

FORTUNE

OCTOBER 1, 2016
FORTUNE.COM

ASIA PACIFIC
EDITION
NUMBER 13

40 UNDER 40

OUR LIST OF
DISRUPTERS,
INNOVATORS &
STARS

The Deep Learning Revolution

WHY GOOGLE &
MICROSOFT
ARE INVESTING
BIG TIME

Europe Bites Apple

A \$14.6 BILLION
BILL FOR
BACK TAXES
CHILLS
U.S. COMPANIES

GM's Startup Geniuses

THE WHIZ KIDS
BUILDING ITS
DRIVERLESS
CARS

Banking's Worst Nightmare

A 22-YEAR-OLD
CODER OUT-BITCOINS
BITCOIN

How Social Media Made 'Hamilton'

A DIGITAL STUNT
HELPS LAUNCH
A BROADWAY
SENSATION

SELFIE COVER PORTRAITS FROM OUR ALL-NEW 40 UNDER 40 LIST: 1. Clay Bavor, VP of virtual reality, Google. 2. Rachel Holt, regional general manager, U.S. and Canada, Uber. 3. Bozoma Saint John, head of global marketing, Apple Music. 4. Scott Farquhar, cofounder and co-CEO, Atlassian. 5. Anthony Tan, cofounder, Grab. 6. Rachel Haurwitz, president and CEO, Caribou Biosciences. 7. Katherine Power, cofounder and CEO, Clique Media Group. 8. Joel Gay, CEO, Energy Recovery.



JASON DAY



RICKIE FOWLER



JUSTIN THOMAS

2 M.A. 2559



JORDAN SPIETH



BROOKS KOEPKA

WHEN YOUR
PERFORMANCE
DEFINES
THE FUTURE,
YOU'VE MADE
HISTORY.

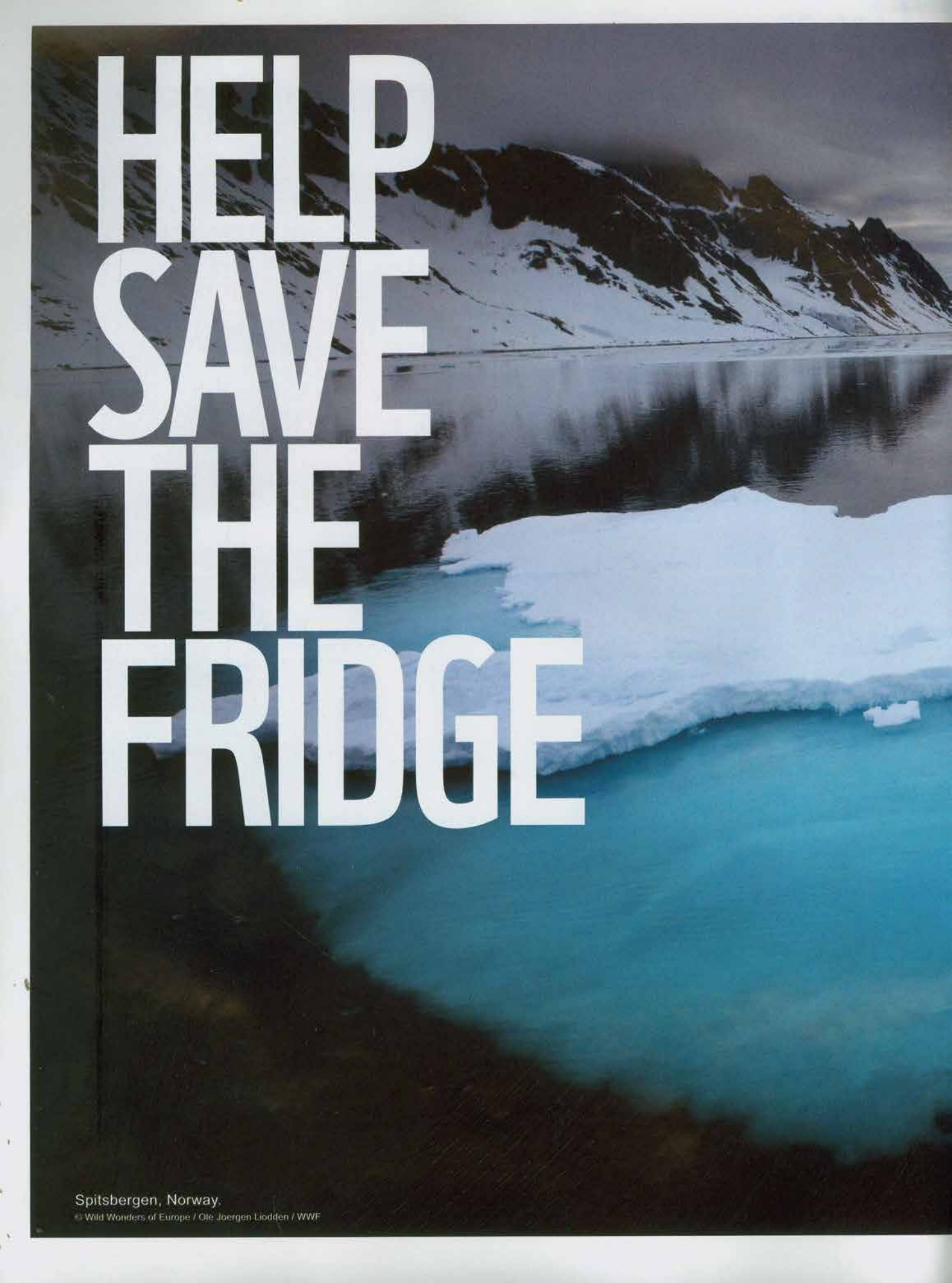
This watch is a witness to golf's next generation. Worn by those destined for great achievements. It doesn't just tell time. It tells history.



OYSTER PERPETUAL DATEJUST 41



ROLEX



HELP SAVE THE FRIDGE

Spitsbergen, Norway.

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FORTUNE

FEATURES

Cruise Automation cofounders Daniel Kan (left) and Kyle Vogt.



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**FORTUNE'S
ALL-NEW
40 UNDER 40**

These are the young stars taking us into the future—our 2016 list of the 40 most influential people in business under the age of 40.

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Kyle Vogt and Daniel Kan just sold Cruise Automation to GM for \$1 billion. But there's no time to enjoy the windfall: They're under crazy pressure as they race to bring a self-driving car to the masses.

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Lin-Manuel Miranda, the 36-year-old creator of the hit musical, talks about trusting his instincts and how he accidentally married the oldest form of entertainment with the newest: social media. INTERVIEW BY

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Dianne McKeever's hedge fund just won its first fight. The next targets are in her sights. CEOs, beware Ides Capital. BY JEN WIECZNER

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BITCOIN?**

Russian-born wunderkind Vitalik Buterin, the creator of Ether, a new cryptocurrency, aims to unleash the power of his blockchain technology to spur radical change in finance, social networks, and even government.

BY ROBERT HACKETT

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**THE DEEP-
LEARNING
REVOLUTION**

Why decades-old discoveries are suddenly changing your life and electrifying the computing industry—and why they'll soon transform corporate America.

BY ROGER PARLOFF



WELLINGTON

Just one more place to love

Singapore Airlines now flies four times weekly to Wellington. Once you're there, take in the brilliant blue skies as you sail around the iconic harbour. Then get acquainted with the unique Māori culture at Te Papa, before enjoying the sweeping views of the entire city from Mount Victoria. Connecting you to more places you love. It's just one of the lengths we go to.

SINGAPORE

SQ291
DEP: 23:00



CANBERRA

TUE, THU, SAT, SUN | SQ291
ARR: 09:35*1 | DEP: 10:50



WELLINGTON

WED, FRI, SUN, MON
ARR: 16:05

WELLINGTON

SQ292
DEP: 21:15



CANBERRA

MON, WED, FRI, SUN | SQ292
ARR: 23:05 | DEP: 00:30



SINGAPORE

TUE, THU, SAT, MON
ARR: 05:50

Schedule is subject to operational changes. All flight timings will change due to daylight savings in Australia and New Zealand.

**1 arrives the next day*



A STAR ALLIANCE MEMBER



FORTUNE

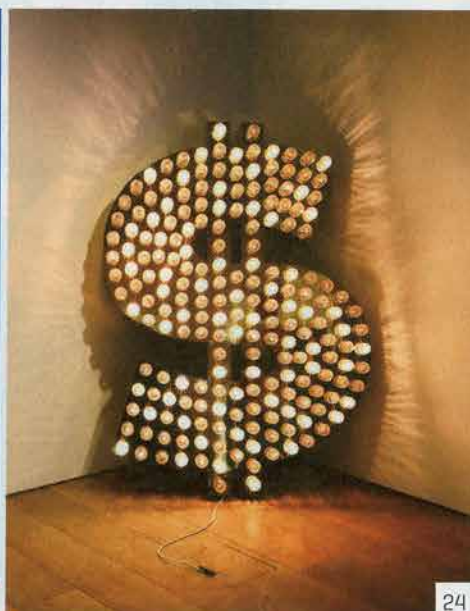
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68 BING!

