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An experimental fire spreading through laser-cut cardboard in the wind tunnel at the Fire Sciences Laboratory in Missoula.Video by Ian Grob/Missoula Technology Development Center

Into the Wildfire

What science is learning about fire and how to live with it.

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Lassen Volcanic National Park, in Northern California, consists of more than 100,000 acres of wilderness and woodlands surrounding Lassen Peak, a volcano named for a pioneer and huckster who guided migrants through the area, that last blew its top in 1915, before anybody knew it was an active volcano. Last summer the park, like much of the West, was in the midst of a yearlong drought — which could be more accurately described as the continuation of a decade-long drought that had merely been less severe for a couple of years.

A forecast of thunderstorms might seem like welcome news for a firefighter in charge of so many acres of dry forest — parts of the park can get so hot and dry during the summer that rain evaporates before it reaches the trees — but Mike Klimek, the firefighter in charge of the park on July 23, 2012, knew better. Storms bring lightning. So Klimek was patrolling the park road, in regular communication with other firefighters, when late that afternoon, he got word that a column of smoke had been spotted. Klimek and a U.S. Forest Service firefighting crew stationed in the park drove as close as the main road would take them to the smoke, then he and a captain from the crew hiked into a wilderness area, where an aircraft reconnaissance team directed them to a single tree that was burning. When they got there, the red fir was smoking and there was some fire on the ground, but it wasn't spreading. Klimek's job at that moment was to decide what to do about the fire: put it out immediately or allow it to burn and monitor it carefully. If he let it burn, it would be for the sake of what wildfire experts call resource benefit: letting fire play its proper role in the ecosystem, and allowing forests in the West to revert to the conditions that characterized them in the days before every wildfire was extinguished as quickly as possible. That practice — pursued for more than a century, and today recognized by scientists as a really dumb idea — allowed younger trees and underbrush to flourish in many places, increasing the density of flammable material and thus exposing forests to fires hotter and more intense than they had evolved in response to. Now firefighters like Klimek look for ways to reduce the potential fuel in the environment, which sometimes means letting lower-intensity fires burn and watching them closely. This seemed like an opportunity for just such a "managed" fire.

“That fire is not going anywhere fast,” Klimek recalls thinking at the time. He took out a notebook and wrote down the altitude: 7,100 feet above sea level. The cooler mountain air was one factor telling him this fire would not spread quickly. Another was the tree’s location: a relatively sparse area where there wasn’t all that much that could burn. And because the tree was on a northern slope, the other trees, underbrush, grasses and fallen branches around it were probably not as dry as they would be on a southern slope, where they would have absorbed more sunlight. There was also a ridge, a road and several creeks nearby. Firefighters are trained to “build a box” around a fire, taking advantage of topographical features that tend to slow a fire’s spread, including existing breaks in the woods, and clearing new breaks as necessary to contain a fire within controllable boundaries. “In suppression training, you always talk about the ‘three R’s’: ridges, roads and rivers,” Klimek told me one day in June. “And I had all three.”

He had evening on its way too, bringing with it a likely rise in relative humidity that would dampen the grasses and woody vegetation around the burning tree. Klimek radioed an interagency fire center in the nearby town of Susanville to say there was time to decide how to deal with the fire.

Left: Scientists at the Fire Sciences Laboratory in Missoula observe the behavior of fire in a wind tunnel. Right: Mark Finney observing the behavior of flames fueled by ethylene gas.

‘By suppressing fires ... we’re saving the landscape for the worst conditions,’ a fire researcher says. ‘We need to choose good fire over bad fire, and if we understand spread we can make better choices.’

Time, yes, but that wasn’t going to make any decision easy. Whatever Klimek and his superiors decided to do would entangle them in a knot of political, economic, legal and ecological issues that involve firefighters, regulators, scientists, politicians, homeowners and others, from Washington, D.C., to state capitals throughout the West. As more and more acres burn, all these different constituencies are asking, without arriving at the same answers, What are we going to *do* about these fires?

The area around Klimek, about 150 miles north of Sacramento, was often still patchy with snow in midsummer, though on that day, after another dry winter, it was bare. And the hottest, driest time of year — the period when Lassen Park is most susceptible to dangerous wildfires — was still to come. Before he left the burning tree, Klimek jotted down one more thing in the margins of his notebook: “August?”

