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Hundreds of Ways to Get S#!+ Done—and We Still Don't

You want to be productive. Software wants to help. But even with a glut of tools claiming to make us all into taskmasters, we almost never master our tasks.
Illustration: Yann Bastard

Back in 2010, Walter Chen and Rodrigo Guzman had a weird idea: a website where you write down the stuff you accomplished that day, and which then emails you a summary. It would be a productivity tool that worked by a neat psychological hack, impressing yourself with your daily wins. "Often you discover that you've done more than you gave yourself credit for," Chen says. "And this kind of motivates you—inspires you!"

Chen was a disenchanted lawyer; Guzman, a witty and talkative hacker. They built the tool in less than a week and launched it as IDoneThis. Soon they built an app by the same name and acquired 6,000 users. Within half a year, IDoneThis was the two creators' full-time job.

But then those users started clamoring for more. People didn't want merely to track the stuff they'd already done. They wanted to help plan for what they were going to do—from projects at work to the blizzard of tasks in their personal lives. Guzman and Chen updated IDoneThis with a new feature: to-do lists.

Which is when things went a little off the rails.

It wasn't long before the two founders noticed something odd in the (anonymized) data they had on their users: People were lousy at finishing their to-dos. Chen and Guzman could see an accumulation of sprawling, ambitious lists of tasks that users utterly failed to accomplish. In 2014, fully 41 percent of to-do items on IDoneThis were never … done.

Sound familiar? The tasks you so diligently enter into your fancy app or productivity method linger for days or weeks or months (or even longer— one colleague recently told me his to-do app has undone tasks from 2019). They stare back, unchecked, with baleful expressions, disappointed at how very un-crossed-off they are.

Another thing that might feel familiar: The things that IDoneThis users actually did accomplish, they did very quickly. Half of completed to-do items were done within a day of writing them down. These weren't longer-term, complex tasks. Ten percent were done within a minute. It was almost like people were writing them down just so they had something to check off. A nice psychological boost, to be sure, but it somewhat defeated the purpose of a to-do list.

More subtly, there was a big disjoint between the tasks people planned to do —i.e., wrote down on lists—and the tasks they actually did. Chen and Guzman found that when people reported their day's accomplishments (the initial point of IDoneThis, you'll recall), barely any of them had even appeared on a to-do list. The majority were tasks that users had just, well, remembered. Or maybe it was something that just popped into their head, or something a colleague had emailed them about.

The more Chen and Guzman pondered it, the more useless to-do lists seemed to be. They thought about getting rid of them. If to-do lists weren't helping people accomplish stuff, what was the point? But they worried that users would squawk.

Which they might have, if they'd hung around—the founders noticed a frustratingly high churn rate. A minority would mind-meld with IDoneThis, but most would, in time, drift away on a seemingly endless hunt for the best way to manage their to-dos. "It involved a lot of, not dilettantes, but people

who wanted to try something new or were interested in a different system," Chen says.

People loved to write down their tasks. But that didn't seem to help with completing them. Chen and Guzman became gradually chagrined. After five years of working on IDoneThis, they sold the company to a private equity firm. "We felt like we'd exhausted what we knew to do," Guzman says. IDoneThis isn't gone; you can still use it today. But its creators couldn't shake the feeling that building the perfect system to effectively manage tasks was itself a task they couldn't accomplish.

I think I know why: It might be impossible.

Most common office tasks have well-settled software "solutions." If I asked you to write a document, you'd probably use Word or Google Docs. To make a presentation, you'd pull up PowerPoint or Keynote or Google Slides.

Not so for to-dos. There is no Way That Everyone Does It. It's a crazy Pokémon deck of options: Trello, Todoist, Gmail's tasks, Microsoft To Do, Remember the Milk, Things, OmniFocus, Any.do, Evernote's Tasks, and Clear, to name just a few. And that doesn't even count the whackload of us using one big ol' Notepad file on our computers, or even plain old paper.

"There are *hundreds* of commercially available to-do lists right now," says my friend Mark Hurst. Fifteen years ago he created one of the first productivity apps, Good Todo. Today it has a relatively small user base, but in general, productivity apps are big business; Americans downloaded them 7.1 billion times last year.

Chen and Guzman's experience with trying to make one turns out to be common. The creators of personal to-do apps—or task management software, as it's sometimes called—generally agree that they haven't cracked the nut. Every one of these apps attempts to handle the same kind of basic actions: Give people a way to write down tasks, like "Get milk" or "Finish the sales memo," and offer tools to sort and prioritize those tasks.

Ideally, that improves your productivity, which broadly is how many things you can actually get done in a given amount of time. It seems easy enough.

But when I talk to folks who use these apps, I see a strange inconclusiveness. A scant minority of us check off everything every day. An equally tiny minority simply Cannot Even and are curled in a fetal ball awaiting imminent firing. But most of us? We're just sort of… meh. We bounce from app to app, never quite finding a home. "I'll try that one. I'll try that one. I'll try that one. Maybe this will do the magic!" as Randy Shulman, editor and publisher of *Metro Weekly*, Washington, DC's LGBTQ paper, tells me. Sure, we're getting work done! But we always feel slightly out of control, haunted by the to-dos at work and home that we just aren't nailing.

The question is, why? Not just why it's so hard to make a to-do app that works, but why people often feel so distraught by their hunt for the perfect organizational system. I've written about software for years, and I can tell you that people often have surprisingly deep feelings about their apps. But rarely is a category of software linked to such vistas of despair.

In the 1920s, the German psychologist Kurt Lewin was dining in a restaurant and noticed something remarkable. As one version of the story goes, Lewin realized that the waiters were able to meticulously recall specific food orders—until they'd served the food and the customer was gone. After that, they couldn't remember any of those details at all. Lewin's student, a Soviet psychologist named Bluma Zeigarnik, became fascinated by this phenomenon. She started working on it in her lab. In a now [classic set of experiments](#), she gave volunteers a series of tasks (assemble a cardboard box, make a figure out of clay, do some arithmetic). Then she'd interrupt them, checking to see what the volunteers actually remembered.

Zeigarnik found a quirk of the human mind: When a task is unfinished, we can't seem to stop thinking about it. We perseverate. Psychologists still argue about why; possibly it's a kind of constant refresh to keep whatever's pending from vanishing from our short-term memory, like putting something by the front door at night so you don't forget to take it with you the next morning.

Whatever the cause, today this is known as the Zeigarnik effect, and psychologists who study task management say it's part of why so many of us feel perpetually frazzled by the challenge of organizing work and life. When we face all that undone stuff—emails to write, calls to return, people to contact, friends to check in on, memos to draft, children to help—it's like being a waiter serving a hundred tables at once. If you've found yourself in bed at 2 am with your brain screaming at you about that thing you didn't do, that's a Zeigarnik moment.

A good to-do tool ought to ease the Zeigarnik effect. In 2011, psychologists E. J. Masicampo and Roy Baumeister showed that this does seem to be the case. They triggered the Zeigarnik effect in volunteers by giving them a task and not letting them complete it. It lingered in their minds and interfered with their ability to do other work. Then the psychologists allowed the subjects to write out a plan for how they'd get that outstanding task done, and, presto, it lessened the effect. Speccing out what you're going to do—getting it outside of your head—seems to help you stop perseverating.

And indeed, those who regularly write down their to-dos seem to possess a mind less jittery. Shamarukh Chowdhury, a PhD student in psychology at Carleton University, has found that people who create to-do lists are less likely to procrastinate than those who don't. More delightfully yet, a study by Baylor University psychologist Michael Scullin found that people who created a to-do list fell asleep nine minutes faster, on average, than those who didn't.

The creators of to-do apps all intuit the challenge of the Zeigarnik effect. They say that a key part of their apps is how frictionless they make it for us to input tasks. They've all worked to make this an instantaneous process: Open the app on your phone, shout at Siri or Alexa, or even email a new to-do item to your software.

Alas, this often makes things worse. Sure, the Zeigarnik effect is eased if you make a plan: I'll do this, then do this, then do this, and then I'm done. One of the most famous productivity systems—David Allen's Getting Things Done—is ruthlessly focused on rigorous planning and editing of tasks. It can take hours, but once you've done that hard work, you can plow

through the tasks, one after another, with the metronomicity of a Chrysler line robot.

The problem is that we too often don't really plan. Digital apps make it easy to add more tasks to the pile, and it feels good to get tasks out of our Zeigarnicized heads. So we do, frenetically.

"We call it snowballing," says Amir Salihefendić, who founded the app Todoist in 2007; it currently has 30 million users. "They keep postponing stuff. And then suddenly you have a hundred tasks that you need to do." Weeks or months later, your Todoist app is a teetering ziggurat of tasks, too painful even to behold. Omer Perchik, the creator of another app—Any.do —calls this problem "the List of Shame."

And then what do we do? You've probably done it: We panic, give up, and quit. We "declare to-do bankruptcy." We toss the list away in defeat and start fresh.

You can blame Zeigarnik again. The mere act of making a to-do list relieves so much itchy stress that it can, paradoxically, reduce the pressure to actually get stuff done. "People feel that when they put all their tasks somewhere, they've already done most of the work," Perchik says. But it's an illusion. The pile of work is still there.

More than a pile! If you feel adrift on a turbulent sea of unmanageable tasks, that might be because there is objectively more expected of us. By one estimate, work hours for those with college degrees went up about 7 percent between 1980 and 2016. Got a graduate degree? For you it went up more than 9 percent. And quite apart from one's paid toil, there's been an increase in social work—all the messaging and posts and social media garden-tending that the philosopher and technologist Ian Bogost calls "hyperemployment."

(We could snap the lens open even wider and have a fuller reckoning with capitalism. Focusing on our individual ability to tread water—with apps and lists—can look like a bleak exercise in blaming the victim, when in reality the only solution is not better apps but non-hideous workloads, debt relief, and a saner landscape of civic care. Frankly, if you took "managing

grotesquely useless and bloodsucking for-profit health insurance" off people's to-do lists, it would remove one remarkably stressful item, as my Canadian upbringing compels me to suggest. But I'm writing this particular article from within the belly of the whale, as it were.)

No matter whose fault it is, we take this stuff personally. American to-do behavior has a deeply puritan streak. Benjamin Franklin was among the first to pioneer to-do lists, creating a [checklist](#) of "virtues"—temperance! frugality! moderation!—that he intended to practice every day. That's what the information scientist Gilly Leshed and computer scientist and cultural theorist Phoebe Sengers, both at Cornell University, [found](#) when they talked to people about their to-do lists. "They abide by the norm of 'We need to be productive citizens of this world,'" Leshed tells me. Doing more is doing good.

To-do lists are, in the American imagination, a curiously moral type of software. Nobody opens Google Docs or PowerPoint thinking "This will make me a better person." But with to-do apps, that ambition is front and center. "Everyone thinks that, with this system, I'm going to be like the best parent, the best child, the best worker, the most organized, punctual friend," says Monique Mongeon, a product manager at the book-sales-tracking firm BookNet and a self-admitted serial organizational-app devotee. "When you start using something to organize your life, it's because you're hoping to improve it in some way. You're trying to solve something."

With to-do apps, we are attempting nothing less than to craft a superior version of ourselves. Perhaps it shouldn't be a surprise that when we fail, the moods run so black.

Programmers often describe software as being "[opinionated](#)." In the guise of helping us try to do things, productivity software recommends we do them in a particular way. A to-do app is offering an opinion about how we ought to organize our lives, which is, when you think about it, a kind of intense opinion for a piece of code to hold, right?

This is part of why we have such strong feelings about any given task-management tool. We either love it or hold it in bitter contempt.

Jesse Patel created the app Workflowy because he had ADHD and wanted a tool that worked as his mind required. In the late 2000s he was working as a head of business development, with "five different big-picture opportunity areas and, like, 30 different subprojects in each of those. It was just so overwhelming." He noticed that each work task tended to spawn tons of subtasks. But most software, he found, wasn't great at allowing for that Russian-nesting-doll quality. He wanted a "fractal" tool where every to-do could contain more little to-dos inside it.

So he taught himself to program and created Workflowy to function just so: When you open a new project, you write items that can spawn endless sub-items, all of which can be dragged around and reorganized. If things look too cluttered, you can collapse everything so you see only your top-level tasks. "It's a universe for your thoughts," Patel says.

It's a big universe—250,000 active users, like the construction site manager who told Patel that he made items for each room, with sub-items for anything the room needed. ("That room has, like, four missing bolts.") I heard from people who loved Workflowy; I also heard from people who thought the whole fractal thing was a dead end. Salihefendić's app Todoist once allowed levels upon levels of subtasks, but he got rid of them after noticing that only a fraction of people used them, and they were mostly just dorking around, organizing their subtasks instead of actually doing work.

Pick virtually any postulate about "the best way to get organized" and app designers will have diametrically opposing views. The app Things lets you put a due date on each task; Hurst, the founder of Good Todo, hissingly denounces due dates as a form of productivity self-harm that turns into a screenful of blinking red overdue alerts.

So the software is opinionated, as are its makers. But they're also weirdly humble. Most of the app builders I spoke with admitted that, for many who try their tool, it won't help. Maybe their app doesn't match the way that customer's mind works. Maybe the customer is a hot mess. Maybe their workload is unreasonable. Either way, the app creators are surprisingly willing to admit defeat. April Ramm, who does customer support for OmniFocus, will sometimes recommend a rival app to a potential customer.

This stance is … kind of unusual in the world of software, yes? One rarely hears founders candidly admit that their tool probably won't fulfill its stated goal for many users, much less that it probably isn't specifically right for you, either.

For years, I had a very rudimentary to-do system. Using a piece of paper, or maybe a document on my PC, I'd list my main areas of work ("WIRED Column," "Household," and so on). Then I'd write out all my tasks under each heading. (Under "WIRED Column": "Call scientist about study.") Finally, I'd make a plan. I'd number all my subtasks. Typically I'd hopscotch from project to project: My number one task would be the fourth item under "Household," then number two was the seventh item under "WIRED Column," and so on. Finally, with my plan laid out, I could power through my list.

Or at least I'd try to. Sometimes my system would work for days or weeks, but eventually it'd balloon into a List of Shame, and I'd guiltily declare bankruptcy.

I often suspected the problem was that my system was visually confusing. I had to scan the page to figure out what my next item was. Wouldn't it be nice if, instead, I could click a button and my to-dos would arrange themselves in numerical order?

So I decided to make the app myself. I'm a hobbyist programmer, and I figured this spec was simple enough that even my hazy coding skills could pull it off.

One evening a year ago, I sat down and bashed out a prototype. The next day I started using it and found, to my delight, that it worked much as I'd hoped. I now had a numbered list I could sort and unsort quickly. I used it every day for months. Projects came and went; I filed stories and juggled tons of household errands. It felt lovely to have a tool designed for precisely the way my mind worked.

The thing is, it didn't improve my productivity. It certainly did not increase how much paid work I accomplished. I was still filing the same number of

stories, and doing the same life chores, in the same amount of time. I still found myself getting piled up and spiraling into to-do bankruptcy.

Sure, I could visualize my tasks better. But that didn't move the needle on my efficiency. In fact, one day while working on the very story you're reading now, I found myself staring at a monstrous List of Shame in my app. I declared bankruptcy, and then I shakily pulled out a single piece of paper and reprioritized, writing down a small handful of things I could actually accomplish.

I still use my app, intermittently. But building it made me realize a grim fact about to-do software, which is that even the most bespoke, personalized version couldn't unfrazzle my mind. And after dozens of interviews with users and coders, talking to them about my failure—and theirs—I began to realize that a big part of our problem lies deeper than interfaces or list-making. It's in the nature of time itself, and our relationship to it.

If you ask people to accomplish a loony amount of work this week, they'll go, *No way. Can't be done*. But if you tell them they'll need to do that same bonkers amount in a single week one year from now? They'll think, *OK, sure, I could do that*.

Something about the future defeats our imaginative capacity. "Present self screws over future self," says Tim Pychyl, a psychologist at Carleton University who studies procrastination. He says that we regard our future self as a stranger, someone onto whose lap we can dump tons of work. On some weird level, we don't get that it'll be us doing it.

One of Pychyl's students recently tried a clever experimental trick to get people to procrastinate less. The student took undergraduates through a guided meditation exercise in which they envisioned themselves at the end of the term—meeting that future self. "Lo and behold," Pychyl says, those people "developed more empathy for their future self, and that was related to a decrease in procrastination." They realized that time wasn't infinite. Future them was no longer a stranger but someone to be protected. To get us off our butts, it seems, we need to grapple with the finite nature of our time on Earth.

This is the black-metal nature of task management: Every single time you write down a task for yourself, you are deciding how to spend a few crucial moments of the most nonrenewable resource you possess: your life. Every to-do list is, ultimately, about death. ("Dost thou love life?" wrote Ben Franklin. "Then do not squander time, for that is the stuff life is made of.")

I began to suspect that this is the truly deep, arterial source of some of the emotions around to-do lists. The people who make to-do apps agreed with me. "What is this class of software supposed to do?" asks Patel, the creator of Workflowy, rhetorically. "It's supposed to answer the question 'What should I do right now in order to accomplish all of my life goals?' The most scarce resource many of us have is time."

Ryder Carroll, the creator of the Bullet Journal paper-based method for organizing your work, puts it in even more starkly existential terms. "Each task is an experience waiting to be born," he tells me. "When you look at your task list that way, it's like, this will become your future." (Or if you want the European literary-philosophical take, here's Umberto Eco: "We like lists because we don't want to die.")

No wonder we get so paralyzed! The stakes with PowerPoint really aren't that high.

Given that life is composed of time, a whole sector of the task-management philosophical magisteria argues that mere lists will always be inherently terrible. Just as Pychyl showed, we overload ourselves with more than we can accomplish and create Lists of Shame because we are terrible at grasping how little time we actually have. The only solution, this line of thinking goes, is to use an organizational system that is itself composed of time: a calendar.

Instead of putting tasks on a list, you do "time blocking," putting every task in your calendar as a chunk of work. That way you can immediately see when you're biting off more than you can chew. Cal Newport, a computer scientist at Georgetown University and guru of what he calls "deep work," is probably the staunchest advocate of time blocking. "I think it is pretty undeniable that time blocking, done well, is going to blow the list method out of the water," Newport tells me. He says it makes you twice as

productive as those suckers who rely on lists. Time blocking forces us to wrestle directly with the angel of death. It's natural that we then screw around less.

Several researchers who study tasks told me they generally agreed that time blocking avoids the problems of to-do apps and lists. One to-do app, Reclaim, actually has an AI that estimates how long each task will take and finds a slot in your calendar. (The secret point is to show you there isn't much room in there.) "We'll not only tell you when tasks are overdue, we'll tell you that tasks are *going* to be overdue," says Patrick Lightbody, Reclaim's cofounder.

Though, as you might expect by this point, other productivity thinkers are equally vehement that calendars alone won't save you. You also have to develop a Jedi-like ability to say no to your own craving to do more, more, more. Salihefendić says the people who are "really into" Todoist—and most productive—are fanatical about completing more tasks than they add.

In this vein, a whole bench of task-management philosophers believe that the best interface isn't digital at all—it's paper.

Paper forces you to repetitively rewrite tasks, as when, say, you transfer all last week's undone to-dos to this week's list, or when you erase and rewrite calendar events. That's what I do when the productivity software I wrote for myself fails me. "Making that choice over and over again," Carroll tells me, "is the first opportunity where you're like, 'Why am I doing this?'" The inconvenience can be clarifying. Making a list on a sheet of paper is an unusually rich metaphor for life: It takes effort, and the space fills up more quickly than you expect.

The usefulness of paper here cuts to the real heart of what makes to-do management such a grim problem. Apps, lists, and calendars can help us put our priorities in order, sure. But only we can figure out what those goals are. And setting limits on what we hope to do is philosophically painful. Every to-do list is a midlife crisis of unfulfilled promise. Winnowing away things you'll never do in a weekly review is crucial, yet we dread it for what it says about the boundaries of existence. Our fragile psyches find it easier to build up a list of shame, freak out, and flee.

This is what makes to-do software unique. The majority of tools we use in our jobs are about communicating with someone else. All that messaging, all those Google docs, all that email—it's about talking to other people, documenting things for them, trying to persuade them. But a to-do list is, ultimately, nothing more or less than an attempt to persuade yourself.

[Geoff Manaugh](#) [Nicola Twilley](#)

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When the Next Animal Plague Hits, Can This Lab Stop It?

A new federal facility in Kansas will house the deadliest agricultural pathogens in the world—and researchers working tirelessly to contain them. Illustration: Simon Prades

There were 16 pathogens on the terrorist's list, written in tall, spiky scribbles that slanted across the page. Next to each one was the incubation period, route of transmission, and expected mortality. Pneumonic plague, contracted when the bacterium responsible for bubonic plague gets into the lungs, was at the top of the list. Left untreated, the [disease](#) kills everyone it infects. Farther down were some names from pandemics past—cholera, anthrax. But what struck General Richard B. Myers was something else: Most of the pathogens didn't affect humans at all. Stem rust, rice blast, foot-and-mouth disease, avian flu, hog cholera. These were biological weapons intended to attack the [global food system](#).

Myers was the chairman of the Joint Chiefs of Staff in 2002, when Navy SEALS found the list in an underground complex in eastern Afghanistan. US intelligence services already suspected that [al Qaeda](#) was interested in biological weapons, but this added weight to the idea that, as Myers put it, "they were indeed going about it." Later that year, he said, another intelligence source reported that a group of al Qaeda members had ended up in the mountains of northeastern [Iraq](#), where they were testing various pathogens on dogs and goats.

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"To my knowledge, they've never gotten to the point where it was of use for them in the battlefield context," Myers told us. "But since al Qaeda, as we found out with the World Trade Center in New York City, never quite give up on an idea, it's not something you can just dismiss." In fact, he said, "I think there's other, probably classified information that would tell you that's *not* the case—but I'm not privy to all that or privy to talk about it."

Even if al Qaeda moved on, other groups appear to have picked up the bioterror baton: In 2014 a dusty Dell laptop retrieved from an ISIS hideout in northern Syria—the "laptop of doom," as it was later dubbed by *Foreign Policy*—was found to contain detailed instructions for producing and dispersing bubonic plague using infected animals.

For a would-be bioterrorist, Myers says, farms and feedlots are a "soft target." They aren't well secured, and effective pathogens are not particularly difficult to manufacture and deploy. Foot-and-mouth disease, a virus named after the large, swollen blisters it causes on the tongues, mouths, and feet of cloven-hoofed animals, is so contagious that the discovery of one case in a herd usually triggers mass culls. "All you do is put a handkerchief under the nose of a diseased animal in Afghanistan, put it in a ziplock bag, come to the US, and drop it in a feed yard in Dodge City," Senator Pat Roberts told a local NPR affiliate in 2006. "Bingo!"

Farming is also highly concentrated: Three states supply three-quarters of the vegetables in the US, and 2 percent of feedlots supply three-quarters of the country's beef. What's more, both crops and livestock are genetically uniform. A quarter of the genetic material in America's entire Holstein herd comes from just five bulls. (One of them, Pawnee Farm Arlinda Chief, contributed nearly 14 percent.) Monocultures like this are exceptionally vulnerable to disease. They are an all-you-can-eat buffet for pests and pathogens. With or without the assistance of a studious terrorist, the world is just as susceptible to an agricultural pandemic as it was to Covid-19— and, if anything, less prepared to fight it.

To diagnose deadly diseases and develop treatments and vaccines for them, researchers need to work with them in a lab, but very few facilities are

secure enough. Foot-and-mouth disease, in particular, is so easily transmitted that the live virus cannot be brought to the US mainland without written permission from the secretary of agriculture. The only place researchers can work with it is Plum Island Animal Disease Center, built on a low-lying islet 8 miles off the Connecticut coast. ("Sounds charming," as Hannibal Lecter, the homicidal antihero in *The Silence of the Lambs*, murmured when offered the possibility of a vacation there.)

Plum Island has the advantage of a natural cordon sanitaire—the ocean. But it opened in 1954, and its laboratories are outdated. They aren't certified to handle pathogens that need the highest level of containment, [Biosafety Level 4](). According to the Centers for Disease Control and Prevention, BSL-4 microbes are "dangerous and exotic, posing a high risk of aerosol-transmitted infections." Typically, they can infect both animals and humans and have no known treatment or vaccine. Ebola is one. So are the more recently emerged Nipah and Hendra viruses. Only three facilities in the world are currently equipped to accommodate large animals at this level. If there were an outbreak of foot-and-mouth disease in the US tomorrow, researchers here would have to beg their Canadian, Australian, or German counterparts for lab space.

That will change next year, when the Department of Homeland Security opens its new $1.25 billion lab, the National Bio and Agro-Defense Facility. Located in Manhattan, Kansas, a college town in America's agricultural heartland, the NBAF will follow the 21st-century trend in infectious disease control: Rather than relying on a Plum Island–style geographic barrier for security, it will use extraordinary engineering controls. Here, amid the corn and cattle, researchers will work to protect the food supply from a coming plague.

We visited the NBAF's 50-acre construction site on a muggy spring day in 2019. One of the late-afternoon thunderstorms for which the Great Plains are famous had just swept through, sending sheets of rain down across the Gothic castles and limestone halls of the Kansas State University campus. The site was selected after a three-year national competition, in part because of Manhattan's existing expertise: It is also home to the Biosecurity

Research Institute, a BSL-3 lab completed in 2007. Senator Tom Daschle has hyped this area as "the Silicon Valley of biodefense."

Still, you can see why critics questioned the wisdom of situating a lab designed to work with the world's most devastating large-animal diseases in a state where ruminants outnumber people by more than two to one. Trace a 200-mile radius around Manhattan and it will include one in 10 of America's cows. If foot-and-mouth were accidentally released here, estimates show it could easily infect herds in surrounding states—nearly half the nation's cattle—and cause as much as $50 billion in damage.

And then there's the weather. After Manhattan won the bid for the NBAF, the Texas Biological and Agro-Defense Consortium, whose preferred site in San Antonio finished runner-up, immediately filed suit with a 50-page list of complaints. In claim 103, the consortium noted that anyone familiar with *The Wizard of Oz* should be aware of Kansas' reputation for dangerous tornadoes. (The suit was dismissed without prejudice a few months later.) According to one estimate, from a report prepared in 2010 for the National Academy of Sciences, the probability of a pathogen escaping over the NBAF's 50-year projected life span is an astonishing 70 percent. In response to these concerns, the Department of Homeland Security "hardened" the design to resist a Category 5 tornado, the most intense possible, then commissioned another risk assessment, which rated the likelihood of an accidental pathogen escape at 0.1 percent.

From our view onto the enormous construction site, this hardening mostly seemed to take the form of an awful lot of concrete. "Enough to build a sidewalk from here to Oklahoma City," said Ron Trewyn, a former cancer researcher who led the effort to get the NBAF built. "Sixty thousand cubic yards, I believe, poured over two and a half years." (It's also a high-performance variety, with a built-in controlled chemical reaction that causes the concrete to expand after setting, leaving no room for cracks.) The site itself was off-limits, but the project's technical director, Eugene Cole, agreed to have coffee with us in a nearby hotel lobby.

Cole, a soft-spoken Southerner, came to the NBAF after leading the design of Building 18, the CDC's new lab for emerging infectious diseases. His passion for animal welfare initially led him to veterinary school, but then he

realized he didn't want to smell like formaldehyde for the rest of his life, so he got into architecture. Now he is something of a star in the small world of bio-containment design. His work on Building 18 received several awards and a special mention in *R&D Magazine*'s Lab of the Year feature. The NBAF, much to his delight, will receive LEED certification, something many in the field considered impossible. (Labs tend to use at least four times more energy per square foot than offices.)

Cole cares about technical specifications—ventilation, cooling, sanitation—but he spends almost as much time thinking about natural light and areas for socializing. "How do I make the space appealing to the best researchers, when it's more or less a tornado bunker?" he said. "You won't find many BSL-4 environments that have an outside window."

Nonetheless, containment is the NBAF's most important function. Cole told us that the windows he has managed to smuggle in are blast- and impact-resistant, with a metal grille on the outside to meet Nuclear Regulatory Commission guidelines for high-wind events. "But in a tornado, it's the pressures that are difficult," he said. BSL-4 rooms are built using the box-inside-a-box principle, in which a negative-pressure lab is surrounded by a positive-pressure buffer, ensuring that air is always sucked inward, deeper into the building, rather than escaping out into the atmosphere. If a slow—moving storm caused a sudden drop in external air pressure, that flow could reverse. But Cole assured us that the NBAF will have barometric systems that can quickly recalibrate.

A BSL-4 laboratory, as Cole described it, is something like a layer cake. At the bottom is an "effluent-handling" floor, then the laboratory floor where all the germs are studied; stacked above that are a filtration level, a mechanical level, and an exhaust-venting "penthouse." All the pipes and wires and ducts are in their own compartmentalized, containable spaces—but they also have to be accessible for regularly scheduled tests and preventive maintenance. This, Cole pointed out, will actually be the largest line item on the facility's annual budget. "Many times, from a design perspective, the focus is all on the science," he said. "That's a huge mistake." Cole and his colleagues have carefully designed pathways through the spaghetti of piping to make access as quick and easy as

possible. The building has a computerized maintenance management system that all but tells the operating staff what it needs.

The NBAF is both bigger and better than its neighbor, the Biosecurity Research Institute. One area of improvement is carcass disposal. The older facility has a tissue digester that dissolves animals in an alkaline soup, reducing bones and teeth to crumbly calcium-phosphate "shadows," stripped of all organic matter. These solids are dried and incinerated. The remaining liquid, a soapy solution of amino acids and peptides, is sterile enough to be released into the municipal sewer system. The only issue is that it is still so full of organic molecules that it can easily overwhelm the capacity of the wastewater treatment plant. So, before every release, Cole explained, the team at the older facility "has to call the city to see if they're ready to take that slug." This usually occurs late at night—the corpses of liquefied animals passing through Manhattan's sewers while residents sleep, blissfully unaware, in their homes above.

At the new facility, Cole said, "our carcass material will never go down the drain." Instead, the NBAF has two thermal tissue autoclaves—"basically a big pressure cooker with a paddle in it," he explained. The autoclaves produce a kind of tissue smoothie that is sterile enough to use as fertilizer. Out of an abundance of caution, it will be put into 55-gallon drums and incinerated instead. "There are just redundancies on top of redundancies," Cole told us.

Cole is most proud of the flooring. Vinyl and tile work well for human foot traffic, but cows, sheep, and pigs have special requirements. Cole didn't want anything that would chip, peel, or crack. He settled on a compound that binds to the concrete subfloor at a molecular level, forming a water—resistant layer that can be efficiently decontaminated again and again. He knew he needed to mix in some grit to keep the animals from slipping, but not so much that it would tear up their hooves and cause discomfort. He consulted the literature and discovered that no one had ever taken the time to scientifically determine what the right amount of grit should be. So he did the research himself, in his basement.

First, Cole acquired a machine used to test the slip resistance of shoes on carpet. Then he persuaded the necropsy lab at Kansas State's veterinary

school to give him some hooves. "They're like your fingernail, just big," he explained. Cole attached the hooves to the slip tester's mechanical foot, then set it in motion. As it stepped in place, he measured the friction and durability of the floor material at varying grit levels, as well as any hoof abrasion. "Yeah, my wife was not happy," he said, recalling the parade of disembodied hooves marching endlessly toward nowhere. But the outcome, he pointed out, is perfect flooring—cleanable, easy on the animals' feet, and completely nonslip. He has published his findings and hopes to have them enshrined as a new international standard.

"We all suffer from OCD," Cole said, with a slightly embarrassed laugh. "I mean, to be in containment design, you do have to be worried about the details."

The first permanent quarantine facility in the world was a brick plague hospital, or *lazaretto*, built on an island in the Venetian lagoon in 1425 to protect the city from the Black Death. Since then, the architecture of containment has failed repeatedly. Often, the escapes have been intentional, if not necessarily malicious. In the 1780s, a guard at the lazaretto in Split, Croatia, smuggled home a beautiful white scarf as a gift for his wife, inadvertently releasing bubonic-plague-infected fleas that killed one in 10 of the city's residents. In the 1830s, a bored Boston ship's pilot took advantage of the temporarily frozen harbor to walk from Quarantine Island to shore, triggering a cholera panic. Other times, pathogens have simply hitchhiked across boundaries with the help of unwitting human carriers; wheat stripe rust, a fungal disease that reduces harvests by up to 40 percent, is thought to have been brought to Australia on an international traveler's trouser cuffs.

"Everyone will tell you, it always comes down to the people," Trewyn said. They have been the Achilles' heel of lazarettos throughout history. Of course, the NBAF is carefully engineered to lower the risk of human error. On the lab floor, people, animals, and stuff can move in only one direction, from clean to contaminated, "cold" to "hot." Everything—including the animals, in carcass form—exits through a fumigation vestibule, a chemical dunk tank, or an autoclave, with the sole exception of people, who have to take two chemical showers and one regular shower before they can leave.

(At Plum Island, researchers often complained that the showers had only a curtain separating them from the adjacent corridor. At the NBAF, decon happens in a personal air lock. "Times have changed," Cole said.)

The NBAF will implement continuous training, detailed record-keeping requirements, and a buddy system, so that staff can inspect one another for trace contamination after showering out. Everyone who works there will have to pass background screening and security checks. The building has concentric rings of facial-recognition and PIN-code checkpoints. The precautions even extend into researchers' private lives: They will not be allowed to keep chickens, on the off chance they bring home a pathogen that jumps species. Even so, the National Research Council has complained that Homeland Security's risk assessment—a 0.1 chance of a pathogen escaping—was "based on overly optimistic and unsupported estimates of human error rates." (The assessment didn't even attempt to quantify the likelihood of malicious or deliberate acts.)

Certainly, Plum Island has had a handful of documented close calls, as have other such facilities around the world. But Trewyn believes that the risk of accidental pathogen escape, in all its uncertainty, is worth taking. These diseases will arrive in the United States anyway, he says, and cause equally incalculable damage.

Trewyn pointed to the very different courses taken by two outbreaks of the same disease in the UK—one caused by a lab leak, the other by an inadvertent introduction. In 2007, foot-and-mouth disease virus slipped out of the Pirbright Institute, an animal—disease research facility, into the Surrey countryside, with the help of heavy rains and poorly maintained pipework. It was quickly caught and contained. Within hours of the first case, the government halted all movement of livestock in the entire country; within two months, the virus was mopped up, having infected just eight farms. The system worked, Trewyn concluded, especially when compared with a very different incident six years earlier.

That outbreak began in Northumberland in 2001, when contaminated pork that had likely been illegally imported from Asia was fed to a herd of pigs, triggering a national epidemic of foot-and-mouth disease. Soldiers were brought in to help slaughter the affected herds. Six million sheep, pigs, and

cattle died. As footage spread of the British countryside alight with animal pyres and bulldozers shoveling rigid carcasses into huge piles for incineration, tourism dropped 10 percent. By the time the outbreak was finished, at least 60 farmers had taken their own lives.

Calculating the cost of such an outbreak is almost as tricky as assessing its risk. It's simple enough to put a price on slaughtered animals and their disposal, but the ripple effects are harder to quantify. Farmers with healthy animals can't sell them at market; governments impose restrictions on export and import. Although animal diseases are unlikely to cause famine, disruptions to the national meat supply can cause prices to skyrocket, leading to deeply discontented consumers. (In 1902, when the price of kosher beef jumped from 12 cents to 18 cents a pound, the women of New York's Lower East Side rioted, breaking windows and throwing steaks.) As Myers told the Senate Agriculture Committee in 2017, "Hungry people are not happy people."

One top priority for NBAF researchers will be to develop a treatment or vaccine for African swine fever, the deadliest outbreak most Americans have never heard of. This highly contagious hemorrhagic disease does not infect humans, but in the past couple of years it has killed a quarter of the world's pigs. The symptoms are indistinguishable from those of hog cholera, item No. 10 on the al Qaeda bioweapon wish list: vomiting, diarrhea, fever, and a distinctive blue—purple discoloration of the snout, tail, and ears, typically followed swiftly by death.