CORRECTION
In "A Drone for Every Job Site" [Sept. 15, 2016], we misstated the value of the global construction industry. It is \$8.5 trillion. *Fortune* regrets the error.



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OCTOBER 1, 2016

MACRO



CLOSER LOOK

THE EUROPEAN HONEYMOON IS OVER

With a \$14.6 billion salvo fired at Apple over its tax deals in Ireland, European regulators are escalating their battle against American business. BY VIVIENNE WALT

IT HAS BEEN more than 200 years since the U.S. waged war with a European power over taxes. But now a more modern transatlantic struggle is brewing over much the same issue—this time with enormous sums in play. In August, European Union officials ordered Apple to pay a whopping \$14.6 billion in back taxes to Ireland, where it stations key parts of its business. Stunned

at the giant fine, the U.S. Treasury told EU officials the ruling would have a “chilling effect” on trade and alleged that Brussels wanted to inflict pain on the largest U.S. company by market cap.

But this battle extends far beyond Apple. At stake is what happens to about \$2 trillion that U.S. companies are estimated to have stashed abroad, out of reach of the U.S.’s 35% corporate tax. With govern-

GETTY IMAGES; PHOTO COLLAGE BY SINGELAR

ments vowing to crack down on tax havens, the scramble to decide where such levies might go has begun, and several EU countries, including France, Italy, and Germany, believe Apple owes them, too, a slice of those revenues.

No matter how the fight plays out, Apple's fine may signal the end of decades of U.S. companies quietly cutting sweetheart tax deals with smaller EU countries. For years the arrangement suited both sides, with cash-strapped governments scheming to create jobs, and U.S. companies eager to boost profits. "For so long the attitude has been, 'Whatever our lawyers can get away with is okay,'" says Markus Meinzer, director of the London-based Tax Justice Network. That's no longer likely to be the case, he says, calling the ruling "historic and tide turning."

It is no wonder, then, that Irish officials are appealing the Apple fine, even though the money it could claim represents more than 5% of Ireland's GDP: Its economy depends heavily on luring foreign companies with mammoth tax exemptions.

That economic model might now face terminal collapse—not only in Ireland, but also across Europe. Although the cut-rate tax deals are legal, the no-nonsense, stunningly effective EU competition commissioner, Margrethe Vestager, has launched multiple cases, arguing that multinationals have overwhelmed competitors

by shaving billions off their taxes—something smaller businesses have too little clout to negotiate. Last year she ordered Starbucks to pay \$35 million in back taxes to the Netherlands, where it had its EU headquarters until 2014. And she ruled against Fiat Chrysler Automobiles for its dealings in the tiny duchy of Luxembourg, famous for its low taxes. Amazon

and McDonald's could face similar punishment.

Taxes aren't the only issue over which the EU and American business are at war. Google faces three antitrust investigations into whether it abused its market dominance. Facebook may also be a target over its use of WhatsApp data. And Microsoft's plans to buy LinkedIn will need EU approval too. In theory, Vestager could

pick hundreds more businesses to probe, and she has made it clear that iconic companies cannot easily win her over. "A case is a case," she told *Fortune* last year.

Many Europeans are cheering from the sidelines, outraged at Vestager's finding that Apple, the world's richest company, paid a piddling 0.05% in taxes to Ireland on its 2011 profits of 16 billion euros (\$18 billion).

The companies that may be EU regulators' next targets



AMAZON LUXEMBOURG

Regulators are investigating Amazon's low-tax deal in 2003 with the government of Luxembourg, where it has its EU headquarters. Until last year, it booked all sales in Europe to the tiny duchy, giving it an unfair advantage over competitors. EU officials contend. Analysts say the fine could reach \$450 million.



APPLE CORK, IRELAND

Ireland, which has lured many businesses to its shores with tax incentives, is appealing the EU's ruling that Apple pay \$14.6 billion in back taxes to the country—even though it would represent more than 5% of Ireland's 2015 GDP.



GOOGLE DUBLIN

Alphabet's Google faces three separate antitrust cases: over whether it shut out competitors by bundling Google Maps and browser apps on Android handsets, restricting third-party search sites from the AdSense platform, and favoring its own shopping services over other providers' in Google searches. The cases are still under investigation.



STARBUCKS

(FORMER OFFICES) AMSTERDAM The EU competition commissioner last year ordered the Seattle-based coffee chain to pay millions to the Netherlands, where it had long had its EU headquarters, shown above. After a public outcry over tax avoidance, Starbucks moved its EU headquarters to London in 2014.



Apple CEO Tim Cook disputes Vestager's figures, calling the ruling "total political crap," and Apple is preparing an appeal. But Thomas Vinje, a partner at Clifford Chance who represents several U.S. tech companies in EU negotiations, says the response of the European Commission to Apple's reaction is "likely to be along the lines of 'Who the hell do you think you are?'" Facebook and Google also say they have worked within the law.

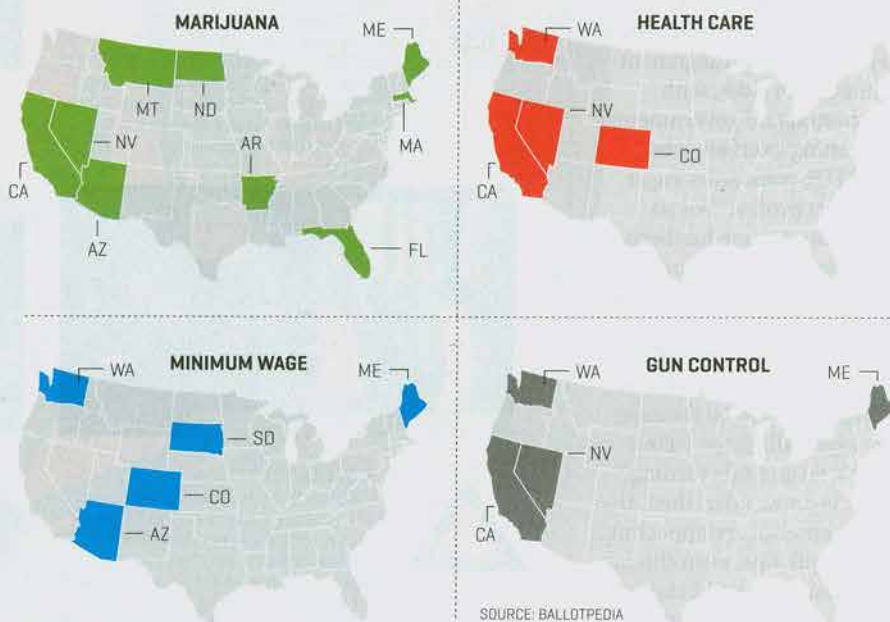
Two major rulings expected this winter will set the tone for the new era. First, an investigation of Amazon could result in a fine of hundreds of millions of euros if the EU finds that it dodged taxes by setting up shop in Luxembourg. Second, McDonald's is also under scrutiny for its low EU tax bill—despite giant profits on the continent.

Yet U.S. companies aren't likely to pull up stakes. The G-20 nations are working on anti-tax-haven rules elsewhere, leaving companies with few good alternatives. Cook says he even intends to expand in Ireland. Apple first set up shop amid Cork's rolling farmland in 1980, when a fresh-faced Steve Jobs tapped a Macintosh computer on Irish TV and said, "It weighs just 12 pounds," adding, "If you don't like what it's doing, you can throw it out the window." Decades later, it's a little more complicated to defenestrate Apple and other U.S. companies, as much as some Europeans might want to. **FB**

ELECTION 2016

POWER TO THE PEOPLE

The chance to weigh in on an unusually consequential presidential contest and control of both chambers of Congress will draw millions to the polls this Election Day. But the stakes are higher still for voters in a number of states that are putting explosive policy decisions directly in voters' hands through referendums. Here's a look at some ballot initiatives that could drive turnout in swing states while resetting the course in key debates. —TORY NEWMYER



SOURCE: BALLOTPEDIA

MARIJUANA

Legal recreational pot use, already on the books in four states, could be vastly expanded this fall when five states weigh in on the issue, and four more vote on medical marijuana. If the measure for recreational legalization passes in California, where it's polling well, it would create easily the largest weed market in the world.

MINIMUM WAGE

Three of the five states considering a minimum-wage change could also help tip the presidential election. Democrats hope initiatives to hike the pay standard in Arizona, Colorado, and Maine will drive their base to show up at the polls, lifting Hillary Clinton's bid in the process.

HEALTH CARE

Of the health care initiatives on the ballot this year, none has drawn as much attention—or money—as Prop. 61 in California. Voters there will decide whether to limit what state agencies pay for prescription drugs to the price paid by the U.S. Department of Veterans Affairs. Drug companies are spending millions to sink it.

GUNS

Gun control advocates frustrated by congressional inaction are aiming for progress in four states. Once again, California is pushing the progressive frontier, proposing a ban on large-capacity magazines.



He's a fan.