Fire has always been a part of the natural ecology — many plant species evolved in direct response to it and couldn’t survive without it; when the sap of some pine cones melts, for example, seeds are released. But the reflexive practice of putting out all fires, which has dominated national policy for so many decades, has turned much of the American West into a tinderbox. On June 30, in the deadliest incident in wild-land firefighting in decades, 19 of the country's most highly trained, highly skilled firefighters died in a fire near Yarnell, Ariz. While awaiting the findings from a federal investigation (expected this month), many have asked whether unexpected changes in the wind's direction and speed, which abruptly exposed the men to the fire, were simply the most immediate factors contributing to their deaths. The Phoenix New Times, for instance, reported that the team should not have been deployed at all that day because its members may have already reached the maximum number of consecutive days they were allowed to be in the field. What's clear, however, is that the buildup of flammable materials in the area and the ongoing drought in the Southwest contributed to the fire's intensity. And it was a fire the firefighters were combating there in order to protect a housing subdivision on the outskirts of town.

Jack Cohen (left) and Mark Finney, of the Missoula fire lab, observing the leading edge of the Lolo Creek Complex Fire near Missoula, Aug. 21, 2013.

Seven weeks later, a hunter's illegal campfire started a wildfire near Yosemite National Park; named the Rim Fire, it would go on to burn an area about the size of San Francisco, San Jose, Oakland and Sacramento combined, involve nearly 5,000 firefighters at one point and cost roughly $90 million to fight. Gov. Jerry Brown declared a state of emergency as the fire threatened San Francisco's water supplies and access to electricity. That same week in August, images of giant flames from a fire burning over a 174-square-mile area near Ketchum, Idaho — close to where a fire in 2007 burned 65 square miles — dominated nightly news coverage.

Wildfires of a size and intensity that only a decade ago were rare are now almost an annual occurrence. This summer, more than 500 homes were destroyed by fire in the Colorado Springs area; last year, the nearby Waldo Canyon Fire burned down 347 structures, at a cost of $453 million. In 2011, 5,600 homes and buildings were destroyed by fires in Texas. In 2009, one wildfire lasting several weeks burned an area in Los Angeles County the size of more than 10 Manhattans and cost $93 million. The amount the federal government spent putting out fires over the last decade was triple what it was in the ’90s.

We probably wouldn’t be as concerned about fires that are getting bigger and spreading farther, of course, were it not for the increasing intrusion of people and buildings into fire-prone landscapes. This development creates what fire experts call the wild-land-urban interface, or WUI (pronounced WOO-ee), and from Bozeman, Mont., to Laurel Canyon in California, more and more of us want to live there, with forested views and coyotes for neighbors — but without the fire. About 80,000 wildfires in the United States were designated for suppression each year between 1998 and 2007, and only an average of 327 were allowed to burn. Yet trying to put out all those fires leads inevitably to more intense, more dangerous and more expensive fires later on. The accumulation of dead wood and unburned “ladder fuels” — what ecologists call lower vegetation that can carry fire to taller trees — turn lower-intensity fires into hotter fires that kill entire stands of trees that otherwise might survive.

The fire-whirl generator inside the Fire Sciences Laboratory in Missoula. We know this, but we haven’t wanted to pay the costs to do things differently. It’s possible to break up and remove smaller trees and other vegetation, but the heavy equipment needed to do that is very expensive.

(The process can inhibit plant growth too.) It’s also possible to set “prescribed” fires, but these carefully controlled operations can take decades to produce the desired effects in a given area. And managing a fire that starts naturally in order to let it clean up ladder fuels is risky and costly.

“If we let fires burn, it takes up resources to watch them, and we don’t have the luxury to do that,” says Ken Pimlott, the director of California’s Department of Forestry and Fire Protection, or Cal Fire. “We’ve got to put it out and move on to the next fire.” A sudden change in wind can send a fire raging toward populated areas, which can lead to fatalities, damage and lawsuits. With responsibility for 31 million acres, almost all privately owned, that have more and more people living on them, Pimlott maintains a strict policy of immediate and full suppression for every fire that starts in his area, even as he recognizes the policy flies in the face of logic and science. “The entire cycle is out of whack,” he says. “The movement of people into the WUI, the fires they start there and infrastructure that needs protection, plus drought, climate, suppression — you combine all these things, and it’s creating more intense fires. It just becomes a larger problem.”