African swine fever hasn't yet been detected in the United States. As the US Department of Agriculture's web page on the disease says, "We want to keep it that way." But in China, the virus has claimed at least 40 percent of the country's pig population, and the price of pork more than doubled from 2018 to 2019—a serious problem for a commodity whose cost has roughly the same political significance in China as gasoline prices do in the United States.

According to a 2019 exposé by Xinhua, the state news agency, criminal gangs, referred to as "swine stir-fry syndicates," have taken advantage of the outbreak. In some cases, they have used drones to drop infected feed onto farms that had yet to be touched by the disease, then swooped in with

an offer to buy the animals at a steep discount, supposedly to cull them. In reality, though, they resell the herd in another province—despite a national ban on pork and pig movement. The report claimed that one gang had smuggled as many as 4,000 pigs between provinces in a single day, bribing inspectors and faking quarantine certificates to get the animals across checkpoints.

In response, one pig farmer in the country's northeast installed an anti-drone device that unfortunately also jammed the navigation systems of planes heading to a nearby airport. China's largest pig producer has recently invested in 12-story bio-secure piggeries. Each floor has its own air—handling and disinfection system to limit the spread of disease, while staff live in dedicated housing onsite, spending two days in quarantine every time they enter the facility, unable to leave until their day off. One farmer in Hunan Province told a *New York Times* reporter that pigs have become so rare in his region that when he transports his animals, people gather around the truck to stare. "It's like they were seeing a panda," he said.

Fifty countries have now confirmed the presence of African swine fever in their herds, as far afield as the Philippines and Poland. Denmark, a porcine powerhouse, has begun construction of a wild-boar-proof fence along the length of its border with Germany to keep the virus out. In Australia, sniffer dogs have been stationed at airports, and mail is screened in order to catch pork being smuggled into the country; the pathogen survives for months on surfaces and in even heavily processed and cooked meat. "Only one country has been able to eradicate this disease," the Australian agriculture minister told reporters in 2019, referring to the Czech Republic's successful four-year elimination campaign. "They sent their army into forests night after night to shoot every single feral pig."

For many experts, the pressing question is not whether the NBAF's containment will fail but what the US will do when African swine fever finally arrives. Myers, who in 2016 moved to Manhattan to become president of Kansas State, his alma mater, says that *when* is the right word. "It has not come to North America—that's great," he said. "To say that it won't in this globalized economy of ours—that is probably a foolish statement for somebody to make." In 2013, more than 10 percent of

American pigs died when a porcine epidemic diarrhea virus arrived on the reusable bulk bags used to transport feed; the half-life of African swine fever virus in shipped feed is two weeks. Pig farmers in the US have been advised to implement disinfection protocols at farm gates, ban foreign visitors, and inspect farmworkers' packed lunches for contraband bacon or hot dogs.

Since Myers' troops discovered al Qaeda's list of pathogens in an Afghan cave, there has been a huge federal investment in research, but not much in the way of local planning. Ron Trewyn told us of one sheriff—the exception, rather than the rule—who had mapped the optimal locations for the 40 roadblocks needed to create a cordon sanitaire, quarantining his entire county in the event of an outbreak. Inside the exposure zone, according to the plan, "all cloven—hoofed animals would be destroyed."

"I wish I could say that every county in this state had that," Trewyn said. Myers agreed: "I think we're intellectually better prepared, but I don't know if we're operationally better prepared. Are we really ready to destroy millions of pigs?"

The logistics of what animal-health experts euphemistically term "depopulation activities" can rapidly become overwhelming. Faced with the need to cull almost 11 million pigs during a swine fever outbreak in the Netherlands, the government resorted to mobile electrocution devices, described chillingly by journalist and WIRED contributor [Maryn McKenna](#) as "a pig-sized box that forced the animals to walk over a wet metal plate while zapping an electric current through their heads." In 2015, 38 million chickens, ducks, and turkeys had to be slaughtered in Iowa because of avian flu. Local landfills stopped accepting diseased carcasses, for fear of lawsuits from their neighbors, and the birds rotted on farms. "I've been in the landfill business probably 26 years, and I've never ever seen this kind of volume, and I hope I never do again," the director of the Northwest Iowa Area Solid Waste Agency told a local public radio affiliate.

In the US, a federal indemnity scheme entitles farmers to compensation for the animals they have sacrificed—although not for income lost because of quarantine measures and wasted production time. What's less clear is who pays for it; the division between state and federal responsibilities is blurred.

"How do you interdict the transportation network to make sure sick animals aren't moving around the United States, infecting more herds?" Myers asked. "What authority do we have to stop them?" These gaps—in terms of legal authority, inter-agency coordination, and the lack of financial and logistical infrastructure to contain disease—are, by now, disturbingly familiar. They are the same issues that plagued the US response to Covid-19.

Myers pointed out that in emergencies, the Department of Defense is responsible for enforcing USDA policies. "Local authorities generally get overwhelmed pretty quickly and then call the DOD," he said. But that's usually where the plan ends. Over the course of his military career, Myers told us, he took part in several role—playing exercises in which government agencies practiced their response to livestock disease outbreaks. Each of these simulations ended in almost exactly the same place: with the pandemic having spread out of control and the USDA requesting assistance.

"When we got to the point where it said, 'Now we're going to call the DOD for help,' the scenario would end," Myers told us. "It's ludicrous, right? The scenario would end and we, the DOD, never got to play out what it is that was needed—is it communications, is it security, is it helicopters? What is it?" Hosting the NBAF at Kansas State might be his best shot at making sure no one ever needs to see what happens next.

Adapted from [Until Proven Safe: The History and Future of Quarantine](#)*, by Geoff Manaugh and Nicola Twilley. Published by MCD/Farrar, Straus and Giroux. Copyright 2021 by Geoff Manaugh and Nicola Twilley.*

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07.01.2021 03:30 PM

Six-Word Sci-Fi: Stories Written by You

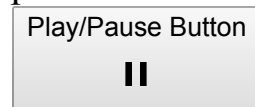Here's this month's prompt, how to submit, and an illustrated archive of past favorites.

Play/Pause Button
⏸

Illustration: Elena Lacey

THIS MONTH'S PROMPT

In six words, write a story about a self-aware self-driving car.

Submit stories on [Twitter](#), [Facebook](#), or [Instagram](#), or email us at [mail@wired.com](#). We'll choose one to illustrate.

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JULY 2021

A Story About a Casual Encounter With Aliens

SO, ABOUT YOUR PLANET'S EXTENDED WARRANTY ….

—@phorne96, via Twitter

Honorable Mentions:

You look nothing like your photo. —@markgyles, via Twitter

Lights, camera … where did it go? —thalia925, via email

They came, too late, for Elvis. —Bruce Lyon, via Facebook

Seeking vital fluids, they commandeered snacks. —Scott Medintz, via email

Do you have the correct spacetime? —Richard Krzemien, via email

I awoke with a probing thought. —@andynez, via Twitter

Take us to the Nigerian prince. —Juan Garcia, via Facebook

Quite unexpectedly, cocktail recipes were exchanged. —John Wagner, via email

You're an alien! No you are! —@simon_staffans, via Twitter

JUNE 2021

A Story About an International Digital Heist

THERE WAS NOTHING LEFT, ONLY ZEROES.

—@jamesnsmith, via Twitter

Honorable Mentions:

"Hand it over," the ATM said. —Lauren Dolan, via email

They never suspected Alexa was Alexei. —Liz Ransom, via email

Why wouldn't I help a prince? —Harleigh Marsh, via Facebook

They said nonfungible. They were wrong. —@eminay86, via Twitter

Use his eyeball while there's time. —Noreen Anastasia, via Facebook

"Update Later" was the incorrect choice. —@terryfphotos, via Instagram

Check Google Maps. Kiev is gone. —r0cket fr0g, via email

They got away on the blockchain. —JYRWG, via email

Every cat photo gone. Police baffled. —@john.cartan, via Instagram

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MAY 2021

A Story About a Freaky Discovery in Physics

ILLUSTRATION: VIOLET REED

GRAVITY WAS A CONSENSUAL, SHARED ILLUSION.

—Mark Crane, via Facebook

Honorable Mentions:

Schrodinger's cat is actually a dog. —@tynanwrites, via Twitter

You're the observed. Not the observer. —@parkerstmailbox, via Instagram

Our last seconds appear the longest. —Paul Hagenaars, via email

It was simultaneously huge and microscopic. —@Cezary_Z, via Twitter

All lost socks found at Cern. —Felix Quarnström, via Facebook

Astonishingly, up was down all along! —Christopher Walton, via email

Actually, the tides pull the moon. —@the4lw, via Instagram

A seventh Infinity Stone is found. —@taayywells, via Instagram

Faster than light announcement scheduled yesterday. —David Cinabro, via email

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APRIL 2021

A Review of a Future Work of Art

ILLUSTRATION: VIOLET REED

IT TICKLED ALL OF MY SENSES.

—Jacky Reif, via Facebook

Honorable Mentions:

So that's an AI self portrait? —Jason Cohen, via Facebook

I prefer Boston Dynamics' earlier work. —@sscarsdale, via Twitter

Uninspired. Lacking originality. Try again, Earth. —Amanda Bull Chafin, via email

NFT or not, it is great. —Peter Boersma, via Facebook

Not as good as Banksy's virus. —Simon O Wright, via Facebook

Brave to show an unfiltered canvas. —@Alcestronaut, via Twitter

Not what teleportation was invented for. —@Arturo_thrdez, via Twitter

Shame mortals will not appreciate it. —@asylbek0205, via Instagram

Reminds me of the Before Times. —Jacqueline Jaeger Houtman, via Facebook

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MARCH 2021

A Story About a Tech-Centric Religion

ILLUSTRATION: VIOLET REED

IN THE BEGINNING WAS THE "WWW" …

—Eduardo Bolívar, via Facebook

Honorable Mentions:

I swiped right and found salvation. —Conrad Dean, via Facebook

Praying to AI got better results. —@jgmclean0, via Twitter

The prophet revealed the source code. —@the4lw, via Instagram

Atop the hill, sayeth he, "reception"? —@dghutt, via Twitter

The app works in mysterious ways. —Tyler Hughs, via Facebook

Move fast. Break things. Repent. Repeat. —@iampinch, via Twitter

Always back up to be saved. —Tadeusz Walter Misztela, via Facebook

Chip implanted, the new priest rose. —@wlmoseley, via Twitter

"Worship the Apple." —iBook of Jobs —ThoreauRug, via email

FEBRUARY 2021

A Story About a WFH Office Scandal

ILLUSTRATION: VIOLET REED

THEY WERE IN THE SAME ROOM.

—@abhignak, via Instagram

Honorable Mentions:

He was never a real person? —Ian Schoen, via Facebook

Wife realized my job is easy. —@jchavizzle, via Twitter

Dress code updated after yesterday's "incident."
@mistermistermistertibbs, via Instagram

He certainly shouldn't have stood up. —Małgorzata Kuś, via Facebook

"Joe's the father." "You're not muted." —Austin Craver, via email

Worker's comp? It is her dog! @thefitzroymclean, via Instagram

It looks real, but it's not. —Jonathan Goode, via Facebook

The window behind her reflected images. —@chmslady, via Twitter

As everyone's computer froze, she laughed. —@mcgroup53, via Twitter

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JANUARY 2021

A Story About a Future American President

ILLUSTRATION: VIOLET REED

<u>Lauren Smiley</u>

<u>Backchannel</u>
06.22.2021 06:00 AM

He Thought He Could Outfox the Gig Economy. He Was Wrong

Jeffrey Fang was a ride-hailing legend, a top earner with relentless hustle. Then his minivan was carjacked—with his kids in the back seat.
 "Get that money!" Jeffrey Fang would cry out to his fellow drivers when the surge hit.Photograph: Kelsey McClellan

Jeffrey Fang, DoorDash delivery guy, knows you judge his parenting skills, and he'll join in your condemnation in a moment. He'll explain that bringing his kids along on his Saturday night shift "made sense, until it didn't," and that in hindsight, he understands that it really, really didn't. But right now, on the night of February 6, he's not thinking clearly, and you'll have to excuse him as he sprints pell-mell down a promenade of swank homes after the thief who just stole his phone.

He sees the thief dive into the back seat of a silver sedan, and as the car accelerates Fang keeps running alongside and grabs the passenger door handle—less DoorDash Dad than some kind of bespectacled Jason Bourne. The phone, you see, is his "moneymaking tool"; it's how he feeds his family. But each stride is taking him farther from his unlocked Honda Odyssey minivan, parked illegally, engine humming, in a driveway where he was making a delivery, with precious cargo in the back seat.

His kids.

This article appears in the July/August 2021 issue. <u>Subscribe to WIRED</u>.

Photograph: Djeneba Aduayom

Earlier that day, Fang's wife said she needed quiet in the house in order to tutor their 6-year-old son, because their kids are sure as hell not going to be gig workers. Fang couldn't afford to miss the money on a Saturday night run near San Francisco's Billionaires' Row, but in this city a babysitter earns nearly what Fang does. His solution was to fasten the younger kids, 4 and nearly 2 years old, into their car seats, ply them with ice cream, and cue *Shrek 2* on the videoscreen in the van. He delivers expensive orders in ritzy neighborhoods, the only way this dumpster fire of a job is marginally worth it. He doesn't expect to need the taser that he stows in his glove box. He figured the kids would be safe.

Now it has all gone sideways. His taser is uselessly back in the van. Yanking open the passenger door of the getaway car, he thrusts in his left leg, which gets battered with punches, and then swoops in to ride shotgun with the thieves. *God, farther from my kids!* Fang starts yelling, "Give me back my phone!" and pushes the door wide with his right foot in hopes of smacking a parked car. The thieves, apparently deciding that some Huawei Mate 20 X phone isn't worth all this, hand Fang his cell. He jumps out, panting, and then runs and speed-walks the two blocks back to his parking spot.

The van is gone.

Fang's Honda Odyssey was carjacked, with his kids in the back, on February 6.

Photograph: Kelsey McClellan

Twelve years after the birth of Uber, the country—the world—is still reckoning with how the on-demand economy has upended the marketplace and people's lives. Companies running on gig work emphasize the upsides: Here's a job where you can be your own boss, set your own hours. They speak of the flexible and temporary nature of gig work, how most people do it part-time or to get back on their feet—points repeated before federal judges and in Facebook ads and *New York Times* op-eds.

Jeffrey Fang represents something else: the long tail of the economy that Uber built.

Fang has worked in the gig economy full-time for seven years. He signed on first with Lyft, and as the app tweaked fares and incentives and his income declined, he added Uber, then Amazon Flex and Kango. Then came the pandemic. As people locked down, he found work driving for delivery apps like DoorDash, Instacart, and Uber Eats. His phone lured him like a blackjack table. Each offer sliding on the screen was an enticing gamble; it might bring 18 bucks, 24 bucks, or, if he played it extremely well, 100 bucks. He ignored his friends' and family's pleas to get out, thinking he could somehow beat the financial odds.

For a long time, he did. He even felt moments of pride. Compatriots speak of Fang as a sort of gigging folk hero. He was one of the top drivers in the ride-hailing industry's hometown. The guy to emulate. Yet here he is, age 39, in the middle of Jackson Street, screaming and dialing 911. Let your judgments pour out; the online chorus certainly let theirs. It's nothing Fang hasn't said in self-loathing ever since: Why in the world did he leave his kids?

Well, hop into Fang's Odyssey. He got it back, dusted in graphite powder from fingerprinting but functioning. Behind the wheel is where Fang can talk. He doesn't want to play victim. He wants to take blame and dole it where he says it's due. He's not going to pretend he's a saint. He made bad decisions. He found ways to exploit the ride-hailing apps too. But to understand how a man could arrive at the point where he abandons his children to chase a phone, you might want to follow him on a journey. He's ready to explain.

2.

"The rideshare years were, in some ways, a tragedy of my own making," Fang says. "By all measures, I should be successful, but I'm not." He got more chances in life than most people do. So where to begin?

Maybe in 1994, when at age 12 he reluctantly stepped off a plane outside of Washington, DC. His father, who worked for Cummins, the multinational maker of diesel fuel engines, had taken a transfer, moving his wife and two sons from Taiwan to the Maryland suburbs. The older son switched his first name from Shao-yu to Jeffrey in order to blend in. He didn't know English, but he loved American sci-fi, especially *Star Trek: The Next Generation* and Captain Jean-Luc Picard—stately, cool-headed, *the guy who gets things done*.

In his own life, Fang tended to biff the execution. He was 15 when another transfer—this time to Cummins' mainland China office—uprooted the family again. The company paid Jeffrey's way at the prestigious International School of Beijing, but he slacked off among the scions of executives and diplomats. He was, he says, the world's "most pathetic" rebel. To his parents' disappointment, he didn't opt for college, so they gave him orders to chaperone his younger brother in San Francisco, where they had family and his brother would finish high school. During the tail end of the dotcom boom, Fang, 18, was sulkily driving his brother to basketball practice and selling jewelry at Fisherman's Wharf. Nudged by his parents, he enrolled in community college, floundered, and dropped out. A classmate referred him to Bank of America, where, soon enough, he was pushing mortgages.

The work didn't come naturally—"You're pushed to treat people like products," he says—but it was a job he could do without a college degree. His mom, who was splitting her time between Beijing and San Francisco, started buying houses as an investment. She tried to help Fang get business by having him process one of her loans. She also urged him to borrow for a place of his own. Fang was 22 and earned only $40,000 after bonuses, but it was 2004. He got an adjustable-rate mortgage for a cookie-cutter $638,000 house in a working-class neighborhood. His parents pitched in on the down payment.

Four years later, scraping along at the bottom of employee performance targets, he quit the bank before he got fired. Now 26, he returned to City College, this time with zeal. He dove into philosophy, sashayed on the waltz team, and won election to the highest student office, student trustee, hoping

to juice a transfer application to his dream schools, Stanford and Berkeley. Fang was on his way up, haranguing the community college board to step up their leadership, lobbying the California legislature in the Mao suit made for his high school prom, presiding over graduation on the same stage as Nancy Pelosi. *The guy who gets things done*.

In 2010, with only a part-time gig at a pet shop, he was also the guy who often missed his $2,500 monthly house payment. His house wasn't worth what he owed on it, and in 2013 he was pushed into the ranks of the 10 million Americans whose homes were put into foreclosure during the Great Recession. He was lucky once more: His parents let him move into one of their investment homes, rent-free. Still, the grind—his money woes, college politicking, the side job—started pulling down his grades. A familiar shame set in: "Forget your dream, you're not going to make it." So, he says, "I left."

During a trip to Beijing in 2013, Fang encountered a more welcome complication. His parents, he says, wanted him to get on with his life—their younger son was married, while Fang had "X number of failed relationships and nothing to show for it," he says. They invited a young physical therapist over for dinner. He was struck by her gentleness and her college education. They stayed in touch, and over the months, via texts and calls, he fell "super in love." They started talking about marriage. He told her that he was broke, his credit shot, and he had no job. She said they'd work it out. "I told myself, 'She's the one.'"

Fang pulled more than half the money from his 401(k) to buy a ticket to China for the wedding in April 2014. The plan was for his wife to eventually join him in San Francisco. But to make sure immigrants don't become public charges, US citizens need assets to sponsor visa applications. Fang figured that it would take months, if not more than a year, to raise enough cash to bring his new bride to California. Soon after returning to San Francisco, married but alone, he learned that his wife was pregnant. Now, with two people to sponsor and his bank account empty, the process was going to take longer. He needed a job where he could save money and also take time off to visit Beijing for a few months a year. *What job would allow that?*

One day, while Fang was walking in Union Square, a car plastered with a Day-Glo mustache drove by. He Googled "pink mustache." While Fang had been consumed with City College politics, his adopted city had become a postrecession boom town. Since Uber's founding, in 2008, venture capital had poured into the so-called on-demand economy. Using freelancers to meet the fluctuations of customer demand, apps promised groceries delivered, Ikea cabinets assembled, dogs walked. The companies' pitch to drivers: In a city of hustling disruption, they too could be entrepreneurs.

Fang just needed the money. He climbed into his dad's 2002 Acura TL and opened the pink app. After a couple hours of driving, he'd earned $71. "I got comfortable with this job really quickly," Fang says, "and I got *good* at it pretty quickly." Looking back, this was precisely the problem.

3.

In the beginning, Fang was the driver of Lyft's marketing fantasies. He cheerily accepted nearly every ride for eight to 10 hours a day. Customers gave him five-star reviews: "Great guy. Very intelligent." He'd wait half an hour, unpaid, for a couple to finish their sidewalk spat before one of them climbed in. He handed out free water bottles. He chatted amiably, played the classical station, and dressed up as Batman for Halloween.

After a few months, Fang got more strategic. He divided up the day to surf the morning and evening rushes, when the surge would push up fares. Thursday through Saturday he ferried the bar crowd home until just before dawn. Fang imposed a tight budget, scoping the $3 Safeway burrito bowl or the $1.50 hot dog and soda at Costco. He was bringing home $1,200 a week before expenses—enough, because he was living rent-free, to put money away and send some to Beijing, where his wife had moved into his parents' home. He'd visit her, usually for about two months at the beginning of the year and again for a month in the fall. The app, the passengers, and his strict frugality aligned in a virtuous circle. *I'm helping people. I'm making money. This is gonna work out.*

On a walkie-talkie app called Voxer, Fang heard about a Lyft driver hangout in a shopping plaza in a nice part of town. Starbucks let them use the

bathroom. One guy spun music on turntables out of his back hatch, people caught naps in their cars, and Fang assessed a landscape of cliques—gym rats, DJs, vapers. A veteran Lyfter told him that $1,500 a week was about the max you could make. *Challenge accepted*. Fang doubled down, taking rides for 60 hours a week, and by the end of 2014 he topped $2,000 a week, then $2,500. He stopped asking the old guard for advice.

Fang found his own clique—the millennial worker bees: Jose Vivanco, a wry film student from Peru who'd started driving full-time and persuaded his girlfriend, Bianca Santori, to drive to support her sewing blog. Fallon Brooks-Magnus, 6 feet tall, proudly intersex and part Native American, who'd moved to San Francisco from Oklahoma for a drafting job but found that driving paid almost as well. Christian Perea, a witty UC San Diego graduate and former bank teller, who drove a Mercedes. Kris Rohr, a gamer from Palm Springs, who was the only driver in the group who could out-earn Fang.

The group traded tips and barbs in their own channel on Voxer, like long-haul truckers on a CB radio. The group cued a recording of Rohr screaming, "There's *Prime Tiiime!*" Or Fang would say, "Good luck. Get that money!" when the surge hit, and everyone knew to follow the playbook they'd worked out: Don't flock to the area with the highest surge—that will be played out by the time the heat map refreshes. Go to the area that's just starting to inch up. Oh, and "Fuck Uber."

A half-decade into the on-demand economy, Uber was the original and dominant juggernaut. By early 2015, 200,000 people across the country were driving for the company. Lyft, the perpetual underdog, had 51,000. But as ride-hailing services expanded, so did the backlash. As contractors, not employees, drivers weren't guaranteed a minimum wage or paid expenses or offered sick days or health insurance. Taxi drivers staged protests. Drivers sued Uber and Lyft, arguing that since the companies dictated the manner and means of work, they met the legal standard of an employer. Fang and some of his group joined the class action suits. (Settlements came years later: Fang got $7,400 from Lyft and $3,800 from Uber but remained a contractor.) The companies retorted that they dealt in

software, not driver services, and that labor laws were hopelessly out of date.

While the Voxer group knew that Lyft was benefiting from the business model, most of them decided their real war was with Uber. They didn't mind that Lyft took a 20 percent commission from their rides if that's what sustained the business. Even with Lyft's commission, each of the Voxers was earning at least $1,200 a week—or about $50,000 to $60,000 a year—before expenses. They were exuberant with the fast cash. Lyft felt like a friendly place; Uber didn't allow tipping and had a more brash, aggressive image. "We looked at Uber like it was Darth Vader," Brooks-Magnus says. Sure, Vivanco drove for Uber in the mornings, because it seemed busier. "But I wasn't happy about it," he says.

No one's allegiance to Lyft was deeper than Fang's, who credited the app with rescuing him from failure. "I was at the lowest point in my life," he says. "Lyft was a lifeline to get back up." He spoke of the company as a benefactor that "takes care of its drivers." Lyft offered a bonus to drivers who accepted 90 percent of calls, and word spread around the Starbucks lot that you could use the phone's airplane mode to decline unprofitable rides —tricking the app—and still get the bonus. Fang argued that the hack wasn't fair to Lyft and refused to do it. "Jeffrey is the oldest young guy you'll ever meet," Brooks-Magnus says.

When the Voxer group met during slow hours at 24-hour diners, Fang would order soup and gobble everyone's leftover fries and burgers, spurring Scrooge McDuck jokes. He and Rohr constantly checked their phones, ready to dart back out when a surge hit. They were the most obsessive drivers in their group. But everyone got pulled into the game more than they'd expected. Despite the flexible schedule, Santori and Vivanco started missing deadlines on her sewing blogs, which Vivanco took pictures for. Rohr put on 20 pounds. For Perea, driving started to feel like his cigarette addiction: When he felt anxious about money, the only way he could relax was to turn on the app and work. "Your brain starts to sort of change," Perea says. "Imagine every time you got a TikTok notification, it gave you 10 or 15 bucks."

At one point, Brooks-Magnus, Vivanco, and Perea convinced Fang to teach them The Way, a tongue-in-cheek name for his sensei-like ability to rack up $2,500 a week while driving "clean"—no cheating shenanigans, just shrewd surge-surfing and grit. After warning them it wouldn't be easy, Fang put them in training. He messaged his acolytes on Voxer at 4 am to make sure they were at the wheel, ready for airport runs. "Rise and shine, go get that money!" he would say. "It's day three, and I'm dead," Vivanco reported. After a month or two of hitting close to $2,000, they quit Fang's program out of exhaustion. Fang didn't want to blemish his reputation by revealing the toll it was taking on him too. He was swigging four espressos a night. Psoriasis flared on his back and scalp; with no health insurance, he went to a free city clinic. His accelerator ankle started to pop like an arthritic knuckle. He grew a gut. He'd work bar close until 3 am, then nap in the Starbucks lot until airport rides started at 4. The group just assumed Fang was intense for intensity's sake, obsessed with the challenge of maximizing his profits. "I just don't understand when he ever slept," Brooks-Magnus says. Nor did they know exactly why he'd disappear to China for weekslong stretches.

Fang met his clique in a Laurel Heights parking lot where drivers hung out.

Photograph: Kelsey McClellan

In 2015 the friends pressured Fang to join them for a July trip to a cabin near Lake Tahoe, nearly four hours east of the city. Fang resisted, wanting to work, but his friends persisted: C'mon, he could take *one* weekend off. Fang finally gave in. One night during the trip, the group gathered at the cabin's hot tub for a boozy game of Truth or Dare. Fang opted for truth, then revealed, matter-of-factly, that he was married and had a baby son in China. His friends erupted in disbelief, congratulations, and, for some, a pang of betrayal that he'd concealed something so vital. They returned to San Francisco chastened by the knowledge that Fang was playing at a different level of stakes.

That year, Fang capped off his best one-year haul—some $71,000 for 10 months of work. On New Year's, he accepted one last ride on his way home at 3 am, then, fatigued, rear-ended a parked SUV.

The Acura needed more repairs than it was worth, so Fang decided it was time to get his dream car. Not only one that could hold more people, to get bigger tips, but the one with space to someday haul his family on adventures.

Aha! Here's a listing: a used minivan. Honda Odyssey.

Rohr drove Fang out to the suburbs to pick it up.

4.

By the time Fang sailed out of the car dealership with his Honda Odyssey in January 2016, the long-running feud between Uber and Lyft had turned into a full-on price war. For years, as the two services became nearly indistinguishable, they battled for customers by cutting fares, tit-for-tat, especially during slow times. They also started taking a bigger commission from new drivers. These experiments hit drivers hard, whittling away their earnings along with any residual sense of loyalty to either app. "Uber was the devil that you know," Fang says. "Lyft felt like a betrayal. It's the betrayal that cuts deeper. You just slowly lose faith." Members of the Voxer group started to drive for their nemesis, Uber. Even Fang had secretly tried some Uber rides.

Around this time, the Voxer group gathered in Vivanco and Santori's apartment in the Castro to launch a podcast. They called it *Run TNC*, for "transportation network company," which is California's official name for ride-hailing apps. On the show, the drivers were battle-hardened, cynical. Perea said he only got through the rides with obnoxious customers by thinking, "I can't wait to fucking one-star your ass." Vivanco mentioned his irritation with Lyft for advertising drivers who gave free candy to passengers: "I can't do that! I don't get paid enough." That January, as Uber slashed fares by 10 percent and Lyft followed suit, everyone talked about feeling taken for granted. Some of their podcast episodes reached more than 9,000 downloads.

"I'm throwing all the money in on baseball season," Rohr said. "You can still make decent."

"What if baseball season is a total bust?" Vivanco asked.

"Hmm … that's a good question," Rohr paused. "Software engineering."

Rohr, then in his mid-twenties, had thought about trying to become a tech worker. The closest he'd come to a stationary job was as a part-time contractor for an informal Lyft call center, something the Voxers all tried, to pad their flagging profits on the road. Lyft paid about $20 an hour for people to call inactive drivers and passengers and urge them to return to the app. They made other calls too. Cities and states were rolling out regulations, including driver background checks and insurance requirements. Lyft was pushing back. The Voxers lobbied Texas voters on an Uber- and Lyft-sponsored ballot measure in Austin, leaning on their status as drivers. Perea bailed after about a month, unwilling to do Lyft any favors. He dove into blogging for *The Rideshare Guy* about labor issues to subsidize his driving. Brooks-Magnus started looking for drafting jobs. She had loved driving for Lyft; she steered a pink-wrapped car in Lyft's contingent of the Pride parade. The fare cuts changed her mind. She had to borrow money from Fang to make rent. "Over time, the love story falls apart and you realize you're just the pawn in this big game," Brooks-Magnus says. "I often felt like a sort of faceless, nameless not-even-a-person. Like the GPS unit or something." In the spring of 2016, she moved back to Oklahoma.

Fang never took to Lyft telemarketing. Santori and Vivanco, though, threw themselves into the task. The $900 a week was less than they had made driving, but it was guaranteed, and they believed it allowed them to network with Lyft managers. The bet paid off. After a couple of months, they were promoted to contractor jobs in the marketing department, inside Lyft's headquarters.

In the summer of 2016, when Fang returned from a long trip to China, he was fixated on how the fare cuts had sliced into his earning potential. He was crestfallen. As he saw it, the apps had broken the mutually beneficial agreement in which he'd toiled ethically for years. He started—tentatively at first, then more boldly—to tease out a new philosophy, this time of mutual exploitation: "Being a choir boy has done nothing for me."

In those days, the drivers were irked by an Uber app feature that blocked them from seeing an incoming ride's destination until the passenger climbed in, at which point it was too late to decline an unprofitable ride. So one day, driving near Golden Gate Park, Fang tried his first, tiny hack: He turned off his phone's cellular data, which disconnected his phone from Uber's network. Then, sweat beading on his neck, he started the next ride. This revealed the destination, even though the passenger wasn't in the car. From then on, if he saw that the rides wouldn't pay enough, he would force-close the app. The passenger would get rerouted to another driver, none the wiser. It was a simple hack, and just the beginning.

Perea was depressed to see the king of clean driving go rogue. If Fang couldn't make money playing by the rules, then *no one* could. "The Way," Perea says, "became the Way to Cheat."

5.

The Voxer squad was now just Fang, Perea, and Rohr. The three joined a WhatsApp group of like-minded drivers, surfing the surge and exploiting loopholes before the companies patched them. "Everything was fair game," Fang says. "It's a tango: They go forward, you go back, give and take. You know you're on the losing end, but you do it anyway."

While Fang hacked with a sense of bittersweet resignation, Perea reveled in it. "It felt like vengeance; it felt wonderful." They steeled themselves for deactivation, but without the hacks the job was no longer worth it anyway. By 2017, rideshare drivers were making 47 percent of what they had in 2013, according to a JP Morgan Chase Institute survey, though they might have been working fewer hours; one think tank estimated that Uber drivers nationally were making $9.21 an hour after all expenses.

For Fang the cheating became something of a crutch. He could make just enough to keep adding a bit to his savings, but he was too drained to look for something better. "I got complacent and tired and a little too comfortable," he said. "At a certain point, it's almost like an addiction." He was still on the hamster wheel. "In Asia," Fang's mom, Annie, says, "everyone wants their children to be a doctor, lawyer, CPA, and an engineer

in Silicon Valley." But over the years, as she realized that Jeffrey's driving wasn't just some temporary gig, she made her peace. Fang was 35, and in 2017 he and his wife had a daughter, their second child—and the next year, they learned their third was on the way. Fang calculated he would easily need more than $100,000 in savings to sponsor the brood. Three years of driving 50 to 80 hours a week and his $5 lunch budget and free rent had gotten him halfway there.

Growing impatient, Fang's father badgered him to bring his family to the US. His younger brother had already graduated from medical school. His mother offered to help with money, but Fang refused out of pride and anger at being pressured. His cousin offered to refer him for a nontechnical role at the tech company he worked for, starting salary $60,000; Fang thought he could still make better money on the road. His wife thought he was in a dead-end loop. Perea saw Fang as less addicted than stubbornly chasing a sunk cost. "The more you change your life to do this job, it's easy to dig deeper and not want to give up on the idea that this is going to pay out." One day, behind the wheel, Fang braced as he recognized his next fare. It was a woman he'd known at City College back in the day. As Fang recalls, the conversation went like this:

Wait, you're Jeff Fang, like City College student trustee?
Yeah, yeah.
Like Jeff Fang?
Yeah, yeah.
Wait—but you're driving now?
Yeah.
Oh … how IS that?

In China, Fang's wife had stopped working to raise the kids; the money he sent was enough for her to make ends meet while living in his parents' home. Still, he knew that being a driver would demote his family in the eyes of their social circle. His wife had told the parents of his son's preschool classmates that Fang worked in law. On one of his trips to Beijing, at a luncheon with some of those parents, Fang gamely perpetuated the ruse. As kids played and adults sat around a table chatting in one of their homes, he parried questions from an actual attorney with bits about

law that he'd picked up at college. "It was like *Catch Me If You Can*," he says.

Bianca Santori and Jose Vivanco bootstrapped up from drivers to corporate jobs.

Photograph: Kelsey McClellan

In October 2018, back in San Francisco, the WhatsApp group huddled in a burger joint and sketched out a drivers' association, a way to organize against the apps. Fang, comfortable speaking publicly from his days as a student trustee, was president. The effort didn't go much of anywhere. They were all too busy driving.

The work itself had become a parade of irritations: Riders who asked about Fang's life then *uh-huh*-ed while phone-scrolling; the jerks who blasted a stadium horn in the car and said, "It's OK. Don't worry. He's Asian"; and the dude who, unforgivably, mistook his Jean-Luc Picard Halloween costume for a concierge.

One day that year, Fang had lunch with Vivanco. After he quit the driving life, Vivanco had learned basic coding and left Lyft for a job test-driving autonomous cars for Cruise, the startup acquired by GM. He had risen to coordinating the road-testing program, and he invited Fang to Cruise's slick SoMa headquarters. Vivanco offered to refer his friend to his new bosses, but Fang wasn't sure test-driving would be any better than ride-hail. Vivanco gave Fang a tour of the game rooms, and they peered in at the garage of cars. Fang thought, *Wow, a full-blown techie*. "I see the growth you've had," Fang told him, "and I wonder if I've missed the boat."

Months later, in spring 2019, Lyft went public. As a token of appreciation, it gave drivers a bonus that they could either get in cash or invest in Lyft stock. Fang received $1,000—the equivalent of a dime for each of the roughly 10,000 rides he'd given over five years. "I call that cheap," he gripes. Critics saw the bonus as a sop to drivers who might resent that the IPO meant a windfall for Lyft executives and the staff classified as employees. By then, Santori was among them. Devouring management books, networking with an employee resource group for Latinos, she had

worked her way up from telemarketing to be the program manager of a team in Lyft's own autonomous vehicle division. Given her limited time on staff, though, Santori received a humble four-figure stock option.