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GUAC IS EXTRA

ACTIVISTS GET MOUTH-WATERING RETURNS

AGGRESSIVE INVESTORS ARE INCREASINGLY GOING AFTER FOOD-CHAIN LAGGARDS.

BY JOHN KELL

WHEN ACTIVIST investors want a seat at the table, should restaurant investors give them a warm welcome—or ask for the check?

That's the question for shareholders at Buffalo Wild Wings and Chipotle. Both had suffered sharp stock declines from their summer 2015 all-time peaks—that is, until Marcato Capital Management took a bite of Buffalo Wings and Bill Ackman's Pershing Square Capital recently got a craving for burritos.

Both activists will have a lot on their plates. B-Dubs's same-store sales are falling after years of consistent growth that was once the envy of the industry. And at

Chipotle, a carefully curated "Food with integrity" mantra became a liability after a prolonged *E. coli* crisis. Revenue slipped 20% this year, to \$1.83 billion, and more pain is expected.

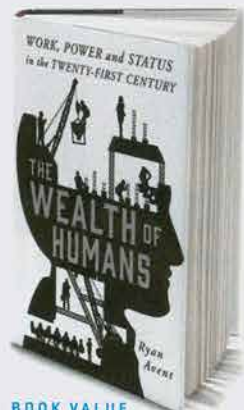
Yet restaurant companies make ripe targets for activists. Most are tiny by market-cap standards, so amassing a sizable stake can be done on the cheap. And investors have scored payoffs for shareholders before. Big wins include Darden

(Starboard compelled it to replace the entire board and boosted sales), Applebee's (sold itself to IHOP under pressure from Breeden Capital Management), and Wendy's (the chain spun off Tim Hortons after Ackman got involved).

While activists often clean house, observers say activism should be taken on a case-by-case basis—not judged by industry. Still, their recent track record implies diners should hold tight for dessert.

Sept. 15, 2015
\$732.08

Sept. 15, 2016
\$413.96



BOOK VALUE

WHAT HAPPENS AFTER THE ROBOTS COME?

The specter of technology automating all our jobs has loomed over American discourse for so long it feels as if it must be exaggerated. But *Economist* senior editor Ryan Avent argues in his compelling new book, *The Wealth of Humans*, that as computers more seamlessly integrate into everything, mass-employee displacement is inevitable and imminent. Government and societal institutions must reform [think new welfare programs] in order to handle the change, he says.

COCKTAIL-PARTY FODDER

Good news for investors, bad news for workers: The share of all income earned from labor has been shrinking since 1990.

—ANNE VANDERMEY

THE SCANDAL CYCLE

WATERGATE HAS COME FULL CIRCLE

WITH HILLARY CLINTON'S LATEST WATER-DRINKING "SCANDAL," THE "-GATE" SUFFIX HAS FINALLY REACHED ITS NATURAL CONCLUSION.



1972 WATERGATE

The scandal to name all scandals brought down President Richard Nixon for campaign abuses.

1976 KOREAGATE

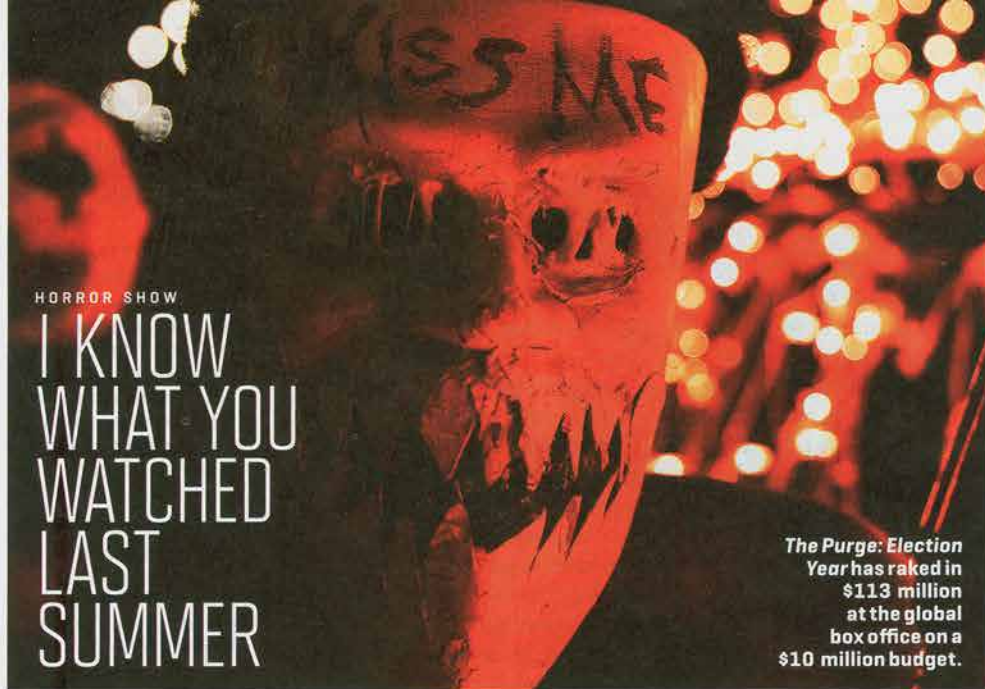
South Korean officials allegedly lavished gifts and money on U.S. congressmen in an attempt to buy influence.



1978 SHOULDERGATE

The Pittsburgh Steelers were caught holding practice in full pads—against league rules.

CHIPOTLE: ALAMY; STOCK PHOTO; BOOK: COURTESY OF ST. MARTIN'S PRESS; NIXON: AP; KOREAGATE: DIANA WALKER—THE LIFE IMAGES COLLECTION



HORROR SHOW

I KNOW WHAT YOU WATCHED LAST SUMMER

The Purge: Election Year has raked in \$113 million at the global box office on a \$10 million budget.

WHAT DO *The Conjuring 2*, *Don't Breathe*, and *The Purge: Election Year* have in common? Yes, all three are aptly named, gore-packed horror flicks. More surprisingly, all three made a killing at the summer box office.

In an otherwise humdrum season, scary movies had a strong showing; four of them cracked the \$100 million mark in global ticket sales. That's nowhere near what typical blockbusters bring in, but it's remarkable

considering their budgets. The genre often relies on unknown actors and basic effects, so costs can be kept to an average of about \$6 million a pop. At that price, a film can break even quickly and often result in fat margins. Consider *Lights Out*, a bloodcurdling tale about a murderous supernatural being. With a shoestring budget of \$4.9 million, the flick brought in \$143 million at the global box office. *The Conjuring 2* cost a slightly

more lavish \$40 million and brought in \$320 million.

That kind of return is attractive in Hollywood, where the performance of big-budget movies—almost always a gamble—has been particularly hard to predict lately. A horror movie, by comparison, is an easy bet. Chances are, even if it flops at the box office, you'll still make your money back. And lately, studios have been making it back in spades.

—MICHAL LEV-RAM



SELFIES RISING THE IPHONE WON, AND DIGITAL CAMERAS LOST

EVERYONE KNOWS that the iPhone handily disrupted the smartphone market, but that's not the only industry that was crushed in Apple's wake. As they say, the best camera is the camera you have with you, and almost half of U.S. adults now carry one built into their iPhone [that number climbs to almost every U.S. adult if you count Android models as well]. As smartphone sales have grown—and Apple and others have continually improved their cameras—fewer people see the need to spend more for a dedicated photo snapper. And sorry, camera makers, the latest iPhone 7 has the best camera yet.

—AARON PRESSMAN AND POLINA MARINOVA

SEEKING A CURE

COULD DECADES-OLD DRUGS LEAD TO A CURE FOR ZIKA? There were nearly 3,000 Zika cases in the U.S. this past summer, including 43 locally acquired in Florida. A vaccine is a long way off, but progress could come from an unlikely place. Dr. Mariano Garcia-Blanco of the University of Texas Medical Branch says several drugs approved long ago to fight other diseases could be effective against the virus. Garcia-Blanco and colleagues recently found that at least 20 existing treatments show promise, including ivermectin, the common head lice medicine. But more studies need to be done to show whether the new [old] drugs will be both effective and safe. —SY MUKHERJEE

1985 IRANGATE

It's better known now as the Iran-Contra scandal, but media at the time also called the illicit arms deal with Iran "Irangate."



1993 NANNYGATE

Two of President Bill Clinton's nominees for attorney general employed undocumented immigrant nannies.

1998 ZIPPERGATE

Monikers for Clinton's indiscretions with a White House intern also included "Monicagate" and "Tailgate."

2003 STRIPPERGATE

A Seattle scandal over a strip-club owner who funneled thousands in campaign cash to city council candidates.

2004 NIPPLEGATE

Better known today as the "wardrobe malfunction," the Super Bowl incident caused nationwide pearl clutching.