‘Nobody really heard about it until after it crossed out of the park, and by that point it was beyond control,’ one resident says about the fire. ‘Manage a fire at the end of July? It was a really bad decision.’

But it’s not an unfamiliar one in its broadest outlines, in the way that the narrow pursuit of short-term gains can undermine longer-term interests. We know we shouldn’t build wooden structures in the wilderness, but we do. We know the Mississippi River will flood disastrously again, as it has at a rate of more than once a decade since 1927, yet we keep planting crops in the rich soils alongside the river and subsidizing farmers in its floodplains. We know it’s only a matter of time before another giant storm smacks the New Jersey shore — as one did in 1903, 1944, 1991, 1999 and 2012 — yet in that state alone we’re hauling in 27 million cubic yards of sand to replace what Sandy washed away and allowing an estimated 200,000 homes to remain — and in some cases be rebuilt — in the possible paths of future storms. We don’t want to pay more for fossil fuels or otherwise make serious sacrifices to limit climate change (which is also amplifying the other problems). We get caught in feedback loops.

Our firefighting policies may have more direct and immediate repercussions than our other environmental choices do, though. “The harder you try to remove fire, the worse it gets,” says Mark Finney, a research scientist at the U.S. Forest Service’s research lab in Missoula, Mont. “By suppressing fires in all the conditions we can, we’re saving the landscape for the worst conditions. We won’t say that’s our policy, but by our actions, we are selecting for only the most extreme fires. We need to choose good fire over bad fire, and if we understand spread, we can make better choices.”

Kyle Shannon, a computer programmer at the Fire Sciences Laboratory in Missoula, operating the mass flow controller for the burner, to control the amount of ethylene gas burned. The burner is used to study flame structure.

Thanks to experiments that Finney and his colleagues are now conducting, we may be on the cusp of a new understanding of fire. Despite the fact that humans have been using fire for at least 300,000 years, “people have no idea how fire actually spreads,” Finney says. It turns out, for example, that one assumption about how grasses and pine needles catch fire — a significant factor built into the computerized models of fire spread used to fight fires — may be completely mistaken. Researchers at Los Alamos National Laboratories, the National Center for Atmospheric Research, the Forest Service and elsewhere are investigating other aspects of fire propagation, like how big fires create their own weather — a process that has contributed to some of the most devastating fires in recent years — and how prescribed and managed burns might affect a landscape’s propensity to catch fire later. Much of this research is so new that it hasn’t made it into any models yet. With results from this new science in hand, foresters in the coming years may be able to keep fires (whether managed, prescribed or otherwise) from becoming as extreme as they have lately. We may yet return to the days of “good fire.”

The day after Klimek found the single tree on fire, he talked things over with Eric Hensel, the fire-management officer at Lassen Volcanic National Park. Among other things, they considered the point of ignition, the surrounding topography and forest, current drought conditions and the potential places where a team could create breaks in the trees to contain the fire. They consulted with the National Park Service’s regional fire ecologist and regional fire management officer, in San Francisco, then presented their findings to the park superintendent. The nearest town was more than 10 miles away, and a lot would have to go wrong before the fire could get close to it. The group decided to manage the fire rather than put it out right away.

Five days later, the fire was doing just what they hoped. Klimek described it to me as “a low-intensity backing fire” — that is, one moving downhill rather than up; an uphill fire tends to spread faster. It was “cleaning up” underbrush and wood on the ground as it moved. On July 30, the fire’s extent was only three acres, and a person could still walk safely in its midst. (When officials describe a fire’s size in terms of acreage, it doesn’t necessarily mean every spot in that space is actively burning.) When I walked the area 10 months later with Scott L. Stephens, a professor of fire science at the University of California, Berkeley, and an expert on prescribed and managed fires, he said, “This looks exactly like what I would’ve aimed for if I were setting a prescribed fire in here.”

Hensel gave thought to initiating a “burnout operation” between the park road and the fire’s location. That would entail starting a second fire that would burn toward the existing one, thus reducing the risk that it would spread beyond a chosen limit, in this case the park road. This line of control was selected because there was a stand of lodgepole pines on the north side of the road. Unlike Ponderosa, Douglas firs and other conifers in the mountain West, lodgepoles are highly susceptible to fire, and this stand, nearly a hundred years old, had never burned; it was like a land mine waiting to be set off. But more thunderstorms were in the forecast, and the cold air they brought with them was likely to create a downdraft with the potential to spread the fire rapidly in any direction (and additional lightning strikes could also start more fires). It was this risk of its becoming unpredictable, Hensel later explained to me, that made a burnout unwise.