Around this time, out on the road, the loopholes that drivers had used to push up their earnings were all getting plugged. Uber continued upping its fees and changed the lucrative surge system to a flat dollar bonus in some cities. Fang saw his pay plunge. If he'd been working full-time, he now would make about $52,000 a year; with his trips to China, he was down to $32,000. Rohr had already begun experimenting with delivering packages for Amazon Flex, and they both signed up for Uber Eats with new emails, to get a hefty sign-up bonus. Fang started plotting a course into another wing of the sharing economy: He'd renovate one of his mother's investment homes to rent on Airbnb.

In the fall of 2019, Vivanco and Santori married in an elegant ceremony in San Francisco's Presidio, paid for with their respective six-figure salaries. They were bootstrapping Silicon Valley success stories. Fang wore the Mao suit from his high school prom and sat at a table with driver friends. While mingling with the tech employees in attendance, he steered clear of job talk.

Fang's wife had given birth to their third child, a boy, the previous spring. Finding out that he actually needed some $150,000 to sponsor his family, Fang finally accepted his parents' help. He headed to Beijing to collect his family just as a new coronavirus was rampaging through Wuhan. After six years of grasping toward the goal, he, his wife, and their three kids—ages 5, 3, and 9 months—landed in San Francisco in late February 2020. Fang wrangled 10 jumbo suitcases of clothes and toys off the baggage carousel. Two weeks later, the Bay Area issued the country's first shelter-in-place order. Office commuters hunkered in their homes.

Perea decided that this was where gigging ended. He left the city for the mountains. Once again, Fang adapted. People were locked down, but they still had to eat. He cued up Amazon Flex and Instacart, then Uber Eats, Caviar, and DoorDash. He and Rohr were the last two standing from the original squad. Having felt increasingly invisible and expendable, they couldn't help but roll their eyes at the new title of respect. So *now* we're essential workers.

6.

Fang snapped on a mask and latex gloves. He'd been through two Covid lockdowns in China. But the uneasiness he felt going out into a world of contagion slackened as he and Rohr chatted into their Bluetooth earpieces and blazed around an empty city. Zero traffic, endless parking, no tickets—nothing but orders upon orders of takeout and end-times tippers, a gold-rush glory he hadn't felt since the earliest driving days.

"Does it make me a bad person to hope the pandemic doesn't get better anytime soon?" Fang said into Rohr's earpiece.

"It just makes us greedy," Rohr would say back. "But is that really so bad?"

Working on three apps on two phones each, the two of them quickly learned to "stack"—delivering for various apps simultaneously—putting the less lucrative ones at the end of the run. Contactless delivery meant ding-dong-ditching sacks on porches and running back to orders waiting in the car. Whole Foods shoppers were stockpiling water, milk, and toilet paper and shelling out $80 tips through Amazon Flex. The app asked freelancers to sign up to work blocks of time. Rohr huddled with a programmer friend, figuring out how to automatically grab all possible Whole Foods shifts available to him as soon as they posted, and he shared it with Fang. They were gunning to make $3,000 a week. Late one Sunday night, Fang's haul was $2,900, and he thought he might crack the goal. Then his phone rang. *The kids smeared lotion all over the house. Get home.*

The new dad life was overwhelming. Fang's wife was locked down in a foreign country without a driver's license or the ability to speak English. Their eldest son was enrolled in a public school kindergarten with a bilingual Mandarin program, but Fang was on duty to help him with the English homework. He loaded up the Costco shopping haul, drove the family to parks in the Odyssey, tucked the kids into bed. "I was trying to be a better husband to share the load," he says, "even though I'm not successful, or you know, with a high-power earning job." Though his bachelor working days were over, with the pandemic frenzy, Fang cleared $12,000 in May 2020.

It couldn't last, of course. After a couple of months, the essential-worker gratitude tips dried up. People who'd lost their jobs in the pandemic joined the delivery ranks, increasing competition. Uber Eats cut its base fare, changing over to a more complex structure; Fang saw his earnings take a nosedive. They adapted again, drifting to DoorDash, scrutinizing incoming orders for profitability like diamond appraisers.

During the pandemic summer, Fang started to pass billboards of smiling ride-hail workers in ads for a state referendum called Proposition 22. In 2019, the California legislature had passed a law that would require gig workers to be classified as employees, conferring on them a minimum wage and benefits. That also meant gig companies would have to pay the state's payroll and unemployment tax; one study showed that the law would deepen Uber's operating loss by more than $500 million. The companies resisted, so the state attorney general sued Uber and Lyft, and the San Francisco district attorney sued DoorDash, to force compliance. Judges ruled against the ridesharing companies, and they threatened to leave the state.

Uber, Lyft, and DoorDash tried a new tack: Go straight to voters. They sponsored a ballot measure that defined "app-based drivers" explicitly as contractors and not employees, but sweetened the deal by requiring companies to help pay for health care insurance for those clocking more than 15 hours a week, to offer access to insurance for on-the-job injuries, and to guarantee an hourly income for "engaged" time spent driving a passenger or a delivery (but not for any time spent waiting). The gig companies claimed it would save jobs, allow workers flexibility, and maintain low fares. They shoveled more than $200 million into the campaign, the most in state electoral history, outspending the labor opponents 10 to 1. Their ads asserted that "the vast majority of app-based drivers say yes on 22."

Fang wasn't sure he wanted to be an employee, but he appreciated that lawmakers had forced clarity from the industry giants. If they want contractors, he reasoned, stop treating us like quasi-employees and don't deactivate us for acting in our own interests. "They're sitting on top of a

volcano," Fang says. "I don't think they understand how much difficulty we're dealing with."

In November, Fang voted no on Prop 22; 59 percent of Californians voted yes.

A month after the Prop 22 vote, [DoorDash held its IPO](#). Like other on-demand companies, it had struggled with anything resembling regular profitability, but that didn't trouble Wall Street. The move made a billionaire of CEO Tony Xu, the 36-year-old cofounder.

Through the fall, to pad their plummeting delivery money, Fang and Rohr worked as census takers. It was the last job the two would do together. Rohr went on unemployment and finally started studying for coding bootcamp. The pandemic had forced him to leave—and he was grateful. In January, Prop 22 became law. Albertson's grocery stores laid off their unionized drivers. They replaced them with DoorDash.

Now, in the mornings, Fang shepherded face-masked students to their private elementary schools for Kango, a hailing app for kids. By the late afternoon, he was delivering for DoorDash. He was eking out just over $800 a week before expenses, better than the federal poverty line for a family of five but well below San Francisco's. Nearing 40, Fang's hair was flecked with gray. He started tapping into his savings for living expenses.

7.

Fang had taken the kids out on his deliveries twice before, to give his wife a break. His cars had been broken into in the past, but now he only delivered in wealthy neighborhoods, and he hadn't yet heard about the [carjackings](#) that were skyrocketing during the pandemic. So, on February 6, he brought the kids to work again.

On a pizza delivery, Fang parked his Odyssey in front of a stately art deco apartment building near Billionaires' Row. His 21-month-old was quiet, probably sleeping. He didn't lock the minivan or turn off the engine, as doing so would cut off *Shrek 2*, which was entertaining his 4-year-old

daughter in the back seat. He'd be gone less than a minute. Fang darted inside, dropping the pizzas in front of a ground-floor door. When he walked out, he saw a man with long curly hair sitting in the Odyssey's driver's seat.

He yanked open the door, yelling, "Get the fuck out of my car!" After a tussle, the man pushed past him and, grabbing the Huawei from his hand, took off running. Fang's phone had been his moneymaker, manager, fixer, and dictator for the past seven years. He thought he had a shot at getting it back.

After the chase, Fang rushed back with his phone in hand. But the van was gone—and his kids with it. He screamed as loud as he could for help. One of the men rushing outside said he knew—literally, *knew*—DoorDash CEO Tony Xu. He'd call him. Soon after, DoorDash texted other drivers asking them to watch for the Odyssey. An old friend of Fang's from City College, a San Francisco journalist, tweeted a cry for help and dialed local reporters. Police pulled up at the scene, blocking off the street, and later issued an Amber Alert.

His wife called to ask when he was getting home, and he broke the news. Officers offered Fang a seat in a patrol car, but he declined: *I'm not taking any comfort*. His journalist friend arrived to wait with him, McDonald's in hand, but Fang couldn't eat. Press gathered, and in the glaring ABC7 News camera light, Fang pleaded to the kidnappers. "I just want my kids back. Times are hard. If you're gonna have to resort to stealing, that's a different matter, but please don't hurt my kids. Help them return safely back to me and my wife. *Please*." For all these years, his tunnel vision, his money-chasing, and his scrimping was for one single purpose: to bring his family together. He'd made many bad decisions—goofing off in high school, dropping out of City College—but none could possibly match the awfulness of this one.

While Fang remained at the crime scene, relatives arrived at his home across town to pray with his wife. After four hours, at nearly 1 am, police on patrol spotted a Honda Odyssey abandoned in a driveway just minutes from Fang's house in the Bayview neighborhood, 7 miles from where the van was stolen. Both kids were in the back, out of their seats, refusing to emerge from the car. The police sped his wife to the scene. She rushed to

the van, Fang says, and the older child fell into her mother's arms, heaving with sobs. Police took the family to the hospital, where doctors looked over the children; they were unharmed.

Meanwhile, Fang continued helping police with the investigation. They drove him from the delivery spot in one of the city's richest neighborhoods to his Odyssey in one of the poorest, asking him to identify anything out of place. They shuttled him to a police station in yet another part of town, where Fang gave a statement and an artist etched his description of the long-haired thief. Police drove Fang home at dawn. Shuffling into his bedroom, he stared at his wife and their children, all sleeping together, and felt waves of relief and guilt.

The following Monday, a payment for $10,000 landed in Fang's DoorDash account. He'd also missed a call from a Silicon Valley area code and called back.

"Hi, who's this? I'm returning a call from you earlier."

It was Tony Xu.

Xu told Fang that, as a father himself, he was happy that the children had been found and that he wanted to make sure Fang had gotten the deposit. Fang listened, surprised at how young Xu sounded. He thanked Xu for the money, but, more than that, for texting the advisory to drivers, adding, "My thoughts about the gig economy are a different matter." He reasoned that there was a time and place for his protests, and a phone call about his kids getting kidnapped wasn't it. Xu told him to feel free to call back if he needed anything. After the call, Fang added the CEO's number to his contacts. When Fang's brother heard about the call, he wanted to know if Jeffrey had asked Xu for a job. He hadn't.

The DoorDash kidnapping became national news. Many blasted Fang for leaving his children alone, but soon another narrative emerged. Prop 22's critics used it as a prime example of workers drowning in the freelance economy. The attention was inevitable, but it outed the secret Fang had carefully maintained for years. A friend of his family's in Beijing, who now lives in the States, texted Fang's wife: "Did you know he was a driver?"

"I still feel the pull," says Fang about being behind the wheel. "I'm basically in rehab now."

Photograph: Kelsey McClellan

8.

Jeffrey Fang's gig odyssey ends here. Well, kind of.

A GoFundMe set up by his reporter friend raised more than $155,000 for the Fangs, an act of charity that Fang is well aware doesn't solve the despair of the gig life for anyone else. This spring, a string of violent confrontations resulted in the killings of DoorDash and Uber Eats workers in New York City, Chicago, and Washington, DC. Fang earmarked the money to send his kids to college.

Rohr is studying for coding school. Brooks-Magnus runs her own home-design business in Oklahoma City. Santori is a technical project manager at Scribd, the ebook subscription service. She and Vivanco worry that the early startup ladders that helped striving drivers into management are harder to find, but Vivanco says his offer to help Fang remains. Perea, who writes an occasional salty post for his own gig economy blog, is also trying to figure out what's next. "If this is the future of work," he says, "we're sincerely fucked."

So how does a 39-year-old dad with a gig résumé change course? Fang still wants what the industry claims it offers: "I've gotten a taste of what it is like to be my own boss, and I want to be my own boss." Fang finally finished the renovation of his mother's investment house this spring and hopes to get it on Airbnb soon. He started studying for notary and real estate licenses.

But he also needed just a little bit of cash on the side. In the spring, passengers began hailing more rides again, and Lyft and Uber cranked up temporary incentives to lure reluctant drivers back. Fang decided to take Uber up on its promotion to give three rides for $100. He did just three and drove home. He worked in the mornings for Kango—"driving kids is

OK"—and occasionally a night on DoorDash. "I still feel the pull. Less than before, but I still feel it." He thinks he can keep it in check. "If you are somewhat enlightened to the cat-and-mouse game that Uber uses to get you back in, you'll take the catnip and you won't get hooked."

Jeffrey Fang, reformed gig worker, knows you're doubting his capacity for restraint. "I'm basically in rehab right now."

Perea called him this spring. Physically leaving gigging was the easy part, Perea had said. But it had taken him an entire year to unplug his mind from the addictive thrum, to reclaim his attention and stop checking his phone.

Fang knows what he meant. The afternoon after the kidnapping, after talking to police and reporters, Fang retreated to a nook in his house behind the garage, where his family tends to leave him alone. It was a bit after 3 pm, the hour he usually started getting ready to make deliveries. Sunday evening is the pinnacle of takeout. Fang peeked at the DoorDash app. A red cloud marked "Busy" hovered over the grid of the city, and the candy-red button to "Dash Now" beckoned. The incentive was high—$4 extra per delivery. The familiar tug: *You're missing out on money*.

With his Odyssey impounded as evidence, he'd have to borrow his parents' car, which would entail asking his mom for permission. He imagined her taciturn disapproval, the justified hell from his wife.

Better not push it.

Fang closed the app. The familiar map disappeared. He headed upstairs to join his family, pretending for the kids that everything was OK, pretending he didn't still want to work.

This article appears in the July/August issue. [Subscribe now](#).

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06.17.2021 08:00 AM

On Microphones, Music, and Our Long Year of Screen Time

Pianist Glenn Gould proved long ago that an existence heavily mediated by technology is not nonexistence.
Illustration: SAM RODRIGUEZ

There is a music-tech controversy that rivals Bob Dylan's choice to plug in his guitar at the Newport Folk Festival in 1965. A year earlier, on April 10, 1964, the pianist Glenn Gould made a radical exit from live concerts.

Gould played seven pieces to a packed house at the Wilshire Ebell Theatre in Los Angeles, including four fugues. He gave no indication that the program was his swan song. Then he strolled—he never stormed—away from his Steinway CD 318 and out the door of the concert hall, into the mild California air. A year later, he boarded a train for the desolate Northwest Territories of his native Canada. He never played another concert. When Arthur Rubinstein bet him in 1971 that he'd be back, Gould took the bet; when he died 11 years later, at 50, he won. He came to regard live music as a "blood sport." He especially held the sociability of concerts in contempt. "Music is something that ought to be listened to in private," he said.

From that evening on, the pianist's life became a testament to the raptures of electronic media. In the studio he found something subtler, kinder, and more intimate than what he considered the relationship of dominance and submission between performer and audience. To Gould, sound engineering

and music production conveyed, as nothing else, "the spine-tingling awareness of some other human voice or persona."

Rejecting as priggish the cliché that technology is "depersonalizing," Gould was smitten. "I was immediately attracted to the whole electronic experience … I fell in love with microphones; they became friends, as opposed to the hostile, clinical inspiration-sappers that many people think they are."

This summer, as people in many countries are attending concerts and [touching each other again](), the case for solitude and computers over community and real life seems especially unpersuasive. It would dishonor the pandemic dead not to take life by the horns and go for broke on packed-yard barbecues and front-row tickets to Lady Gaga. But Gould proved at least that an existence heavily mediated by technology is not *non*-existence. Screen nausea and social media compulsions are no joke, but the current self-loathing about the long year of screen time is misplaced. It was not lost time. Rather, the boring and sometimes hallucinatory quarantine opened new portals for imagination that the culture hasn't yet begun to assimilate.

Because he idealized northerliness and mused often on solitude, Gould after 1964 is figured as a recluse. But he was hidden away only if you don't count telephones, photography, recorded sound, recorded video, and speedy distribution networks. For his two electronic decades, Gould managed to be nowhere and everywhere. Though often sequestered, he suffused tens of millions of television sets, movie theaters, car radios, and eventually outer space, when, in 1977, his stunning interpretation of Bach's *Well-Tempered Clavier* was launched out of Earth's atmosphere on the phonographic time capsule aboard the Voyager spacecraft. Gould may be best experienced by curious extraterrestrials, ones with decent turntables or at least working ESP.

Gould had a sweet tooth for some pop music, including Petula Clark; he called Barbra Streisand's voice "an instrument of infinite diversity and timbral resource." And though he himself had perfect pitch, he was captivated by unusual speaking voices, off-key or otherwise. He invented a form of documentary film known as contrapuntal, in tribute (maybe) to Bach, in which speaking voices are made to overlap with weird effects. The

most evocative example is Gould's film about the bleak Canadian tundra, *The Idea of North*, which sits easily among the most avant-garde fare on YouTube.

Though he hummed compulsively while he played, avoided shaking hands for fear of disease, developed an addiction to prescription pills, and dressed for a winter storm whatever the weather, Gould managed to stay in the flicker of electric eccentricity, never quite slipping into the monotony of madness. This delicate psychic balance is palpable in the erudite stem-winders he delivered straight to the camera. It comes through in his experimental acoustic collages and the innumerable radio broadcasts he recorded. Gould also spoke for hours on end to friends and unwitting acquaintances on landlines and pay phones, sometimes putting his companions to sleep as he reeled off theories of everything, a one-man soundscape whose changeable cadences of speech were uncannily like his piano playing. "No supreme pianist has ever given of his heart and mind so overwhelmingly while showing himself so sparingly," said Gould's close friend, the violinist Yehudi Menuhin.

Gould became what might be known now as a pandemic musician. Tim Page, the music critic and a close Gould confidant, was asked last year what his friend might have made of quarantine living. "Glenn would have loved the internet," Page replied. "He was a germophobe and didn't like much physical contact. But he would have enjoyed things like Skype and Facebook [so he could] still enjoy his friendships while keeping his distance." Indeed, Gould was at his best *at a distance*—far from the baroque chamber and the modern stage, holed up where he could send a signal to just one other person, lonely, like him, afraid of touch, across the very same untenanted Canadian expanses that inspired the media philosopher Marshall McLuhan, a frequent interlocutor of Gould.

Between 2016 and 2019, the English musician Leyland Kirby, under the pseudonym the Caretaker, layered and edited samples from old, worn 78s to create an album in stages called *Everywhere at the End of Time*. The theme of the album is decay and deterioration; each record represents a phase of dementia until, in the last one, the reeling musical signals are all but drowned out by noise, the static of the mind's final exhalation.

During the pandemic, an extraordinary fate befell *Everywhere at the End of Time*. It galvanized adolescents. And not just any adolescents—the adolescents of [TikTok](#). Shut up at home, they seemed to find in the recording an opportunity to glut private sorrows and test their intellects on difficult music. In the Caretaker challenge, they dared each other to listen to the whole piece, which runs at six and a half hours, and record their responses in videos. "Literally the definition of pain," wrote 16-year-old Owen Amble in a caption on the music last fall. "Never cried listening to something." There are now hundreds of such videos, some with tens of thousands of views.

The vertical TikTok rectangles show young faces, alone, framed as if in a narrow closet. Often the listeners are crying as they listen and listen and listen. "The justification of art is the internal combustion it ignites in the hearts of men and not its shallow, externalized, public manifestations," Glenn Gould once wrote.

Over the course of the pandemic, housebound students created Spotify and YouTube playlists that offer music not for exercise or seduction but for scholarship. Some of these compilations promote relaxation with [lo-fi beats](#). But others don't sedate. They keep the isolated mind alive and awake. Work by the Caretaker sometimes makes an appearance on these lists. But it's baroque music that still best serves the thrill-seeking intellect, and the most stimulating study playlists feature Bach's *Goldberg Variations*, performed by Glenn Gould. The tracks are 30 contrapuntal variations beginning and ending with an aria.

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[Meghan O'Gieblyn](#)

[Ideas](#)
06.16.2021 08:00 AM

Why Do I Like Waiting for My Smartphone Photos to 'Develop'?

WIRED's spiritual advice columnist on apps, impatience, and the struggle to control time itself.
Illustration: Cha Pornea

SUPPORT REQUEST:
I recently downloaded one of those camera apps that makes you wait a few days before you can access the photos. The delay reminds me of waiting to get photos developed as a kid and makes the whole process more enjoyable. But aren't I supposed to use technology to make things faster and more efficient? Am I deluding myself by trying to somehow live in the past?

—FOCUSED

Dear Focused—

It's difficult to talk about cameras without also talking about time. Photography is an attempt to outwit the clock and the calendar, an art that, as the film critic André Bazin once put it, "embalms time, rescuing it simply from its proper corruption." Even as the technology grows more sophisticated, cameras maintain some of their ancestral trappings, as though they too are frozen in time. The capture button on your phone's camera app still makes the mechanical clack of a physical shutter. The filters fade images and alter the color palette, mimicking an aging process to which digital photos are immune.

With that said, I'm doubtful that simple nostalgia led you to download this app. If you'd wanted to entertain the fantasy of living in the past, you could have easily hopped on eBay or headed over to a second-hand shop, those graveyards of analog technologies, and picked up an old SLR. My guess is that the app is satisfying a more specific desire, that the wait itself is the primary draw.

Most of us, of course, have the opposite instinct. It's well known that people usually opt for immediate pleasures, even when waiting costs less or offers a greater reward. This cognitive bias, which is known in behavioral economics as "hyperbolic discounting," is so basic to human nature that it is dramatized in our earliest myths. (Faced with the choice between an apple and immortality in paradise, Adam and Eve chose the forbidden fruit.) If anything, the speed of contemporary life has only further diminished our ability to wait. The one-hour photo boom that coincided, in the late 1970s, with the invention of the mini lab is a prime example of how profitable impatience can be for those who know how to exploit it. Customers proved willing to pay almost twice as much to get their film developed in 60 minutes as opposed to several days. "We live in an instant-gratification society," one early mini lab owner told *The New York Times*. "We want things now."

You strike me, Focused, as one of those rare souls who is capable of monumental self-control, the kind of person who is willing to forgo the $50 offered now in favor of the $100 promised later. It's a trait that is undoubtedly useful in many situations, though in the case of the camera app, there's no real virtue in delayed gratification. The reward does not increase with time; you get the same photos. In a sense, your desire to wait is even more irrational than hyperbolic discounting, which has, at least, an evolutionary advantage (those who decline life-sustaining rewards might not live to see more distant ones).

For people like you, economics and marketing psychology will be less helpful, I think, than philosophy. Bertrand Russell noted as early as 1930 that the endless novelties of modern existence could become tiresome. "A life too full of excitement is an exhausting life, in which continually stronger stimuli are needed to give the thrill that has come to be thought an

essential part of pleasure," he wrote. Russell believed that instant gratification had eradicated our ability to endure those periods of boredom and idleness that made pleasure truly enjoyable, just as long winters increase the joy of spring's arrival. We are creatures of the earth, he writes, and "the rhythm of Earth life is slow; autumn and winter are as essential to it as spring and summer, and rest is as essential as motion." The irony is that in cultures that are intently focused on the "now," promising to fulfill any whim instantaneously (a guarantee echoed in the names of the major photo-sharing platforms: Instagram, Flickr), it becomes difficult to actually enjoy the present, so fixated are we on the next entertainment, the next post, the next dopamine hit.

I imagine, Focused, that you might be feeling some of that exhaustion. Perhaps choosing to wait for your photos is an attempt to escape the tyranny of pleasure, to exempt yourself from the daily grind of novelty that threatens, like the eternal scroll of the newsfeed or the bottomless well of search results, to go on forever. The speed with which we can now produce and access images comes with burdens of its own. The duty to immediately scrutinize, edit, and share the photos you've taken often prevents you from fully experiencing the moment that was presumably beautiful enough to capture.

Traditionally, even those innovations designed to accelerate the pace of life have brought with them unexpected pockets of idleness. The one-hour photo lab generated an awkward interval, too short for many errands, that some customers probably filled by taking a stroll around town or wandering over to the park for a cigarette. The MP3 introduced a five-minute window of download time (can we ever have waited so long for music?) during which you could write an email or make a cup of coffee. The author Douglas Coupland once wrote about "time snacks," moments of "pseudo-leisure created by computers when they stop responding." Our snacks have become more meager over the years, reduced to those fleeting seconds when our gaze drifts away from the screen while waiting for a page to refresh or an app to download, though the reprieve is still palpable. The beauty of such moments is not unlike the relief we feel when a blizzard or a rainstorm brings life to a halt, rendering us helpless, granting us permission to be still. The delay imposed by your camera app is an attempt to capture

and extend those moments of forced indolence—to "embalm" them, so to speak.

Even so, instant gratification is a difficult habit to break. I probably shouldn't mention this, but some early users of slow camera apps have confessed to tampering with their phone's time and date settings—literally moving time forward—in order to override the delay and get their photos immediately. What else can you expect from a species that prides itself on its ability to control time? We are a civilization, after all, that decided to bump the sun's rising forward one hour each summer, and that now purchase SAD lamps and sunrise alarm lights to fine-tune our diurnal cycles. In the 1920s, the founder of Kodak, George Eastman, became so exasperated with the irregular lengths of each month—which made it difficult to compare sales periods—that he ran his company on its own 13-month calendar, inaugurating a new month, Sol, between June and July.

All of which is to say, as much as we might begrudge the fact, we are each fully responsible for how we experience time. We have long since severed ourselves from the earth's rhythms. Our lives no longer slide along the linear continuum of past, present, and future but step to the tempo of the 24-hour news cycle, the weekly ritual of software updates, the sporadic arrival of new television seasons or whatever other media and entertainment we decide to consume. If you find satisfaction in delaying certain pleasures, you should accept it as a deliberate choice, keeping in mind that it can always be revisited and revised. Photo developing, after all, has no natural, fixed duration, and whether it passes quickly or slowly depends—much like the length of a month or the span of a day—on how you choose to spend it.

Faithfully,

Cloud

Be advised that [CLOUD SUPPORT](#) is experiencing higher than normal wait times and appreciates your patience.

[Cecilia D'Anastasio](#)

[Backchannel](#)
06.10.2021 06:00 AM

How *Roblox* Became a Playground for Virtual Fascists

Thousands of players flocked to a digital world filled with draconian rules, slavery, and anti-Semitism—and tested how far "just a game" can go. Illustration: Toma Vagner

Ferguson, a middle schooler in Ontario, Canada, had been tapping out the same four-letter sequence on his keyboard for hours.

W, A, S, D.

W, A, S, D.

He was steering his digital avatar, a Lego-man-like military grunt, in laps around a futuristic airfield. Although his fingers ached, he would gladly have gone on for hours more. Every keystroke brought the 11-year-old closer to his goal: scaling the ranks of a group in the [video game](#) *[Roblox](#)*.

The group had rules. Strict rules. Players dressed as pilots and marines went around barking out orders in little speech bubbles. When Ferguson wasn't running laps, he was doing drills or scaling walls—boot camp stuff. The only three words he could say during training were "YES," "NO," and "SIR." And "SIR" generally applied to one person, Malcolm, the domineering adolescent who ruled the group. "His thing was the winky face," Ferguson says. "He was charming. He was funny. He always had a response; it was instant. He was a dick."

This article appears in the July/August 2021 issue. [Subscribe to WIRED](#).

Photograph: Djeneba Aduayom

At the time, in 2009, *Roblox* was just over two years old, but several million people—most of them kids and teens—were already playing it. The game isn't really a game; it is a hub of interconnected virtual worlds, more like a sprawling mall video arcade than a stand-alone *Street Fighter II* machine. *Roblox* gives players a simple set of tools to create any environment they want, from *Naruto*'s anime village to a high school for mermaids to Somewhere, Wales. Players have built games about beekeeping, managing a theme park, flipping pizzas, shoveling snow, using a public bathroom, and flinging themselves down staircases. They have also built spaces to hang out and role-play different characters and scenarios—rushing a sorority, policing Washington, DC.

Ferguson was attracted to the more organized, militaristic role-plays. (Now 23, he asked that I refer to him only by his online name. He says he hears it more often than his given name; also, he doesn't want to be doxed.) Growing up, he says, he was an annoying kid. He was checked out of school, had no hobbies or goals or friends. "Literally, like, zero," he says. Self-esteem issues and social anxiety made him listless, hard to relate to. It didn't matter. When he got home from school every day, he'd load up *Roblox*. There, he says, "I could be king of the fucking world."

Or at least the king's errand boy. In that early group he was in with Malcolm—a role-play based on the sci-fi military game [Halo](#)—Ferguson proved his loyalty, drill after drill, lap after lap. Malcolm (not his real name) didn't demand control; he simply behaved with the total assurance that he would always have it. "It very much was like being in a small military team," Ferguson says. "You value that person's opinion. You strive to do the best. You have to constantly check up to their standards." Eventually, Ferguson became one of Malcolm's trusted lieutenants.

To grow their influence, the boys would invade other groups, charging in as Malcolm shouted the lyrics to System of a Down's "[Chop Suey!](#)" over Skype. They funneled new followers into their own role-plays—one based on *Star Wars*, where they were the Sith; another based on Vietnam, where they were the Americans; and one based on World War II, where they were the Nazis.

Ferguson says that Malcolm's interest in Nazism began with his discovery of the edgelord messaging board 4chan. From there, he started fixating on anti-Semitic memes and inversions of history. He built a German village where they could host reenactments—capture the flag, but with guns and SS uniforms. Malcolm's title would be Führer.

Ferguson describes himself as an "anarchist shithead." At first, this sensibility expressed itself as irreverence. Then it became cruelty. He had finally found his community and established some authority within it. He didn't mind punching down to fit in. At the same time, he believed that Malcolm was attracted to contrarianism, not out-and-out fascism. He says he chafed at Malcolm's "oven talk," the anti-Semitic jokes he made over late-night voice calls. Malcolm's favorite refrain was "muh 6 million," a mocking reference to the victims of the Holocaust. "It was at a point in the internet where it's like, OK, does he mean it?" Ferguson recalls. "He can't mean it, right? Like, he'd be crazy." (Malcolm says it was "a little bit of typical trolling, nothing too serious.")

In 2014, according to Ferguson, Malcolm watched HBO's *Rome*, which depicts the Roman Republic's violent (and apparently very raunchy) transformation into an empire. Inspired, he told Ferguson they would be swapping their uniforms for togas. Together, they forged Malcolm's proudest achievement within *Roblox*—a group called the Senate and People of Rome. The name conjured high-minded ideals of representative democracy, but this was a true fascist state, complete with shock troops, slavery, and degeneracy laws. Malcolm took the title YourCaesar. In 2015, at the height of the group's popularity, he and Ferguson claim, they and their red-pilled enforcers held sway over some 20,000 players.

Roblox is no longer the lightly policed sandbox it once was. The company that owns it [went public in March](#) and is valued at $55 billion. Tens of millions of people play the game daily, thanks in part to a recent pandemic surge. It has stronger moderation policies, enforced by a team of humans and AIs: You can't call people your slaves. You can't have swastikas. In fact, you can't have any German regalia at all from between 1939 and 1945.

Still, present-day *Roblox* isn't all mermaids and pizzaiolos. Three former members of the Senate and People of Rome say the game still has a

problem with far-right extremists. In early May, the associate director of the Anti-Defamation League's Center for Technology and Society, Daniel Kelley, found two *Roblox* re-creations of the Christchurch mosque shooting. (They have since been taken down.) And there are still Nazi role-plays. One, called Innsbruck Border Simulator, received more than a million visits between mid-2019 and late May or early June of this year, when—not long after I asked a question about it—*Roblox* removed it.

But how do these communities shape who young players become? [Dungeons & Dragons](#) was supposedly going to turn kids into devil worshippers. [*Call of Duty*](#) was going to make them feral warhounds. "It's the same thing you see in relation to alt-right recruitment," says Rachel Kowert, the director of research at Take This, a nonprofit that supports the mental health of game developers and players. "'*And* they play video games' or '*And* this happened in video games.'" It's harder to pin down *because*. "There's a line of research talking about how games are socially reinforcing," she says. "There's this process of othering in some games, us versus them. All of these things do seem to make a cocktail that would be prime for people to recruit to extreme causes. But whether it does or not is a totally different question. Because nobody knows."

Ferguson, who today claims he is penitent for his role in the Senate and People of Rome, says he wants people to know about it, to make sense of it, to learn something, and hopefully, eventually, make it stop. They just have to get it first. "I say, 'Oh, when I was a kid, I started playing this game. Suddenly, I'm hanging out with Nazis, learning how to build a republic on the back of slavery,'" he says. "But no one understands how. 'It's just a game.'"

Earlier this year, Ferguson took me to Rome. Or rather, he took me to a dusty, far-flung Roman outpost called Parthia, which, for complex reasons involving a catfish and some stolen source code, is the most Malcolm ever got around to building. My avatar materialized beyond the settlement's walls, beside some concrete storehouses. The label "Outsider" appeared next to my username. Ferguson was pacing toward me in a cowboy hat with antlers, and I hopped over a line of wooden looms to meet him.

The area appeared deserted. On a typical day in 2014 or 2015, he explained over [Discord](#) voice chat, this was where "random children" would craft weapons and tools. He gestured toward some stone barracks in the distance. "Over there," he said, "there would be legionaries watching the barbarians and practicing formations." A barbarian was any player who hadn't yet been admitted into Parthia's rigid hierarchy. Inside the outpost, the rankings got more granular—commoner, foreigner, servant, patrician, legionary, commander, senator, magistrate.

Ferguson, whose title was aedile, was in charge of the markets and the slaves. "They're not technically slaves," he explained. "They're, in a sense, submitting their free will to participate in a system where they're told everything to do." (*W, A, S, D.*) Slaves could earn their citizenship over time, either through service or by signing up to be gladiators. When a Roblox employee visited the group once, he says, Ferguson helped stage a battle between two slaves in the amphitheater.

As Ferguson and I walked the rust-colored pathways toward Parthia's towering gate, he described the exhaustive spreadsheets that he and others had kept about the group's economic system, military strategy, governance policies, and citizenry. Unlike other *Roblox* role-plays of its era, Parthia stored your inventory between login sessions, which meant that whatever you crafted or mined would still be there the next time. This apparently cutting-edge development enticed some players, but what kept them logging in day after day was the culture.

Another of Malcolm's former followers, a player I'll call Chip, joined when he was 14. He says he liked the structured social interactions, the definite ranks, how knowable it all was. "I've always been the kind of gamer who prefers a serious environment," he says. As a middle schooler in Texas, he felt like a computer missing part of its code—never quite sure "how to be normal, how to interact with people, how to not be weird."

Parthian society was a product of Malcolm's increasingly bigoted politics and his fierce need for control, three former members say. The outpost's laws classified support for race-mixing, feminism, and gay people as "degeneracy." They also required one player in the group, who is Jewish in real life, to wear "the Judea tunic or be arrested on sight." Inside Parthia,

vigiles patrolled the streets. We'd be stopped, Ferguson said, for having the wrong skin tone. (My avatar's skin was olive.) The players voted overwhelmingly to allow Malcolm to execute whomever he wanted.

We approached Parthia's gate, which was on the other side of a wooden bridge. Ferguson faced me and stuck his hand out. "If you're an outsider, they'd go like this to you," he said, blocking my avatar's path. A bubble with the words "Outsiders not allowed" appeared above his head. The gate itself was closed, so Ferguson and I took turns double-jumping off each other's heads to scale the wall. On the other side, I got my first glimpse inside Parthia.

Ferguson and Malcolm had talked a talented *Roblox* architect into designing it. Everything was big, big, big—columned public buildings, looming aqueducts, a mud-brown sprawl of rectangular buildings stocked with endless tiny rooms. After a brief tour, we ascended a ladder into a half-dome cupola. "If you had wealth or a name, you were standing here," Ferguson said. "You're supposed to be admiring yourself, your success, and looking down on the barbarians." Romans would hang out, talk, collect social status, and, in Ferguson's words, "smell their own farts all day."