CALM AND CARRYING ON

THE BREXIT CRISIS THAT WASN'T

VOTING TO LEAVE THE EU WAS SUPPOSED TO TRIGGER ECONOMIC COLLAPSE IN BRITAIN. WHAT HAPPENED?
BY GEOFFREY SMITH

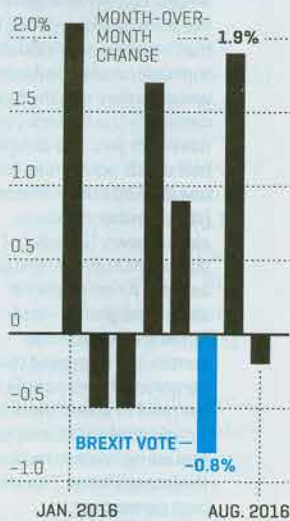
WORLD LEADERS from Barack Obama to the International Monetary Fund's Christine Lagarde had warned the U.K. of economic calamity if it chose to leave the EU. But the first hard statistics coming in since the fateful "Brexit" vote suggest that the sky isn't falling... yet.

According to the Confederation of British Industry, exporters' order books hit their highest level in two years in July, and most expect them to keep rising in coming months. Retail sales climbed in July, and the FTSE 100 companies have

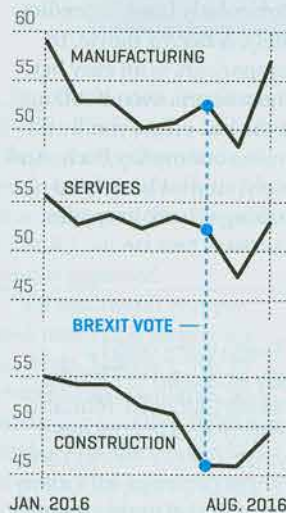
recouped their post-Brexit losses and then some.

So were the doomsayers wrong? Not necessarily. In the short run the U.K.'s first interest rate cut since 2009 (and the 11% drop in sterling that anticipated it) has acted as a shock absorber, just as economics textbooks describe. Of course, Brexit still has the potential to do real harm through new barriers to trade, capital inflows, and labor movement. But at least the first major risk—that of a self-reinforcing spiral of fear and recession—has failed to materialize.

U.K. RETAIL SALES VOLUME



U.K. PMI OUTPUT INDEXES



CHANGE IN U.K. STOCK MARKET



SOURCES: BLOOMBERG, MARKIT, S&P GLOBAL

EXCUSE TRACKER

DONALD TRUMP ATE MY PROFITS

Bad quarter? There are always a bunch of possible explanations for slumping sales—not all requiring a mea culpa from management. That may be one reason companies are growing increasingly fond of citing the election in earnings calls.

—PHIL WAHBA

"The preoccupation with this election is keeping them at home glued to their TVs and their desktops."

LEONARD RIGGIO
BARNES & NOBLE FOUNDER,
CHAIRMAN, TOP SHAREHOLDER,
AND EX- AND INTERIM CEO

"[Consumers are] trying to gauge their financial security going forward, whether through elections or through global events... When families are uncertain, caution starts to prevail, and they start to hold back on spending."

STEVE EASTERBROOK
MCDONALD'S PRESIDENT AND CEO

"There's this incredible uncertainty, distraction, negativity. I would even say, in a small way, fear."

MINDY GROSSMAN (TO CNBC)
HSN CEO

"When a consumer is a little uncertain around their future and really trying to figure out what this election cycle really means to them, they're not as apt to spend as freely."

TODD PENEGOR
WEINER'S PRESIDENT AND CEO

THE SCANDAL CYCLE

2010 ANTENNAGATE

The placement of the antenna on the iPhone 4 caused it to occasionally drop calls if it was held a certain way.

2011 WEINERGATE

That [first] time then-Congressman Anthony Weiner was caught sending sexual messages on Twitter.



2013 BRIDGEGATE

Prosecutors say staffers of New Jersey Gov. Chris Christie caused a traffic jam in Fort Lee, whose mayor didn't endorse him.

2015 DEFLATEGATE

The New England Patriots allegedly cheated in the 2015 AFC championship game by playing with under-inflated footballs.

2016 WATERGATE

A dehydrated and pneumonic Hillary Clinton fell sick at an event on 9/11. She reportedly avoids drinking any water on the campaign trail.





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OCTOBER 1, 2016

PASSIONS & PERKS



Albaisa's Infiniti Q60 was the first American car allowed into Cuba in decades; it's seen here in front of the Tropicana, the iconic nightclub designed by his great-uncle.

ON THE ROAD

A VISIT TO THE CUBAN HOME- LAND

Infiniti's chief designer, Alfonso Albaisa, goes to his parents' birthplace and finds inspiration.

BY SUE CALLAWAY

AS A CHILD growing up in Florida, Alfonso Albaisa heard endless tales about his relatives in Cuba: A great-aunt had been married to José Martí, considered a national hero; a grandfather had been a governor at the time of the revolution; and a great-uncle was an important architect. In August 1962, two years before his birth, his parents fled the island on a secret night flight, paid for with his father's Rolex and Edsel sedan. "My only experience of Cuba was through my family's stories and photos," says Albaisa, Infiniti corporate vice presi-



Residents of Old Havana (above) admire the Infiniti Q60. Albaisa and his cousin (far left) explore the grounds of their grandfather's Havana estate. Albaisa (left) sketches a car for Havana gallery owner Adán Perugorria.

dent and design chief.

So with restrictions on Americans traveling to Cuba loosening, this summer Albaisa visited his family's homeland for the first time. And with Infiniti's blessing, he brought with him his latest effort, the new Infiniti Q60 coupe, making it the first time a new car from the U.S. had entered Cuba in 58 years.

In a four-day whirlwind

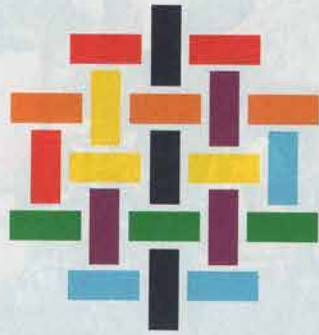
tour, Albaisa met a cousin; visited a onetime Havana estate of his grandfather, the former governor of the province of Camagüey; and saw for himself the clean-lined, mid-century modern architecture of his great-uncle Max Borges-Recio.

Borges-Recio masterminded Club Náutico and the legendary '50s hotspot the Tropicana Club, among other iconic Havana

structures—all of which influenced Albaisa as a designer from the time he was a young boy studying family snapshots of the sites. The flowing rooflines, fender flares, and wheel arches of Albaisa's own automotive work echo the curved forms of Borges-Recio's buildings.

But the last night of the trip, when Albaisa unveiled the Infiniti at a private art gallery, was a highlight

for him. About 150 Cuban designers, architects, and artists showed up to meet Albaisa, and a few students told him that they, too, wanted to design cars. "From the passion in their eyes, I could see that DNA-wise, we are the same," he says, adding, "If my family could escape the island and I could end up designing luxury cars in Japan, then they can do great things too." **FN**



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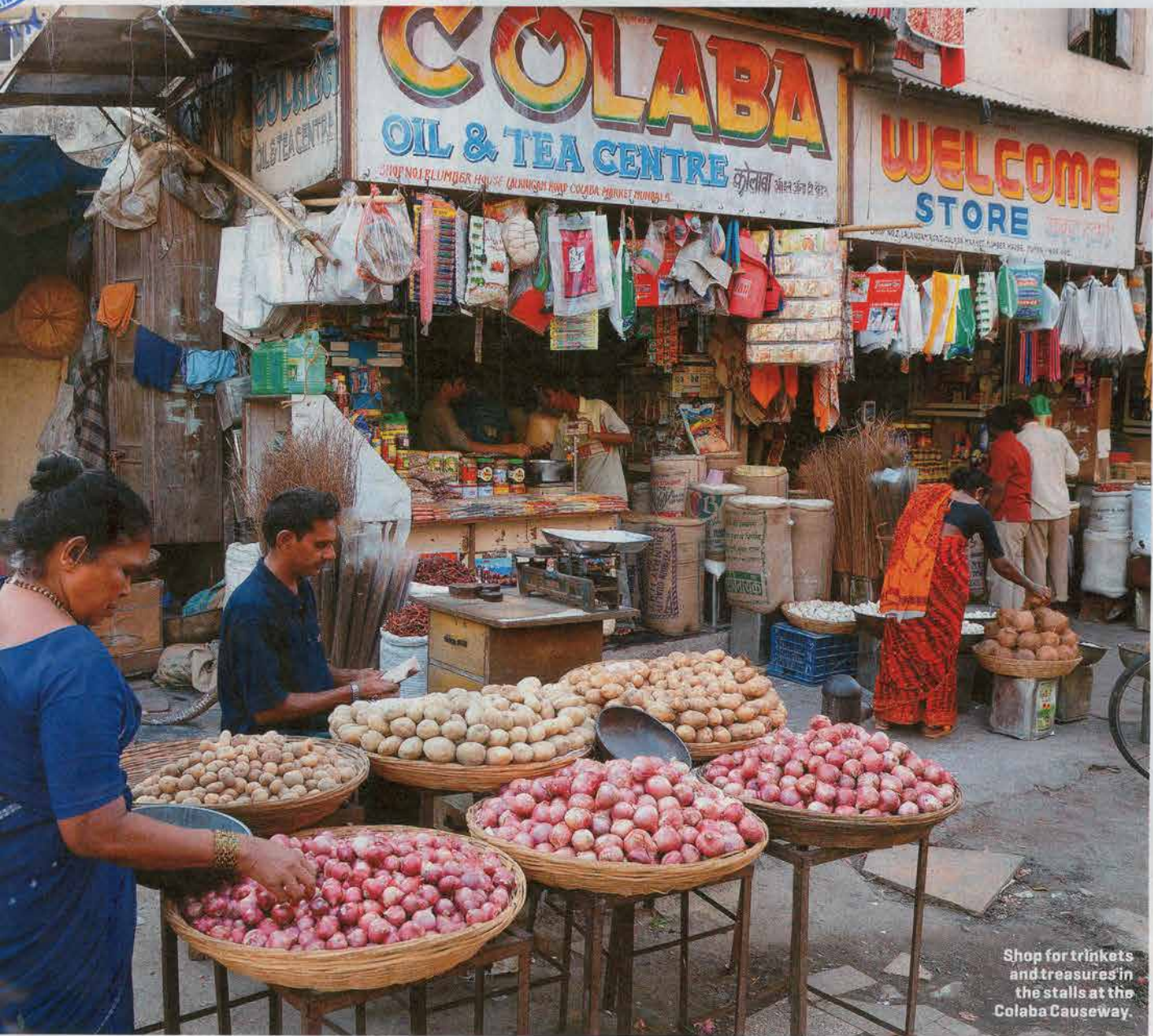