Jack Cohen next to the reflector tunnel, which is used to produce a steady level of radiant heat to examine how different materials heat up to ignition.

As Hensel weighed the options, Calvin Farris, the Park Service fire ecologist in charge of Lassen Volcanic, was working with an analyst who studies fire behavior for the Forest Service. They were using a computer model that Mark Finney helped develop, called FSPro (Fire Spread Probability), which predicts a wildfire's likely movement, based on variables like topography, weather, the types of trees in a forest and how dry they are. In a typical year it works well, but for whatever reason, as August and its heat approached, that wasn't the case. It was consistently underestimating the likelihood that particular areas would burn. This wasn't unusual; at one point during the 1988 fires that burned nearly 800,000 acres in and around Yellowstone National Park, the statistician whose work underlies many fire-spread models used his own model to project where the fire would be in two weeks. It spread twice as far in the next 24 hours.

On Aug. 6, 2012, the weather in Lassen Volcanic National Park changed: the wind turned around and picked up significantly, blowing the fire across the road and into the lodgepole pines. Once the fire spread into the lodgepoles, it became very hard to control, because of the surrounding terrain and the weather at the time. The next day, a federal interagency fire-management team was brought in to coordinate suppression efforts. On Aug. 8, the fire expanded beyond the park's borders, and it became a threat to the town of Old Station.

The new people in charge held a public meeting to inform area residents about the fire's status and possible evacuation procedures. Both Hat Creek Valley and Old Station had evacuated their homes because of wildfires twice in the previous 10 years, most recently in 2009, when lightning ignited fires that burned 9,300 acres.

Darlene Koontz, who is the park superintendent at Lassen Volcanic, was in charge of some federal lands in New Mexico a few years after a prescribed fire there spread out of control and burned part of Los Alamos in 2000; 400 families lost their homes, and the fire's total cost was estimated to be $1 billion. So she was familiar with balancing the risks in a drought-stricken forest and aware of the public outcry that could follow mistakes. Yet efforts to notify the community near the Lassen Fire were minimal, and reports in the local news media seemed to add a measure of anger to the public's anxiety.

"It was a really hostile setting," according to one firefighter who was at the meeting. Because the fire began as a managed wildfire, he says, it was regarded differently from past fires. "They had a particular place and person to, in their perception, set blame, and that was the park and the park superintendent. I thought she was going to get accosted."

Top: The gate of a house that burned in the Lolo Creek Complex Fire near Missoula. Bottom: Landscape burned along U.S. Highway 12 in Montana.

Koontz confirmed the tension. “I have very little butt left after last summer,” she told me.

Pam Giacomini, whose family has been ranching in the area for generations and who now represents Old Station on the Shasta County Board of Supervisors, says Koontz should have consulted with Cal Fire before deciding to manage the fire. “Nobody really heard about it until after it crossed out of the park, and by that point it was beyond control,” Giacomini says. Lassen Park officials “act like they’re an autonomous unit, but they reside within the community where they’re located. Manage a fire at the end of July? It was a really bad decision.” More than one firefighter told me that one mistake with a prescribed or managed burn can set public acceptance back a decade.

As August stayed hot, the Reading Fire, as it was named (after Reading Peak, near the fire’s starting point), raced north toward Old Station. On Aug. 9, 10 and 11, with the temperature topping 90 degrees and relative humidity around 5 percent, the fire had a high potential to grow significantly and act unpredictably. It started to create its own weather: the fire’s heat generated a mass of upward-moving energy that spread flames in all directions. On Aug. 13, embers carried by the wind ignited a satellite fire just four miles south of Old Station. When the fire-management team reached its maximum allowed number of days in the field and was rotated out, another, more experienced team was brought in.

How do we reintroduce fire into this landscape?”