One of the most exclusive cliques in Parthia was the Praetorian Guard, Malcolm's personal army. According to several former members, he sometimes asked high-ranking members to read SS manuals and listen to a far-right podcast about a school shooter. ("Simple friendly banter among friends," Malcolm says.) Chip started an Einsatzgruppen division, a reference to the Nazis' mobile death squads—partly because he thought it would get laughs, he says, and partly to please the caesar. In one case, memorialized on YouTube, Malcolm's henchmen executed someone for saying they didn't "care about" the architect's girlfriend, Cleopatra. Chip still thinks that, for a lot of people, fascism started as a joke. "Until one day it's not ironic to them," he says. "One day they are arguing and fully believe what they're saying."

When it comes to Malcolm's fascist leanings, Chip says, "On the stand, under oath, I would say yes, I believe he actually thought these things." Malcolm, who says he is "just a libertarian on the books," disagrees. "It's

always been just trolling or role-playing," he says. "I'm just a history buff. I don't care for the application of any of it in a real-world setting."

Chip and Ferguson estimate that a third of the 200 players who ran the Senate and People of Rome—most of them young adults—were IRL fascists. Enforcing the group's draconian rules was "a game-play function to them," Ferguson says. In other words, they enjoyed it.

Here is one vision of how far-right recruitment is supposed to work: Bobby queues up for a *Fortnite* match and gets paired with big, bad skinhead Ryland. Ryland has between two and 20 minutes to make his pitch to Bobby over voice or text chat before enemy player Sally shotguns them both in the face. If Ryland's vibe is intriguing, maybe Bobby accepts his *Fortnite* friend request; they catch some more games and continue their friendship on Discord. Over time, weeks or months, Ryland normalizes extremist ideology for Bobby, and eventually the kid becomes radicalized.

Or, just as likely: Bobby thinks that guy is wack and sucks at *Fortnite*, and he doesn't accept Ryland's friend request. Next game, he'll go for the shotgun.

Radical recruitment in games is a tricky subject to study. For one thing, all the useful data on Ryland and Bobby is locked away in private corporate databases. Also, this is an illness with a bewildering array of causes. In March, the Department of Homeland Security hosted a digital forum called Targeted Violence and Terrorism Prevention in Online Gaming and Esports Engagement, designed to highlight how "violent extremists maliciously manipulate the online gaming environment to recruit and radicalize." The ADL's Daniel Kelley, who gave a keynote address, struck a more cautious note than the event's name would suggest. He pointed to the New Zealand government's official report on the Christchurch mosque attack. The shooter played games, yes. But he also used Facebook and Reddit and 4chan and 8chan, and he told the Kiwi authorities that YouTube was, as the report put it, a "significant source of information and inspiration."

Earlier this year, I asked Rabindra Ratan, an associate professor of media and information at Michigan State University, what the latest research said about far-right recruitment in games. Curious himself, he put it to

GamesNetwork, a listserv he's on that goes out to some 2,000 game scholars and researchers.

Responses trickled in. A couple of scholars pointed to the ADL's [survey](#) on harassment and racism in online games, in which nearly a quarter of adult gamers said they'd been exposed to talk of white supremacy while playing. Others noted the existence of alt-right messaging boards for gamers, the deep links between edgelord internet culture and white supremacy, and the popularity of Felix "PewDiePie" Kjellberg, a gaming YouTuber who has made several anti-Semitic jokes to his audience. When one designer questioned the idea that radicalization in games is widespread, someone else shot them down: "I think it's a dangerous mistake to dismiss radicalization in gaming communities and culture as merely 'urban legend,'" they wrote.

Then a switch seemed to flip. Chris Ferguson, a psychology professor at Florida's Stetson University, brought up the lack of data. "To the best of my knowledge, there is not evidence to suggest that the 'alt right' is any more prevalent in gaming communities than anywhere else," he wrote. Further, he said, there doesn't seem to be evidence that recruitment in games is happening on a large scale. "I do worry that some of this borders on Satanic panics from the '80s and '90s," he said.

Chris Ferguson is known as a bit of a brawler. In the book *Moral Combat: Why the War on Violent Video Games Is Wrong*, he and a colleague tear into the now mostly debunked idea that, say, *Grand Theft Auto* could turn a kid into a carjacker or a drugstore robber. Last July, with researchers in New Zealand and Tasmania, he published a peer-reviewed analysis of 28 previous studies involving some 21,000 young gamers in total. "Current research is unable to support the hypothesis that violent video games have a meaningful long-term predictive impact on youth aggression," the paper concluded.

On the listserv, some researchers bristled. Was Chris Ferguson dismissing their more qualitative approach to the work, which they considered equally valid? Someone dropped a Trump meme: "Very fine people on both sides." The reply: "Can you not."

The thread exploded. There were ad hominem attacks, pointed uses of the word "boomer." "Casting aspersions such as these crosses a line into the unacceptably unprofessional," one researcher wrote. "For shame."

Several scholars quit the listserv in a fury. Nearly 100 messages were sent before the thread petered out. Nobody could reconcile the lack of data on extremist recruitment in games with the fact that so many signs seemed to point in that direction.

In the very broadest sense, the qualities associated with gamers—young, white, male, middle class-ish, outsider—overlap with the qualities associated with people who might be candidates for radicalization. Of course, most of the nearly 3 billion people who play games don't fit that stereotype. The word "gamer" summons these qualities because, for a long time, this was the consumer class that [corporations like Nintendo marketed to](). Over the decades, that consumer class became a passionate, even obsessive cultural faction. And in 2014, with the Gamergate controversy, a sexist harassment campaign founded on a lie, parts of it curdled into a reactionary identity. Right-wing provocateurs such as Milo Yiannopoulos spurred it on, seeing in the "frustrated male stereotype" a chance to transform resentment into cultural power. Gaming and gamer culture belonged to a particular type of person, and that type of person was under attack, Gamergate's adherents held. "Social justice warriors" were parachuting into *their* games to change *their* culture. Nongamers, or gamers who didn't resemble them, became "normies," "[e-girls]()," "Chads," "NPCs" (non-playable characters).

"It's a good target audience, mostly male, that's often been very susceptible to radicalization," says Julia Ebner, a counterterrorism expert for the United Nations. Ebner has gone undercover in a number of extremist groups, both online and offline, including jihadists, neo-Nazis, and an antifeminist collective. She watched as subcultures that grew out of 4chan—initially trolling, not explicitly political—slowly became more political, and then radical. Gradually, inherently extremist content camouflaged as satire became normalized. Then it became real. The vectors, she says, were people like Malcolm.

"Recruitment" isn't always the right word, Ebner told me. Sometimes "grooming" is a better descriptor. "It's often not really clear to the people who are recruited what they're actually recruited into," she says.

Ebner does not believe that video games are radicalizing people on any large scale. But she has seen extremists use gamification or video games as a method of recruitment, partly because of those qualities associated with capital-G gamers. "There is a big loneliness issue in parts of the gaming community," she says. "And there's also a certain desire for excitement, for entertainment."

Ebner argues that there should be more intervention programs targeting fringe communities on the internet, staffed by trained psychologists and recovered extremists. But first, she says, society needs to change the way it talks about far-right recruitment and gaming. People write off entire communities as being "completely extremist, being alt, being radical," she says. But extremists "lure individuals from those subcultures into their political networks." It's a complex, diffuse problem, and the conversation about it, she says, "isn't nuanced enough."

The Senate and People of Rome fell in 2015. It wasn't sacked by Lego-man Visigoths or brought down by the parasitic forces of degeneracy. What happened was that Parthia's architect fell in love with Cleopatra, whom he married in-game and gave his login credentials. But Cleopatra turned out to be a catfish, and the dude behind the account leaked Parthia's source code. Anyone could copy Malcolm's empire and rule over it themselves. The increasingly paranoid caesar began exiling players. He tried to forge a new fascist dystopia, but the attempt fizzled. Rome was dead. By 2016, he and Ferguson had stopped spending time in the same groups.

A year after that, though, 4chan users on the infamous /pol/ board would reminisce about the Senate and People of Rome in its heyday. /Pol/, short for "politically incorrect," is infamous specifically for hate speech and political trolling, and as an engine of extremism. One person wrote that most of the high-ranking members of Parthia were "/pol/tards"—frequent commenters on the board. User after user thanked Malcolm for red-pilling them. One said that after "simulating life under Fascism" as a 14-year-old,

he had since become even "more supportive" of it. (Malcolm says that his "cult of personality is strictly built off of trolls.")

After the Unite the Right rally in Charlottesville, Virginia, in 2017, the left-wing activist collective Unicorn Riot obtained hundreds of thousands of messages from white supremacist Discord servers. They suggested that communities like Parthia existed elsewhere in *Roblox*. In a /pol/ gaming server, a user named Lazia Cus welcomed new arrivals. "Currently," they wrote, "we have started a 'Redpill' the Youth project which is going on in 'Roblox.' We've created a clan in which we will operate Raids/Defences and expand on this project into other platforms." (The clan was a "futuristic Roman legion," though not necessarily modeled after Malcolm's Rome or one of its many offshoots.)

Ferguson still isn't sure whether he participated in a fascist recruitment campaign. It was a role-play. Sure, the structure of the Senate and People of Rome normalized and even gamified fascism. And there were people like Malcolm who browbeat kids into adopting extremist beliefs. "I've never interacted with people who were like, 'OK, we're going to make more neo-Nazis,'" he says. "But I feel like it's inevitable. It's indirect." Ferguson pointed out a *Roblox* role-play of the US-Mexico border in which players are Border Patrol agents. Nearly 1.1 million people had visited the game. "It's not *racially motivated*," Ferguson says, dripping with irony. "They're just *pretending* to be a law enforcement agency that has a long history of extremely racist and xenophobic tendencies." (A Roblox spokesperson said the company reviews "every single image, audio file, and video before it is uploaded.")

Members of Malcolm's Praetorian Guard have gone on to join the military and the TSA and to become police officers, or what Ferguson calls "actual Nazis." Malcolm himself now owns a *Star Wars* role-play group with 16,000 members. To become citizens, players must follow the group's social media accounts. "Hail the Empire," one winky-faced commenter wrote.

Earlier this year, back in *Roblox*, Ferguson took me to the Group Recruiting Plaza. Booths manned by avatars lined the perimeter. Next to a *Star Wars*

group was a red, white, and blue booth and a bearded man in a suit. The poster above him featured a Confederate flag. It read:

(Were not racist, were just a war group) 5th Texas Infantry Regiment, Confederate States. We're at war with a USA Group.

A Discord handle appeared below.

When I approached, the avatar behind the booth explained to me that they role-play the Confederacy.

"Why does your sign say 'We're not racist'?" I asked.

"It's just Southern pride, and a war group," he responded. A human-sized scorpion walked through me. A boxy gentleman with aviators and a blue Napoleon jacket came over to offer support to his friend in the suit.

"But how is that not racist?" I asked. The booth operator hopped over the counter and stood in front of me. "You can't call a nation racist," he responded. "That's just unfair."

Ferguson and I decamped to another role-play: Washington, District of Columbia. The server was nearly full, 60 players. I spawned inches from the National World War II Memorial honoring American troops. "Visitor" appeared above my avatar's head. Ferguson was sitting in a police car. The officer had a gun on him. "You should hop in," Ferguson said.

On our way to federal prison, Ferguson explained that, like the Senate and People of Rome, this role-play had a strict hierarchy—senators, FBI and NSA agents, and so on. We exited the car as it did a midair triple-flip beside a mob of people just standing around talking. As I was escorted in, a Department of Justice official with beaded hair asked a man in a headscarf what he thought about Black Lives Matter. We were forced into an interrogation room. The interrogator, our driver, jumped on the table. He demanded to know what race we were. Washington, DC, was apparently at war with South Korea.

In his real life these days, Ferguson travels around Ontario, sometimes living with his dad, sometimes living elsewhere, picking up manual labor jobs when he can. He has taught infiltration methods to the youth, he says, so they can investigate *Roblox* groups for extremist behavior. They then report the groups or take them over. And for years, he has been growing his own online group, the Cult, which he calls "a family of friends to protect younger people"—particularly over *Roblox*. Right now, members of the Cult pay him between $100 and $1,000 a month for his efforts. He says he's closer to them than to his family.

Ferguson is sorry, he says, for his role in connecting so many people to Malcolm, and for his own bigotry. The Cult's values are the antithesis of all of that, he says. He made his followers read "Desiderata," a prose poem by the American writer Max Ehrmann about how to be "kind, nurturing souls." Right now he's on a farm, growing arugula, he says. He hopes to one day buy a plot of land and till it with the Cult's most dedicated members. At some point, he says, he had a realization: "If we took all of what we did online and slowly shifted it toward real life, we'd never be alone."

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What Really Happened When Google Ousted Timnit Gebru

She was a star engineer who warned that messy AI can spread racism. Google brought her in. Then it forced her out. Can Big Tech take criticism from within?
Photograph: Djeneba Aduayom

One afternoon in late November of last year, Timnit Gebru was sitting on the couch in her San Francisco Bay Area home, crying.

Gebru, a researcher at Google, had just clicked out of a last-minute video meeting with an executive named Megan Kacholia, who had issued a jarring command. Gebru was the coleader of a group at the company that studies the social and ethical ramifications of [artificial intelligence](#), and Kacholia had ordered Gebru to retract her latest research paper—or else remove her name from its list of authors, along with those of several other members of her team.

The [paper in question](#) was, in Gebru's mind, pretty unobjectionable. It surveyed the known pitfalls of so-called large language models, a type of AI software—most famously exemplified by a system called GPT-3—that was stoking excitement in the tech industry. Google's own version of the technology was now helping to power the company's search engine. [Jeff Dean](#), Google's [revered](#) head of research, had encouraged Gebru to think about the approach's possible downsides. The paper had sailed through the company's internal review process and had been submitted to a prominent conference. But Kacholia now said that a group of product leaders and

others inside the company had deemed the work unacceptable, Gebru recalls. Kacholia was vague about their objections but gave Gebru a week to act. Her firm deadline was the day after Thanksgiving.

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Photograph: Djeneba Aduayom

Gebru's distress turned to anger as that date drew closer and the situation turned weirder. Kacholia gave Gebru's manager, Samy Bengio, a document listing the paper's supposed flaws, but told him not to send it to Gebru, only to read it to her. On Thanksgiving Day, Gebru skipped some festivities with her family to hear Bengio's recital. According to Gebru's recollection and contemporaneous notes, the document didn't offer specific edits but complained that the paper handled topics "casually" and painted too bleak a picture of the new technology. It also claimed that all of Google's uses of large language models were "engineered to avoid" the pitfalls that the paper described.

Gebru spent Thanksgiving writing a six-page response, explaining her perspective on the paper and asking for guidance on how it might be revised instead of quashed. She titled her reply "Addressing Feedback from the Ether at Google," because she still didn't know who had set her Kafkaesque ordeal in motion, and sent it to Kacholia the next day.

On Saturday, Gebru set out on a preplanned cross-country road trip. She had reached New Mexico by Monday, when Kacholia emailed to ask for confirmation that the paper would either be withdrawn or cleansed of its Google affiliations. Gebru tweeted a cryptic reproach of "censorship and intimidation" against AI ethics researchers. Then, on Tuesday, she fired off two emails: one that sought to end the dispute, and another that escalated it beyond her wildest imaginings.

The first was addressed to Kacholia and offered her a deal: Gebru would remove herself from the paper if Google provided an account of who had reviewed the work and how, and established a more transparent review process for future research. If those conditions weren't met, Gebru wrote, she would leave Google once she'd had time to make sure her team

wouldn't be too destabilized. The second email showed less corporate diplomacy. Addressed to a listserv for women who worked in Google Brain, the company's most prominent AI lab and home to Gebru's Ethical AI team, it accused the company of "silencing marginalized voices" and dismissed Google's internal diversity programs as a waste of time.

Relaxing in an Airbnb in Austin, Texas, the following night, Gebru received a message with a ☺ from one of her direct reports: "You resigned??" In her personal inbox she then found an email from Kacholia, rejecting Gebru's offer and casting her out of Google. "We cannot agree as you are requesting," Kacholia wrote. "The end of your employment should happen faster than your email reflects." Parts of Gebru's email to the listserv, she went on, had shown "behavior inconsistent with the expectations of a Google manager." Gebru tweeted that she had been fired. Google maintained—and still does—that she resigned.

Gebru's tweet lit the fuse on a controversy that quickly inflamed Google. The company has been dogged in recent years by accusations from employees that it mistreats women and people of color, and from lawmakers that it wields unhealthy technological and economic power. Now Google had expelled a Black woman who was a prominent advocate for more diversity in tech, and who was seen as an important internal voice for greater restraint in the helter-skelter race to develop and deploy AI. One Google machine-learning researcher who had followed Gebru's writing and work on diversity felt the news of her departure like a punch to the gut. "It was like, oh, maybe things aren't going to change so easily," says the employee, who asked to remain anonymous because they were not authorized to speak by Google management.

Dean sent out a message urging Googlers to ignore Gebru's call to disengage from corporate diversity exercises; Gebru's paper had been subpar, he said, and she and her collaborators had not followed the proper approval process. In turn, Gebru claimed in tweets and interviews that she'd been felled by a toxic cocktail of racism, sexism, and censorship. Sympathy for Gebru's account grew as the disputed paper circulated like samizdat among AI researchers, many of whom found it neither controversial nor

particularly remarkable. Thousands of Googlers and outside AI experts signed a public letter castigating the company.

But Google seemed to double down. Margaret Mitchell, the other coleader of the Ethical AI team and a prominent researcher in her own right, was among the hardest hit by Gebru's ouster. The two had been a professional and emotional tag team, building up their group—which was one of several that worked on what Google called "responsible AI"—while parrying the sexist and racist tendencies they saw at large in the company's culture. Confident that those same forces had played a role in Gebru's downfall, Mitchell wrote an automated script to retrieve notes she'd kept in her corporate Gmail account that documented allegedly discriminatory incidents, according to sources inside Google. On January 20, Google said Mitchell had triggered an internal security system and had been suspended. On February 19, she was fired, with Google stating that it had found "multiple violations of our code of conduct, as well as of our security policies, which included exfiltration of confidential, business-sensitive documents."

Google had now fully decapitated its own Ethical AI research group. The long, spectacular fallout from that Thanksgiving ultimatum to Gebru left countless bystanders wondering: Had one paper really precipitated all of these events?

The story of what actually happened in the lead-up to Gebru's exit from Google reveals a more tortured and complex backdrop. It's the tale of a gifted engineer who was swept up in the [AI revolution](#) before she became one of its biggest critics, a refugee who worked her way to the center of the tech industry and became determined to reform it. It's also about a company —the world's fifth largest—trying to regain its equilibrium after four years of scandals, controversies, and mutinies, but doing so in ways that unbalanced the ship even further.

Beyond Google, the fate of Timnit Gebru lays bare something even larger: the tensions inherent in an industry's efforts to research the downsides of its favorite technology. In traditional sectors such as chemicals or mining, researchers who study toxicity or pollution on the corporate dime are

viewed skeptically by independent experts. But in the young realm of people studying the potential harms of AI, corporate researchers are central.

Gebru's career mirrored the rapid rise of AI fairness research, and also some of its paradoxes. Almost as soon as the field sprang up, it quickly attracted eager support from giants like Google, which sponsored conferences, handed out grants, and hired the domain's most prominent experts. Now Gebru's sudden ejection made her and others wonder if this research, in its domesticated form, had always been doomed to a short leash. To researchers, it sent a dangerous message: AI is largely unregulated and only getting more powerful and ubiquitous, and insiders who are forthright in studying its social harms do so at the risk of exile.

In April 1998, two Stanford grad students named Larry Page and Sergey Brin presented an algorithm called PageRank at a conference in Australia. A month later, war broke out between Ethiopia and Eritrea, setting off a two-year border conflict that left tens of thousands dead. The first event set up Google's dominance of the internet. The second set 15-year-old Timnit Gebru on a path toward working for the future megacorp.

At the time, Gebru lived with her mother, an economist, in the Ethiopian capital of Addis Ababa. Her father, an electrical engineer with a PhD, had died when she was small. Gebru enjoyed school and hanging out in cafés when she and her friends could scrape together enough pocket money. But the war changed all that. Gebru's family was Eritrean, and some of her relatives were being deported to Eritrea and conscripted to fight against the country they had made their home.

Gebru's mother had a visa for the United States, where Gebru's older sisters, engineers like their father, had lived for years. But when Gebru applied for a visa, she was denied. So she went to Ireland instead, joining one of her sisters, who was there temporarily for work, while her mother went to America alone.

Reaching Ireland may have saved Gebru's life, but it also shattered it. She called her mother and begged to be sent back to Ethiopia. "I don't care if it's safe or not. I can't live here," she said. Her new school, the culture, even the weather were alienating. Addis Ababa's rainy season is staccato, with

heavy downpours interspersed by sunshine. In Ireland, rain fell steadily for a week. As she took on the teenage challenges of new classes and bullying, larger concerns pressed down. "Am I going to be reunited with my family? What happens if the paperwork doesn't work out?" she recalls thinking. "I felt unwanted."

The next year, Gebru was approved to come to the US as a refugee. She reunited with her mother in Somerville, Massachusetts, a predominantly white suburb of Boston, where she enrolled in the local public high school—and a crash course in American racism.

Some of her teachers, Gebru found, seemed unable or unwilling to accept that an African refugee might be a top student in math and science. Other white Americans saw fit to confide in her their belief that African immigrants worked harder than African Americans, whom they saw as lazy. History class told an uplifting story about the Civil Rights Movement resolving America's racial divisions, but that tale rang hollow. "I thought that cannot be true, because I'm seeing it in the school," Gebru says.

Piano lessons helped provide a space where she could breathe. Gebru also coped by turning to math, physics, and her family. She enjoyed technical work, not just for its beauty but because it was a realm disconnected from personal politics or worries about the war back home. That compartmentalization became part of Gebru's way of navigating the world. "What I had under my control was that I could go to class and focus on the work," she says.

Gebru's focus paid off. In September 2001 she enrolled at Stanford. Naturally, she chose the family major, electrical engineering, and before long her trajectory began to embody the Silicon Valley archetype of the immigrant trailblazer. For a course during her junior year, Gebru built an experimental electronic piano key, helping her win an internship at Apple making audio circuitry for Mac computers and other products. The next year she went to work for the company full-time while continuing her studies at Stanford.

At Apple, Gebru thrived. When Niel Warren, her manager, needed someone to dig into delta-sigma modulators, a class of analog-to-digital converters,

Gebru volunteered, investigating whether the technology would work in the iPhone. "As an electrical engineer she was fearless," Warren says. He found his new hardware hotshot to be well liked, always ready with a hug, and determined outside of work too. In 2008, Gebru withdrew from one of her classes because she was devoting so much time to canvassing for Barack Obama in Nevada and Colorado, where many doors were slammed in her face.

As Gebru learned more about the guts of gadgets like the iPhone, she became more interested in the fundamental physics of their components—and soon her interests wandered even further, beyond the confines of electrical engineering. By 2011, she was embarking on a PhD at Stanford, drifting among classes and searching for a new direction. She found it in computer vision, the art of making software that can interpret images.

Unbeknownst to her, Gebru now stood on the cusp of a revolution that would transform the tech industry in ways she would later criticize. One of Gebru's favorite classes involved creating code that could detect human figures in photos. "I wasn't thinking about surveillance," Gebru says. "I just found it technically interesting."

In 2013 she joined the lab of Fei-Fei Li, a computer vision specialist who had helped spur the tech industry's obsession with AI, and who would later work for a time at Google. Li had created a project called ImageNet that paid contractors small sums to tag a billion images scraped from the web with descriptions of their contents—cat, coffee cup, cello. The final database, some 15 million images, helped to reinvent machine learning, an AI technique that involves training software to get better at performing a task by feeding it examples of correct answers. Li's work demonstrated that an approach known as deep learning, fueled by a large collection of training data and powerful computer chips, could produce much more accurate machine-vision technology than prior methods had yielded.

Li wanted to use deep learning to give computers a more fine-grained understanding of the world. Two of her students had scraped 50 million images from Google Street View, planning to train a neural network to spot cars and identify their make and model. But they began wondering about other applications they might build on top of that capability. If you drew

correlations between census data and the cars visible on a street, could that provide a way to estimate the demographic or economic characteristics of any neighborhood, just from pictures?

Gebru spent the next few years showing that, to a certain level of accuracy, the answer was yes. She and her collaborators used online contractors and car experts recruited on Craigslist to identify the make and model of 70,000 cars in a sample of Street View images. The annotated pictures provided the training data needed for deep-learning algorithms to figure out how to identify cars in new images. Then they processed the full Street View collection and identified 22 million cars in photos from 200 US cities. When Gebru correlated those observations with census and crime data, her results showed that more pickup trucks and VWs indicated more white residents, more Buicks and Oldsmobiles indicated more Black ones, and more vans corresponded to higher crime.

This demonstration of AI's power positioned Gebru for a lucrative career in Silicon Valley. Deep learning was all the rage, powering the industry's latest products (smart speakers) and its future aspirations (self-driving cars). Companies were spending millions to acquire deep-learning technology and talent, and Google was placing some of the biggest bets of all. Its subsidiary DeepMind had recently celebrated the victory of its machine-learning bot over a human world champion at Go, a moment that many took to symbolize the future relationship between humans and technology.

Gebru's project fit in with what was becoming the industry's new philosophy: Algorithms would soon automate away any problem, no matter how messy. But as Gebru got closer to graduation, the boundary she had established between her technical work and her personal values started to crumble in ways that complicated her feelings about the algorithmic future.

Gebru had maintained a fairly steady interest in social justice issues as a grad student. She wrote in *The Stanford Daily* about an incident in which an acquaintance wondered aloud whether Gebru was "actually smart" or had been admitted due to affirmative action. At Stanford's graduate school, Gebru encountered a significantly less diverse student population than she had during her undergraduate years, and she felt isolated. She bonded with people who, like her, had experienced global inequality firsthand. "Once

you've seen the world in terms of its injustice and the ways in which the United States is not always the answer to everybody's problems, it's very difficult to unsee," says Jess Auerbach, a student from South Africa who became friends with Gebru at Stanford, and who is now an anthropologist at North West University in South Africa.

In 2016, Gebru volunteered to work on a coding program for bright young people in Ethiopia, which sent her on a trip back home, only her second since she had fled at the age of 15. Her coding students' struggles, she felt, exposed the limits of US meritocracy. One promising kid couldn't afford the roughly $100 required to take the SAT. After Gebru paid the fee for him, he won a scholarship to MIT. She also pitched in to help students who had been denied visas despite having been accepted to US schools. "She tried all she could to help these kids," says Jelani Nelson, the UC Berkeley professor who founded the program.

Li, Gebru's adviser at Stanford, encouraged her to find a way to connect social justice and tech, the two pillars of her worldview. "It was obvious to an outsider, but I don't think it was obvious to her, that actually there was a link between her true passion and her technical background," Li says. Gebru was reluctant to forge that link, fearing in part that it would typecast her as a Black woman first and a technologist second.

But she also became more aware that technology can sometimes reflect or magnify society's biases, rather than transcend them. In 2016, ProPublica reported that a recidivism-risk algorithm called COMPAS, used widely in courtrooms across the country, made more false predictions that Black people would reoffend than it did for white people (an analysis that was disputed by the company that made the algorithm). This made Gebru wonder whether the crime data she'd used in her own research reflected biased policing. Around the same time, she was introduced to Joy Buolamwini, a Ghanaian American MIT master's student who had noticed that some algorithms designed to detect faces worked less well on Black people than they did on white people. Gebru began advising her on publishing her results.

It wasn't just the algorithms or their training data that skewed white. In 2015, Gebru got her first glimpse of the worldwide community of AI

researchers at the field's top conference, Neural Information Processing Systems (NIPS), in Montreal. She noticed immediately how male and how white it was. At a Google party, she was intercepted by a group of strangers in Google Research T-shirts who treated the presence of a Black woman as a titillating photo op. One man grabbed her for a hug; another kissed her cheek and took a photo. At the next year's conference, Gebru kept a tally of other Black people she met, counting just six among the 8,500 attendees— all people she already knew, and most of whom she'd already added to an email list she'd started for Black people in the field. After the event, Gebru posted a warning to AI researchers on Facebook about the dangers of their community's lack of diversity. "I'm not worried about machines taking over the world, I'm worried about groupthink, insularity, and arrogance in the AI community," she wrote. "If many are actively excluded from its creation, this technology will benefit a few while harming a great many."

Gebru's awakening roughly coincided with the emergence of a new research field dedicated to examining some of the social downsides of AI. It came to be centered on an annual academic workshop, first held in 2014, called Fairness, Accountability, and Transparency in Machine Learning (FATML) and motivated by concerns over institutional decisionmaking. If algorithms decided who received a loan or awaited trial in jail rather than at home, any errors they made could be life-changing.

The event's creators initially found it difficult to convince peers that there was much to talk about. "The more predominant idea was that humans were biased and algorithms weren't," says Moritz Hardt, now a UC Berkeley computer science professor who cofounded the workshop with a researcher from Princeton. "People thought it was silly to work on this."

By 2016 the event had grown into a meeting that sold out a hall at NYU School of Law. The audience included staffers from the Federal Trade Commission and the European Commission. Yet the presenters, by and large, applied a fairly detached and mathematical lens to the notion that technology could harm people. Researchers hashed out technical definitions of fairness that could be expressed in the form of code. There was less talk about how economic pressures or structural racism might shape AI systems, whom they work best for, and whom they harm.

Gebru didn't attend the FATML workshop that year or the next—she was still mainly focused on building AI, not examining its potential for harm. In January 2017, at a one-day event centered on how AI could shake up finance, Gebru stood in a gray turtleneck in a large octagonal room overlooking Stanford's terracotta-roofed campus and presented the findings of her PhD thesis to members of Silicon Valley's elite. She clicked through slides showing how algorithms could predict factors like household income and voting patterns just by identifying cars on the street.

Gebru was the only speaker who was not a professor, investment professional, or representative of a tech company, but, as one organizer recalls, her talk generated more interest than any of the others. Steve Jurvetson, a friend of Elon Musk and an early investor in Tesla, enthusiastically posted photos of her slides to Facebook. A longtime AI aficionado, he wasn't surprised that machine-learning algorithms could identify specific cars. But the way Gebru had extracted signals about society from photos illustrated how the technology could spin gold from unexpected sources—at least for those with plenty of data to mine. "It was, 'My God, think of all the data that Google has,'" Jurvetson says. "It made me realize the power of having the biggest data set."

For Gebru, the event could have been a waypoint between her grad school AI work and a job building moneymaking algorithms for tech giants. But she decided that she wanted to help contain the technology's power rather than expand it. In the summer of 2017, she took a job with a Microsoft research group that had been involved in the FATML movement from early on. Gebru wrote her pivot into the final chapter of her thesis: "One of the most important emergent issues plaguing our society today is that of algorithmic bias. Most works based on data mining, including my own works described in this thesis, suffer from this problem," she wrote. Her plan for a career, she went on, was "to make contributions towards identifying and mitigating these issues."

While Gebru was completing her thesis at Stanford, Margaret Mitchell was developing her own doubts about AI, 800 miles north at Microsoft's verdant campus outside Seattle.

In 2015, Mitchell, an expert in software that generates language from images, was working on an app for blind people that spoke visual descriptions of the world. She had christened it Seeing AI, and she loved the idea that the flourishing power of machine learning could lift up society's most vulnerable. But Microsoft didn't seem willing to seriously invest in such projects at the time.

Mitchell also noticed some troubling gaffes in the machine-learning systems she was training. One would describe someone with pale skin, like the red-haired Mitchell, as a "person," but a figure with dark skin as a "Black person." In another test, an image of an inferno at an oil storage depot was captioned "great view." She began to fear that AI was laced with land mines, and the industry was not paying enough attention to finding them. "Oh crap," she remembers thinking. "There are serious issues that we have to solve right now because no one else is working on them and this technology is evolving."

In 2016, Mitchell moved to Google to work full-time on those problems. The company appeared to be embracing this new, conscientious strand of AI research. A couple of weeks before she started, Google published its first research paper on machine-learning fairness. It considered how to ensure that a system that makes predictions about people—say, assessing their risk of defaulting on a loan—offered equal treatment to individuals regardless of their gender, race, religion, or other group identity. The company highlighted its research in a blog post for a general audience, and signed up, alongside Microsoft, as a corporate sponsor of the FATML workshop.

When Mitchell got to Google, she discovered a messier reality behind the company's entrée into fairness research. That first paper had been held up for months by internal deliberations over whether Google should publicly venture into a discourse on the discriminatory potential of computer code, which to managers seemed more complex and sensitive than its labs' usual output. Mitchell's own first publication at the company, on making smile-detection algorithms perform well for people of different races and genders, also met with a degree of corporate hesitancy that didn't seem to encumber more conventional AI projects. She chose to work on smiles in part because

of their positive associations; still, she endured rounds of meetings with lawyers over how to handle discussions of gender and race.

At other times, Mitchell's work inside Google faced little resistance, but also little enthusiasm. "It was like people really appreciated what I was saying, and then nothing happened," she says. Still, Mitchell hadn't expected to change the company overnight, and gradually her efforts gained momentum. In late 2017 she formed a small team dedicated to "ethical AI research" and embarked on a campaign of meetings with teams across Google to spread the word and offer help. This time people seemed more receptive—perhaps in part because broader attitudes were shifting. Some of Google's rivals, like Microsoft, appeared to be taking AI fairness more seriously. Industry hype about AI was still intense, but the field's culture was becoming more reflective.

When Gebru presented her PhD thesis on computer vision to members of Silicon Valley's elite, her talk generated intense interest.

Photograph: Djeneba Aduayom

One person driving that change was Timnit Gebru, who was introduced to Mitchell by an acquaintance over email when Gebru was about to join Microsoft. The two had become friendly, bonding over a shared desire to call out injustices in society and the tech industry. "Timnit and I hit it off immediately," Mitchell says. "We got along on every dimension."

Gebru was also hitting it off with others who wanted to work in AI but found themselves misunderstood by both people and algorithms. In December 2017, Inioluwa Deborah Raji, a young Nigerian-Canadian coder at an AI startup called Clarifai, stood in the lobby of the Long Beach Convention Center in a crowd of mostly white faces at that year's NIPS conference. She was beginning to feel that working in AI was not for her. At Clarifai, Raji had helped to create a machine-learning system that detected photos containing nudity or violence. But her team discovered it was more likely to flag images of people of color, because they appeared more often in the pornography and other material they'd used as training data. "That really hit me," Raji says. "I built this thing, and it was actively discriminatory in a way that hurt people of color."

The NIPS conference provided a look at the world of AI beyond her startup, but Raji didn't see people like herself onstage or in the crowded lobby. Then an Afroed figure waved from across the room. It was Gebru. She invited Raji to the inaugural Black in AI workshop, an event born out of Gebru's email list for Black researchers. Raji changed her plane ticket to stay an extra day in Long Beach and attend.

The event mixed technical presentations by Black researchers with networking and speeches on how to make AI more welcoming. Mitchell ran support for remote participants joining by video chat. At the post-event dinner, on the cruise ship *Queen Mary*, permanently docked in Long Beach, Gebru, Raji, and other Black AI researchers mingled and danced with big names from Amazon and Google.

Other events at NIPS that year had made the hype-saturated world of AI research appear seamy and elitist. Intel threw a corporate party that featured provocatively dressed women performing acrobatics, and Elon Musk made an anatomical joke about the conference's acronym. NIPS organizers released a "statement on inappropriate behavior," promising tougher policies for attendees and sponsors. (They also ended up changing the event's acronym, in due course, to NeurIPS.)

