the curious tendency of wildfires to gut some homes in a residential development while leaving others unscathed. "We know these houses don't suddenly disintegrate," says Cohen. "They have to ignite and burn. That means there have to be requirements for combustion. What we want to know is how those requirements are being met."

To better understand what might happen if a raging inferno tears through a community on the outskirts of Los Angeles or ravages the hills east of Oakland, Cohen thought it would be a good idea to erect

It was one of the worst years for wildfires in Montana's history: In 2003, more than 2,300 fires torched three-quarters of a million acres – nearly 20 percent of the total burned by wildfires across the US. The western part of the state was hardest hit, especially in late August, when multiple blazes devoured tens of thousands of acres of pristine Rocky Mountain wilderness. Some 2,000 firefighters were deployed throughout the region, as well as nearly every available fire engine, bulldozer, helicopter, and water-tanker plane. Local commanders were flying wildfire specialists in from around the country.

"We had more fire than we could manage and were out of aces, so they started relying on old, beat-up people like me," recalls Dave Bunnell, a retired wildfire expert who spends summers at his cabin near Ronan, Montana.

Shortly after Bunnell arrived at a command center in Kalispell, two more blazes erupted when lightning struck near Beta Lake and Doris Ridge. (Lightning triggers 90 percent of wildfires in the western US. In the east, it's just 10 percent; arsonists take care of the rest.) These fires, dubbed Beta-Doris after they merged, were only 20 miles southwest of Glacier National Park, where on any given summer afternoon about 10,000 people are roaming a million acres, ogling ice-clad peaks, soaring waterfalls, and the occasional grizzly bear.

"The fire making a run to Glacier was well within the realm of possibility," says Bunnell. Worse, Beta-Doris was on a ridge directly above a power station at the north end of the Hungry Horse Reservoir. "If the station went out, we could have had brownouts all the way to Portland." And just beyond the power station lay the town of Martin City. Making the wrong choice about where to deploy the few remaining fire crews could be disastrous. But where would Beta-Doris go? Toward the power station? The town? Or some other direction?

Predicting the path of wildfires has long been a notoriously difficult task because they continually react to an infinite mix of ever-changing conditions. Wind speed, varying terrain, and differing vegetation, for instance, can all influence how fast and furiously a fire burns. Big gusts can drive flames 200 feet into the air and fan fires that wipe out thousands of acres of timber within minutes. Temperatures can reach 2,000 degrees, roughly that of molten lava. The heat creates violent updrafts that loft thousands of golf ball-sized embers, called firebrands, hundreds of feet high, raining a fiery hell onto ground crews and igniting dozens of new fires. The conventional strategy for containing these kinds of big blazes – besides praying for rain – has been brute force. Ground crews, called hotshots, dig trenches and clear vegetation to create "fuel breaks" in the path of approaching flames. Firefighters also rely on tanker planes that drop thousands of gallons of water and chemical retardant. Yet the intense heat and speed of a big blaze can overwhelm almost any attempt to stop it.

Hotshots and tanker planes still play a vital role in battling wildfires, but the overall firefighting strategy – the where, when, and how many – is increasingly being left to computers. Consider a simulation program called Farsite (short for Fire Area Simulator). Created by Mark Finney, a researcher at the US Department of Agriculture's Fire Sciences Lab in Missoula, Montana, Farsite can can crunch more than a dozen variables – including wind, air temperature, humidity, altitude, terrain, and vegetation – and in a few minutes spit out 3-D animations that chart the most probable path of a wildfire.

Like the other commanders, Bunnell assumed the Beta-Doris fire would move northwest – away from Martin City. That's because the reservoir placed a big, wet barrier between the fire's northeast perimeter and the town. But he called Finney for a second opinion.

Finney, too, thought the reservoir would stop the flames. Yet when he crunched the data, Farsite predicted a surprisingly different scenario: Beta-Doris would catapult firebrands half a mile across the reservoir and ignite spot fires along the opposite shore. If unchecked, these could overrun Martin City and make a beeline toward Glacier.

There must be an error, thought Finney. Just to be sure, he ran the simulations twice more. The results were the same.

Bunnell was apprehensive about pulling crews from the existing fire and sending them across the reservoir to wait for an unlikely result predicted by a computer program. If he bet wrong, there would be hell to pay – Beta-Doris would likely take out the power station. He took a deep breath, and put his faith in Farsite: "I go to area command and make my play," he says. "I'm old, half bald, people don't remember me very well. And they're wondering, Who is this guy?"

The fire commanders eventually relented and agreed to send four fire trucks and six 20-member crews armed with shovels and Pulaskis to the reservoir's eastern shore. Meanwhile, Finney had uploaded Farsite's Beta-Doris model to a server that wildfire managers could access from the command center. They sent up an aircraft with infrared mapping capabilities that could see through the fire's smoky cloak and track its movement. To everyone's amazement, at 6 pm the next day a sudden wind squall lobbed firebrands across the reservoir. Thanks to Finney and Farsite, crews on the other side were already in position. As spot fires flared up, teams methodically attacked each one, snuffing them out before any torched more than a few acres.