It was the middle of June this year, and a Forest Service expert in tree cultivation named John H. Bassman was crouched on a steep, damp slope in the Priest River Experimental Forest, in Idaho’s panhandle, putting that question to a couple of dozen ecologists, soil scientists, firefighters and others on a Forest Service-sponsored field trip. The Priest River Forest is 6,300 acres of mixed-conifer woodlands about 60 miles northeast of Spokane, Wash. The Forest Service probably leads the federal bureaucracy in quaint traditions, and field trips where scientists from different forests can get together at camps like the one located here are a big part of its culture. “We learn best when our boots are in the dirt” is how Bassman put it to me over a breakfast of biscuits and gravy in the Depression-era Civilian Conservation Corps-built bunkhouse. He lamented the loss of the tableware adorned with the Forest Service logo and said that with budget cuts and virtual training, “this kind of thing is getting rarer.”

The experimental forest, which has some of the most complex and productive woodlands in the country, has been used for wildfire research since its founding a year after the great fires of 1910 first brought the issue of fire’s impact on the West to national prominence and prompted the young Forest Service to elevate “over all other duties and activities,” as an agency bulletin that year put it, its policy of suppressing fires. The early work was on seed growth — to figure out how to replace what burned — and until then, virtually the only places where Americans were studying forestry were in Europe or back East.

Research foresters from around the region like to come to Priest River and have a local fire officer torch some trees and plant various seeds afterward to see how they respond, testing the effectiveness of prescribed fire and seeing how a burned area recovers. Bassman and the others were here to focus on different ways to reduce the accumulated vegetation in a landscape, through prescribed fire, for example, or mechanical thinning. Research by Finney in the last decade indicates that burning or cutting up as little as 30 percent of a forest can, if done strategically, have an outsize effect on limiting a wildfire’s spread. (The federal government, however, has slashed the budget for putting those experiments into practice.) The visitors’ hope was that they’d be able employ these tactics to influence how fire moves through the forests where they work. Bassman wants to restore Montana’s Flathead National Forest so that the frequency and severity of its fires more closely resemble what the land was like before the Forest Service started fighting every fire a century ago.

Even if he successfully manages his forest, the social geography will still be fraught. “In parts of the northern Rockies, the historical fire-return interval is 100 years,” Bassman said, referring to the average time between fires in a forest. “But those are stand-replacing fires, and nobody’s going to put up with that. So understanding landscape-fuel treatments is the key to how those forces can be altered so we can better protect people and property and wilderness.”

The remains of a house near Lolo Creek that was burned by a wildfire.

Jack Cohen, who works at the Forest Service’s Fire Sciences Lab in Missoula, probably understands “landscape-fuel treatments” as well as just about anyone else thinking about fire in America. Cohen told me that he started stealing matches and lighting fires when he was 5. He knew this would get him in trouble, he said, so he made sure to keep his fires small. This proved to be excellent experience, decades later, when he was the lighting supervisor for prescribed fires in the San Bernardino National Forest in Southern California.

Cohen noticed then, to his surprise, that live foliage could keep a fire going in the absence of dead plant matter. He discovered he could rearrange piles of vegetation in various manners and still get them to sustain fire. By changing his ignition methods, he could increase the height of flames and get fires to spread when they otherwise wouldn't. Cohen describes this as "campfire knowledge," but it occurred to him these sorts of observations were missing from — or contrary to — what was reflected in the models.

Years later, when he came to the Fire Sciences Lab, the only facility in the world dedicated to studying wildfire through experiments in a chamber, he worked a great deal on what he would call the Home Ignition Zone, or H.I.Z. He decided to try to figure out how close a fire needed to get to a house to set it aflame. On seven occasions, Cohen placed walls like those used in house exteriors at distances of 33, 66 and 98 feet from the edge of an experimental forest plot, where he set trees ablaze. Three times the walls at 33 feet failed to catch on fire. The walls at 66 and 98 feet were never even scorched.

Intrigued by how unsusceptible the walls seemed to be to nearby fire, he started investigating houses that had burned in wild-land-urban areas: how near to the most dangerous flames had they been? "Not very," he learned, reinforcing what he saw in his tests. In Los Angeles in 1961, houses on fire in Bel Air were the sources of the fire that burned houses in Brentwood a mile away: residential structures facilitated the fire's spread. In San Bernardino in 1980, some 280 houses were destroyed in a fire that might have stopped at the forest's edge, if they hadn't had wooden roofs.

When I visited Cohen, who is 63 now, in his office last June, he showed me a picture taken from a helicopter over Lake Arrowhead, Calif., in 2007, that showed a house on fire eight hours after the fire had moved through the neighborhood. "We see wildfire destroying houses," he said, "but 90 percent of the houses burn down after the wildfire has ceased its significant activity in the vicinity."