At the Black in AI event, by contrast, there was an atmosphere of friendship and new beginnings. People spoke openly and directly about the social and political tensions hidden beneath the technical veneer of AI research. Raji started to think she could work in the field after all. Jeff Dean, the storied Googler who had cofounded the Google Brain research group, posed for selfies with attendees. He and another top Google Brain researcher, Samy Bengio, got talking with Gebru and suggested she think about joining their group.

Gebru's research was also helping to make work on AI fairness less academic and more urgent. In February 2018, as part of a project called Gender Shades, she and Buolamwini published evidence that services offered by companies including IBM and Microsoft that attempted to detect the gender of faces in photos were nearly perfect at recognizing white men, but highly inaccurate for Black women. The problem appeared to be rooted in the fact that photos scraped from the web to train facial-recognition

systems overrepresented men as well as white and Western people, who had more access to the internet.

The project was a visceral demonstration of how AI could perpetuate social injustices—and of how research like Gebru's could hold companies like her own employer to account. IBM and Microsoft both issued contrite statements. Gebru had not informed her bosses of Microsoft's inclusion in the Gender Shades project much in advance, but Microsoft's research division was known for being kept relatively isolated from the business in order to give its researchers freedom. A product manager quizzed her about the study, but that was it. The lab promoted a *New York Times* write-up of the project on its homepage, with a photo of Gebru over the newspaper's headline: "Facial Recognition Is Accurate, If You're a White Guy."

Gebru's primary research project at Microsoft contrasted her experience as an electrical engineer with the working habits of machine-learning experts. At Apple, Gebru and her coworkers had studied standardized data sheets detailing the properties of every component they considered adding to a gadget like the iPhone. AI had no equivalent culture of rigor around the data used to prime machine-learning algorithms. Programmers generally grabbed the most easily available data they could find, believing that larger data sets meant better results.

Gebru and her collaborators called out this mindset, pointing to her study with Buolamwini as evidence that being lax with data could infest machine-learning systems with biases. Gebru's new paper proposed a framework called Datasheets for Datasets, in which AI engineers would document the patterns and contents of their data to avoid nasty surprises later. The project treated AI systems as artifacts whose creators should be held to standards of responsibility. "For the first time it gave some structure in my mind about how to think about implementing fairness," says Krishna Gade, who led a team developing machine learning for Facebook's News Feed before founding Fiddler Labs, which creates AI transparency tools.

The Datasheets project bolstered Gebru's prominence in the movement to scrutinize the ethics and fairness of AI. Mitchell asked her to think about joining her Ethical AI team at Google.

Some people warned Gebru about joining the company. While she was interviewing, Google employees were pressuring their leaders to abandon a Pentagon contract known as Project Maven, which would use machine learning to analyze military drone surveillance footage. Gebru signed a letter with more than 1,000 other researchers urging the company to withdraw. Her uncomfortable experience at the 2015 Google party in Montreal preyed on her mind, and multiple women who had worked at Google Brain told her that the company was hostile to women and people of color, and resistant to change.

Gebru considered walking away from the job offer, until Mitchell offered to make her colead of the Ethical AI team. They would share the burden and the limelight in hopes that together they could nudge Google in a more conscientious direction. Gebru reasoned that she could stick close to Mitchell and keep her head down. "I thought, OK, I can do my work and be careful who I collaborate with, and try to ignore some of the other things," she says. "My number one concern was: Can I survive in this environment?"

Gebru arrived at the Googleplex in September 2018. She took a desk not far from Jeff Dean's in one of the buildings that housed Google Brain, across the main courtyard from the volleyball court and the replica of a *Tyrannosaurus rex* skeleton. She didn't keep a low profile for long. Two months into her new job, she walked out, joining thousands of employees worldwide to protest the company's treatment of women after *The New York Times* reported that Google had paid $90 million in severance to an executive accused of sexual harassment.

Gebru joined a discussion about the protest on an internal email list called Brain Women and Allies. She pointed out some problems she'd noticed at her new workplace, including "toxic men" and a lack of women in senior positions. She was summoned to a brief meeting with Dean—now her boss's boss—and a representative from human resources to discuss her observations.

Soon after, Gebru met with Dean again, this time with Mitchell at her side, for another discussion about the situation of women at Google. They planned a lunch meeting, but by the time the appointment rolled around, the

two women were too anxious to eat. Mitchell alleged that she had been held back from promotions and raises by performance reviews that unfairly branded her as uncollaborative. Gebru asserted that a male researcher with less experience than her had recently joined Google Brain at a more senior level. Dean said he'd look into the pair's claims. Gebru was promoted; Dean told her that the hiring committee had not previously seen all parts of her résumé, an explanation she found dubious. After more back and forth over Mitchell's position, Dean let her switch supervisors.

Gebru and Mitchell's work didn't fit easily into Google's culture, either. The women and their team were a relatively new breed of tech worker: the in-house ethical quibbler. After the dustup at Google over Project Maven, and in the wake of research like Buolamwini and Gebru's, tech giants began trumpeting lofty corporate commitments to practice restraint in their AI projects. After Google said it would not renew its controversial Pentagon contract, it announced a set of seven principles that would guide its AI work. Among them: AI projects had to be "socially beneficial" and could not relate to weapons or surveillance (though other defense work was still permitted). Microsoft posted six AI principles that were less specific, including "inclusiveness" and "accountability." Both companies created internal review processes for cloud computing deals that they said would weed out unethical projects. In 2016, Microsoft and Google were the only corporate sponsors of the FATML workshop; in 2019, they were joined by Google's Alphabet sibling DeepMind, as well as Spotify and Twitter, as sponsors of an entire conference that had in part grown out of the FATML workshop. Gebru was one of its organizers.

Despite those changes, it remained unclear to some of the in-house quibblers how, exactly, they would or could change Google. The Ethical AI team's primary job was to conduct research, but Mitchell also wanted the group to shape the company's products, which touched billions of lives. Indifference and a lack of support, however, sometimes stood in their way. In some cases, Mitchell herself wrote code for product teams that wanted to implement AI safeguards, because engineering resources weren't regularly made available for their kind of work.

So the Ethical AI team hustled, figuring out ways to get traction for their ideas and sometimes staging interventions. In one case, they noticed problems in Gmail's Smart Reply feature, which suggests short responses to emails: It made gendered assumptions, such as defaulting to "he" if a message included mention of an engineer. A member of the Ethical AI team met with an engineer on the project for a quiet chat. That helped set off a series of conversations, and the feature was adjusted to no longer use gendered pronouns.

Mitchell also developed a playbook for turning ethical AI itself into a kind of product, making it more palatable to Google's engineering culture, which prized launches of new tools and features. In January 2019, Mitchell, Gebru, and seven collaborators introduced a system for cataloging the performance limits of different algorithms. The method, which built on Gebru's earlier work documenting the contents and blind spots of data sets, noted the conditions under which algorithms were most likely to return accurate results and where they were likely to falter. Mitchell's team named the concept Model Cards, to make it sound generic and neutral, and shopped it around to other teams inside the company. The cloud computing division adopted Model Cards, using them as a form of disclosure, like a nutrition label, to show the public how well, say, Google's facial detection algorithm performs on different kinds of images.

On at least one occasion, the Ethical AI team also helped convince Google to limit its AI in ways that ceded potential revenue to competitors. Microsoft and Amazon had for years offered face-recognition services that could be used for more or less anything, including law enforcement. With the Ethical AI team's help, Google launched a limited service that just recognized public figures and was offered only to customers in the media after careful vetting.

Mitchell and Gebru believed their successes derived in part from the fact that their team provided refuge from Google's internal culture, which they and some other researchers found hostile, territorial, and intensely hierarchical. The dozen or so people on the Ethical AI team took pride in being more diverse in terms of gender, race, and academic background than the rest of the company. Gebru fondly thought of them as misfits and

believed that diversity made the group more likely to spot problems or opportunities that Google's largely white male workers might overlook. Gebru and Mitchell also successfully lobbied executives to allow them to bring in sociologists and anthropologists—not just the usual computer science PhDs. "A lot of people in our team would either not be at Google or maybe even in the tech industry if they didn't join," Gebru says.

Over time, the team seemed to show how corporate quibblers could succeed. Google's Ethical AI group won respect from academics and helped persuade the company to limit its AI technology. Gebru and Mitchell both reported to Samy Bengio, the veteran Google Brain researcher, whom they came to consider an ally. The company had built up a handful of other teams working on AI guardrails, including in the research and global affairs divisions, but they were tied more closely to the company's business priorities. The Ethical AI team was more independent and wide-ranging. When Mitchell started at Google, the field mainly took a narrow, technical approach to fairness. Now it increasingly asked more encompassing questions about how AI replicated or worsened social inequalities, or whether some AI technology should be placed off-limits. In addition to creating handy tools for engineers, members of the team published papers urging AI researchers to draw on critical race theory and reconsider the tech industry's obsession with building systems to achieve mass scale.

At the same time, however, Mitchell and Gebru's frustrations with Google's broader culture mounted. The two women say they were worn down by the occasional flagrantly sexist or racist incident, but more so by a pervasive sense that they were being isolated. They noticed that they were left out of meetings and off email threads, or denied credit when their work made an impact. Mitchell developed an appropriately statistical way of understanding the phenomenon. "What is the likelihood that I will not be invited to a meeting that I should be at? What is the likelihood that my male colleague will be invited? You start to see the trends," she says.

Together, the two women joined and sometimes led attempts to change Google's culture. In 2019, with two others, they circulated a pointed internal document listing concerns about the treatment of women in Google's research teams. Women were treated as "punching bags," the

document asserted, and senior managers dismissed observations about inequality as "temper tantrums." Mitchell disseminated a chart explaining how to support marginalized groups at work, including checklist items like "Did you listen to their answer and respond with empathy?"

Gebru was the more outspoken of the two—usually because she felt, as a Black woman, that she had to be. She admits that this won her enemies. She dismissed as backward diversity programs that placed an emphasis on mentoring for women: The company's problems, she would say, were rooted in its culture and leadership, not in the marginalized workers. Gebru's willingness to speak up sometimes led to blowups. In one incident, she and another woman warned Dean that a male researcher at Google had previously been accused of sexual harassment. Managers did not appear to act until the man was accused of harassing multiple people at Google, after which he was fired. The man's lawyers then sent Google a letter in which they accused Gebru and the other woman of defaming him. Google lawyers in turn advised the pair to hire their own counsel. Gebru and her coworker did so, and their own lawyers warned Google that it had a duty to represent its employees. After that expensive pushback, the two women didn't hear more about the issue. (Google did not respond to a request for comment on the incident, but told Bloomberg it began an investigation immediately after receiving reports about the man and that he departed before the investigation concluded.)

Some Googlers chafed at Gebru's willingness to confront colleagues. "Timnit's behavior was very far outside the norm," says one researcher at Google who was not authorized to speak to the press. The researcher recalls an incident in the summer of 2020, during the wave of Black Lives Matter protests, when Gebru got into a dispute on an internal mailing list dedicated to discussing new AI research papers. A male colleague posted a short, enthusiastic message about a new text-generation system that had just been opened up for commercial use. Gebru, acutely conscious of the demonstrations roaring across America, replied to highlight a warning from a prominent woman in the field that such systems were known to sometimes spew racist and sexist language. Other researchers then replied to the initial post without mentioning Gebru's comment. Gebru called them out for ignoring her, saying it was a common and toxic pattern, and she says

one man privately messaged her to say he wasn't surprised she got harassed online. A hot-tempered debate ensued over racism and sexism in the workplace.

According to the Google employee, the incident—which is also described in anonymous posts on Reddit—showed how Gebru's demeanor could make some people shy away from her or avoid certain technical topics for fear of being pulled into arguments about race and gender politics. Gebru doesn't deny that the dispute became heated but says it ultimately proved productive, forcing attention to her negative experiences and those of other women at Google.

About a year after Gebru first arrived at Google, in October 2019, the company summoned journalists to its headquarters in Mountain View to raise the curtain on a new technology. After a sumptuous breakfast buffet, reporters were shepherded into a narrow meeting room to hear from Dean and two vice presidents in charge of Google's search engine. The trio touted a new kind of machine-learning system that they said made the company's signature product better able to understand long queries.

Dean raised a polite chuckle when he explained that the new system was called Bidirectional Encoder Representations from Transformers, but was generally known by a name borrowed from *Sesame Street*: BERT. It was an example of a new type of machine-learning system known as a large language model, enabled by advances that made it practical for algorithms to train themselves on larger volumes of text, generally scraped from the web. That broader sampling allowed models like BERT to better internalize statistical patterns of language use, making them better than previous technology at tasks like answering questions or detecting whether a movie review was positive or negative.

When a reporter asked whether BERT would also learn, say, sexist language patterns, Dean responded, "This is something that we definitely look at for all the machine-learning-related product launches and also in our own research," citing the work of people like Mitchell and Gebru. "We want to make sure that our use of machine learning is free of unfair forms of bias." The Q&A also revealed that Google had other reasons to value BERT.

When another journalist asked if it was being used by Google's ads team, one of the search executives replied, "I'm sure they must be applying it."

In the months that followed, excitement grew around large language models. In June 2020, OpenAI, an independent AI institute cofounded by Elon Musk but now bankrolled by a billion dollars from Microsoft, won a splurge of media coverage with a system called GPT-3. It had ingested more training data than BERT and could generate impressively fluid text in genres spanning sonnets, jokes, and computer code. Some investors and entrepreneurs predicted that automated writing would reinvent marketing, journalism, and art.

These new systems could also become fluent in unsavory language patterns, coursing with sexism, racism, or the tropes of ISIS propaganda. Training them required huge collections of text—BERT used 3.3 billion words and GPT-3 almost half a trillion—which engineers slurped from the web, the most readily available source with the necessary scale. But the data sets were so large that sanitizing them, or even knowing what they contained, was too daunting a task. It was an extreme example of the problem Gebru had warned against with her Datasheets for Datasets project.

Inside Google, researchers worked to build more powerful successors to BERT and GPT-3. Separately, the Ethical AI team began researching the technology's possible downsides. Then, in September 2020, Gebru and Mitchell learned that 40 Googlers had met to discuss the technology's future. No one from Gebru's team had been invited, though two other "responsible AI" teams did attend. There was a discussion of ethics, but it was led by a product manager, not a researcher.

That same month, Gebru sent a message to Emily M. Bender, a professor of linguistics at the University of Washington, to ask if she had written anything about the ethical questions raised by these new language models. Bender had not, and the pair decided to collaborate. Bender brought in a grad student, and Gebru looped in Mitchell and three other members of her Google team.

The resulting paper was titled "On the Dangers of Stochastic Parrots: Can Language Models Be Too Big? 🦜" The whimsical title styled the software

as a statistical mimic that, like a real parrot, doesn't know the implications of the bad language it repeats.

The paper was not intended to be a bombshell. The authors did not present new experimental results. Instead, they cited previous studies about ethical questions raised by large language models, including about the energy consumed by the tens or even thousands of powerful processors required when training such software, and the challenges of documenting potential biases in the vast data sets they were made with. BERT, Google's system, was mentioned more than a dozen times, but so was OpenAI's GPT-3. Mitchell considered the project worthwhile but figured it would come across as boring. An academic who saw the paper after it was submitted for publication found the document "middle of the road."

Plenty of people inside Google knew about the paper early on, including Dean. In October, he wrote in a glowing annual review that Gebru should work with other teams on developing techniques to make machine-learning software for language processing "consistent with our AI Principles." In her reply, she told him about the paper she was drafting with Bender and others. Dean wrote back: "Definitely not my area of expertise, but would definitely learn from reading it." Gebru also informed Google's communications department about the project and mentioned it to Marian Croak, a Black engineering executive on Google's Advanced Technology Review Council, an internal review panel that was added after the Maven protests. Croak said the paper sounded interesting and asked Gebru to send her a copy. But Gebru never got the chance before the fatal controversy over "Stochastic Parrots" erupted.

It's not clear exactly who decided that Gebru's paper had to be quashed or for what reason. Nor is it clear why her resistance—predictable as it was—prompted a snap decision to eject her, despite the clear risk of public fallout. Other researchers at Google say it isn't unusual for publications about AI to trigger internal corporate sensitivities before public release, but that researchers can usually work through managers' objections. Gebru, with her track record of rattling management about Google's diversity and AI ethics problems, got little such opportunity. One reason managers were not more open in explaining their feedback to Gebru, according to Google, was that

they feared she would spread it around inside the company. Those fears may have been compounded when Gebru took to an internal listserv to criticize Google for "silencing marginalized voices," even as she offered to kill her own paper in exchange for greater transparency.

On the night of her forced exit from Google, in early December, members of Gebru's team joined a tearful Google Meet video call that lasted until early the next morning. In normal times, they might have hugged and huddled in a bar or someone's home; in a pandemic they sniffled alone over their laptops. Two weeks later, the remaining team members sent an email to Google CEO Sundar Pichai demanding an apology and several changes, including Gebru's reinstatement (and Kacholia's reassignment). Mitchell's firing two months later brought new pain. She hired lawyers who blasted out a press release saying she had been fired after "raising concerns of race and gender equity at Google."

Dean became the face of Google's displeasure with the "Stochastic Parrots" paper. He sent an email to the members of Google Research, also released publicly, saying the work "didn't meet our bar for publication," in part because one of its eight sections didn't cite newer work showing that large language models could be made less energy-hungry. Dean repeated the point so often inside Google that some researchers joked that "I have an objection to Parrots section three" would be inscribed on his tombstone. The complaint made little sense to many AI researchers, who knew that grumbles about citations typically end with authors revising a paper, not getting terminated. Dean's argument suffered another blow when reviewers accepted the paper to the conference on fairness and technology.

Others, including Gebru, offered a different explanation from Dean's: Google had used an opaque internal process to suppress work critical of a technology that had commercial potential. "The closer the research started getting to search and ads, the more resistance there was," one Google employee with experience of the company's research review process says. "Those are the oldest and most entrenched organizations with the most power." Still others surmised that Gebru was the casualty of a different kind of turf battle: that other internal groups working on responsible AI—ones

with closer relationships to Google's product teams—felt that Gebru and her coauthors were encroaching where they didn't belong.

The repercussions of Gebru's termination quickly radiated out from her team to the rest of Google and, beyond that, to the entire discipline of AI fairness research.

Some Google employees, including David Baker, a director who'd been at the company for 16 years, publicly quit over its treatment of Gebru. Google's research department was riven by mistrust and rumors about what happened and what might happen next. Even people who believed Gebru had behaved in ways unbecoming of a corporate researcher saw Google's response as ham-handed. Some researchers feared their work would now be policed more closely. One of them, Nicholas Carlini, sent a long internal email complaining of changes that company lawyers made to another paper involving large language models, published after Gebru was fired, likening the intervention to "Big Brother stepping in." The changes downplayed the problems the paper reported and removed references to Google's own technology, the email said.

Soon after, Google rolled out its response to the roiling scandal and sketched out a more locked-down future for in-house research probing AI's power. Marian Croak, the executive who had shown interest in Gebru's work, was given the task of consolidating the various teams working on what the company called responsible AI, including Mitchell and Gebru's. Dean sent around an email announcing that a review of Gebru's ouster had concluded; he was sorry, he said, that the company had not "handled this situation with more sensitivity."

Dean also announced that progress on improving workforce diversity would now be considered in top executives' performance reviews—perhaps quietly conceding Gebru's assertion that leaders were not held accountable for their poor showing on this count. And he informed researchers that they would be given firmer guidance on "Google's research goals and priorities." A Google source later explained that this meant future projects touching on sensitive or commercial topics would require more input from in-house legal experts, product teams, and others within Google who had relevant expertise. The outlook for open-minded, independent research on ethical AI

appeared gloomy. Google claimed that it still had hundreds of people working on responsible AI, and that it would expand those teams; the company painted Gebru and Mitchell's group as a tiny and relatively unimportant cog in a big machine. But others at Google said the Ethical AI leaders and their frank feedback would be missed. "For me, it's the most critical voices that are the most important and where I have learned the most," says one person who worked on product changes with Gebru and Mitchell's input. Bengio, the women's manager, turned his back on 14 years of working on AI at Google and quit to join Apple.

Outside of Google, nine Democrats in Congress wrote to Pichai questioning his commitment to preventing AI's harms. Mitchell had at one point tried to save the "Stochastic Parrots" paper by telling executives that publishing it would bolster arguments that the company was capable of self-policing. Quashing it was now undermining those arguments.

Some academics announced that they had backed away from company events or funding. The fairness and technology conference's organizers stripped Google of its status as a sponsor of the event. Luke Stark, who studies the social impacts of AI at the University of Western Ontario, turned down a $60,000 grant from Google in protest of its treatment of the Ethical AI team. When he applied for the money in December 2020, he had considered the team a "strong example" of how corporate researchers could do powerful work. Now he wanted nothing to do with Google. Tensions built into the field of AI ethics, he saw, were beginning to cause fractures.

"The big tech companies tried to steal a march on regulators and public criticism by embracing the idea of AI ethics," Stark says. But as the research matured, it raised bigger questions. "Companies became less able to coexist with internal critical research," he says. One person who runs an ethical AI team at another tech company agrees. "Google and most places did not count on the field becoming what it did."

To some, the drama at Google suggested that researchers on corporate payrolls should be subject to different rules than those from institutions not seeking to profit from AI. In April, some founding editors of a new journal of AI ethics published a paper calling for industry researchers to disclose who vetted their work and how, and for whistle-blowing mechanisms to be

set up inside corporate labs. "We had been trying to poke on this issue already, but when Timnit got fired it catapulted into a more mainstream conversation," says Savannah Thais, a researcher at Princeton on the journal's board who contributed to the paper. "Now a lot more people are questioning: Is it possible to do good ethics research in a corporate AI setting?"

If that mindset takes hold, in-house ethical AI research may forever be held in suspicion—much the way industrial research on pollution is viewed by environmental scientists. Jeff Dean admitted in a May interview with CNET that the company had suffered a real "reputational hit" among people interested in AI ethics work. The rest of the interview dealt mainly with promoting Google's annual developer conference, where it was soon announced that large language models, the subject of Gebru's fateful critique, would play a more central role in Google search and the company's voice assistant. Meredith Whittaker, faculty director of New York University's AI Now Institute, predicts that there will be a clearer split between work done at institutions like her own and work done inside tech companies. "What Google just said to anyone who wants to do this critical research is, 'We're not going to tolerate it,'" she says. (Whittaker herself once worked at Google, where she clashed with management over AI ethics and the Maven Pentagon contract before leaving in 2019.)

Any such divide is unlikely to be neat, given how the field of AI ethics sprouted in a tech industry hothouse. The community is still small, and jobs outside big companies are sparser and much less well paid, particularly for candidates without computer science PhDs. That's in part because AI ethics straddles the established boundaries of academic departments. Government and philanthropic funding is no match for corporate purses, and few institutions can rustle up the data and computing power needed to match work from companies like Google.

For Gebru and her fellow travelers, the past five years have been vertiginous. For a time, the period seemed revolutionary: Tech companies were proactively exploring flaws in AI, their latest moneymaking marvel— a sharp contrast to how they'd faced up to problems like spam and social network moderation only after coming under external pressure. But now it

appeared that not much had changed after all, even if many individuals had good intentions.

Inioluwa Deborah Raji, whom Gebru escorted to Black in AI in 2017, and who now works as a fellow at the Mozilla Foundation, says that Google's treatment of its own researchers demands a permanent shift in perceptions. "There was this hope that some level of self-regulation could have happened at these tech companies," Raji says. "Everyone's now aware that the true accountability needs to come from the outside—if you're on the inside, there's a limit to how much you can protect people."

Gebru, who recently returned home after her unexpectedly eventful road trip, has come to a similar conclusion. She's raising money to launch an independent research institute modeled on her work on Google's Ethical AI team and her experience in Black in AI. "We need more support for external work so that the choice is not 'Do I get paid by the DOD or by Google?'" she says.

Gebru has had offers, but she can't imagine working within the industry anytime in the near future. She's been thinking back to conversations she'd had with a friend who warned her not to join Google, saying it was harmful to women and impossible to change. Gebru had disagreed, claiming she could nudge things, just a little, toward a more beneficial path. "I kept on arguing with her," Gebru says. Now, she says, she concedes the point.

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One Man's Amazing Journey to the Center of the Bowling Ball

Mo Pinel spent a career reshaping the ball's inner core to harness the power of physics. He revolutionized the sport—and spared no critics along the way.
Photograph: Elizabeth Renstrom

The sweet clang of scattering pins echoed through Western Bowl, a cavernous 68-lane bowling alley on the edge of Cincinnati. It was day one of the 1993 Super Hoinke, a Thanksgiving weekend tournament that drew hundreds of the nation's top amateurs—teachers, accountants, and truck drivers who excelled at the art of scoring strikes. They came to the Super Hoinke ("HOING-key") to vie for a $100,000 grand prize and bowling-world fame.

Between games, many bowlers drifted to the alley's pro shop to soak in the wisdom of Maurice "Mo" Pinel, a star ball designer for the sporting-goods giant AMF. Pinel had come to Cincinnati to promote his latest creation, the Sumo. The bowling ball had launched the year before, backed by a [TV commercial](#) featuring a ginormous Japanese wrestler bellyflopping down a lane, with the tagline "Flat out, more power than you've ever seen in a bowling center." The ball had quickly become a sensation, hailed for the way it naturally darted sideways across the lane—a quality known as flare. To congratulate Pinel on the sale of the 100,000th Sumo, AMF had given him a chunky medallion embossed with writing in kanji, a bauble that dangled from his neck as he held court at the Super Hoinke.

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The paunchy, shaggy-haired Pinel spent hours regaling the pro-shop crowd with his opinions on the Sumo and all things ball-related. His blunt commentary, delivered in the thick Brooklynese of his youth, ranged from the correct technique for drilling finger holes to his rival designers' failure to appreciate Newton's second law. The audience lapped up his acerbic takes on how to improve the sport's most essential piece of equipment.

Fifteen-year-old Ronald Hickland Jr. was among the enthralled. A gifted math and science student who was falling in love with bowling, Hickland was captivated by Pinel's zest for breaking down the technical minutiae of why balls roll the way they do. He was equally impressed by the flashiness of Pinel's jewelry: In addition to the gaudy kanji necklace, Pinel sported a top-of-the-line Movado wristwatch—a luxury he was able to afford thanks to the $3-per-ball royalty he was getting from AMF.

Hickland had traveled from Indiana to cheer on his dad at the Super Hoinke. Listening to Pinel, he found his calling in life. "It was like lightning," he recalls. "And I was like, well, how do I get your job when I grow up?"

Pinel cautioned the teenager that the road ahead would be difficult. He would first have to earn a degree in mechanical or chemical engineering, after which he'd need vast amounts of persistence and luck: The number of full-time bowling ball designers in the world could be counted on two hands.

Asymmetrical cores, it turned out, can make a dramatic difference in the spin and trajectory of a bowling shot.

Hickland took that advice to heart, and he would eventually become one of the fortunate few to carve out a long career in ball design. He knows many would dismiss his chosen profession as frivolous. Bowling is easy to shrug

off as a mere leisure pursuit—a boozy weekend pastime in which anyone with decent hand-eye coordination can perform well enough. But hardcore bowlers have a very different take on the sport: To them it's a physics puzzle so elaborate that it can never be mastered, no matter how many thousands of hours they spend pondering the variables that can ruin a ball's 60-foot journey to the pins. The athletes who obsess over this complexity also understand the debt they owe to Pinel, whose career as a ball designer was just beginning when he attended the Super Hoinke in 1993. Notorious as a bit of a colorful crank, he is also the figure most responsible for transforming how bowlers think about the scientific limits of their sport.

In the early days of the pandemic, when ambulance sirens wailed nonstop in my hard-hit Queens, New York, neighborhood, I often soothed myself by bingeing YouTube clips of bowling. I can't remember how I first plunged down that rabbit hole, though it might have involved clicking a "Recommended for You" video in the sidebar next to the [Jesus Quintana scene from *The Big Lebowski*](). My personal experience with bowling amounted to little more than a few madcap nights with friends, yet I devoured hours' worth of highlights from professional matches, marveling at the athletes' ability to arc their shots with such precision. Flair atop flare. There was something hypnotic about the physics of the balls' movement, how those sleek orbs danced along the gutters before gracefully breaking toward the pins as if nudged by unseen hands.

Gorging on this content piqued my curiosity about the role a ball's physical properties play in determining the outcome of each shot. A bowler's prowess is clearly what matters most, but I assumed the composition of the balls must factor into the equation—arguably more so than in any other sport, given bowling's simplicity. I became keen to learn how bowling balls are constructed and how much of an edge a bowler can glean by using a ball that's been tailored to enhance their skills.

Grasping the basics of ball design turned out to be more complicated than I'd imagined. When I waded into the archives of *[Bowling This Month]()* to study the magazine's ball reviews, I was overwhelmed by nearly a thousand detailed evaluations, each peppered with jargon: "radius of gyration," "positive axis point," "mass bias location." And up to a dozen new balls are

released each month, almost all claiming to represent technological breakthroughs that will revolutionize the sport. The promotional copy for Storm Bowling's Parallax Effect, a ball that debuted in March, offers a typically impenetrable boast: "The strategically positioned depressions on the Z-axis 6-¾" from the pin mimic the effect of an extra hole in a similar space and keeps the intermediate differential at a more workable amount."

My bowling-ball education might have stalled early on were it not for the cutaway diagrams included in most spec sheets. These illustrations reveal the hidden guts of balls, showing a dazzling assortment of shapes and sizes. Unlike baseballs and golf balls, which are built around spherical cores, bowling balls contain cores that defy easy description: They can bear vague resemblance to gas masks, hand grenades, guitar bodies, Easter Island statues, Rorschach ink blots.

When I looked into the scientific reasons these cores are so strangely shaped, the name Mo Pinel kept popping up. He was widely credited as the designer who'd sparked the proliferation of funky cores in the early to mid-1990s, and at the age of 78 he was still espousing his theories as the technology director for Radical Bowling, a ball manufacturer that prides itself on catering to "geeks, physicists, and performance junkies." His primary venue for reaching bowlers online was his weekly YouTube series, #MoMonday, in which he often uses a dry-erase board to elucidate the arcana of ball behavior.

Pinel struck me as the ideal Virgil to guide me through the nuances of bowling ball design. But when he failed to return several of my emails and voicemails, I feared he might be too much of a curmudgeon to help an outsider like me. The persona he conveys on YouTube can charitably be described as gruff, and his acquaintances confirmed my hunch that Pinel could be a prickly sort. "Mo, if he doesn't like you, he's not going to spend any time or anything with you," says Neil Stremmel, a former executive at the United States Bowling Congress, the sport's governing body, who now manages an alley in central Florida. "He won't go out of his way to be a jerk or make a fool out of you, but he won't spend any of his time with you."

I was delighted, then, when Pinel finally gave me a ring in late January, right as I was about to give up on my project. He said he'd never received my emails, perhaps because—despite his job title at Radical—he's fairly computer-averse. ("I had to have someone turn it on for me," he half jokes.) He'd been slow to reply to my phone calls in part because he'd been waiting for a coworker to vet my credentials, but also because he was so busy. He had recently left his home in Virginia, where he lives with his wife of nearly 10 years, to embark on an extended driving tour of southern bowling alleys. Though the pandemic was just past its peak in the US, he was spending the next two months teaching pro-shop employees how to match clients to their ideal balls.

Over the next few weeks, as Pinel trekked across Georgia and Florida, we chatted on the phone about the finer points of bowling ball design. It turned out Mo could indeed turn cantankerous when I asked questions that betrayed my ignorance, and he'd press me to read a slew of complex documents before we spoke again. But I didn't mind Pinel's fits of crankiness, because I was so moved by the joy he exuded when sharing his bowling ball knowledge—an intellectual treasure that took him a lifetime to amass.

A former drag racer, Pinel didn't fully embark on his legendary ball design career until he was nearing his 50s.

Photograph: Elizabeth Renstrom; Portrait courtesy of Monica Westfall-Pinel

Pinel grew up in Brooklyn's Bedford-Stuyvesant neighborhood, in a household that he describes as "technically oriented." His father was a patent attorney at the International Nickel Company, where he handled the paperwork for inventions such as a method for iridium plating and a new type of slide rule. Pinel was bright enough to get into Cornell University, where he earned a degree in chemical engineering, but he had no intention of following in his dad's footsteps. Rather than step onto a corporate ladder after graduation, he hung around his college town of Ithaca, New York, and got heavy into drag racing. When not tinkering with hot-rod engines, he could usually be found on a tennis court, hustling lesser players for pocket money.

After narrowly surviving two wrecks at a drag strip, Pinel thought it wise to find a safer way to satisfy his yen for competition. So he made the switch to bowling in 1969. He came to view the pastime as a spiritual cousin to drag racing: Both involve a few seconds of precise and rapid travel down a narrow path, and both appeal to those who relish technical conundrums. "A bowling ball is just a gyroscope that's not on its preferred spin axis, right?" Pinel says when trying to describe his affection for the sport. "So ball motion is one gyroscope operating in the field of a bigger gyroscope, which is the earth."

Pinel quickly taught himself the game well enough to win small purses at regional tournaments. He soon began to wonder whether he could reach the sport's next tier by hacking his equipment. His main aim was to tease more flare potential out of a ball—in essence, reconfigure it to create a sharper hooking motion. That hook is essential because of how the sport's pins are arrayed. There is an inches-wide "pocket" on either side of the front pin that all bowlers aim to hit at the optimum entry angle; if they manage to do so, they have a 95 percent chance of scoring a strike.

When Pinel looked into the discourse around ball performance, he found that most everyone believed that all that mattered was the quality of coverstock—that is, the exterior layer of a ball that is visible to the naked eye. Coverstocks are studded with microscopic spikes, the roughness of which is measured by the average distance from each spike's peak to valley—a metric known as Ra. The higher a ball's Ra, the more friction it can create with the lane and thus the greater the potential that it will hook well under the right circumstances. The hardness of the material that underlies the spikes is also an important factor. In the early 1970s, several pros had enjoyed great success by soaking their balls in methyl ethyl ketone, a flammable solvent that softened the coverstocks. (The balls became so gelatinous, in fact, that a bowler could indent the surface with a fingernail.) These softer balls gripped the lane much better than their harder counterparts, and so they tended not to skid unpredictably when encountering patches of oil used to dress the wooden boards. The use of methyl ethyl ketone had increased scores so much that rules were put in place mandating a degree of coverstock hardness as measured by a device known as a Shore durometer.

Pinel thought that too much attention was being paid to coverstocks and not nearly enough to what was inside the ball. The hearts of bowling balls, he discovered, were virtually all the same. Each had a round and centered core topped by a pancake-shaped weight block. Based on his experiences with drag racing, a sport in which the engine is every bit as important as the tires, Pinel figured he could change a ball's dynamics by tweaking its internal structure.

He started to conduct experiments at an Ithaca pro shop where he knew the manager. Pinel used the shop's drill and off-the-shelf components to alter balls. He'd pock them with deep holes that he'd then fill with dense wads of barium, a soft metal. "So I'd drill a hole, fill it with either dense or light stuff, and plug it to the top," he says. "And I started playing around with that, and I started to see some differences in motion."

Never lacking confidence, Pinel contacted several ball manufacturers in 1973 and proposed a deal: If they would sign a nondisclosure agreement, he'd brief them on his experimental results and help them design balls that would allow amateurs and pros alike to increase their strike rates. Company executives responded that they were willing to listen to Pinel's ideas, but he was the one who would have to sign a release affirming that nothing he said was confidential. Miffed by what he saw as attempts to steal his ideas, Pinel veered away from a career in ball design.

Pinel continued to bowl in mid-size pro tournaments for a few more years, but he was never good enough to make a splash on the national scene. After getting into a bad car accident, he shifted into the business side of bowling. He cofounded a lane-resurfacing company, Resurfaced by Us, and ran an alley in New York's Mohawk Valley. Through the spring and summer months, Pinel traveled constantly for the resurfacing company, spending post-work nights chewing the fat with fellow bowling nerds. After a few cocktails, the conversation would often turn to the physics of bowling balls, and Pinel would sketch out ideas for novel cores on bar napkins. But there seemed to be no feasible way for him to execute his visions.