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Shop for trinkets and treasures in the stalls at the Colaba Causeway.

SEE MUMBAI IN A DAY

On a business trip to India's biggest city? Make sure to hit these hotspots. **BY ADAM ERACE**

DECODING THE FRENETIC, densely populated metropolis of Mumbai requires a savvy guide like Satender Tomar, head of a fleet of 35 concierge-like butlers at the luxurious new St. Regis Mumbai. When Tomar's guests want to get an insider's look at the city, previously called Bombay, here's where he sends them.



Best new restaurant:

The owners of Henry Tham's, a defunct, much-beloved Mumbai bar that was known for its world-music nights, just opened **Koko** in the Kamala Mills area. An atmospheric, gray, stone-walled space, the restaurant specializes in Asian gastropub dishes like glazed spareribs, scallop dumplings, and crispy pork belly.

Emerging neighborhood:

Located on the very tip of the tiny peninsula that makes up Mumbai, **Colaba** is a diverse and dynamic section of the city, filled with bustling markets, hipster art galleries, historic monuments, and great places to eat and party. Once considered a tourist trap, the area now draws sophisticated travelers and locals alike thanks to a new wave of trendy establishments.

Cocktail spot:

If you want to blend with the beautiful people of Mumbai, don't miss Thursday's bar nights at iconic **Olive**, which has been in the business for over 10 years. Mediterranean-themed

and elegantly decorated in white, Olive has seating indoors and outdoors in its courtyard. It's also one of the best places in Mumbai for Sunday brunch.

Under-the-radar museum:

Credited as Mumbai's first museum, **Dr. Bhau Daji Lad Mumbai City Museum** showcases the city's cultural heritage and history through a rare collection of 19th-century fine and decorative arts that highlights the early modern period as well as the craftsmanship of various practitioners in the Bombay School of Art. Some of my personal favorites from the permanent collection are the books that document the life of the people of Mumbai and the photographs of old Bombay.

Heat beater:

A great place to veg out, catch the latest Bollywood flick, and escape the heat is the **Regal Cinema**. At the end of Colaba Causeway, it's a hulking Art Deco jewel, hardly changed since it opened in 1933. Don't forget to stand up for the Indian national anthem at the start of the show.



1

[1] A view of Mumbai's famed Bollywood cinema. [2] A look inside the dining hotspot Koko.

Urban escape: If you love the sea, then a must-try experience is a private boat ride to **Alibag**, a coastal town about 75 miles from Mumbai. It's a peaceful place with clean, beautiful beaches, ideal for a quick, stress-bursting escape from the hustle-bustle of Mumbai.



2

THE \$10,000 DAY



We asked Tomar to plan us a bust-the-budget day:

I'd recommend combining two of the "aficionado programs" we offer at the St. Regis Mumbai. The first: a personal shopping experience at Good Earth and an investment in its crockery. Let me know, and I'll put in a word so they monogram your initials. I'd follow that up by planning city-centric shopping: Nirav Modi for exquisite jewelry and Ensemble for clothes with an Indian aesthetic.

Then pop off to a private evening cruise with Rajesh Dullaji, an Asian Games medalist, in a swanky yacht. Our butlers will accompany you and serve hors d'oeuvres and champagne. I'd end the night by reserving the Magazine Street Kitchen, a theatrical kitchen and dining space, and having a local celebrity chef cook you a superlative meal before you head back to the Metropolitan Suite—my favorite—at the St. Regis.

ILLUSTRATION BY MARTIN LANSKAN; CINEMA: DHRUJ SINGH/BLUMENBERG VIA GETTY IMAGES; BAR: COURTESY OF KOKO

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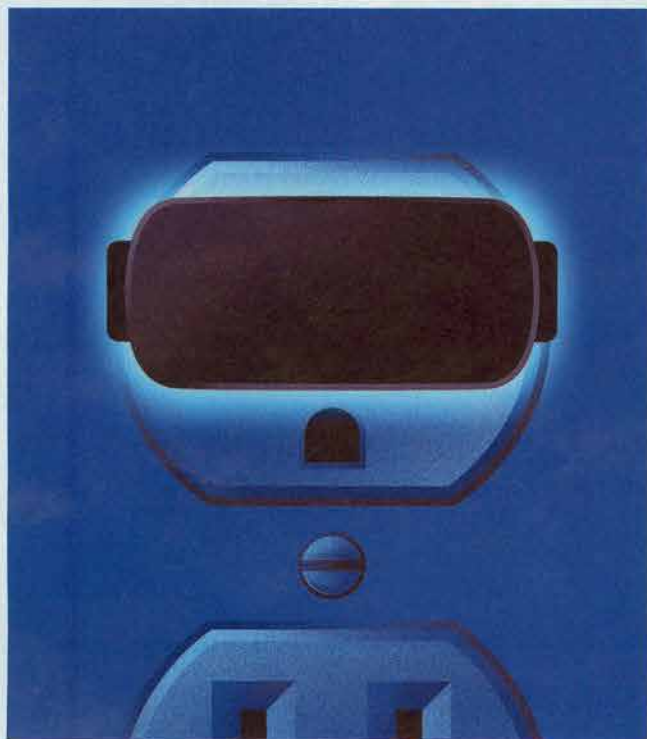


Photo of Ascott Raffles
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VIRTUAL REALITY GOES ELECTRIC

Utility PG&E thinks VR technology may make inspecting equipment faster and safer.

BY JONATHAN VANIAN

FOR AN ELECTRIC UTILITY, a technical glitch could trigger a huge blackout, plunging entire cities into darkness.

Typically such an event would require utility workers to scramble to a faraway substation. But what if they instead strap on virtual-reality headsets and walk through a model of the facility to troubleshoot?

Could technology once seen only in sci-fi films

**"WHEN YOU GO THREE-DIMENSIONAL, YOUR BRAIN OPERATES ENTIRELY DIFFERENTLY."
—ERIC BACK, PG&E**

help a utility company save precious minutes diagnosing a critical problem?

This is the future as envisioned by California utility PG&E, which is working on virtual-reality technology with data-crunching startup Space-Time Insight. PG&E says virtual reality could provide a quicker and safer way for workers to inspect equipment without the risk of getting zapped.

At this point, the experiment is still more dream than reality. Space-Time has created a 3D copy of only one PG&E substation. And during a recent demonstration, that imagery seemed cartoonish—like a 1990s-era videogame. But as virtual-reality technology improves and the testing continues, the companies hope to create more comprehensive and realistic imagery of the utility's electrical grid.

Eric Back, who oversees PG&E's facility infrastructure, says the advantage of viewing data in 3D is that it's more immersive and easier to absorb. Numbers on a computer screen are more difficult to digest.

"When you go three-dimensional, your brain operates entirely differently," Back says.

Workers wearing virtual-

reality goggles, for example, could be alerted to a failing circuit breaker by the image of faux green gas spewing from the equipment. After approaching, they could make a small screen appear showing information like the circuit breaker's age and manufacturer.

Inspecting and maintaining equipment is a huge challenge for PG&E, which has nearly 150,000 miles of transmission and distribution lines. By crunching data, PG&E hopes to better predict when its infrastructure might fail.

That's where Space-Time Insight, based in San Mateo, Calif., comes in. It handles data crunching, hosted on Amazon Web Services, for utilities in addition to selling tools to help those utilities monitor equipment health and performance.

Space-Time Insight built a version of its data-viewing tool using the Oculus Rift, the headset made by the Facebook-owned VR company. PG&E's experiment also relies on the Oculus Rift.