In these cases, embers, which can be as small as a thumbnail, were carried by the wind from the fire to some flammable part on or near the house (wood shake-shingle roofs that aren't treated with flame retardant are especially vulnerable). When residents had been evacuated and firefighters were off fighting the wildfire, or were too few in number to protect every house, nobody was around to put out the smoldering firebrand.

"It's all embers," Cohen said. "That's not an intense igniter; that's an insidious igniter." Burning pine trees toppling onto roofs weren't causing these fires to spread, in other words; the problem was burning material blown under wooden decks or into gutters clogged with dead pine needles, where it smoldered for hours amid other flammable stuff. "Embers don't ignite houses if the houses aren't susceptible to them, and that's something we can mitigate through engineering." And, he admonished, get the dead leaves and branches and pine needles off your house.

California has been a leader in adopting building codes and brush-removal regulations, but for the most part, despite the clear evidence from Cohen's published research, municipal governments in the western United States have been slow to follow. Some people don't want to cut down trees; others don't want government telling them what to do with their property. Cohen said that when he took his research to urban firefighters, he didn’t find an enthusiastic audience. His experience with fire departments that had not been “kicked multiple times” by wildfire has been that they don’t want to be the ones telling homeowners they’re part of the problem; his impression is that urban firefighters prefer instead to say, “This fire was so big and fast, there was nothing we could do to save your house.” And that’s true, as far as it goes. But until people grasp or act on what Cohen has demonstrated — that homeowners would not need to rely on firefighters as much as they do if their houses were better built and maintained and the properties around them were prepared to withstand fire — changes to forest management and firefighting policies are unlikely to significantly improve matters.

One person who is putting Cohen’s message into practice is his colleague at the Fire Sciences Lab, Mark Finney. A former wild-land firefighter, he uses prescribed fire on his own property to maintain a defensible space around his house outside Missoula. For eight days in 2007, he defied an evacuation notice — in Montana, the police cannot order an adult to evacuate his residence — and stayed home with his Labrador retriever while the Black Cat Fire raged to the west of him. (Convincing firefighters that he was not insane and that they should *not* build a fire break through his back yard with a bulldozer was challenging, but ultimately he prevailed.) About a decade ago, Finney and Cohen started engaging in long conversations in the hallway at the lab, and Cohen, discouraged by the lack of public response to his research on the home-ignition zone, joined him in focusing on the physical properties of fire itself.

Top: A block of wood ignited after exposure to radiant heat. Bottom: A fire experiment in the wind tunnel of the Fire Sciences Laboratory in Missoula.

Finney would tell Cohen something like, “I was burning this pile on my property, and I didn’t see ignition until the flame touched.” And Cohen, drawing on his experience in Southern California, would say, “I can get live vegetation to burn without dead vegetation.”

The more they talked, the more they realized that many of the things they’d observed, both in the field and the lab, weren’t incorporated into the computer programs firefighters were using to predict the likelihood that a particular forest would catch fire, or that an existing fire would spread from one point to another over a period of days or weeks.

One day a scientist named Don Latham, who was retired from the Fire Sciences Lab but was still friends with Cohen and Finney, told them about his attempts to measure the amount of energy being transferred by radiation to a pine needle when it caught fire, but that the pine needle wouldn’t ignite. Latham hadn’t been trying to determine *what* causes pine needles to catch on fire — he assumed it was radiant heat — so he basically ignored what he figured was an anomaly. In the context of Cohen’s and Finney’s other observations, though, it took on new significance. “I said to Mark, ‘Well, we’ve got to try this,’ ” Cohen said.

They had a machine that emitted radiative heat at 1,800 degrees Fahrenheit without convective heat, and they started placing different flammable materials in front of it. (Radiative heat is transmitted by electromagnetic waves from one point to another without warming the space between them. Convection transfers heat from place to place — and through the space in between — by the movement of a medium like air or water.) When I visited Finney and Cohen in June, they showed me video of a wood block placed in front of this apparatus, which they call the death ray. (“Don’t worry, it won’t actually kill you,” Finney assured me when I saw it later.) The block ignited after about 25 seconds, but nothing happened to a pine needle placed in the same spot. Other fine fuels — grasses, shredded wood — did not ignite, either. Their higher surface-to-volume ratio allowed the surrounding air to cool them faster than radiation could heat them to the ignition point.