As he approached his 50th birthday, Pinel decided to take one last stab at becoming a bona fide ball designer: He set out to make a ball that would change the sport by reliably flaring into the pins.

To accomplish this, he had to tinker with a specification known as radius of gyration, or RG. Put simply, RG is a measurement of the distance between the ball's center of mass and the tip of the invisible axis that extends to the ball's surface. (The technical definition: "The square root of the moment of inertia divided by the mass of the object.") The lower a ball's RG, the more spin a bowler can create by applying torque; the higher the RG, the more power required to rotate the ball. The most common analogy that ball designers use is that of a spinning figure skater, who can slow down their speed by extending their arms away from their center of mass.

In recent years, the design of bowling ball cores has become even more extreme.

Photograph: Elizabeth Renstrom

Every ball has a narrow range of different RGs, based on how the ball is manufactured and where the finger holes are drilled; if a ball is rolling directly over the finger holes, for example, its axis of rotation, and thus its RG, will be on the smaller side. Pinel's hypothesis, based on intuition and his layman's grasp of physics, was that by creating cores that were asymmetric—that is, which move the center of mass closer to a ball's surface—he would nudge up the ratio between a ball's maximum and minimum RG. He believed this would cause a ball to exhibit an organic wobble that would bend it toward the pins over the final third of a lane— sort of like how the edges of a spinning top dip toward the ground as its inertia slows.

Pinel drew up a variety of designs for asymmetric ball cores, then, in April 1990, filed a patent for his favorite. It was a bulbous hunk of polyester with both a central indention and a conic tail, and portions of it resembled the sides of an octagon. (The best visual analogy may be a top-down view of Master Chief's helmet in the video game *Halo*, but that's a gross oversimplification.) The purpose of all this weirdness, as Pinel wrote in his patent application, was to make the ball's motion volatile by design: "By utilizing different masses and/or dimensions for the head and tip portions, an asymmetrical weight distribution about the roll axis of the ball can be developed."

Shortly after submitting his patent, Pinel received a call from Phil Cardinale, whom he knew from his business travels for Resurfaced by Us. A financial analyst from Long Island who moonlighted as a ball driller in a pro shop, Cardinale passed along some odd yet exciting news: Through a labyrinthine series of events, he'd been hired to revive a financially troubled ball brand called Star Traxx, which he had renamed Track. He recalled Pinel's napkin sketches of unorthodox cores and invited him to help design a new Track ball. It was a one-time chance to test out whether his theories would hold up in the real world.

Pinel seized the opportunity. He created a core based on the "tip-and-tail" concept he'd just applied to patent. The resulting ball, the Shark, flared even when a bowler didn't apply much spin at the moment of release. It was an innovation that caught the eye of the bowling division at AMF, which poached Pinel with the promise of a healthy royalty for each ball sold.

The AMF Sumo, the smash-hit ball that would earn Pinel his kanji pendant, was released in 1992. This time, Pinel opted for a core that bears a passing resemblance to the video game character Q*Bert, albeit with a disc at the base in lieu of feet. The ball came out right as new regulations called for more oil to be poured on lanes, a change that decreased friction; this sapped shots of spin and power. The extra oil was no match for the Sumo, however, because Pinel's core caused it to slice hard across the boards near the pins. The ball would eventually sell well enough to make Pinel a modestly wealthy man.

Pinel says the size of his royalty eventually became a problem for AMF, and the company terminated his contract in 1995. He was barely out of work a week before he was hired by Faball, a struggling manufacturer in Baltimore. Pinel toured Faball's factory and examined a freshly made core that the company used in its Hammer brand. It had a symmetrical and unexciting shape—the center looked like a lemon, and there were two convex caps of equal size on either side. In a moment that has now passed into ball-design legend, Pinel grabbed the core, which was still soft because the polyester had yet to cure, and sliced off the ends with a palette knife. Then he smooshed the caps back on into positions that were slightly askew, so that the contraption now looked like a Y-wing fighter from *Star Wars*.

The ball that contained this revamped core, the Hammer 3D Offset, would become Pinel's signature achievement. "That ball sold like hotcakes for three years, where the average life span of a ball was about six months," says Del Warren, a former ball designer who now works as a coach in Florida. "They literally couldn't build enough of them." In addition to flaring like few other balls on the market, the 3D Offset was idiot-proof: The core was designed in such a way that it would be hard for a pro shop to muck up its action by drilling a customer's finger holes incorrectly, an innovation that made bowlers less nervous about plunking down $200 for a ball.

"What he did was he helped to bring asymmetry into a better understanding," says Ronald Hickland, the teenage Pinel fan who went on to design more than 400 balls for Ebonite International. "He had a good way of marketing those balls and those shapes to get people to begin to understand. And so I think a lot of the current philosophies around asymmetry, he was influential in helping to explain that to the consumer."

Pinel was delighted by the 3D Offset's success not just because it affirmed his beliefs about the importance of asymmetry but also because it inflicted pain on his former employer. "AMF had been doing $12 million a year; Hammer had been doing $1 million," he told me. "When we came out with the 3D Offset, Hammer did $12 million a year and AMF did $1 million. Not that I enjoyed that at all." AMF would file for bankruptcy four years later.

Pinel's 3D Offset became his signature achievement.

With his reputation at its zenith after the success of the 3D Offset, Pinel decided—at the age of 57—to become a bowling ball entrepreneur. In 1999, he and his partner from Resurfaced by Us joined forces to launch a Virginia-based ball-manufacturing startup called MoRich. They aimed to produce an ever more daring series of asymmetric balls to keep pushing the boundaries of flare.

Pinel was now a minor celebrity in the bowling world and much in demand as a speaker and teacher. His pronouncements, often delivered with an edge that could be interpreted as arrogance, could be grating. "I don't know if I'd go so far as to say you either love him or you hate him," says Neil

Stremmel, the former USBC official. "I think it's more you either love him or you, you know, keep him at a distance [because you] don't understand him."

Victor Marion is one of several bowling industry figures whom Pinel irritated. In 2006, Marion attended a Pinel-led seminar at a Las Vegas conference for pro shop owners. "He was writing some physics on the board, and he had it wrong," recalls Marion, who had studied the topic as a hobby in school. "And I called him out. I was like, 'Hey, Mo, I think you forgot a step there. You skipped some variables and didn't do a couple of things.' And he yelled at me, like, 'Who's teaching this class?'" Marion claims that a slightly intoxicated Pinel berated him for being a know-it-all, then ordered him to pipe down when one of his colleagues confirmed the mathematical error. (Marion eventually became a ball designer himself and now runs his own company, Big Bowling, in Spokane, Washington.)

Pinel also formed a bitter rivalry with a designer named [Richie Sposato, a former pro bowler](). In the late 1980s, around the same time that Pinel was refining his hypothesis about how core shape influences motion, Sposato went to a fateful Pink Floyd laser light show in Syracuse, New York. "I came home and I was really intrigued by these lasers," he says. "And I just wanted to draw these lasers. And so I drew this diamond, and this light bulb went off in my head. It was like an aha moment—like, bingo, this is the perfect shape for a bowling ball."

Sposato patented his diamond-shaped core, which he claims produces 20 percent more inertia than any competitor, and placed it in balls that he manufactured under the brand name Lane #1. But while he's adamant that his core is the most advanced on the market, Sposato has always lagged behind Pinel in terms of sales and recognition. That dynamic led to years of conflict between the two ornery men. After one tussle in the online forum Bowling Ball Exchange, Pinel was banned for his caustic replies to Sposato's criticism.

"See, Mo, he talks above everybody, talks down to people," Sposato says. "People can't understand what he's talking about—physics-wise, all these big words, stuff like that. So they just look at him and they agree with him. But I can see right through it. I know what he's talking about, what he's

saying, and I can always throw it right back in his face." (In addition to designing Lane #1 balls, Sposato also owns a nightclub in Syracuse; he made headlines last year for openly flouting the state's lockdown by hosting a party.)

Sposato was partially vindicated when MoRich flamed out. The company suffered from typical startup woes, notably maintaining quality control when dealing with contract factories. More fundamentally, demand was down. Between 1996 and 2006, the number of league bowlers—the folks willing to splash out for a new ball or three every year—decreased by 36 percent. But Pinel's ideas had also been copied by bigger competitors, who were now touting audaciously asymmetric balls of their own. Unlike MoRich, those companies had the means to put their products into the hands of the most influential pros. (Getting a brand approved for use on the Professional Bowlers Association Tour, the sport's top circuit, costs in excess of $100,000 in certification fees.)

Pinel kept sinking his dwindling savings into MoRich until 2011. Shortly thereafter, he was offered a lifeline by an old friend. Phil Cardinale, the man who'd given Pinel his first design opportunity for Track more than two decades earlier, had recently become the CEO of Radical Bowling, a niche ball brand owned by Brunswick Bowling. Cardinale and the VP of Brunswick Bowling invited Pinel to become Radical's technology director. In addition to designing cores for the brand, Pinel became Radical's chief ambassador. His [#MoMonday YouTube series](#) drew thousands of viewers every week, and he also scheduled more than a hundred personal appearances a year. Though in his seventies, Pinel would regularly put 45,000 miles a year on his black 2006 Chevy Malibu Maxx. He'd drive across the Dakotas in midwinter, dropping into tiny alleys to talk up the cores he'd designed for Radical, balls with names like the Ludicrous, the Katana Legend, and the Conspiracy Theory.

Pinel was still trying to maximize flare potential in his designs, an effort that was arguably becoming outmoded. A new generation of pro bowlers, both stronger and more technically sophisticated than their predecessors, have achieved unprecedented amounts of spin on their balls—sometimes as much as 600 revolutions per minute for those who opt for the increasingly

popular two-handed throwing technique. Such bowlers don't need as much hook assistance as in days gone by, so they're using more stable balls—a strategic trend that may be having a trickle-down effect on the league bowlers who worship the sport's stars.

In our conversations, Pinel never displayed any hint that he was worried about the future of his cores. He seemed grateful to still have a place in the industry, and he was happy to be on the road preaching about the intricate relationship between core design and ball motion. When we spoke in mid-February, he called from Fort Myers. His upcoming Southern-tour itinerary sounded brutal: Two more stops in Florida, then he'd be hitting pro shops in Baton Rouge, New Orleans, Memphis, Nashville, and Louisville. At the trip's conclusion, he was slated to help announce the release of Radical's newest balls, the Incognito Pearl and the Pandemonium Solid, which promises "a strong mid-lane motion and lots of continuation through the pin deck."

Pinel did admit that his travels could be taxing on his creaky knees, but he otherwise expressed delight at his fantastic health. He said he had low blood pressure and, more important, excellent genes that he'd inherited from a grandmother who lived until 99. He affirmed that he had no plans to retire anytime soon. "I'm just an old man having a good time," he told me. "I'm a kid in the street having a good time. I'm a hot rodder that happens to be a 78-year-old hot rodder."

A few days after that conversation, I called Pinel to ask yet another batch of follow-up questions; I had recently finished reviewing a 385-slide PowerPoint presentation that he'd shared, and I needed help processing some of the concepts. When my voicemail went unanswered after a few days, I tried again, and then again, and again. I emailed and texted, too, all to no avail. I worried that Pinel had heard that I'd spoken to Richie Sposato, his sworn enemy, and that he was giving me the silent treatment as a result.

Pinel never made it to the elite level as a bowler, but his legacy is assured.

Photograph: Elizabeth Renstrom

On March 2, I received a call from a man named Paul Ridenour, a colleague of Pinel's at Radical. He had upsetting news: Pinel had fallen ill while on the road and was now in a Baton Rouge hospital, where he'd been diagnosed with Covid-19. After he was admitted, the doctors had discovered that he had previously undiagnosed chronic lymphocytic leukemia. The slow-moving cancer made him a high-risk Covid patient, and he'd gone through a rough patch in the ICU. But he was now improving. Ridenour assured me that Pinel would get in touch as soon as he was able— hopefully within a week, given the encouraging trajectory of his recovery.

Three days later, an email from Ronald Hickland arrived in my inbox. I'd spoken with him a month earlier, when he told me the story of having his life changed by Pinel at the Super Hoinke in 1993. Hickland was no longer a ball designer, having left the manufacturing side of the industry in 2015— a decision that, by his estimation, had reduced the number of full-time ball designers in the world to a mere four or five.

His email consisted of just two staggering sentences: "I'm not sure if you knew this or not but Mo passed away. He was the reason I got into bowling ball design."

Pinel, like so many other Covid-19 patients, had fallen victim to a cytokine storm: His immune system had been duped into releasing too much of a certain protein that then overwhelmed his body and caused massive organ failure. His wife and one of his three adult sons had made it to Baton Rouge just in time to be by his side as he passed.

Pinel received no obituaries of note in the mainstream press. But there was a mighty outpouring of grief for Mo from bowling aficionados when the death was announced on Pinel's Facebook fan page:

You were a genius at your craft and will be missed.

Thank you for all that you taught me about why bowling balls do what they do.

He was truly a giant in the bowling world and nobody will ever eclipse his achievements to modernize the sport.

Most of my life's memories and stories that make me smile all come from the door that Mo creatively opened for me decades ago.

We lost a legend, a scientist, and a brilliant man. Mo, may you build that perfect ball in the afterlife.

But the Facebook eulogy that stayed with me the most was one that seemed to grapple with the uncertainty of Pinel's legacy. "Hopefully the knowledge of ball motion from this man that was passed on is retained by those he taught," the mourner wrote, "and his memory will live on."

Pinel dedicated a fair portion of his life to disseminating his ideas, and he left behind artifacts such as his YouTube videos that will forever serve as repositories of his eccentric wisdom. But there was so much he never managed to articulate, so much teaching he still had left to do. And because he operated in a field that withered a great deal during his decades of involvement, there is perhaps no one left with his breadth of experience nor his bone-deep sense of bowling's elemental splendor.

This is what the mercilessness of the pandemic has abruptly robbed from us: tens of thousands of men and women whose rare and hard-won knowledge can never be replicated. This is how artisanal skills are forgotten, how dialects vanish, how the stories meant to sustain us ebb away from our collective memory. And it's all happening at a pace far faster than we can grieve.

After meditating on all that's been lost, I could come up with only one fitting way to honor what Mo's time here meant. As I write these words, I stand precisely 12 days away from being fully vaccinated against the coronavirus. I plan to celebrate by taking my kids bowling.

Let us know what you think about this article. Submit a letter to the editor at mail@wired.com.

Angela Watercutter

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Coder Dee Tuck Is on a Mission to Help Diversify Hollywood

At Ava DuVernay's Array film collective, Tuck is making it easy for showbiz types to hire a more inclusive workforce.
Illustration: JIAQI WANG

Dee Tuck has heard all the excuses. "I want to hire more women, but I just don't know where they are." Yep. "I want to hire more people of color, I just don't know anybody." That too. She's been working in tech for more than a decade and has often been the only Black female engineer on her team. She has reviewed company hiring practices and pointed out that "maybe you're weeding out a lot of people who can't code with eight non-people-of-color watching them on Zoom." Tuck doesn't want to hear the excuses anymore.

Last November she was tapped to be chief technology officer at Array, the film collective founded by director Ava DuVernay. Her main objective: launching Array Crew, a database of women and people of color that studios can use when staffing up for movies and TV shows. The goal is to see if the industry will diversify its ranks when the "We can't find anybody" barrier is removed. "When we really diagnosed the issue, it wasn't that people weren't willing to do it, it was that people weren't willing to be inconvenienced to do it," DuVernay says. "So what we tried to do is create a platform that made it really easy. And so now we're in a space where, to be frank, if you still don't do it, you never really wanted to."

Hollywood has been in the midst of a yearslong reckoning with its overabundance of white male directors and stars. But less noticed is how

few women and people of color appear in what are known as below-the-line jobs—the ones on the bottom half of the production budget. For decades, the industry has relied on people hiring the folks they already know for these gigs, leaving out swaths of qualified applicants. "It's harder to manage on the production side, because hundreds of productions come and go each year within each studio," says Kevin Hamburger, head of production at Warner Horizon Unscripted Television. [Array Crew](), which debuted online in February and will be available as a mobile app in June, allows job seekers to create a profile that includes their résumé, location, images, reels, and contact information so that line producers can pull up every candidate near their film set; it also has tools to help managers keep track of the people they hire for each shoot.

On its face, there's a tension in how Array is using technology to solve Hollywood's inclusivity problem. We now have search engines optimized to find everything from adoptable pets to dinner (for better or worse), but leaving something as complicated as workplace diversity to machines is far more tricky. Which might be why Array's fix is purposefully simple. The database's results are organic; there aren't algorithms boosting some folks and not others. Someone crewing up a movie can search for certain positions (makeup artist, grip), locations (Los Angeles, New York), names, trade union membership, and experience level, but that's it. Unlike, say, Google results, Crew's list of candidates comes up in the most analog way possible: alphabetically. Hiring managers can sort by first or last name or those most recently added, but from there it's up to them to pick a team.

Zooming from her Atlanta home, wearing a sweatshirt from her alma mater, Tuskegee University, Array's CTO speaks pointedly about the best ways to remove barriers. Tuck has witnessed roadblocks to hiring throughout her career, and from the beginning her team was intentional about spotting and eliminating them. "We have conversations about the smallest things," she says. Like that search function. Array could have made every field on a user's profile searchable, but doing so might have left someone out of the results just because they didn't include a certain keyword. "We realized that could've created some type of barrier to entry for people," Tuck says. That puts an onus on the line producer to look through the list of candidates. But that's the point—to make them look somewhere they hadn't been looking.

Born and raised in Cincinnati, Tuck started trying to figure out Windows 95 at her uncle's house when she was about 11 years old. "A few times," she laughs, "he had to call me and be like, 'What did you do? I can't get in.'" She spent time at IBM and worked on missile defense at Lockheed Martin. By the time Tuck got to GitHub in 2020, she was making sure every job she took gave her a say in hiring decisions. "I really do believe in building diverse teams, because we ship better products that way," Tuck says. "If you just have one demographic building a thing, you're not going to end up with the best solution."

Array chief technology officer Dee Tuck (left) with filmmaker Ava DuVernay in Atlanta.

Photograph: Paul Garnes/Array

When Tuck and I spoke, Array Crew had more than 5,000 verified users. It's free for work-seekers; studios pay an annual fee. "This is an investment. It's incumbent upon us to make sure this works," says Jennifer Lynch, who oversees corporate social responsibility at Paramount Pictures, one of several studios, including Netflix and Disney, that signed on to be a Crew launch partner. "We're in this for the long haul."

That footslogging is key. Too often diversity efforts fail when old habits creep back in. Studios must buy in, because for the effort to succeed it's essential that their employees and partners use the service. One function Tuck's team is working on is the ability to provide demographic breakdowns for each production. DuVernay notes that she doesn't want Crew to become just a "report card" for whether studios keep their promises, but Tuck sees other benefits: "We have to be able to tell a story of how we impacted the industry."

As we're wrapping up our Zoom, Tuck's team jumps on. She opens the conversation by asking everyone to name the song they currently have on repeat. (Bill Withers, Big K.R.I.T., and "Baby Shark" are all represented.) Kelsey Kearney, who handles Array's relationships with studios, notes that it's been a week of questions and requests from partners wanting more from the Crew database, like support and help desk functions. A lot of these

wants will be fulfilled by the new mobile app. "I love a deliverable," she laughs.

But there's something else they want. Hollywood's push for diversity goes far beyond LA. Could Crew release an international version? Tuck says it's at the top of her to-do list and promises there's "more to come on that." So, yes, she's on it. No excuses.

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The Full Story of the Stunning RSA Hack Can Finally Be Told

In 2011, Chinese spies stole the crown jewels of cybersecurity—stripping protections from firms and government agencies worldwide. Here's how it happened.
Illustration: Eduardo Ramón Trejo; Getty Images; Alamy

Amid all the sleepless hours that Todd Leetham spent hunting ghosts inside his company's network in early 2011, the experience that sticks with him most vividly all these years later is the moment he caught up with them. Or almost did.

It was a spring evening, he says, three days—maybe four, time had become a blur—after he had first begun tracking the hackers who were rummaging through the computer systems of RSA, the corporate security giant where he worked. Leetham—a bald, bearded, and curmudgeonly analyst one coworker described to me as a "carbon-based hacker-finding machine"—had been glued to his laptop along with the rest of the company's incident response team, assembled around the company's glass-encased operations center in a nonstop, 24-hours-a-day hunt. And with a growing sense of dread, Leetham had finally traced the intruders' footprints to their final targets: the secret keys known as "seeds," a collection of numbers that represented a foundational layer of the security promises RSA made to its customers, including tens of millions of users in government and military agencies, defense contractors, banks, and countless corporations around the world.

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Photograph: Djeneba Aduayom

RSA kept those seeds on a single, well-protected server, which the company called the "seed warehouse." They served as a crucial ingredient in one of RSA's core products: SecurID tokens—little fobs you carried in a pocket and pulled out to prove your identity by entering the six-digit codes that were constantly updated on the fob's screen. If someone could steal the seed values stored in that warehouse, they could potentially clone those SecurID tokens and silently break the two-factor authentication they offered, allowing hackers to instantly bypass that security system anywhere in the world, accessing anything from bank accounts to national security secrets.

Now, staring at the network logs on his screen, it looked to Leetham like these keys to RSA's global kingdom had already been stolen.

Leetham saw with dismay that the hackers had spent nine hours methodically siphoning the seeds out of the warehouse server and sending them via file-transfer protocol to a hacked server hosted by Rackspace, a cloud-hosting provider. But then he spotted something that gave him a flash of hope: The logs included the stolen username and password for that hacked server. The thieves had left their hiding place wide open, in plain sight. Leetham connected to the faraway Rackspace machine and typed in the stolen credentials. And there it was: The server's directory still contained the entire pilfered seed collection as a compressed .rar file.

Using hacked credentials to log into a server that belongs to another company and mess with the data stored there is, Leetham admits, an unorthodox move at best—and a violation of US hacking laws at worst. But looking at RSA's stolen holiest of holies on that Rackspace server, he didn't hesitate. "I was going to take the heat," he says. "Either way, I'm saving our shit." He typed in the command to delete the file and hit enter.

Moments later, his computer's command line came back with a response: "File not found." He examined the Rackspace server's contents again. It was empty. Leetham's heart fell through the floor: The hackers had pulled the seed database off the server seconds before he was able to delete it.

After hunting these data thieves day and night, he had "taken a swipe at their jacket as they were running out the door," as he says today. They had slipped through his fingers, escaping into the ether with his company's most precious information. And though Leetham didn't yet know it, those secrets were now in the hands of the Chinese military.

The RSA breach, when it became public days later, would redefine the cybersecurity landscape. The company's nightmare was a wake-up call not only for the information security industry—the worst-ever hack of a cybersecurity firm to date—but also a warning to the rest of the world. Timo Hirvonen, a researcher at security firm F-Secure, which published an [outside analysis of the breach](#), saw it as a disturbing demonstration of the growing threat posed by a new class of state-sponsored hackers. "If a security company like RSA cannot protect itself," Hirvonen remembers thinking at the time, "how can the rest of the world?"

The question was quite literal. The theft of the company's seed values meant that a critical safeguard had been removed from thousands of its customers' networks. RSA's SecurID tokens were designed so that institutions from banks to the Pentagon could demand a second form of authentication from their employees and customers beyond a username and password—something physical in their pocket that they could prove they possessed, thus proving their identity. Only after typing in the code that appeared on their SecurID token (a code that typically changed every 60 seconds) could they gain access to their account.

The SecurID seeds that RSA generated and carefully distributed to its customers allowed those customers' network administrators to set up servers that could generate the same codes, then check the ones users entered into login prompts to see if they were correct. Now, after stealing those seeds, sophisticated cyberspies had the keys to generate those codes without the physical tokens, opening an avenue into any account for which someone's username or password was guessable, had already been stolen, or had been reused from another compromised account. RSA had added an extra, unique padlock to millions of doors around the internet, and these hackers now potentially knew the combination to every one.

This past December, when it became public that the company SolarWinds was hacked by Russian spies, the world woke up to the notion of a "supply chain attack": a technique in which an adversary compromises a point of vulnerability in a software or hardware supplier positioned upstream from —and out of sight of—its target, a blind spot in the victim's view of their cybersecurity risks. The Kremlin operatives who hacked SolarWinds hid espionage code in an IT management tool called Orion, used by as many as 18,000 companies and institutions globally.

Using the SolarWinds supply chain compromise, Russia's foreign intelligence agency, known as the SVR, penetrated deep into at least nine US federal agencies, including the State Department, the US Treasury, the Department of Justice, and NASA. In another world-shaking supply chain attack just a few years earlier, Russia's military intelligence agency, known as the GRU, hijacked a piece of obscure Ukrainian accounting software to push out a data-destroying worm known as NotPetya, inflicting $10 billion in damage worldwide in the worst cyberattack in history.

For those with a longer memory, though, the RSA breach was the original massive supply chain attack. State cyberspies—who were later revealed to be working in the service of China's People's Liberation Army—penetrated infrastructure relied on across the globe to protect the internet. And in doing so, they pulled the rug out from under the entire world's model of digital security. "It opened my eyes to supply chain attacks," says Mikko Hypponen, chief research officer at F-Secure, who worked with Hirvonen on the company's analysis of the RSA breach. "It changed my view of the world: the fact that, if you can't break into your target, you find the technology that they use and break in there instead."

In the decade that followed, many key RSA executives involved in the company's breach have held their silence, bound by 10-year nondisclosure agreements. Now those agreements have expired, allowing them to tell me their stories in new detail. Their accounts capture the experience of being targeted by sophisticated state hackers who patiently and persistently take on their most high-value networked targets on a global scale, where an adversary sometimes understands the interdependencies of its victims'

systems better than victims do themselves, and is willing to exploit those hidden relationships.

After 10 years of rampant state-sponsored hacking and supply chain hijacks, the RSA breach can now be seen as the herald of our current era of digital insecurity—and a lesson about how a determined adversary can undermine the things we trust most.

On March 8, 2011, a brisk late-winter day, Todd Leetham finished a smoke break and was walking back into RSA's headquarters in Bedford, Massachusetts—a pair of connected buildings on the edge of a forest in the Boston suburbs—when a systems administrator pulled him aside and asked him to take a look at something strange.

The admin had noticed that one user had accessed a server from a PC that the user didn't typically work on, and that the permissions setting on the account seemed unusual. A technical director investigating the anomalous login with Leetham and the admin asked Bill Duane, a veteran RSA engineer, to take a look. To Duane, who was busy working on a cryptographic algorithm at the time, the anomaly hardly looked like cause for alarm. "I frankly thought this administrator was crazy," he remembers. "Fortunately he was stubborn enough to insist that something was wrong."

Leetham and the company's security incident responders started to trace the aberrant behavior and analyze the forensics of every machine the anomalous account had touched. They began to see more telltale oddities in employees' credentials, stretching back days. The admin had been right. "Sure enough," Duane says, "this was the tip of the iceberg."

Over the next several days, the security team at RSA's security operations center—a NASA- style control room with rows of desks and monitors covering one wall—meticulously traced the interlopers' fingerprints. The RSA staffers began putting in nearly 20-hour workdays, driven by the chilling knowledge that the breach they were tracking was still unfolding. Management demanded updates on their findings every four hours, day or night.

The analysts eventually traced the origin of the breach to a single malicious file that they believed had landed on an RSA employee's PC five days before they'd started their hunt. A staffer in Australia had received an email with the subject line "2011 Recruitment plan" and an Excel spreadsheet attached to it. He'd opened it. Inside the file was a script that exploited a zero-day vulnerability—a secret, unpatched security flaw—in Adobe Flash, planting a common piece of malicious software called Poison Ivy on the victim's machine.

That initial point of entry onto RSA's network, F-Secure's Hirvonen would later point out in his own analysis, wasn't particularly sophisticated. A hacker wouldn't have even been able to exploit the Flash vulnerability if the victim had been running a more recent version of Windows or Microsoft Office, or if he'd had limited access to install programs on his PC—as most security administrators for corporate and government networks recommend, Hirvonen says.

But it was from this ingress that the RSA analysts say the intruders began to demonstrate their real abilities. In fact, several RSA executives came to believe that at least two groups of hackers were in their network simultaneously—one highly skilled group exploiting the other's access, perhaps, with or without their knowledge. "There's the trail through the woods that the first one left, and right in the middle of it, branching off, is the second trail," says Sam Curry, who was RSA's chief security officer at the time. "And that second attack was much more skilled."

On that Australian employee's PC, someone had used a tool that pulled credentials out of the machine's memory and then reused those usernames and passwords to log into other machines on the network. They'd then scraped those computers' memories for more usernames and passwords—finding some that belonged to more privileged administrators. The hackers eventually got to a server containing hundreds of users' credentials. Today that credential-stealing hopscotching technique is common. But in 2011 the analysts were surprised to see how the hackers fanned out across the network. "It was really just the most brutal way to blow through our systems that I'd ever seen," Duane says.

Breaches as extensive as the one carried out against RSA are often discovered months after the fact, when the intruders are long gone or lying dormant. But Duane says that the 2011 incident was different: Within days, the investigators had essentially caught up to the intruders and were watching them in action. "They'd try to get into a system, then we'd detect them a minute or two later and go in and shut down that system or disable access to it," Duane says. "We were fighting them tooth and nail, in real time."

It was in the midst of that feverish chase that Leetham caught the hackers stealing what he still believes was their highest-priority target: the SecurID seeds.

RSA executives told me that the part of their network responsible for manufacturing the SecurID hardware tokens was protected by an "air gap"—a total disconnection of computers from any machine that touches the internet. But in fact, Leetham says, one server on RSA's internet-connected network was linked, through a firewall that allowed no other connections, to the seed warehouse on the manufacturing side. Every 15 minutes, that server would pull off a certain number of seeds so that they could be encrypted, written to a CD, and given to SecurID customers. That link was necessary; it allowed RSA's business side to help customers set up their own server that could then check users' six-digit code when it was typed into a login prompt. Even after the CD was shipped to a client, those seeds remained on the seed warehouse server as a backup if the customer's SecurID server or its setup CD were somehow corrupted.

Now, instead of the usual once-every-15-minutes connections, Leetham saw logs of thousands of continuous requests for data every second. What's more, the hackers had been collecting those seeds on not one but three compromised servers, relaying requests through the one connected machine. They had packaged up the collection of seeds in three parts, moved them off to the faraway Rackspace server, and then recombined them into what appeared to be the full database of every seed RSA had stored in the seed warehouse. "I was like, 'Wow ,'" Leetham says. "I kind of admired it. But at the same time: 'Oh crap.'"

As it dawned on Leetham that the seed collection had likely been copied—and after he had made his seconds-too-late attempt to delete the data off the hackers' server—the enormity of the event hit him: The trust that customers placed in RSA, perhaps its most valuable commodity, was about to be obliterated. "This is an extinction event," he remembers thinking. "RSA is over."

It was late at night when the security team learned that the seed warehouse had been plundered. Bill Duane made the call: They would physically cut off as many of RSA's network connections as necessary to limit the damage and stop any further theft of data. They hoped, in particular, to protect any customer information that mapped to the seeds, and which might be necessary for the hackers to exploit them. (Some RSA staff also suggested to me that the seeds had been stored in an encrypted state, and cutting off network connections was intended to prevent the hackers from stealing the key necessary to decrypt them.) Duane and an IT manager walked into the data center and started unplugging Ethernet cables one by one, severing the company's connections to its manufacturing facility, parts of its network that handled core business processes like customer orders, even its website. "I basically shut off RSA's business," he says. "I crippled the company in order to stop any potential further release of data."

The next day, RSA's CEO, Art Coviello, was in a meeting in the conference room that adjoined his office, preparing a public statement about the ongoing breach. Coviello had been getting updates since the intrusions were discovered. As the extent of the breach had grown, he'd canceled a business trip to Brazil. But he'd remained relatively sanguine. After all, it didn't sound like the hackers had breached any credit card data or other sensitive customer information. They'd kick out the hackers, he figured, post their statement, and get on with business.

But in the middle of the meeting, he remembers, a marketing executive at the table with him looked at her phone and murmured, "Oh dear."

Coviello asked her what was wrong. She demurred. He took the phone out of her hand and read the message. It said that Bill Duane was coming up to Coviello's office; he wanted to update the CEO in person. When he got

upstairs, he delivered the news: The hackers had reached the SecurID seeds. "I felt like a cannonball had been shot through my stomach," Coviello says.

In the hours that followed, RSA's executives debated how to go public. One person in legal suggested they didn't actually need to tell their customers, Sam Curry remembers. Coviello slammed a fist on the table: They would not only admit to the breach, he insisted, but get on the phone with every single customer to discuss how those companies could protect themselves. Joe Tucci, the CEO of parent company EMC, quickly suggested they bite the bullet and replace all 40 million-plus SecurID tokens. But RSA didn't have nearly that many tokens available—in fact, the breach would force it to shut down manufacturing. For weeks after the hack, the company would only be able to restart production in a diminished capacity.

As the recovery effort got under way, one executive suggested they call it Project Phoenix. Coviello immediately nixed the name. "Bullshit," he remembers saying. "We're not rising from the ashes. We're going to call this project Apollo 13. We're going to land the ship without injury."

At 7:00 the next morning, March 17, RSA's head of North American sales, David Castignola, finished up an early workout on a treadmill at his local gym in Detroit. When he picked up his phone, he saw that he had missed no fewer than 12 calls—all from just that morning, and all from RSA's president, Tom Haiser. RSA, Haiser's voicemails said, was about to announce a major security breach. He needed to be in the building.

A few hours and a last-minute flight later, Castignola literally ran into RSA's headquarters in Bedford and up to the fourth-floor conference room. He immediately noticed the pale, drawn faces of the staff who had been dealing with the unfolding crisis for more than a week. "Every little indicator I got was: This is worse than I can even get my head around," Castignola remembers.

That afternoon, Coviello published an open letter to RSA's customers on the company's website. "Recently, our security systems identified an extremely sophisticated cyberattack in progress," the letter read. "While at this time we are confident that the information extracted does not enable a successful direct attack on any of our RSA SecurID customers, this information could

potentially be used to reduce the effectiveness of a current two-factor authentication implementation as part of a broader attack," the letter continued—somewhat downplaying the crisis.

In Bedford, Castignola was given a conference room and the authority to ask for as many volunteers from the company as he needed. A rotating group of nearly 90 staffers began the weeks-long, day-and-night process of arranging one-on-one phone calls with every customer. They worked from a script, walking customers through protective measures like adding or lengthening a PIN number as part of their SecurID logins, to make them harder for hackers to replicate. Castignola remembers walking down the halls of the building at 10 pm and hearing calls on speaker phones behind every closed door. In many cases customers were shouting. Castignola, Curry, and Coviello each did hundreds of those calls; Curry began to joke that his title was "chief apology officer."

At the same time, paranoia was beginning to take hold in the company. The first night after the announcement, Castignola remembers walking by a wiring closet and seeing an absurd number of people walking out of it, far more than he imagined could have ever fit. "Who are those people?" he asked another nearby executive. "That's the government," the executive responded vaguely.

In fact, by the time Castignola had landed in Massachusetts, both the NSA and the FBI had been called to help the company's investigation, as had defense contractor Northrop Grumman and incident response firm Mandiant. (By chance, employees of Mandiant had already been on-site prior to the breach, installing security sensor equipment on RSA's network.)

RSA staff began to take drastic measures. Worried that their phone system might be compromised, the company switched carriers, moving from AT&T to Verizon phones. Executives, not trusting even the new phones, held meetings in person and shared paper copies of documents. The FBI, fearing an accomplice in RSA's ranks because of the apparent level of knowledge the intruders seemed to have of company systems, started doing background checks. "I made sure that all members of the team—I don't care who they were, what reputation they had—were investigated, because you have to be sure," Duane says.