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Suddenly the wind lobbed firebrands across the reservoir. Just as Farsite predicted.

The lab has become a kind of MIT for pyros. And for firefighters, its work is indispensable.

a couple of prefab garage kits in the path of a wildfire. In 1997, he traveled to a remote area of Canada's Northwest Territories and assembled the kits in a clearing along the edge of a timber stand that he would later ignite. "They were 25- by 25-foot garage packages with 9-foot ceilings," he says. "Like something you'd find at Home Depot." To compare how different materials react to intense heat and flames, Cohen added vinyl and cedar siding and composite shingles onto each structure. He swapped out the garage doors for standard front entries and added double-pane plate-glass windows.

Cohen continued these experiments for the next three summers. He tested whether smoldering pine needles ignited composite shingles; the temperature at which plate-glass windows would shatter; how quickly flames melted vinyl siding. "I lit a small pile of twigs on the vinyl side and another on the cedar side and basically watched the response," he says. He also determined at what distance a wood structure would burst into flames solely from exposure to heat. "I wanted to know how close is close enough for a house to combust without a spark directly igniting the structure." Close enough turned out to be about 60 feet.

Cohen is compiling the results of his work into a modeling program called SIAM (Structure Ignition Assessment Model) that will help builders produce structures less prone to catch fire. The program takes into account home dimensions, number and size of windows and doors, construction materials, location and types of surrounding vegetation, and proximity to other homes, then generates recommendations. These might include redesigning a deck or using specific types of fire-resistant siding. Astronomers at the Mt. Graham International Observatory in southeast Arizona recently consulted Cohen on how to protect their telescope from wildfires. "The observatory is sitting on top of a 10,720-foot-tall mountain in the middle of a spruce forest," he explains. Based on SIAM's calculations, Cohen suggested creating a 200-foot buffer around the complex by clearing away dead vegetation and cutting back overgrown tree branches.

In June, a medium-size blaze breaks out in a remote wilderness about 60 miles north of Grand Junction, Colorado. Forest managers determine this fire isn't a threat to local residents; it will improve habitat by burning off undergrowth without killing the bigger trees. So instead of attacking it, they will let the flames run their natural course. They'll use Farsite models to track and predict its movements, while keeping a few hotshots and aerial tankers on standby, just in case.

Fire ecologist Lathan Johnson takes me to an area near the edge of the blaze. He's here to help supervise a small team of specialists and gather hourly data for input into fire-behavior models. In six days, the fire has razed about 6,900 acres, killing mostly tall grasses and shrubs. As we traverse a blackened ridge, there's a familiar smell in the air – a campfire, only marvelously sweet and earthy. "That's sage, juniper, and pinion pine," says Johnson. The ground is still warm, and wisps of smoke rise from burned-out stumps. The sky is overcast and monochromatic. Aside from our gaudy matching outfits – orange hard hats, plus olive-green pants and bright yellow shirts made from a fireproof fabric called Nomex – the world is utterly black and white.

We pause at a vista about a quarter-mile from the flames. In our day packs we're carrying fire shelters, basically self-pitching pup tents made from a heat-resistant material that resembles aluminum foil. We're supposed to throw these over ourselves if we're unexpectedly trapped by flames. As I ponder the notion of being baked alive in a teepee of Reynolds Wrap, Johnson starts removing gadgets from his pack. With the first one, a digital anemometer, he measures wind speed, force, and direction. Next he takes the air temperature and uses a spinning sling psychrometer to check the dew point and humidity. He notes the scorch height on the tree trunks and the fire's rate of spread, then uses a GPS receiver to pinpoint our location and elevation. He also jots down the shape, color, and opacity of smoke plumes and any obvious thermal inversions (that's when a column of smoke appears to butt up against an invisible glass ceiling). Finally, Johnson takes out a red binder and consults charts to calculate the POI, or probability of ignition – a figure that gives wildfire managers a sense of how quickly and easily the flames will spread under certain conditions. Today, with the cloud cover and high humidity, POI is only 40 percent, well within the safety zone. Johnson repeats this process every hour, collecting real-time data on every conceivable aspect of the fire and surrounding environment, then in the evening delivers the results to the command center in nearby Meeker.

Farsite's detailed projections help direct where to send firefighters in the field; this blaze set by lightning in Yosemite eventually covered 5,000 acres.

It's dusk when we return to town and join other specialists. Firelab forester Rob Seli enters the data Johnson collected along with the blaze's GPS coordinates into a form on the National Weather Service Web site. In return, he'll get a pinpointed local forecast. Everyone is gathering data as fast as possible because the sooner they can fill in the blanks, the sooner they can run Farsite models.

The next day, as my flight climbs out of Grand Junction, smoke plumes rise in the distance, but they're smaller now. Farsite has done what it's supposed to do – ensure that the forest managers can keep a blaze tame and manageable while it steadily reinvigorates the forest. As Jack Cohen likes to say, Farsite has shown us "how to be compatible with the inevitable." ■ ■ ■