We all know that kindling ignites faster than logs, though, so this is not only puzzling to anyone who’s ever tried to light a campfire; it’s also, Finney said, “absolutely contrary to the models,” most of which assume that radiation from a wildfire lights the flammable materials at the fire’s leading edge.

Cohen searched the scientific literature for experimental support for this assumption and found nothing. Because the models are based on what has been observed in the field, of course they sometimes accurately predict what happens there. But because they don’t take into account what has been learned from experiments in the lab, they sometimes fail to explain a fire’s unexpected behavior. Cohen likes to quote the statistician George E. P. Box: “All models are wrong, but some are useful.” Until Cohen and Finney thought to test radiation in controlled conditions, no one realized that flames must touch the fine fuels to ignite them.

“If radiation can’t ignite the stuff next to it, the fire doesn’t spread,” Cohen said. And yet, clearly, fires are spreading; it’s just that the models aren’t telling us why. “We’ve allowed modeling to get way ahead of our actual understanding,” Cohen continued. “The models have become illusions of understanding.”

So, if radiation isn’t lighting the stuff at the edge of a fire, Cohen said, “that means flame contact is required.” But flames are hot; they rise. So how do flames extend laterally? Fire can spread horizontally even when there’s no wind.

And that’s what leads you to look in other places for convection, Finney explained. With a laser cutter, he started making his own objects to ignite inside a wind tunnel. He filmed them burning with a high-speed camera so he and his colleagues could watch the results in superslow motion. It turns out that fires have frequencies, like radio or magnetic waves. The pulses that create a flame’s peaks and troughs come at intervals that aren’t random.

“And here’s where the thing gets blown open,” Finney said, jumping up from his desk to point at a big flat-screen TV on the wall. It showed the U-shape of a flame from one of his chamber experiments. What he and Cohen found is that that U-shape is caused by air being drawn into the fire and spinning in two counter-rotating vortices that converge (picture interlocking gears) and push the flame down and forward, scorching whatever is beneath it. That establishes the contact necessary for ignition.“Flame is just a hot, buoyant fluid,” Finney said, “but no one was looking at that, because they assumed radiation was lighting fine fuels.”

On the wall next to the TV was a photograph of some flames. The resolution was low, and there were no discernible objects in the picture, so you couldn’t tell the scale of the photo. It happened to be a picture of an enormous grass fire in Australia, photographed from a satellite. The structure of the flame in the photo was the same as in the video. “You can see these peaks and troughs in any fire," Finney said. "That's cool! That means you're on to something." He said that previously he and other fire scientists "were watching fire, but we weren't *seeing* it. We were observing the wrong phenomenon." No one sought to understand flame structure before, he said, because of their assumptions about radiation. "Well, they couldn't have been more wrong," Finney said. "And we demonstrate that very, very clearly."

"All this stuff that's not in the models is affecting the propagation of fire, particularly those that produce big flames," Cohen told me. "And every time we have big flames in the WUI, people get scared. And that causes us to go to suppression." Suppression, in turn, allows forests to grow to the point where they produce big flames. "And we end up with a 200,000-acre fire instead of a 10,000-acre fire," he continued. "So we'd better figure out how fire burns."

The Fire Sciences Lab is hoping to come up with a physics-based model that would incorporate the findings. More than that, they want their research to lead to a better understanding of fire and hence better decisions in the field. The dynamics that Finney, Cohen and their collaborators have observed would explain a lot of fire behavior that has puzzled firefighters — a wildfire suddenly spreading rapidly without wind, say, or failing to be tamped down by cooler, moist night air. "There may be a general principle that can be applied to every wildfire," Finney said.

What that general principle might be is still unformulated, so exactly how it might change the way we approach any specific fire remains unknown. But what we do know now is that fire spreads in ways we didn't realize before. This argues even more strongly for a policy that encourages removal of underbrush and managed or prescribed burns, and for the regulation of communities living at a forest's edge. The way to make wildfires, and the people living near them, safer is by making peace with the idea that we need to let more of them burn longer.