The windows of some executives' offices and conference rooms were covered in layers of butcher paper, to prevent laser microphone surveillance —a long-distance eavesdropping technique that picks up conversations from vibrations in window panes—by imagined spies in the surrounding woods. The building was swept for bugs. Multiple executives insisted that they did find hidden listening devices—though some were so old that their batteries were dead. It was never clear if those bugs had any relation to the breach.

Meanwhile, RSA's security team and the investigators brought in to help were "tearing the house down to the studs," as Curry put it. In every part of the network that the hackers touched, he says, they scrubbed the contents of potentially compromised machines—and even ones adjacent to them. "We physically went around and, if there was a box they were on, it got wiped," Curry says. "If you lost data, too bad."

In late May 2011, about two months after the breach announcement, RSA was still recovering, rebuilding, and apologizing to customers when it was hit with an aftershock: A [post appeared on the influential tech blogger Robert X. Cringely's website](#), titled "InsecureID: No More Secrets?"

The post was based on a tip from a source inside a major defense contractor, who'd told Cringely that the company was responding to an extensive intrusion by hackers who seemed to have used stolen RSA seed values to get in. Everyone at the defense contractor was having their RSA tokens replaced. Suddenly RSA's breach seemed far more severe than the company's original announcement had described it. "Well it didn't take long for whoever cracked RSA to find a lock to fit that key," Cringely wrote. "What if every RSA token has been compromised, everywhere?"

Two days later, [Reuters revealed the name of the hacked military contractor](#): Lockheed Martin, a company that represented a cornucopia of ultra-secret plans for weapons and intelligence technologies. "The scab was healing," Castignola says. "Then Lockheed hit. That was like a mushroom cloud. We were back at it again."

In the days that followed, defense contractors [Northrop Grumman and L-3 were also named in news reports](#). Hackers with SecurID's seed values had

targeted them too, the stories said, though it was never clear how deeply the intruders had penetrated the companies. Nor was it revealed what the hackers had accessed inside Lockheed Martin. The company claimed it had prevented the spies from stealing sensitive information like customer data or classified secrets.

In another open letter to customers in early June 2011, RSA's Art Coviello admitted, "We were able to confirm that information taken from RSA in March had been used as an element of an attempted broader attack on Lockheed Martin, a major US government defense contractor."

Today, with 10 years of hindsight, Coviello and other former RSA executives tell a story that starkly contradicts accounts from the time: Most of the former RSA staff who spoke to me claim that it was never proven that SecurID had any role in the Lockheed breach. Coviello, Curry, Castignola, and Duane all argued that it was never confirmed that the intruders inside RSA's systems had successfully stolen the full list of seed values in an uncorrupted, unencrypted form, nor the customer list mapped to those seeds necessary to exploit them. "I don't think that Lockheed's attack was related to us at all," Coviello states flatly.

By contrast, in the years since 2011, Lockheed Martin has detailed how hackers used information stolen in RSA's SecurID breach as a stepping stone to penetrate its network—even as it insists that no information was successfully stolen in that event. A Lockheed source with knowledge of the company's incident response reaffirmed to WIRED the company's original claims. "We stand by our forensic investigation findings," the source says. "Our analysis determined the breach of our two-factor authentication token provider was a direct contributing factor in the attack on our network, a fact that has been widely reported by the media and acknowledged publicly by our vendor, including Art." In fact, the Lockheed source says the company saw the hackers entering SecurID codes in real time, confirmed that the targeted users hadn't lost their tokens, and then, after replacing those users' tokens, watched the hackers continue to unsuccessfully enter codes from the old tokens.

The NSA, for its part, has never had much doubt about RSA's role in subsequent break-ins. In a briefing to the Senate Armed Services

a year after the RSA breach, NSA's director, General Keith Alexander, said that the RSA hack "led to at least one US defense contractor being victimized by actors wielding counterfeit credentials," and that the Department of Defense had been forced to replace every RSA token it used.

In the hearing, Alexander went on to pin those attacks, vaguely, on an increasingly common culprit: China. *The New York Time*s and the security firm Mandiant would later publish a groundbreaking exposé on a Chinese state hacker group that Mandiant had named APT1. The group was believed to be People's Liberation Army Unit 61398, based on the outskirts of Shanghai. Among its dozens of targets over the previous five years: the governments of the United States, Canada, South Korea, Taiwan, Vietnam; and the United Nations—and RSA.

After those reports became public, Bill Duane printed out a picture of the hackers' headquarters, a 12-story white building off of Shanghai's Datong Road. He taped it to a dartboard in his office.

I asked Duane, who retired from RSA in 2015 after more than 20 years at the company, at what point he considered RSA's breach truly over: Was it the morning after he made the lonely decision to unplug a chunk of the company's network? Or when the NSA, the FBI, Mandiant, and Northrop had wrapped up and left? "Our view was that the attack wasn't ever over," he responds. "We knew that they left backdoors, that they're always going to be able to break in, that the attacker can, with their resources, get in when they want to get in."

Duane's harrowing experience in response to the intrusion taught him—and perhaps should teach all of us—that "every network is dirty," as he puts it. Now he preaches to companies that they should segment their systems and cordon off their most sensitive data so that it remains impenetrable even to an adversary that's already inside the firewall.

As for Todd Leetham, he watched the SolarWinds fiasco unfold over the past six months with a grim sense of déjà vu. "Everybody was shocked. But in hindsight, well, duh, it was kind of everywhere," he says of SolarWinds. As was, by analogy, SecurID, 10 years earlier.

Leetham sees the lessons of RSA's supply chain compromise in starker terms than even his colleague Bill Duane: It was "a glimpse of just how fragile the world is," he says. "It's a house of cards during a tornado warning."

SolarWinds demonstrated how precarious this structure remains, he argues. As Leetham sees it, the security world blindly put its trust in something that existed outside its threat model, never imagining that an adversary might attack it. And once again, the adversary pulled out a supporting card underpinning the house's foundation—one that had been confused for solid ground.

Let us know what you think about this article. Submit a letter to the editor at mail@wired.com.

Virginia Heffernan

Ideas
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To Observe the Muon Is to Experience Hints of Immortality

Attempting to model the universe as precisely as possible is to try to see the one thing that even the strictest atheist agrees is everlasting.
Illustrations by Kate Dehler

All people want to enact a paradigm shift, don't they? Even if it's not mRNA, or Lego, we want at least, on our one chance on Earth, to make a meme happen.

So imagine the excitement on April 7, when more than 200 physicists from seven countries convened on a Zoom call for a kind of nonexplosive gender-reveal party. What was to be disclosed was not a baby's sex but the fate of particle physics.

While the rest of the world has spent more than a year preoccupied with epidemiology, this team of physicists has spent three years collecting data for something called the Muon g-2 experiment, a much anticipated project headquartered at Fermilab, a physics and accelerator laboratory in Batavia, Illinois, that is overseen by the Department of Energy. The physicists had done their work half in the dark, with a key variable concealed. If you want a eureka badly enough, after all, you might be tempted to help the data along. Now the lights were coming on.

"We had no idea" of the outcome, Rebecca Chislett, a physicist at University College London, told *Scientific American*. "It was exciting and nerve-racking."

Eureka.

The experiment had aimed to determine, to the finest measurement, the strength of the internal magnetic field generated by a muon, a particle similar to an electron but 200 times more massive and supremely unstable, with a lifetime of 2.2 microseconds. Muons rain down on us all the time, the indirect product of [cosmic rays](#) colliding with particles in Earth's atmosphere. But Fermilab's accelerator makes its own.

Many subatomic particles act like magnets, and the so-called Standard Model predicts the strength of their magnetism with great exactitude. To test the model, the team watched muons as they wobbled in a magnetic field and clocked whether the wobble deviated from what theory had predicted it would be. Indeed, it did. As Galileo might have said: *Eppur si deviare*.

In the journal *Physical Review Letters,* the researchers reported that the infinitesimal deviation—0.0000002 percent away from what theory stipulated—was highly significant. In its press release, Fermilab even suggested that the discovery could force us to revise our basic model of how subatomic particles work.

"The strong evidence that muons deviate from the Standard Model calculation might hint at exciting new physics. Muons act as a window into the subatomic world and could be interacting with yet undiscovered particles or forces," read the press release. Graziano Venanzoni, a physicist at the Italian National Institute for Nuclear Physics in Pisa, called the findings "an incredible result … long awaited not only by us but by the whole international physics community."

The known universe seemed, briefly, muonstruck. But it took only 12 days for another Italian physicist to throw cold water on the bliss. Carlo Rovelli, a founder of loop quantum gravity theory, which seeks to combine quantum mechanics and general relativity, and the author of [*Helgoland: Making Sense of the Quantum Revolution*](#), which was published in English in May, wrote in *The Guardian*, "Physicists love to think of themselves as radical."

This self-conception, Rovelli went on, is understandable, especially among physicists, who make their names in the outer reaches of human

understanding. But it also leads labs to overhype their findings. He cited examples of would-be "discoveries" in supersymmetry that initially seemed groundbreaking but didn't live up to the hype. Rovelli especially zeroed in on the word "hint," which appeared in that Fermilab press release. "I do not remember a time without some colleague talking about 'hints' that new supersymmetric particles had been 'nearly discovered.'" The *nearlys* and *hints*, presumably, are often at a value that, unlike Fermilab's 0.0000002 percent, may not be statistically significant.

In 1807, William Wordsworth published an ode that was to Romantic poetry as the discovery of quarks was to particle physics in 1964: a breakthrough. "Intimations of Immortality from Recollections of Early Childhood" chronicles the poet's emotional detachment from nature; his blissful rediscovery of it in memories of childhood; and his bittersweet resolution that, though the Earth will die, the suggestions of deathlessness in the present moment will sustain him in his grief.

Though nothing can bring back the hour
Of splendour in the grass, of glory in the flower;
We will grieve not, rather find
Strength in what remains behind;
In the primal sympathy
Which having been must ever be;
In the soothing thoughts that spring
Out of human suffering; In the faith that looks through death …

An intriguing approach to literature called ecocriticism, pioneered in the 1990s by the English philosopher Jonathan Bate, argues that Romantic poetry like this ode can suggest ways to conceive of our dying planet as one that we must save—or perhaps, in sorrow, and maybe love, allow to die. But Wordsworth's poem doesn't just concern the fate of humans and the blue planet. Its subject is also intimations—what the physicists on the Muon g-2 project call "hints."

As it happens, they are hints of the same thing: immortality.

The central contention of physics has it that the building blocks of the universe will endure even if, or even when, the humans who tally them, and

the planet we live on, all die. To see into the deathless universe is to try to see nothing so flamboyant as Wordsworth's favorite daffodils and walnut groves, but to peer into the coldest spaces, the black holes and the fractional electric charge of theoretical subatomic particles. These entities have no blood flow, of course, but also no DNA; they're not susceptible to pandemics, however virulent, or the dividends and ravages of carbon. They don't live, so they don't die. To model the universe as precisely as possible is to try to see the one thing that even the strictest atheist agrees is everlasting—to try to achieve, in a lab, an intimation of immortality.

Back to the living world that's under our feet. Rovelli is right to caution against the potential delusions of those who are greedy for eurekas. But, as a fellow physicist with a radical streak, he is also sympathetic to their ambitions, a drive to "learn something unexpected about the fundamental laws of nature." To Rovelli, whose latest book describes quantum mechanics as an almost psychedelic experience, a truly radical discovery entails the observation of phenomena that fall outside three existing frameworks in physics: quantum theory, the Standard Model of particle physics, and general relativity. Only by blowing up one of those frameworks can one achieve the kind of immortality that scientists get, the glory of someone like Einstein or Heisenberg.

But to keep looking, as Rovelli has, as Fermilab has with this study on the muon's magnetism, is also to apprehend hints. To follow hints. In that way, the physicist's work and the poet's are the same. And if Wordsworth is right, immortality can be found, of all places, in the hint—the staggering proposition by nature itself that, in spite of all the dying around us, something of all we love might be imperishable, might still flicker or shine or wobble when the rest of our world is gone.

[Megan Molteni](#)

[Backchannel](#)
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The 60-Year-Old Scientific Screwup That Helped Covid Kill

All pandemic long, scientists brawled over how the virus spreads. *Droplets! No, aerosols!* At the heart of the fight was a teensy error with huge consequences.
Photograph: Naila Ruechel

Early one morning, Linsey Marr tiptoed to her dining room table, slipped on a headset, and fired up Zoom. On her computer screen, dozens of familiar faces began to appear. She also saw a few people she didn't know, including Maria Van Kerkhove, the World Health Organization's technical lead for Covid-19, and other expert advisers to the WHO. It was just past 1 pm Geneva time on April 3, 2020, but in Blacksburg, Virginia, where Marr lives with her husband and two children, dawn was just beginning to break.

Marr is an aerosol scientist at Virginia Tech and one of the few in the world who also studies infectious diseases. To her, the new [coronavirus](#) looked as if it could [hang in the air](#), infecting anyone who breathed in enough of it. For people indoors, that posed a considerable risk. But the WHO didn't seem to have caught on. Just days before, the organization had tweeted "FACT: #COVID19 is NOT airborne." That's why Marr was skipping her usual morning workout to join 35 other aerosol scientists. They were trying to warn the WHO it was making a big mistake.

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Photograph: Djeneba Aduayom

Over Zoom, they laid out the case. They ticked through a growing list of [superspreading events](#) in restaurants, call centers, cruise ships, and a [choir rehearsal](#), instances where people got sick even when they were across the room from a contagious person. The incidents contradicted the WHO's main safety guidelines of keeping 3 to 6 feet of distance between people and frequent handwashing. If SARS-CoV-2 traveled only in large droplets that immediately fell to the ground, as the WHO was saying, then wouldn't the distancing and the handwashing have prevented such outbreaks? Infectious air was the more likely culprit, they argued. But the WHO's experts appeared to be unmoved. If they were going to call Covid-19 airborne, they wanted more direct evidence—proof, which could take months to gather, that the virus was abundant in the air. Meanwhile, thousands of people were falling ill every day.

On the video call, tensions rose. At one point, Lidia Morawska, a revered atmospheric physicist who had arranged the meeting, tried to explain how far infectious particles of different sizes could potentially travel. One of the WHO experts abruptly cut her off, telling her she was wrong, Marr recalls. His rudeness shocked her. "You just don't argue with Lidia about physics," she says.

Morawska had spent more than two decades advising a different branch of the WHO on the impacts of air pollution. When it came to flecks of soot and ash belched out by smokestacks and tailpipes, the organization readily accepted the physics she was describing—that particles of many sizes can hang aloft, travel far, and be inhaled. Now, though, the WHO's advisers seemed to be saying those same laws didn't apply to virus-laced respiratory particles. To them, the word *airborne* only applied to particles smaller than 5 microns. Trapped in their group-specific jargon, the two camps on Zoom literally couldn't understand one another.

When the call ended, Marr sat back heavily, feeling an old frustration coiling tighter in her body. She itched to go for a run, to pound it out footfall by footfall into the pavement. "It felt like they had already made up their minds and they were just entertaining us," she recalls. Marr was no stranger to being ignored by members of the medical establishment. Often seen as an epistemic trespasser, she was used to persevering through

skepticism and outright rejection. This time, however, so much more than her ego was at stake. The beginning of a global pandemic was a terrible time to get into a fight over words. But she had an inkling that the verbal sparring was a symptom of a bigger problem—that outdated science was underpinning public health policy. She had to get through to them. But first, she had to crack the mystery of why their communication was failing so badly.

Marr spent the first many years of her career studying air pollution, just as Morawska had. But her priorities began to change in the late 2000s, when Marr sent her oldest child off to day care. That winter, she noticed how waves of runny noses, chest colds, and flu swept through the classrooms, despite the staff's rigorous disinfection routines. "Could these common infections actually be in the air?" she wondered. Marr picked up a few introductory medical textbooks to satisfy her curiosity.

According to the medical canon, nearly all respiratory infections transmit through coughs or sneezes: Whenever a sick person hacks, bacteria and viruses spray out like bullets from a gun, quickly falling and sticking to any surface within a blast radius of 3 to 6 feet. If these droplets alight on a nose or mouth (or on a hand that then touches the face), they can cause an infection. Only a few diseases were thought to break this droplet rule. Measles and tuberculosis transmit a different way; they're described as "airborne." Those pathogens travel inside aerosols, microscopic particles that can stay suspended for hours and travel longer distances. They can spread when contagious people simply breathe.

The distinction between droplet and airborne transmission has enormous consequences. To combat droplets, a leading precaution is to wash hands frequently with soap and water. To fight infectious aerosols, the air itself is the enemy. In hospitals, that means expensive isolation wards and N95 masks for all medical staff.

The books Marr flipped through drew the line between droplets and aerosols at 5 microns. A micron is a unit of measurement equal to one-millionth of a meter. By this definition, any infectious particle smaller than 5 microns in diameter is an aerosol; anything bigger is a droplet. The more she looked, the more she found that number. The WHO and the US Centers

for Disease Control and Prevention also listed 5 microns as the fulcrum on which the droplet-aerosol dichotomy toggled.

There was just one literally tiny problem: "The physics of it is all wrong," Marr says. That much seemed obvious to her from everything she knew about how things move through air. Reality is far messier, with particles much larger than 5 microns staying afloat and behaving like aerosols, depending on heat, humidity, and airspeed. "I'd see the wrong number over and over again, and I just found that disturbing," she says. The error meant that the medical community had a distorted picture of how people might get sick.

Linsey Marr stands in front of a smog chamber in her laboratory at Virginia Tech. For years, she says, the medical establishment treated her as an outsider.

Photograph: Matt Eich

Epidemiologists have long observed that most respiratory bugs require close contact to spread. Yet in that small space, a lot can happen. A sick person might cough droplets onto your face, emit small aerosols that you inhale, or shake your hand, which you then use to rub your nose. Any one of those mechanisms might transmit the virus. "Technically, it's very hard to separate them and see which one is causing the infection," Marr says. For long-distance infections, only the smallest particles could be to blame. Up close, though, particles of all sizes were in play. Yet, for decades, droplets were seen as the main culprit.

Marr decided to collect some data of her own. Installing air samplers in places such as day cares and airplanes, she frequently found the flu virus where the textbooks said it shouldn't be—hiding in the air, most often in particles small enough to stay aloft for hours. And there was enough of it to make people sick.

In 2011, this should have been major news. Instead, the major medical journals rejected her manuscript. Even as she ran new experiments that added evidence to the idea that influenza was infecting people via aerosols, only one niche publisher, *The Journal of the Royal Society Interface*, was

consistently receptive to her work. In the siloed world of academia, aerosols had always been the domain of engineers and physicists, and pathogens purely a medical concern; Marr was one of the rare people who tried to straddle the divide. "I was definitely fringe," she says.

Thinking it might help her overcome this resistance, she'd try from time to time to figure out where the flawed 5-micron figure had come from. But she always got stuck. The medical textbooks simply stated it as fact, without a citation, as if it were pulled from the air itself. Eventually she got tired of trying, her research and life moved on, and the 5-micron mystery faded into the background. Until, that is, December 2019, when a paper crossed her desk from the lab of Yuguo Li.

An indoor-air researcher at the University of Hong Kong, Li had made a name for himself during the first SARS outbreak, in 2003. His investigation of an outbreak at the Amoy Gardens apartment complex provided the strongest evidence that a coronavirus could be airborne. But in the intervening decades, he'd also struggled to convince the public health community that their risk calculus was off. Eventually, he decided to work out the math. Li's elegant simulations showed that when a person coughed or sneezed, the heavy droplets were too few and the targets—an open mouth, nostrils, eyes—too small to account for much infection. Li's team had concluded, therefore, that the public health establishment had it backward and that most colds, flu, and other respiratory illnesses must spread through aerosols instead.

Their findings, they argued, exposed the fallacy of the 5-micron boundary. And they'd gone a step further, tracing the number back to a decades-old document the CDC had published for hospitals. Marr couldn't help but feel a surge of excitement. A journal had asked her to review Li's paper, and she didn't mask her feelings as she sketched out her reply. On January 22, 2020, she wrote, "This work is hugely important in challenging the existing dogma about how infectious disease is transmitted in droplets and aerosols."

Even as she composed her note, the implications of Li's work were far from theoretical. Hours later, Chinese government officials cut off any travel in and out of the city of Wuhan, in a desperate attempt to contain an as-yet-

unnamed respiratory disease burning through the 11-million-person megalopolis. As the pandemic shut down country after country, the WHO and the CDC told people to wash their hands, scrub surfaces, and maintain social distance. They didn't say anything about masks or the dangers of being indoors.

A few days after the April Zoom meeting with the WHO, Marr got an email from another aerosol scientist who had been on the call, an atmospheric chemist at the University of Colorado Boulder named Jose-Luis Jimenez. He'd become fixated on the WHO recommendation that people stay 3 to 6 feet apart from one another. As far as he could tell, that social distancing guideline seemed to be based on a few studies from the 1930s and '40s. But the authors of those experiments actually argued for the possibility of airborne transmission, which by definition would involve distances over 6 feet. None of it seemed to add up.

Scientists use a rotating drum to aerosolize viruses and study how well they survive under different conditions.

Photograph: Matt Eich

Marr told him about her concerns with the 5-micron boundary and suggested that their two issues might be linked. If the 6-foot guideline was built off of an incorrect definition of droplets, the 5-micron error wasn't just some arcane detail. It seemed to sit at the heart of the WHO's and the CDC's flawed guidance. Finding its origin suddenly became a priority. But to hunt it down, Marr, Jimenez, and their collaborators needed help. They needed a historian.

Luckily, Marr knew one, a Virginia Tech scholar named Tom Ewing who specialized in the history of tuberculosis and influenza. They talked. He suggested they bring on board a graduate student he happened to know who was good at this particular form of forensics. The team agreed. "This will be very interesting," Marr wrote in an email to Jimenez on April 13. "I think we're going to find a house of cards."

The graduate student in question was Katie Randall. Covid had just dealt her dissertation a big blow—she could no longer conduct in-person

research, so she'd promised her adviser she would devote the spring to sorting out her dissertation and nothing else. But then an email from Ewing arrived in her inbox describing Marr's quest and the clues her team had so far unearthed, which were "layered like an archaeology site, with shards that might make up a pot," he wrote. That did it. She was in.

Randall had studied citation tracking, a type of scholastic detective work where the clues aren't blood sprays and stray fibers but buried references to long-ago studies, reports, and other records. She started digging where Li and the others had left off—with various WHO and CDC papers. But she didn't find any more clues than they had. Dead end.

She tried another tack. Everyone agreed that tuberculosis was airborne. So she plugged "5 microns" and "tuberculosis" into a search of the CDC's archives. She scrolled and scrolled until she reached the earliest document on tuberculosis prevention that mentioned aerosol size. It cited an out-of-print book written by a Harvard engineer named William Firth Wells. Published in 1955, it was called *Airborne Contagion and Air Hygiene*. A lead!

In the Before Times, she would have acquired the book through interlibrary loan. With the pandemic shutting down universities, that was no longer an option. On the wilds of the open internet, Randall tracked down a first edition from a rare book seller for $500—a hefty expense for a side project with essentially no funding. But then one of the university's librarians came through and located a digital copy in Michigan. Randall began to dig in.

In the words of Wells' manuscript, she found a man at the end of his career, rushing to contextualize more than 23 years of research. She started reading his early work, including one of the studies Jimenez had mentioned. In 1934, Wells and his wife, Mildred Weeks Wells, a physician, analyzed air samples and plotted a curve showing how the opposing forces of gravity and evaporation acted on respiratory particles. The couple's calculations made it possible to predict the time it would take a particle of a given size to travel from someone's mouth to the ground. According to them, particles bigger than 100 microns sank within seconds. Smaller particles stayed in the air. Randall paused at the curve they'd drawn. To her, it seemed to

foreshadow the idea of a droplet-aerosol dichotomy, but one that should have pivoted around 100 microns, not 5.

The book was long, more than 400 pages, and Randall was still on the hook for her dissertation. She was also helping her restless 6-year-old daughter navigate remote kindergarten, now that Covid had closed her school. So it was often not until late at night, after everyone had gone to bed, that she could return to it, taking detailed notes about each day's progress.

One night she read about experiments Wells did in the 1940s in which he installed air-disinfecting ultraviolet lights inside schools. In the classrooms with UV lamps installed, fewer kids came down with the measles. He concluded that the measles virus must have been in the air. Randall was struck by this. She knew that measles didn't get recognized as an airborne disease until decades later. What had happened?

Part of medical rhetoric is understanding why certain ideas take hold and others don't. So as spring turned to summer, Randall started to investigate how Wells' contemporaries perceived him. That's how she found the writings of Alexander Langmuir, the influential chief epidemiologist of the newly established CDC. Like his peers, Langmuir had been brought up in the Gospel of Personal Cleanliness, an obsession that made handwashing the bedrock of US public health policy. He seemed to view Wells' ideas about airborne transmission as retrograde, seeing in them a slide back toward an ancient, irrational terror of bad air—the "miasma theory" that had prevailed for centuries. Langmuir dismissed them as little more than "interesting theoretical points."

But at the same time, Langmuir was growing increasingly preoccupied by the threat of biological warfare. He worried about enemies carpeting US cities in airborne pathogens. In March 1951, just months after the start of the Korean War, Langmuir published a report in which he simultaneously disparaged Wells' belief in airborne infection and credited his work as being foundational to understanding the physics of airborne infection.

How curious, Randall thought. She kept reading.

In the report, Langmuir cited a few studies from the 1940s looking at the health hazards of working in mines and factories, which showed the mucus of the nose and throat to be exceptionally good at filtering out particles bigger than 5 microns. The smaller ones, however, could slip deep into the lungs and cause irreversible damage. If someone wanted to turn a rare and nasty pathogen into a potent agent of mass infection, Langmuir wrote, the thing to do would be to formulate it into a liquid that could be aerosolized into particles smaller than 5 microns, small enough to bypass the body's main defenses. Curious indeed. Randall made a note.

When she returned to Wells' book a few days later, she noticed he too had written about those industrial hygiene studies. They had inspired Wells to investigate what role particle size played in the likelihood of natural respiratory infections. He designed a study using tuberculosis-causing bacteria. The bug was hardy and could be aerosolized, and if it landed in the lungs, it grew into a small lesion. He exposed rabbits to similar doses of the bacteria, pumped into their chambers either as a fine (smaller than 5 microns) or coarse (bigger than 5 microns) mist. The animals that got the fine treatment fell ill, and upon autopsy it was clear their lungs bulged with lesions. The bunnies that received the coarse blast appeared no worse for the wear.

For days, Randall worked like this—going back and forth between Wells and Langmuir, moving forward and backward in time. As she got into Langmuir's later writings, she observed a shift in his tone. In articles he wrote up until the 1980s, toward the end of his career, he admitted he had been wrong about airborne infection. It was possible.

A big part of what changed Langmuir's mind was one of Wells' final studies. Working at a VA hospital in Baltimore, Wells and his collaborators had pumped exhaust air from a tuberculosis ward into the cages of about 150 guinea pigs on the building's top floor. Month after month, a few guinea pigs came down with tuberculosis. Still, public health authorities were skeptical. They complained that the experiment lacked controls. So Wells' team added another 150 animals, but this time they included UV lights to kill any germs in the air. Those guinea pigs stayed healthy. That was it, the first incontrovertible evidence that a human disease—

tuberculosis—could be airborne, and not even the public health big hats could ignore it.

The groundbreaking results were published in 1962. Wells died in September of the following year. A month later, Langmuir mentioned the late engineer in a speech to public health workers. It was Wells, he said, that they had to thank for illuminating their inadequate response to a growing epidemic of tuberculosis. He emphasized that the problematic particles—the ones they had to worry about—were smaller than 5 microns.

Inside Randall's head, something snapped into place. She shot forward in time, to that first tuberculosis guidance document where she had started her investigation. She had learned from it that tuberculosis is a curious critter; it can only invade a subset of human cells in the deepest reaches of the lungs. Most bugs are more promiscuous. They can embed in particles of any size and infect cells all along the respiratory tract.

What must have happened, she thought, was that after Wells died, scientists inside the CDC conflated his observations. They plucked the size of the particle that transmits tuberculosis out of context, making 5 microns stand in for a general definition of airborne spread. Wells' 100-micron threshold got left behind. "You can see that the idea of what is respirable, what stays airborne, and what is infectious are all being flattened into this 5-micron phenomenon," Randall says. Over time, through blind repetition, the error sank deeper into the medical canon. The CDC did not respond to multiple requests for comment.

In June, she Zoomed into a meeting with the rest of the team to share what she had found. Marr almost couldn't believe someone had cracked it. "It was like, 'Oh my gosh, this is where the 5 microns came from?!'" After all these years, she finally had an answer. But getting to the bottom of the 5-micron myth was only the first step. Dislodging it from decades of public health doctrine would mean convincing two of the world's most powerful health authorities not only that they were wrong but that the error was incredibly—and urgently—consequential.

While Randall was digging through the past, her collaborators were planning a campaign. In July, Marr and Jimenez went public, signing their

names to an open letter addressed to public health authorities, including the WHO. Along with 237 other scientists and physicians, they warned that without stronger recommendations for masking and ventilation, airborne spread of SARS-CoV-2 would undermine even the most vigorous testing, tracing, and social distancing efforts.

The news made headlines. And it provoked a strong backlash. Prominent public health personalities rushed to defend the WHO. Twitter fights ensued. Saskia Popescu, an infection-prevention epidemiologist who is now a biodefense professor at George Mason University, was willing to buy the idea that people were getting Covid by breathing in aerosols, but only at close range. That's not airborne in the way public health people use the word. "It's a very weighted term that changes how we approach things," she says. "It's not something you can toss around haphazardly."

The mannequins in this chamber were used to test the efficacy of masks.

Photograph: Matt Eich

Days later, the WHO released an updated scientific brief, acknowledging that aerosols couldn't be ruled out, especially in poorly ventilated places. But it stuck to the 3- to 6-foot rule, advising people to wear masks indoors only if they couldn't keep that distance. Jimenez was incensed. "It is misinformation, and it is making it difficult for ppl to protect themselves," he tweeted about the update. "E.g. 50+ reports of schools, offices forbidding portable HEPA units because of @CDCgov and @WHO downplaying aerosols."

While Jimenez and others sparred on social media, Marr worked behind the scenes to raise awareness of the misunderstandings around aerosols. She started talking to Kimberly Prather, an atmospheric chemist at UC San Diego, who had the ear of prominent public health leaders within the CDC and on the White House Covid Task Force. In July, the two women sent slides to Anthony Fauci, director of the National Institutes of Allergy and Infectious Diseases. One of them showed the trajectory of a 5-micron particle released from the height of the average person's mouth. It went farther than 6 feet—hundreds of feet farther. A few weeks later, speaking to an audience at Harvard Medical School, Fauci admitted that the 5-micron

distinction was wrong—and had been for years. "Bottom line is, there is much more aerosol than we thought," he said. (Fauci declined to be interviewed for this story.)

Still, the droplet dogma reigned. In early October, Marr and a group of scientists and doctors published a letter in *Science* urging everyone to get on the same page about how infectious particles move, starting with ditching the 5-micron threshold. Only then could they provide clear and effective advice to the public. That same day, the CDC updated its guidance to acknowledge that SARS-CoV-2 can spread through long-lingering aerosols. But it didn't emphasize them.

That winter, the WHO also began to talk more publicly about aerosols. On December 1, the organization finally recommended that everyone always wear a mask indoors wherever Covid-19 is spreading. In an interview, the WHO's Maria Van Kerkhove said that the change reflects the organization's commitment to evolving its guidance when the scientific evidence compels a change. She maintains that the WHO has paid attention to airborne transmission from the beginning—first in hospitals, then at places such as bars and restaurants. "The reason we're promoting ventilation is that this virus can be airborne," Van Kerkhove says. But because that term has a specific meaning in the medical community, she admits to avoiding it—and emphasizing instead the types of settings that pose the biggest risks. Does she think that decision has harmed the public health response, or cost lives? No, she says. "People know what they need to do to protect themselves."

Yet she admits it may be time to rethink the old droplet-airborne dichotomy. According to Van Kerkhove, the WHO plans to formally review its definitions for describing disease transmission in 2021.

Yuguo Li, an indoor-air researcher, set out to show that most respiratory diseases spread through aerosols.

Photograph: Yufan Lu

For Yuguo Li, whose work had so inspired Marr, these moves have given him a sliver of hope. "Tragedy always teaches us something," he says. The lesson he thinks people are finally starting to learn is that airborne

transmission is both more complicated and less scary than once believed. SARS-CoV-2, like many respiratory diseases, is airborne, but not wildly so. It isn't like measles, which is so contagious it infects 90 percent of susceptible people exposed to someone with the virus. And the evidence hasn't shown that the coronavirus often infects people over long distances. Or in well-ventilated spaces. The virus spreads most effectively in the immediate vicinity of a contagious person, which is to say that most of the time it looks an awful lot like a textbook droplet-based pathogen.

For most respiratory diseases, not knowing which route caused an infection has not been catastrophic. But the cost has not been zero. Influenza infects millions each year, killing between 300,000 and 650,000 globally. And epidemiologists are predicting the next few years will bring particularly deadly flu seasons. Li hopes that acknowledging this history—and how it hindered an effective global response to Covid-19—will allow good ventilation to emerge as a central pillar of public health policy, a development that would not just hasten the end of this pandemic but [beat back future ones](#).

To get a glimpse into that future, you need only peek into the classrooms where Li teaches or the Crossfit gym where Marr jumps boxes and slams medicine balls. In the earliest days of the pandemic, Li convinced the administrators at the University of Hong Kong to spend most of its Covid-19 budget on upgrading the ventilation in buildings and buses rather than on things such as mass Covid testing of students. Marr reviewed blueprints and HVAC schematics with the owner of her gym, calculating the ventilation rates and consulting on a redesign that moved workout stations outside and near doors that were kept permanently open. To date, no one has caught Covid at the gym. Li's university, a school of 30,000 students, has recorded a total of 23 Covid-19 cases. Of course Marr's gym is small, and the university benefited from the fact that Asian countries, scarred by the 2003 SARS epidemic, were quick to recognize aerosol transmission. But Marr's and Li's swift actions could well have improved their odds. Ultimately, that's what public health guidelines do: They tilt people and places closer to safety.

On Friday, April 30, the WHO quietly updated a page on its website. In a section on how the coronavirus gets transmitted, the text now states that the virus can spread via aerosols as well as larger droplets. As Zeynep Tufekci noted in *The New York Times,* perhaps the biggest news of the pandemic passed with no news conference, no big declaration. If you weren't paying attention, it was easy to miss.

But Marr was paying attention. She couldn't help but note the timing. She, Li, and two other aerosol scientists had just published an editorial in *The BMJ*, a top medical journal, entitled "Covid-19 Has Redefined Airborne Transmission." For once, she hadn't had to beg; the journal's editors came to her. And her team had finally posted their paper on the origins of the 5-micron error to a public preprint server.

In early May, the CDC made similar changes to its Covid-19 guidance, now placing the inhalation of aerosols at the top of its list of how the disease spreads. Again though, no news conference, no press release. But Marr, of course, noticed. That evening, she got in her car to pick up her daughter from gymnastics. She was alone with her thoughts for the first time all day. As she waited at a red light, she suddenly burst into tears. Not sobbing, but unable to stop the hot stream of tears pouring down her face. Tears of exhaustion, and relief, but also triumph. *Finally*, she thought, *they're getting it right, because of what we've done*.

The light turned. She wiped the tears away. Someday it would all sink in, but not today. Now, there were kids to pick up and dinner to eat. Something approaching normal life awaited.

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[Science](#)
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Awesome, Hypnotic Photos of Swirling, Crystal Chemistry

A new book goes micro to show the wonderful world of close-up chemical reactions.

The very structure of crystals provided scientists with a way of taking their first peek into the atomic world in the early 1910s. That's when William and Lawrence Bragg, father and son, developed a technique called x-ray crystallography. By shining an x-ray beam through a crystal, a delicate process that takes advantage of the x-ray's short wavelength (just about equal to the distance between atomic layers), the Braggs were able to see the interior structure of a diamond. (This photo of a copper sulfate crystal was shot with a less exotic macro lens.)Photograph: Wenting Zhu and Yan Liang

If you memorized the periodic table, if you whipped up exothermic reactions in your kitchen, Wenting Zhu and Yan Liang are here to renew your relationship with the elements.