Rob Schilling, CEO of Space-Time Insight, sees a big future for the intersection of virtual reality and data. But headset prices must drop first, he says, and the technology must improve so workers in virtual reality don't get seasick.

"It's still not all the way there," Schilling says, "but it's coming fast." ■

\$2.7 TRILLION EXPECTED SPENDING ON CORPORATE IT IN 2020

IDC

WHEN MOONSHOTS FALL BACK TO EARTH

Google's parent company loved sci-fi research, until it didn't. BY ERIN GRIFFITH

ALPHABET is in a pretty cushy place these days: Its revenue is growing, it has \$78 billion in cash, and its \$500 billion-plus market cap ranks among the top five of all publicly traded companies. The biggest complaint at the company's latest shareholder meeting was the lack of free swag. To investors, Google's parent can do no wrong. And even if it did screw up, investors could do little: Alphabet's dual-class voting structure prevents shareholder meddling.

Such dual-class shares are meant to free companies to experiment—and fail—by handing control to insiders. Companies can invest in long-term innovation instead of obsessing about short-term

gains. At the heart of Alphabet's long-term, fail-friendly strategy are its "moonshots," or wildly ambitious and maybe impossible research projects. Since 2014, those moonshots, from Google Glass to self-driving cars, have gotten more attention than the company's boring old ad business, responsible for 90% of overall revenue.

Alphabet executives always made clear that many moonshots would fail. They never hinted that projects could be killed from within.

Last year, when Google restructured as Alphabet, the corporate rejiggering

felt meaningless. A year later, with the new structure revealing big losses on Google's "Other Bets" (the non-ad businesses), another narrative has emerged: The carefree attitude about experimentation has shifted, and that shift is being felt by money-losing projects.

Reports link the new cost-conscious regime of chief financial officer Ruth Porat, a former Morgan Stanley CFO, with the departures of executives like Google Ventures CEO Bill Maris and Jeff Huber, who helped create lab X (see "Google Gets Disciplined" on Fortune.com).

Meanwhile, the company's most viable moonshot projects are seeking joint ventures to share the cost of turning research into real businesses. In January, Verily, Alphabet's life-sciences moonshot, partnered with GlaxoSmithKline, while its Calico "life-extension" project allied with AbbVie.

Alphabet's most promising bet lately isn't a moonshot—it's in the cloud, where the company is playing catch-up to Amazon. Alphabet is willing to spend freely on cloud computing, including \$725 million for two new software acquisitions. The deals are investments in the future, just different from what we're used to reading about.

Alphabet's moonshots are returning to earth. For now, the bean counters have won. **■**

EXECS NEVER HINTED THAT PROJECTS COULD BE KILLED FROM WITHIN.



"SOON IT WILL BE LIKE BUYING A MICROWAVE."

BGC Financial analyst Colin Gillis on the dwindling excitement for new Apple smartphones

FOR MORE

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INVEST



A visitor studies Andy Warhol's *Dollar Signs* in Sotheby's London showroom.

STOCKS AND THE ART MARKET

WHAT'S GOOD FOR SOTHEBY'S IS GOOD FOR THE WORLD

Art sales are in a two-year slump—and that's a distressing sign for stocks. Why investors are rooting for a rebound for the art market and one of its top auctioneers. BY MICHELLE CELARIER

THIS PAST SUMMER there was a quiet but historic shift at Sotheby's, the venerable art auctioneer. Chen Dongsheng, the founder and CEO of China's Taikang Life Insurance and owner of a Chinese auction house, disclosed in July that he had become Sotheby's biggest shareholder, with a 13.5% stake. This October and November, when Sotheby's and its competitors hold major auctions in London and New York, the art world will be watching to see whether Chen bought a mas-

terpiece at a bargain price or overpaid for a gaudy conversation piece.

Stock investors will be watching the auctions too, even if they don't know a Modigliani from a Grandma Moses, because the fate of the broader art market has implications far beyond the coterie of collectors. Driven

as they are by the fortunes and tastes of the global elite, art sales aren't a direct proxy for the "real" economy. But they correlate strongly with more important indicators, particularly stocks and oil (see the chart). While researchers disagree about whether art leads or lags other markets, robust sales

MARY TURNER—GETTY IMAGES

are a sign that the world's wealthiest people feel bullish—making a hot art market something point-one-percenters and the other 99.9% can be equally excited about.

The market (like the economy) is anything but sizzling right now. Global art sales peaked in 2014 at \$68.2 billion, according to the European Fine Art Foundation. They fell 7% in 2015, and they're on pace to drop by double-digit percentages this year. Investors in Sotheby's, the biggest publicly traded auction house, have suffered in tandem, with the stock tumbling more than 60% from its 2014 highs before a rebound this year.

The collecting class has had reason to be stingy. With crude prices down, oil barons have been sitting on their auction paddles. Flat stock markets have made hedge fund titans more cautious. And a slowdown at home has dulled the enthusiasm of China's collectors. In the near term, demand is expected to remain weak. In an August poll, 87% of art-world insiders surveyed by ArtTactic, a London art advisory, said the market would either stay flat or decline over the next six months.

STILL, IF THE BIG art-sales events this fall surprise to the upside, it could be good news for the global economy. Which brings us to Sotheby's itself. Should investors bullish about a recovery bet on the auctioneer as a leading indicator? This year some

have been doing just that, bidding Sotheby's stock up from a low of \$19 to \$38. Part of that boost reflects confidence in the efforts of the company's previous largest shareholder, activist hedge fund manager Dan Loeb, who amassed a big stake in 2013. At the behest of Loeb—a collector himself—Sotheby's replaced its CEO, overhauled its business model, and leaped into the then-booming contemporary art category. (Think Jeff Koons's balloon dogs, one of which sold for \$58.4 million in 2013, or the off-kilter self-portraits of Martin Kippenberger, which have sold for north of \$15 million.)

Sotheby's is now a strong contemporary player, neck and neck with privately held rival Christie's. The problem: Sales in that category have fallen sharply this year, in what insiders regard as a

bursting bubble. "What we saw in the last five years were some ridiculous prices being paid," says Philip Hoffman, a former Christie's executive and the founder and CEO of the Fine Art Group, an art-investment house. "When the stock and oil markets dried up, those speculators pulled out."

Some investors believe that Sotheby's is now better positioned to weather such slumps. For years, hypercompetition between Sotheby's and Christie's led both houses to promise sellers a guaranteed price to win commissions—a practice that squeezed profit margins. Tad Smith, who became Sotheby's CEO in 2015, says the auctioneer is now "more judicious" about guarantees.

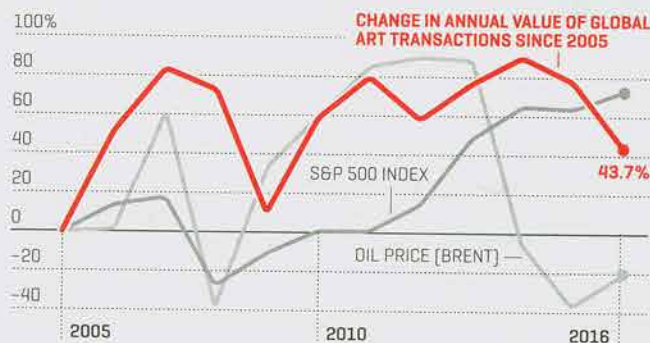
Sotheby's has also moved aggressively into lending to art owners—a promising

revenue source when art sales are down. Borrowing against art lets owners extract value from their collections without having to sell low; lenders, meanwhile, can charge rates much higher than those on traditional loans. Over the past four years, Sotheby's lending has tripled, and loan revenue through June was up 20% year over year, to \$29.5 million. Still, competition may cap that growth. Private equity giant the Carlyle Group entered the lending market last year, and the Fine Art Group will soon do the same—one more reason bears think the stock's recent rise has peaked.

There is, of course, one scenario that could save Sotheby's and the art market from their rut: a resurgence of optimism from deep-pocketed buyers. For that, some dealers are betting on China. Sotheby's biggest coup of 2016 so far is the sale of Jenny Saville's painting *Shift* for 6.8 million pounds (\$9 million)—triple the presale estimate—to the founders of Shanghai's Long Museum. "There are perhaps 2,000 billionaires in China, and only maybe 20 of them are buying quality Western art," says Hoffman. "It's only a matter of time." One of those billionaire buyers? Chen Dongsheng, Sotheby's new top shareholder. If his investment is a sign that China's elite are regaining confidence in their own economy, investors could soon be painting in cheerier colors. **IN**

A BLURRY PICTURE

IN THE ART MARKET, the volume of sales often closely tracks oil and stock prices. A recent plunge in sales, especially of contemporary art, has been a sign of weakness in those other assets.



SOURCES: S&P GLOBAL, EIA, ARTS ECONOMICS; SOTHEBY'S: 2005-15 ARE END-OF-YEAR VALUES. FOR 2016, AMOUNT FOR ART TRANSACTIONS IS PROJECTED; OTHER VALUES ARE AS OF SEPTEMBER.