In June, I toured the Reading Fire's burn area with Hensel and Klimek. We were joined by Calvin Farris and Robin Wills, fire ecologists with the Park Service; Scott Stephens, from Berkeley; and Carl Skinner, a research geographer with the Forest Service who is highly regarded for both his experience as a wild-land firefighter and his scholarship. Skinner grew up on a farm not far away, where his family regularly set fires to manage their land, until the state strictly limited the practice.

We were 20 yards from the stand of lodgepoles that ignited on Aug. 6 last year; it was too dangerous to walk among the dead trees, which can drop limbs at the slightest breeze. Since it was devastated by the eruption of Lassen Peak nearly 100 years ago, the area has become what foresters call "parklike" — mostly grass, with Ponderosa pines, white firs, some lodgepole pines, wild currants and various species of ceanothus, which elk prefer, sprinkled throughout. It's as aesthetically appealing and as ecologically rich as any stand of trees in the region (or, for that matter, in any of the undeveloped areas I visited in six states while reporting this article). And it wouldn't have happened without the fire that followed the volcano's eruption.

As I listened to them speak, it was evident that there is still much to learn about fire and its effects, which was why several of the top scientists in the country who study fire had gathered here in the first place. But a few conclusions were emerging. Through interventions driven less by fear and more by data and science, it would be possible to get forests closer to the state they were in a century ago, before firefighting policies began to turn them into tinderboxes. But to let — or help — nature run its course again would mean tolerating greater risk, and as Cohen says, we'd have to keep our roofs clean. With each passing year, though, it becomes clearer, at least to those whose interests lie in not fighting ever-larger and more destructive fires, that this is the only sensible course of action.

We talked about the impacts, both ecological and political, of the Reading Fire. The alternative to managing it, Stephens said, was to "kick the problem down the line and have a worse situation later. What the hell were you going to do with this lodgepole-pine bomb? The prescribed-fire budget is being reduced, so we're forcing fire managers into wildfire management. Then they're panicking as the season goes on and suppressing any fires that ignite. It takes away the only tool they have."

Wills said, "If this had been a suppression fire from the outset, we probably would've built the same box around it and formulated the same plan."

The plan later involved using bulldozers to create a number of breaks in the trees south of Old Station as the fire moved north. But to the east, they didn't need the fire breaks. Lassen Park fire managers had, over the previous decade and a half, conducted a prescribed burn and managed several other fires that, taken together, formed "a nice, continuous solid layer of previously burned areas, which had consumed a lot of the forest," as Farris put it.

I talked to him days after he first saw data on the severity of the Reading Fire. The forest had been successfully managed, he said, so firefighters confidently allowed the east and northeast flanks of the fire to burn out on their own, while they focused on protecting Old Station, due north. "Had it not hit those treatments" — the places where the prescribed burns were conducted in the past — "it could've gone over the ridge into lower-elevation, high-temperature areas," he said. "But it got to the prescribed fire zone and stopped."

Wills pointed toward Raker Peak, where patches of trees that had survived the Reading Fire could be seen, indicating that pockets of less-intense flames had passed through. "You look at that mosaic pattern, and it's exactly what you'd want," Wills said. "We always struggled over what to do about Raker Peak, then the Reading Fire did it for us. From an incident-management standpoint, it's an example of success and patience" — even if that's not at all how the public viewed it.

Wills continued, joking: "If this had been a suppression fire from Day 1, the firefighters would all be getting cash rewards — 'You saved Old Station, not a single structure was burned, no loss of life.' The biggest lesson here was not operational or ecological, it was sociopolitical: what we perceived versus what the public perceived. So that's the place where potential change resides. We're never going to eliminate fire or fire risk. We have to develop some acceptance. And we're not going to stop managing fire, no matter how unpopular it is. We're managing a fire right now, in Yosemite."

The Rim Fire near Yosemite hadn't ignited yet — Wills was talking about a much smaller fire, which would creep around harmlessly for several more weeks. When the Rim Fire crossed into

Yosemite two months after we spoke, the Park Service didn't commit any additional resources to it. But the portion of the fire in the park didn't present any threat, and two weeks later, the entire fire was almost completely contained.

In early September, the fire chief in Ketchum, Idaho, where so many square miles had recently burned, announced he would be "fighting tooth and nail" to ban wood-shingle roofs in his city.

Maybe the people of Ketchum will take his message to heart, and wise and needed change will follow. And maybe this summer, with all the lives and property lost, will mark the time when we began to reckon rationally with fire.

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