To generate the images in their 300-photo collection *The Beauty of Chemistry*, out today, Zhu and Liang utilized infrared thermal imaging techniques, along with high-speed and time-lapse micro photography to plunge readers into the minute world of molecules and the often stunning reactions between them. With atomic clarity, science writer Philip Ball narrates this visual tour through the under-appreciated chemical beauty that surrounds us, from describing the principles that generate the unique symmetry of a snowflake to connecting the lifelike tendrils created by silicate salts to the origins of life itself.

Perhaps the most basic—and astonishing— of these concepts is the hydrogen bond, which holds together the literal stuff of life: water. Each water molecule is comprised of two hydrogen atoms bonded to an oxygen atom, but oxygen has six electrons in its outer shell. Only two electrons are needed to form that chemical bond with hydrogen, so four negatively charged electrons, grouped by twos in "dangling" pairs, are hovering out there in micro-space hoping for a way to balance themselves out. These pairs pull weakly on the hydrogen atoms bonded to neighboring water molecules, forming brief, one-trillionth-of-a-second bonds before breaking and reforming with another hydrogen atom. And it's this constant, unceasing dance that allows for the chemical motion that makes life possible, what Ball calls a "molecular dialog" that hovers between order and chaos.

Chromium(III) hydroxide

Photograph: Wenting Zhu and Yan Liang

This chromium hydroxide precipitate is in the process of solidifying as it swirls and dilutes within its container. This reaction occurs when two liquid compounds, containing both positively and negatively charged ions, come together and perform a molecular reel, in which they trade partners. In this case, chromium chloride and sodium hydroxide swap ions. The positively charged chromium and negatively charged hydroxide molecules are attracted to one another because they balance out energetically. They form tight bonds that freeze the molecules into place, creating a solid byproduct that doesn't have room for all those water molecules to fit neatly. The reaction also creates sodium chloride, commonly known as table salt, which dissolves in water just fine.

Copper sulfate crystal

Photograph: Wenting Zhu and Yan Liang

Crystals are the pinnacle of atomic efficiency—from a tiny seed of highly organized atoms, their structure grows as more of the surrounding molecules repeat the same pattern and build on each other. Copper sulfate

crystals, like the one pictured above, are also easy for would-be chemists to make at home with a few ingredients and a bit of patience.

Fractal crystals of nicotinic acid

Photograph: Wenting Zhu and Yan Liang

Dendritic growth, like that pictured above, is a type of crystallization that forms branching, tree-like structures instead of a large crystal mass. Above, nicotinic acid (also known as the essential vitamin niacin) forms dandelion-like crystal structures after a supersaturated solution of the acid is cooled very rapidly. The physical process for forming dendrites is essentially the same as crystallization, only sped up by a sudden change in temperature or chemical composition.

Potassium dichromate

Photograph: Wenting Zhu and Yan Liang

What you see here is a potassium dichromate solution crystalizing as the surrounding water rapidly evaporates. The patterns themselves are created by variations in the solution. This is an example of what's called growth instability, in which certain areas tend to aggregate more particles and crystalize faster, making for elaborate fractal patterns.

Liesegang rings

Photograph: Wenting Zhu and Yan Liang

First discovered by a German chemist named Raphael Liesegang in 1986, these odd-looking rings are the result of a precipitation reaction in gel. Silver nitrate is added to a petri dish containing potassium dichromate. The two compounds precipitate, or trade ions, and create silver chromate where they meet. There are competing theories as to why these rings form, but many scientists believe that the initial deposit of silver chromate becomes supersaturated and diffuses through the gel to create a new chemical pile-up zone, where the concentration becomes saturated once again, forming concentric rings.

Reduction of potassium permanganate by sucrose

Photograph: Wenting Zhu and Yan Liang

Potassium permanganate, also known as the "chameleon mineral," is an ultra-positively charged compound known as an oxidizing agent. Oxygen on its own likes to borrow electrons from surrounding atoms. In a sugar solution, the oxygen in potassium permanganate pulls electrons from the sugar molecules, creating a "redox" reaction. As the permanganate gains electrons and gets closer to chemical equilibrium, it changes color from purple to green to blue to reddish brown.

Ammonium iron sulfate

Photograph: Wenting Zhu and Yan Liang

This hollow branch of ammonium iron sulfate is suspended within a chemical garden—a silicate solution full of dissolved iron salts that then precipitate out. Because silicate ions tend to form long chains and sheets, they turn a typical precipitation reaction into a process that generates an inorganic garden full of angled branches and vibrant blooms. As iron salts trade ions with the surrounding solution and solidify, they form a thin, hollow membrane with a water-filled interior that is less dense than the liquid outside. As pressure builds inside these tubes, they branch out and grow in unpredictable ways.

Updated 5-13-21, 4:30 pm EST: The caption for an image of potassium dichromate crystallization was updated.

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<u>Will Knight</u>

<u>Business</u>
05.10.2021 08:00 AM

The Pentagon Inches Toward Letting AI Control Weapons

Drills involving swarms of drones raise questions about whether machines could outperform a human operator in complex scenarios.
Photograph: Getty Images

Last August, several dozen military <u>drones</u> and tanklike <u>robots</u> took to the skies and roads 40 miles south of Seattle. Their mission: Find terrorists suspected of hiding among several buildings.

So many robots were involved in the operation that no human operator could keep a close eye on all of them. So they were given instructions to find—and eliminate—enemy combatants when necessary.

The mission was just an exercise, organized by the <u>Defense Advanced Research Projects Agency,</u> a blue-sky research division of the Pentagon; the robots were armed with nothing more lethal than radio transmitters designed to simulate interactions with both friendly and enemy robots.

The drill was one of several conducted last summer to test how <u>artificial intelligence</u> could help expand the use of automation in military systems, including in scenarios that are too complex and fast-moving for humans to make every critical decision. The demonstrations also reflect a subtle shift in the Pentagon's thinking about autonomous weapons, as it becomes clearer that machines can outperform humans at parsing complex situations or operating at high speed.

General John Murray of the US Army Futures Command told an audience at the US Military Academy last month that swarms of robots will force military planners, policymakers, and society to think about whether a person should make every decision about using lethal force in new autonomous systems. Murray asked: "Is it within a human's ability to pick out which ones have to be engaged" and then make 100 individual decisions? "Is it even necessary to have a human in the loop?" he added.

Other comments from military commanders suggest interest in giving autonomous weapons systems more agency. At a conference on AI in the Air Force last week, Michael Kanaan, director of operations for the Air Force Artificial Intelligence Accelerator at MIT and a leading voice on AI within the US military, said thinking is evolving. He says AI should perform more identifying and distinguishing potential targets while humans make high-level decisions. "I think that's where we're going," Kanaan says.

At the same event, Lieutenant General Clinton Hinote, deputy chief of staff for strategy, integration, and requirements at the Pentagon, says that whether a person can be removed from the loop of a lethal autonomous system is "one of the most interesting debates that is coming, [and] has not been settled yet."

A report this month from the National Security Commission on Artificial Intelligence (NSCAI), an advisory group created by Congress, recommended, among other things, that the US resist calls for an international ban on the development of autonomous weapons.

Timothy Chung, the Darpa program manager in charge of the swarming project, says last summer's exercises were designed to explore when a human drone operator should, and should not, make decisions for the autonomous systems. For example, when faced with attacks on several fronts, human control can sometimes get in the way of a mission, because people are unable to react quickly enough. "Actually, the systems can do better from not having someone intervene," Chung says.

The drones and the wheeled robots, each about the size of a large backpack, were given an overall objective, then tapped AI algorithms to devise a plan to achieve it. Some of them surrounded buildings while others carried out

surveillance sweeps. A few were destroyed by simulated explosives; some identified beacons representing enemy combatants and chose to attack.

The US and other nations have used autonomy in weapons systems for decades. Some missiles can, for instance, autonomously identify and attack enemies within a given area. But rapid advances in AI algorithms will change how the military uses such systems. Off-the-shelf AI code capable of controlling robots and identifying landmarks and targets, often with high reliability, will make it possible to deploy more systems in a wider range of situations.

But as the drone demonstrations highlight, more widespread use of AI will sometimes make it more difficult to keep a human in the loop. This might prove problematic, because AI technology [can harbor biases or behave unpredictably](). A vision algorithm trained to recognize a particular uniform might mistakenly target someone wearing similar clothing. Chung says the swarm project presumes that AI algorithms will improve to a point where they can identify enemies with enough reliability to be trusted.

Use of AI in weapons systems has become controversial in recent years. Google faced employee protest and public outcry in 2018 after [supplying AI technology to the Air Force]() through a project known as [Maven]().

To some degree, the project is part of a long history of autonomy in weapons systems, with some missiles already capable of carrying out limited missions independent of human control. But it also shows how recent advances in AI will make autonomy more attractive and inevitable in certain situations. What's more, it highlights the trust that will be placed in technology that can still behave unpredictably.

[Paul Scharre](), an expert at the Center for New American Security and author of [*Army of None: Autonomous Weapons and the Future of War*](), says it is time to have a more sophisticated discussion about autonomous weapons technology. "The discussion surrounding 'humans in the loop' ought to be more sophisticated than simply a binary 'are they or aren't they?'" Scharre says. "If a human makes a decision to engage a swarm of enemy drones, does the human need to individually select each target?"

The Defense Department issued a [policy on autonomous weapons](#) in November 2012, stating that autonomous weapons systems need to have human oversight—but this need not mean soldiers making every decision.

Those who believe that militaries could use AI to cross a Rubicon when it comes to human responsibility for lethal force see things differently.

"Lethal autonomous weapons cheap enough that every terrorist can afford them are not in America's national security interest," says [Max Tegmark](#), a professor at MIT and cofounder of the [Future of Life Institute](#), a nonprofit that opposes autonomous weapons.

Tegmark says AI weapons should be "stigmatized and banned like biological weapons." The NSCAI report's opposition to a global ban is a strategic mistake, he says: "I think we'll one day regret it even more than we regret having armed the Taliban."

[William Ralston](#)

[Backchannel](#)
05.04.2021 07:00 AM

They Told Their Therapists Everything. Hackers Leaked It All

A mental health startup built its business on easy-to-use technology. Patients joined in droves. Then came a catastrophic data breach. Illustration: Mark Harris

Jere woke up on the morning of October 24, 2020, expecting what Finnish college students call *normi päivä*, an ordinary day. It was a Saturday, and he'd slept in. The night before, he had gone drinking by the beach with some friends. They'd sipped cheap apple liqueur, listened to Billie Eilish on his boom box. Now Jere (pronounced "yeh-reh") needed to clear his head. He was supposed to spend this gray fall day on campus, finishing a group physics project about solar energy. The 22-year-old took a walk around the lake near his apartment outside Helsinki. Then, feeling somewhat refreshed, he jumped on the bus.

The day went quickly. Jere caught up with his friends, many of whom he hadn't seen since the pandemic began. They chatted about their Christmas plans, ordered pizzas from a favorite local spot, and knuckled down to work in the cafeteria.

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At around 4 pm, Jere checked Snapchat. An email notification popped up on his screen. His hands began to shake. The subject line included his full name, his social security number, and the name of a clinic where he'd

gotten mental health treatment as a teenager: Vastaamo. He didn't recognize the sender, but he knew what the email said before he opened it.

A few days earlier, Vastaamo had announced a catastrophic data breach. A [security flaw](#) in the company's IT systems had exposed its entire patient database to the open internet—not just email addresses and social security numbers, but the actual written notes that therapists had taken. A group of hackers, or one masquerading as many, had gotten hold of the data. The message in Jere's inbox was [a ransom demand](#).

"If we receive €200 worth of Bitcoin within 24 hours, your information will be permanently deleted from our servers," the email said in Finnish. If Jere missed the first deadline, he'd have another 48 hours to fork over €500, or about $600. After that, "your information will be published for all to see."

Jere had first gone to Vastaamo when he was 16. He had dropped out of school and begun to self-harm, he says, and was consuming "extreme amounts" of Jägermeister each week. His girlfriend at the time insisted he get help; she believed it was the only way Jere would see his 18th birthday.

During his therapy sessions, Jere spoke about his abusive parents—how they forced him, when he was a young kid, to walk the nearly 4 miles home from school, or made him sleep out in the garden if he "was being a disappointment." He talked about using marijuana, LSD, DMT. He said he'd organized an illegal rave and was selling drugs. He said he'd thought about killing himself. After each session, Jere's therapist typed out his notes and uploaded them to Vastaamo's servers. "I was just being honest," Jere says. He had "no idea" that they were backing the information up digitally.

In the cafeteria, Jere grabbed his bag and told his friends he'd turn in his portion of the physics project the next day. On the bus ride home, he frantically texted his best friend to come over. Then his mother called; as the adult listed on his old account, she'd received the ransom note too. She and Jere were on good terms now, but if she got involved she might learn what he'd said in his sessions. Then, he says, he'd probably lose her from his life completely. He told his mother not to worry. That afternoon, he filed an online police report.

Jere poured himself a shot of vodka, then two or three more. He found his vape pen and took a Xanax, prescribed to him years earlier for anxiety. He'd stored a few pills in his bedroom drawer just in case, but he never believed he'd need them again. He passed out shortly after his friend arrived.

The next morning, Jere checked Twitter, where he was both horrified and relieved to learn that thousands of others had received the same threat. "Had I been one of the only people to get the mail, I would have been more scared," he says.

Vastaamo ran the largest network of private mental-health providers in Finland. In a country of just 5.5 million—about the same as the state of Minnesota—it was the "McDonald's of psychotherapy," one Finnish journalist told me. And because of that, the attack on the company rocked all of Finland. Around 30,000 people are believed to have received the ransom demand; some 25,000 reported it to the police. On October 29, a headline in the *Helsinki Times* read: "Vastaamo Hacking Could Turn Into Largest Criminal Case in Finnish History." That prediction seems to have come true.

If the scale of the attack was shocking, so was its cruelty. Not just because the records were so sensitive; not just because the attacker, or attackers, singled out patients like wounded animals; but also because, out of all the countries on earth, Finland should have been among the best able to prevent such a breach. Along with neighboring Estonia, it is widely considered a pioneer in digital health. Since the late 1990s, Finnish leaders have pursued the principle of "citizen-centered, seamless" care, backed up by investments in technology infrastructure. Today, every Finnish citizen has access to a highly secure service called Kanta, where they can browse their own treatment records and order prescriptions. Their health providers can use the system to coordinate care.

Vastaamo was a private company, but it seemed to operate in the same spirit of tech-enabled ease and accessibility: You booked a therapist with a few clicks, wait times were tolerable, and Finland's Social Insurance Institution reimbursed a big chunk of the session fee (provided you had a diagnosed mental disorder). The company was run by Ville Tapio, a 39-year-old coder

and entrepreneur with sharp eyebrows, slicked-back brown hair, and a heavy jawline. He'd cofounded the company with his parents. They pitched Vastaamo as a humble family-run enterprise committed to improving the mental health of all Finns.

For nearly a decade, the company went from success to success. Sure, some questioned the purity of Tapio's motives; Kristian Wahlbeck, director of development at Finland's oldest mental health nonprofit, says he was "a bit frowned-upon" and "perceived as too business-minded." And yes, there were occasional stories about Vastaamo doing shady-seeming things, such as using Google ads to try to poach prospective patients from a university clinic, as the newspaper *Iltalehti* reported. But people kept signing up. Tapio was so confident in what he'd created that he spoke about taking his model overseas.

Before "the incident," Tapio says, "Vastaamo produced a lot of social good." Now he is an ex-CEO, and the company he founded is being sold for parts. "I'm so sad to see all the work done and the future opportunities suddenly go to waste," he says. "The way it ended feels terrible, unnecessary, and unjustified."

Tapio grew up in a "peaceful and green" neighborhood in northern Helsinki during a bad recession. His mother, Nina, was a trauma psychotherapist, and his father, Perttu, a priest. His grandparents gave him a used Commodore 64 when he was 10, which led him to an interest in coding. Something in his brain resonated with the logical challenge of it, he says. He also saw it as a "tool to build something real."

The obsession endured: In middle school Tapio coded a statistics system for his basketball team, and in high school he worked for the Helsinki Education Department, showing teachers how to use their computers. Rather than going to college, he set up an online shop selling computer parts—his first business, funded with "a few tens of euros," he says. A couple of years later, at age 20, he joined a small management consultancy.

The idea for Vastaamo came to Tapio when he was working with the Finnish Innovation Fund, a public foundation that invests in solutions to social and environmental problems. The fund sent him on a survey of health

care systems in Western Europe. Being his mother's son, he noticed that the Netherlands and other countries seemed to do a better job of providing mental health services than Finland did; the public system at home was known for patchy coverage and long wait times. Ever the coder, he wondered whether a web-based counseling service would help. It could sell vouchers to cities and towns, which could distribute the vouchers for free to residents. People could use the service anonymously. They wouldn't have to worry about the stigma of seeking care, and they'd have access anytime, anyplace.

In 2009, the Finnish Innovation Fund backed Tapio's idea with an initial grant of about $12,000. He and his parents used the money—along with more than $13,000 of their own savings—to start Vastaamo, Finnish for "a place where you get answers from." Tapio registered the company as a social enterprise, meaning that the bulk of its profits would be poured back into its mission to improve mental health services. He would own around 60 percent, and most of the remainder would belong to his parents. Perttu would serve as CEO.

Clients could send a message to Vastaamo, and within 24 hours they'd get a personal response from a qualified therapist. (Wahlbeck, of the mental health nonprofit, notes that such services aren't regulated by the government.) But counseling by internet "was not enough for customers," Tapio says. Many of them needed access to in-person therapy.

One way to meet that need was to grow Vastaamo into a network of brick-and-mortar clinics. Tapio planned to digitize whatever he could, from bookings to invoices to medical records—everything but the appointment itself. The idea was that independent therapists would join Vastaamo to avoid dealing with their own administrative headaches. Freed by automation, they'd have more time to spend with clients (and rack up billable hours).

To deliver on this vision, Vastaamo needed an electronic medical record system, but Tapio didn't like the options he found. Either the systems bristled with irrelevant features or they were too tightly tailored to a different area of medicine. The lack of good software, Tapio says, was one

of the "main reasons" nobody had done what Vastaamo was about to attempt.

A Vastaamo clinic location in Espoo, near where Jere lives.

Illustration: Mark Harris

Rather than use an existing system, the company designed its own. It launched in late 2012, around the same time Vastaamo's first in-person clinic opened, in the Malmi district of Helsinki. Tapio wouldn't go into technical detail about the system, but in court documents he suggests it was browser-based and stored patients' records on a MySQL server. More important for Vastaamo's purposes, the interface was easy to use. When therapists applied for a job at the company, they heard all about how much it would quicken their work.

But the slick exterior concealed deep vulnerabilities. Mikael Koivukangas, head of R&D at a Finnish medtech firm called Onesys Medical, points out that Vastaamo's system violated one of the "first principles of cybersecurity": It didn't anonymize the records. It didn't even encrypt them. The only thing protecting patients' confessions and confidences were a couple of firewalls and a server login screen. Anyone with experience in the field, Koivukangas says, could've helped Vastaamo design a safer system.

At the time, though, fears of a breach were far from Tapio's mind. The summer after Vastaamo's first clinic opened its doors, he took over as CEO and set the company on a path toward expansion.

In 2014 there was a change in the regulations around Vastaamo's business. The Finnish Parliament decided to split medical information systems into two categories. Class A systems would connect with Kanta, the national health data repository, so they'd need to meet strict security and interoperability standards. Anyone who planned to keep their patients' records in long-term electronic storage would have to use a Class A system.

Smaller organizations, the kind that kept vital records in manila envelopes and filing cabinets, would be allowed to use Class B systems. These weren't as tightly regulated, in part because they wouldn't make very interesting

targets for a hacker. Class B operators would simply self-certify to the government that their setup met certain requirements. "The government" being, in this case, a single man—Antti Härkönen—whose purview includes all 280 Class B systems in Finland.

The new law gave Vastaamo several years to adopt a Class A system. The problem, Tapio says, is that the Finnish government hadn't specified how psychotherapy practices should format their data. Vastaamo could build a Class A system and plug into Kanta, but there was "no way to stop, for example, general practitioners at health care centers or occupational health physicians from accessing" therapy records, he says.

Outi Lehtokari, Kanta's head of services, pushes back against this claim. "Tapio might have misunderstood how Kanta works," she says. Patients can choose to restrict access to their information.

In any event, on June 29, 2017, Vastaamo registered a Class B system. As Tapio tells it, the company was eager to upgrade to Class A as soon as the government released formatting specs for psychotherapy. But that didn't happen. Instead, when the specs came out, Vastaamo kept on going with its Class B.

Tapio says that Finland's "supervisory authorities" then signed off on the system "numerous times" in the years ahead. Härkönen, who is one of those authorities, says that to monitor all the Class B systems carefully would be "mission impossible" for him. He adds, however, that there should be more "proactive inspections."

By 2018, Vastaamo was operating nearly 20 clinics and employing around 200 therapists and staff. By the end of 2019, annual revenue had risen to more than $18 million. The company drew the interest of Intera Partners, a Finnish private equity firm, which bought out the majority of Tapio's and his parents' stakes. Tapio took home nearly $4 million from the deal.

With each new clinic that opened, the original process repeated: Härkönen reviewed Vastaamo's self-certification and gave the thumbs-up. More patient data flowed into the MySQL server. And the reservoir behind the dam rose a little higher.

Tapio first heard from the hacker on September 28, 2020. The demand was 40 bitcoin, around half a million dollars at the time. The message came to him and a pair of developers he'd hired in 2015, Ilari Lind and Sami Keskinen. Lind was responsible for maintaining the company's IT systems, including its servers and firewalls; Keskinen was the data protection officer.

According to a statement Tapio made to Helsinki District Court, he immediately notified various government authorities, including the police. Lind sifted through Vastaamo's network traffic logs but reported finding no evidence of a hack. Tapio hired a security company called Nixu to investigate further. Two days later, Tuomas Kahri, COO of Intera Partners and chairman of the board of Vastaamo, sent an email to Tapio to thank him for his diligence in handling the breach. Kahri would later say that some of his own loved ones had been targeted in the attack.

In early October, Tapio got another shock. Keskinen and Lind called with a confession: Just before they'd joined Vastaamo, they had been arrested as part of a security breach at Tekes, the Finnish Funding Agency for Technology and Innovation. Lind had discovered that he could download Tekes' entire database, containing information on as many as 20,000 companies, by changing the URL on a funding application. He informed Tekes, which fixed the vulnerability—but he also notified Keskinen, who downloaded the database. There was a pretrial investigation for aggravated fraud, breach of confidentiality, and burglary, but the prosecution could not establish that Lind and Keskinen had used the database for financial gain.

Tapio says that if he had known about the two men's histories, he would never have hired them. (Keskinen and Lind declined to comment.) As it was, though, he had more pressing problems to worry about.

On the morning of Wednesday, October 21, the hacker posted a message on Ylilauta, an anonymous public discussion board. "We have attempted to negotiate with the Ville Tapio, the CEO of vastaamo, but he has stopped responding to our emails," they wrote in English. Until they got their 40 bitcoin ransom, they were going to leak 100 patient records each day. The first batch was already up on a Tor server. Anyone who wanted to could go read them.

The hacker started emailing with Henrik Kärkkäinen, a reporter at the newspaper *Ilta-Sanomat*. To prove they were the real McCoy, they uploaded a file to the Tor server called "henrik.txt"—a snippet of their exchange. In emails to Kärkkäinen, the hacker scorned Vastaamo: A company with security practices that weak was the real criminal, he recalls them writing. They claimed to have been sitting on the stolen database for 18 months, unaware of its value.

When Ylilauta's moderators removed the posts, the conversation migrated to Torilauta, a popular discussion forum on the dark web. The hacker took on a name: ransom_man. At least one desperate person offered to pay the full 40 bitcoin. Another wrote, in English, "I have discussed about very private things with my therapist and will literally kys myself if they are released." They had their bitcoin ready: "I can send it in minutes, I'm constantly refreshing this page." About 30 payments ended up going to the hacker's Bitcoin wallet, according to Mikko Hyppönen, the chief research officer at F-Secure, a global cybersecurity company. It is unclear whether ransom_man actually deleted anyone's information.

The hacker did follow through on another promise, however. On October 22, they leaked 100 more patient records. Some belonged to politicians and other public figures. They contained details about adulterous relationships, suicide attempts, pedophilic thoughts. The next batch came around 2 am the following morning. The hacker also put all the records they'd leaked so far into a single file called "Vastaamo.tar."

And then something strange happened. Ransom_man replaced the first "Vastaamo.tar" with a much bigger one. It was 10.9 gigabytes—the entire leaked database. This file also contained a Python script that the hacker had used to organize the therapy records. The 10.9 GB upload seems to have been a mistake, because it disappeared in a matter of hours, along with the entire Tor server. Some speculated that Vastaamo had paid the 40 bitcoin, though company officials denied it.

Either way, ransom_man soon changed tactics and started extorting individual patients. This was unusual. Most of the time, cybercriminals go after institutions, according to Hyppönen. He knew of only one earlier instance of patients being singled out—in late 2019, after a breach at the

Center for Facial Restoration in Miramar, Florida. (Since the Vastaamo attack, he adds, two other hacks have also targeted patients of plastic surgery clinics.) "Most attackers want money, and health care data is not directly monetizable," Hyppönen says. But with real-world examples of the crime paying off, he adds, "it could become more common."

Vastaamo reacted by offering patients a free counseling session. Therapy continued as normal. One patient says her therapist advised her to consider that not everything being said in the news was true. Some patients picked up a physical copy of their records, to learn what had been stolen, and others joined Facebook groups dedicated to victim support. Jere, however, opted not to; he wanted to minimize his online presence. He changed his phone number and purchased credit protection. He never seriously considered paying the hacker, he says, because "there was absolutely no guarantee they would obey" their own terms.

A Vastaamo clinic location in Turku.

Illustration: Mark Harris

On the Monday after the breach became public, Tapio went to Vastaamo headquarters in Helsinki. He'd been summoned there by Tuomas Kahri, the Intera COO who a month earlier had thanked him. Instead of speaking to Tapio face to face, Kahri had a consultant hand him a letter. It said that Tapio's contract as CEO was terminated.

Hours later, the company announced Tapio's dismissal. Shortly after that, in response to a legal motion filed by Intera, the Helsinki District Court ordered the temporary seizure of $11.7 million worth of the Tapio family's assets—exactly what Intera had paid for its share of Vastaamo. Kahri declined several requests to comment on Intera's claims, but they're described in public (albeit redacted) court documents.

In its filings, Intera says it became aware of two previously unreported breaches at Vastaamo, in late 2018 and the spring of 2019. The second date fell shortly before the buyout went through. "Based on the information received so far, it is reasonable to assume that Ville Tapio was aware of the

breach," Intera argues. Not only that, but he "sought to conceal" it. Intera wanted to dissolve the transaction and reclaim the purchase price.

Tapio, as the defendant, submitted written testimony in rebuttal. He claims to have been blindsided by the news of the 2019 breach. The reason he didn't find out about it at the time, he writes, is that Keskinen and Lind— the "system architects"—never told him about it.

On the morning of March 15, Vastaamo's servers crashed and the patient database was replaced with a blackmail message. Tapio notified staff of the crash at 11:18 am, but no one appears to have discussed the possibility of a breach in either of the reports submitted to the government.

According to Tapio's testimony, Keskinen and Lind—who shared an administrator account—told him that the crash might have been caused by some minor adjustments they'd made shortly beforehand. But he says that Nixu, the cybersecurity company he hired in September, found something else: The shared account read the ransom message and deleted it.

In Tapio's version of events, then, whoever was using that account covered up the March breach. And the reason they did it, he contends, was to conceal a vulnerability they'd created themselves—one that had left Vastaamo's patient database "without firewall protection" for more than a year.

There were supposed to be three levels of security surrounding the database, Tapio tells me: one firewall at the network level, which blocked connections from the public internet; another around the individual server that stored the patient database; and the server configuration itself, which prevented connections from outside accounts. In November 2017, Lind spent a few hours configuring the server to allow remote access. Tapio believes that Lind and Keskinen wanted to be able to manage the server from offsite, and that instead of going to the trouble of setting up a VPN, they simply peeled back the firewalls.

"Those are two professionals that know much more about the network and firewall and server management than I," Tapio says. "I was not responsible."

Keskinen and Lind have not testified in the Intera case. They declined to comment on Tapio's numerous allegations. Until the dispute is resolved, the $11.7 million that Intera wants back—the fortune that Vastaamo built—will remain frozen.

In early January of this year, the Vastaamo patient database reappeared on at least 11 anonymous file-sharing services across the public internet. The file contained all the same records as before but was a fraction as big, so it spread easily. Without an accompanying message, the motivations for the upload are hard to discern—but it did appear fewer than 48 hours before Vastaamo's board was due to discuss the company's future. Was this a spiteful push to bring the company down?

If so, then it was a success. On January 28, Vastaamo was put into liquidation, and it filed for bankruptcy two weeks later. In early March, its staff and services were transferred to Verve, a provider of occupational welfare services. The acquisition did not include Vastaamo's customer data, and Verve will use a Class A system.

Almost immediately after the hack happened, Parliament fast-tracked legislation that would allow victims like Jere to change their social security numbers in case of a serious breach. But patients were spooked, one counselor told the newspaper *Helsingin Sanomat*. "Not everyone who needed help may have sought treatment," he said. Some argue that therapists should never be able to enter session notes into Kanta; now more than ever, patients will not risk having their data travel beyond the consultation room.

In wider medicine, Koivukangas says, the Vastaamo scandal has highlighted the "unmet demand" for electronic medical record systems that are scalable, easy to use, and—crucially—secure. This is an area ripe for disruption, he says, and "prior to this breach, many thought with good reason that Vastaamo would've been one of those disruptors." Until the marketplace improves, he says, expect more bespoke solutions, and more breaches.

Unless ransom_man is caught and the Finnish authorities sort out everything that happened at Vastaamo, it will be impossible to know exactly how "the incident" began. Would it have happened, for example, if Finland

had been more proactive in policing electronic medical systems? Or if Tapio had implemented a more secure system? What's clear is how it ended —in the most painful way possible for tens of thousands of patients. As more health care systems across the world go digital, the risk of that outcome rises.

"Being honest about my mental health turned out to be a bad idea," Jere says. He worries about identity theft, about some debt collection company calling him out of the blue and demanding tens of thousands of euros. He worries that his history of teenage alcoholism, so well documented on the web, will make it hard for him to find meaningful work as an adult. And he still worries that his mother may read his file one day. It's somewhere in the ether, accessible to anyone.

Photographs: Akseli Valmunen; Getty Images

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The WFH Exodus Creates an Opportunity for Small Cities

Workers from urban centers will continue to work from home, at least part-time. Officials and developers are planning the shops and services they'll want.
During the pandemic, residents were more likely to leave Boston for nearby cities like Natick than exotic, far-off locales. What should these smaller downtowns look like if virus-era habits stick?Photograph: Wangkun Jia/Alamy

Much has been made of the pandemic-era exodus to Lake Tahoe, Martha's Vineyard, or Aspen. White-collar workers, freed of the constraints of the office, last year decamped for more skiing- and hiking-friendly climes—the pandemic's Zoom towns. The locals were annoyed. The labor market was reordered. American life changed irrevocably. Or so the story goes.

But more recent data suggests that Zoom Town USA looks a lot more like Alameda County, California, across the bay from San Francisco. Eighteen percent of those who moved out of San Francisco last year landed there, just a subway, bus, or ferry ride away. Ditto for smaller cities surrounding Boston—Natick, Worcester, and Weymouth.

According to Postal Service data crunched by the real estate firm CBRE, those who picked up stakes during the pandemic were less likely to hightail to the hinterlands than to move to neighboring, less-dense cities, slightly farther from the downtown core. A [*CityLab* analysis](#) found that 84 percent of the people who moved out of the country's 50 largest cities between

March 2020 and February 2021 stayed within the same metro area. An additional 7.5 percent stayed within the same state.

An analysis from the University of Chicago published last week suggests that these office exiles will continue to work from home. Using a series of surveys from 30,000 working-age Americans, researchers estimate that 20 percent of post-pandemic workdays will happen at home, compared with 5 percent before the virus.

That suggests one legacy of the virus could be an upside for smaller cities and bedroom communities. More people might stick around home base—and spend money there. The same Chicago research estimates that the long-term shift to working from home will reduce spending in city centers by 5 to 10 percent. But people will spend *somewhere*.

"People who are working from home still want to go out, either during the day or after work, and they still want to spend their money on interesting things and interesting places," says Bill Fulton, who directs Rice University's Kinder Institute for Urban Research. "If you move from San Francisco, you're not going to want to spend all your money at Applebee's, right?"

Tracy Hadden Loh, a fellow at the Brookings Institution who studies real estate development, puts it another way: "I think annoying people with laptops are going to be everywhere. They're coming for your favorite spot."

The changes have elected officials, city planners, and developers mulling how to plan for this still-hazy future—and asking plenty of questions. Who will live here? Who will work here? Who will drive or take transit here, and when? Most essentially: What kinds of housing should we be building and for what sorts of people?

MassINC, a Massachusetts think tank that focuses on pro-middle-class economic development in the state, this month suggested that employers considering a "hybrid" working model—a mix of in-office and work-from-home employment—consider putting satellite offices in the state's smaller cities, many of which have empty storefronts. It's a win-win, the think tank says: Companies get bigger office space, without the Boston rents, and

smaller places get more tax revenue from commercial tenants and the money workers spend while hanging around a few days a week.

"This is an opportunity for these smaller cities to reposition themselves and capture some of the growth from folks who may want to not live right in the middle of the city anymore," says Andre Leroux, who leads the group's Transformative Transit-Oriented Development program. Places such as Lowell, Springfield, and Worcester do not need to be smaller branches of Boston, he says. "They can assure their historic places as hubs of their region."

Ellen Dunham-Jones is a professor of architecture at Georgia Tech and directs its Urban Design Program. For years, she has tracked the suburban detritus of "dead malls" and underused office parks. She says the pandemic "has accelerated a lot of the preexisting trends"—more developers are buying up more underused malls, strip malls, and office parks. Many have outlined plans to transform them into live-work-play spaces, mixed-use developments that allow suburbanites to access walkable, urban-like space —the fun city parts without the city price tag. Though Dunham-Jones hopes suburban places will continue to adopt urban design strategies, she's not sure how many of these projects will come to fruition. "I think it depends a lot on where they are, the shape of the market. There are reasons to be somewhat skeptical," she says.

City planners and economic development officials recognize that there's an opening here. But most say that the work so far has been the equivalent of building the plane while it's in the air. Work has been quick, a little harried, and focused on helping businesses just make it to the next day. Longer-term economic development—planning for places that might host new stores, restaurants, and housing—is more time consuming. It also demands more information on post-pandemic life.

Weymouth, Massachusetts, is a 58,000-person city south of Boston. Last spring, just before everything closed down, the planning department launched a study of one of the city's three village centers, an area called Jackson Square. The area is next to a commuter rail station and a newly turfed soccer field that draws families to the area. But it doesn't have the

sort of storefronts that might attract nice restaurants or flagship retail stores, says Robert Luongo, the city's planning director.

Now, after a year of an all-virtual planning process—complete with an online walking tour for community members—the town this month released a plan calling for zoning changes that would allow a new mix of housing and business in the area, including multifamily developments and a wider range of retail establishments.

Still, Weymouth planners say they'd love more solid intelligence—and data —about what the future of work and play might look like. "Are people going to work from home more? Are they going to look for some of the amenities around the home that they looked for in the bigger cities—more shops, more restaurants? Is retail going to come back? Are people sick of ordering online and want to touch and feel and look?" asks Luongo. "We don't know what the heck is happening."