CHINA'S
HOMEGROWN RIVAL
STANDS STRONG
AGAINST UBER'S
ATTEMPT AT
MARKET DOMINANCE

WESTERN TECH
STILL STRUGGLING
TO BE ACCEPTED
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WHAT DOES "DISRUPTION" EVEN LOOK LIKE ANYMORE? The 22-year-old coder who comes up with an idea that upends incumbents and mints billions may be the image that captures the popular imagination. But in reality, as you'll see in the pages that follow, disruption is everywhere—seeping into all corners of business. We have plenty of founder types: the people behind startups Cruise Automation, Blue Apron, Stitch Fix, and more. But there's also the new CIO of SAP, a mild-mannered 31-year-old who's ushering in not just a digital transformation of the \$106 billion company's business but a rejuvenation of its workforce, or the analytics whiz who's turning Caterpillar into a data-driven company. Disruption is working its way through popular culture too, whether it's Marie Kondo sparking a global decluttering movement, Lin-Manuel Miranda reigniting Broadway, or James Corden blasting onto the scene with a 21st-century comedy franchise that rests on a 19th-century invention: the (nonautonomous) car. These are the names taking us into the future. Disruption has never been this creative. —Leigh Gallagher



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BRENDAN BECHTEL 35

CEO, BECHTEL GROUP

ON SEPT. 1, Bechtel took the helm of his family's century-old dynasty, one of the largest engineering and construction companies in the world (heard of the Hoover Dam or the Channel Tunnel?). The fifth-generation leader now commands one of the biggest privately held companies in the U.S., with \$40 billion in 2015 revenue. It falls on Bechtel, formerly president and COO, to steer the company through challenges like a collapse in commodities prices and new competition from Chinese contractors. He's been preparing for the role since 2010, but he has a lifetime of experiences to draw from: His first stint at a Bechtel construction camp was when he lived in a trailer in the jungle in Borneo while his father worked as a supervisor on a liquefied-natural-gas plant. He was 3 years old.

WE ASKED: WHAT ADVICE WOULD YOU GIVE YOUR 20-YEAR-OLD SELF?

FUN FACTS

"I'D TELL MYSELF TO BE VERY SUSPICIOUS WHEN SOMEONE TELLS YOU A PROBLEM IS IMPOSSIBLE TO

MACKENZIE STROH PHOTOGRAPH BY MACKENZIE STROH; BECHTEL: CLIFF OWEN—AP; KATSUYAMA: STEVE RODGERS—GETTY IMAGES

2. YE JIANMING ³⁹

CHAIRMAN AND EXECUTIVE DIRECTOR, **CEFC CHINA ENERGY**



Ye runs a \$42-billion-a-year oil business in China, [No. 229 on the

Fortune Global 500], yet few in China know much about the mysterious tycoon or the firm he created, CEFC. Ye bought a collection of oil assets in his twenties and secured loans from state-owned banks to expand abroad, a privilege for a private company. CEFC has oil agreements in Kazakhstan, Qatar, Abu Dhabi, and Chad and has gone into ventures with state-owned giants to transport oil to China, making him a rare powerful private player aligned with the Chinese government.

4. EMMANUEL MACRON ³⁸

FORMER FRENCH ECONOMY MINISTER



The boyish maverick sparked outrage by challenging

France's ruling Socialist government to ditch cherished welfare-state orthodoxies and embrace wealth creation. He stepped down in August, fueling speculation that he's running for President; tens of thousands have already joined his new movement, *En Marche!* There are doubters aplenty, but Macron is accustomed to breaking the mold: He married his high school teacher, who was 20 years his senior, then made a fortune as a Rothschild banker.



3. JAKE SULLIVAN ³⁹

SENIOR POLICY ADVISER, **HILLARY FOR AMERICA**



The Minnesota native earned Hillary Clinton's trust as an adviser to her

2008 presidential campaign, and at the State Department, where he was the youngest-ever director of policy planning. After she left, Sullivan stayed on to see through the Iranian nuclear deal he was instrumental in launching. He rejoined Clinton for her second run, expanding his foreign-policy portfolio to include domestic affairs and outreach to businesses. If Clinton wins, look for Sullivan to take a senior White House post, possibly deputy chief of staff.

5. THOMAS SAUERESSIG ³¹

CIO, **SAP**



When the German multi-billion-dollar enterprise software com-

pany tapped Saueressig as its new chief information officer, it made the native of Lobbach, Germany, the youngest-known CIO at a *Fortune* Global 500 company. Saueressig, who began coding at 6, started at SAP while still a student and rose quickly up the ladder. Now the millennial CIO—who's a fan of U2 and *The Big Bang Theory*—is charged with implementing the company's digital transformation strategy from within and shaping IT's role in that strategy.

6

JEFF LAWSON ³⁹

COFOUNDER AND CEO, **TWILIO**

TWILIO BECAME Wall Street's knight in shining armor after a massively successful 2016 IPO, the first and so far only U.S. "unicorn" to brave the public markets this year. A former Amazon Web Services and StubHub engineer, Lawson founded Twilio in 2008 to create a simpler way to add messaging or calls to websites and apps. Now it has almost 31,000 customers, including Salesforce and Uber (which uses it to deliver texts from passengers to drivers); since the IPO, Twilio shares have quadrupled. CEO he most admires: late Intel chief executive Andy Grove.

SOLVE, OR THAT A CURRENT SITUATION CAN'T BE CHANGED." RACHEL HOLT

7. DANIEL KAN ²⁹ KYLE VOGT ³¹

COFOUNDERS,
CRUISE AUTOMATION



In March, General Motors showed how important self-driving

cars are to the future of the auto industry, shelling out \$1 billion to acquire Cruise Automation, a small, yet-to-launch self-driving software startup founded by Vogt and Kan [see the story in this issue]. The deal marked the second billion-dollar exit for CEO Vogt, a robot-obsessed MIT dropout who competed in two seasons of *BattleBots*. It's a first for COO Kan, who has entrepreneurship in his blood—his mother and brother have each founded multiple companies.

8. MIKE CANNON-BROOKES ³⁶ SCOTT FARQUHAR ³⁶

COFOUNDERS AND CO-CEOs,
ATLASSIAN



Atlassian, based in Sydney, is an anomaly in modern-day

techland: The enterprise software firm is 14 years old yet had one of 2015's most successful IPOs. Cannon-Brookes and Farquhar, who met in college in their native Australia, colead the company, which provides collaboration software to 60,000 customers [Tesla, Amazon, P&G, and Coca-Cola among them]. Farquhar heads engineering and research; Cannon-Brookes, product design and sales and marketing.



SELFIE STATION



22 JOE ZADEH
AIRBNB

"You can never provide enough context to your team. It's really easy to forget that people don't know every detail."



21 FIDJI SIMO
FACEBOOK

"You become much more successful when you strive to make the people around you successful."

9. RACHEL HOLT ³³

REGIONAL GENERAL MANAGER,
U.S. AND CANADA, UBER



Uber's efforts in China may have grabbed headlines this year, but back

at home the ride-sharing giant has continued to grow, largely thanks to Holt, who was elevated to run the company's North American operations. A Stanford MBA who worked at Bain and Clorox—where she oversaw Hidden Valley vinaigrettes—Holt joined Uber in 2011 when she was hired to set up the then-fledgling startup's Washington, D.C., operations: "I love finding solutions to problems and doing whatever it takes to get the best end result." Quirkiest habit: Falls asleep watching *Frasier* on her iPad.

10. BILL READY ³⁶

SVP, GLOBAL HEAD OF PRODUCT AND ENGINEERING, PAYPAL



Ready, who grew up in rural Kentucky and never saw a computer until

he got to college, landed at the \$46 billion payments giant in 2013 when it acquired the company he ran, Braintree, for \$800 million. He's since been credited for turning millennial favorite Venmo into the next billion-dollar payments app. With mobile payments expected to soar, Ready's task is to help PayPal take on Apple, Google, and Samsung in the mobile wallet wars. Secret to his success: "I've always been willing to jump in the deep end of the pool before knowing how to swim."

11. JOEY LEVIN ³⁷

CEO,
IAC



The former investment banker runs the \$3.2 billion Internet empire

built by Barry Diller as an "anticonglomerate." His first year as CEO brought the \$460 million IPO of Match Group; now the 13-year IAC veteran is seeking ways to spin off the company's digital businesses, which were restructured in 2016 into six operating units. Next up, the Chicago-area native tries his hand at video site Vimeo, which has more than 280 million monthly viewers: "I look at all that clay and momentum and say, 'There's a lot we can do here.'" First concert: Bob Dylan, with his dad.

12. RYAN SMITH ³⁸

COFOUNDER AND CEO,
QUALTRICS



Smith isn't your typical tech entrepreneur: His online survey

company is based in Provo, Utah, and his cofounders are not fellow techies but include his dad and brother. After bootstrapping for more than a decade, Smith has now raised \$220 million in funding. The company's swanky new offices [ice cream parlor, basketball hoop] might sound right out of Silicon Valley, but unlike many of today's startups, Smith's is already profitable—and expected to go public in the next year or two. Fan of: Diet Mountain Dew.

FUN
FACTS

WHAT'S THE HARDEST DECISION YOU'VE EVER MADE?

"SHUTTING DOWN A PRODUCT THAT PEOPLE WORKED THEIR ASSES OFF TO GET OUT THE DOOR." MIKE CANNON-BROOKES

13. JOEL GAY ³⁸

CEO,
ENERGY RECOVERY



Two decades ago, Gay was playing soccer professionally in Belgium, sporting a bleached-blond hairdo. Today, after climbing the ranks of the business world, he is CEO of Energy Recovery, which makes gear that recycles energy for, among other companies, those in the fracking industry. When he took over in 2015, he became one of the youngest black CEOs of a public company and was able to usher in a game-changing deal with oil services giant Schlumberger. As a result his company's stock has more than quadrupled in value. In the family: His sister is the writer Roxane Gay.

14

BOZOMA SAINT JOHN ³⁹

HEAD OF GLOBAL MARKETING, APPLE MUSIC, APPLE

THE STAR OF APPLE'S annual developers event in June wasn't CEO Tim Cook or a new device but Saint John, who persuaded the audience of thousands to rap to the Sugar Hill Gang's "Rapper's Delight." A former head of music and entertainment marketing at PepsiCo, where she inked its \$50 million sponsorship deal with Beyoncé, Saint John joined Apple in 2014 when the tech giant acquired Beats, for which she led marketing. Since then, she has been charged with making Apple Music into the next big thing—and so far has signed marketing deals with Mary J. Blige and Taylor Swift.

15. BRAD KATSUYAMA ³⁸

COFOUNDER AND CEO,
IEX GROUP



Katsuyama became an instant hero to average Joe investors when Michael Lewis's book *Flash Boys* portrayed his IEX Group—with its alternative trading platform that adds a split-second speed bump to stock orders—as the antidote to front-running by high-frequency traders. His vision became reality this summer when he won SEC approval and officially launched IEX as a national stock exchange alongside the likes of Nasdaq and NYSE. Overall, despite backlash from Wall Street traditionalists, IEX has raised more than \$100 million in funding.

16. KIM POSNETT ³⁹

COHEAD, TECHNOLOGY INVESTMENT BANKING, GOLDMAN SACHS



Posnett headed to Hollywood after college, but after two years (her biggest role was an extra in *Phone Booth*, a 2003 Colin Farrell thriller), she decided to move on. It set up her true starring role: Posnett has become one of tech's most prominent dealmakers, leading deals like crafts retailer Etsy's IPO and Demandware's \$2.8 billion acquisition by Salesforce. "Doing a deal is all about telling a story. And how to tell a story, particularly someone else's story, is something I learned from acting," she says. Most admirers: Angela Merkel.



17. ANTHONY TAN³⁴ HOOLING TAN³²

FOUNDERS, GRAB



While at Harvard Business School, Anthony and Hooling bonded

over the idea of making taxis safer in their native Southeast Asia (both hail from Malaysia). Since then the pair have built a business currently valued at more than \$1.6 billion and operating in over 30 cities. In the past year, Singapore-based Grab has raised \$350 million (and will possibly raise an extra \$1 billion soon), opened an engineering office in Seattle, and partnered with China's Didi Chuxing, India's Ola, and Lyft in the U.S. to serve one another's customers.

18. MATT SALZBERG³³

COFOUNDER AND CEO,
BLUE APRON



Launched four years ago, Blue Apron has quickly gone from a novel

curiosity to a \$2 billion powerhouse and the leader of the "meal kit" pack. The 4,000-person startup passed its six-year sales target in its second year in business and now sells 8 million boxed meals each month, which adds up to \$1 billion in sales. Salzberg attributes the company's success to logistics and its team of agro-ecologists, who work with hundreds of farms to help them grow foods more sustainably and predictably. First concert: Phish.

FUN
FACTS

MATT SALZBERG was a black belt in tae kwon do at age 13. > CLAY BAVOR made a portrait of Abraham Lincoln out of 1,702 pennies.

APRIL UNDERWOOD was concertmistress of her high school orchestra. > RACHEL HAURWITZ has run six marathons in the past five years.



SELFIE STATION



34 APRIL UNDERWOOD SLACK

WHAT ADVICE WOULD YOU GIVE YOUR 20-YEAR-OLD SELF?

"Focus on asking questions instead of answering them."



35 KATHERINE POWER CLIQUE MEDIA

WHAT'S THE HARDEST THING ABOUT MANAGING?

"Scaling the organization while making sure each employee is fulfilled in his or her career."

19. DIANNE MCKEEVER³⁸

COFOUNDER AND CHIEF INVESTMENT OFFICER, IDES CAPITAL



When McKeever launched Ides Capital last summer, she

became the only woman running an activist hedge fund that's shaking up U.S. companies (see the story in this issue). She's already winning her first activist fight: In June, Boingo Wireless, provider of Wi-Fi hotspots, reached a settlement with Ides, agreeing to add three new directors—including the first woman—after Ides criticized its board as "stale, pale, and male." Boingo's shares have risen more than 20% since McKeever announced the campaign. Hobby: She's a "hard-core videogamer."

21. FIDJI SIMO³⁰

DIRECTOR OF PRODUCT, FACEBOOK



You won't find video production skills on this French-raised, former

eBay strategist's résumé. Yet Simo heads one of Facebook's most important features to date, according to her boss, Mark Zuckerberg: live-streaming service Facebook Live. Video has long been huge for Facebook, but Facebook Live started life in 2015 as a promotional tool for celebrities and has evolved into a powerful—and polarizing—spotlight on social crises, capturing several chilling shooting deaths that became news events. Most admires: Bob Iger.

20. MATT MULLENWEG³²

FOUNDER AND CEO,
AUTOMATIC



More than a quarter of the web runs on WordPress's blogging software.

Although the Texas native has built a healthy business out of parent company Automattic—it now has 500 employees and its first marketing chief and recently raised \$160 million at a \$1 billion-plus valuation—he's focused on the long term, he says. That's why he's doing his best to avoid an IPO (for now at least) and continues to run the WordPress Foundation, whose mission is to keep the blogging software freely available to all. Fun fact: He's a fan of qwerty keyboard alternative Dvorak.

22. JOE ZADEH³⁵

VICE PRESIDENT OF PRODUCT,
AIRBNB



Zadeh, the son of Iranian immigrants, got a Ph.D. in bio-engineering

but fell in love with product design after learning to use Photoshop. In 2010 he found his way to the then-nascent home-sharing startup, where he joined as the ninth employee. Today "Joebot," as he's known around the office, leads product efforts for the company, which hit 100 million users this summer. Up next, Airbnb plans to help guests experience more than just a local roof, and Zadeh's job as the "conductor" of Airbnb's apps and website will be more important than ever.

Homework in backpack, backpack on kid, kid on bus. Gold star.

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23. RACHEL HAURWITZ ³¹

PRESIDENT AND CEO,
CARIBOU BIOSCIENCES



She thought she was going to be a biotech patent IP lawyer, but

Haurwitz's love of science propelled her in another direction: partnering with famed biochemistry researcher Jennifer Doudna to cofound Caribou, one of the leading startups pursuing commercial applications of the genome-editing tool Crispr. So far Crispr-based research has largely focused on cancer, but the Texas native says Caribou's gene therapies hold promise for modifying the body's microorganisms to treat other illnesses. Her hobby: knitting.

25. SOPHIE WATTS ³⁰

PRESIDENT,
STX ENTERTAINMENT



Watts' mission at STX, an ambitious Hollywood studio founded in

2014, is to build out its various divisions: film, TV, digital, and music. Launching a new entertainment conglomerate is no small feat, but Watts has the pedigree—she cut her teeth working on productions with the likes of Beyoncé, Elton John, and Madonna (and her late mother, Tessa Watts, was a lauded record executive and music-video producer). STX is well capitalized, giving Watts \$7 billion over the next five years for developing and distributing films alone. Admires: Richard Branson.

27. JON STEIN ³⁷

COFOUNDER AND CEO,
BETTERMENT



In 2010, when Stein was launching his New York City-based "robo-

adviser" startup, plenty of grizzled banking veterans told him he would never reach \$5 billion in assets under management. The warnings were "intimidating," he says, but they didn't stop him: Betterment now has almost \$6 billion in AUM for its 175,000 customers, making it the largest startup in the wealth management industry. In January the 200-person company launched Betterment for Business to help companies manage their employees' 401(k) plans.

29. KATRINA LAKE ³⁴

FOUNDER AND CEO,
STITCH FIX



Lake has grown online styling service Stitch Fix into a force in the retail

world. Customers of the subscription service receive regular "fixes," or boxes of clothes it curates using a mix of data analytics and human artistry; patrons can either purchase them or send them back. Outside revenue estimates for 2015 hover around \$250 million, with reportedly less than \$50 million in outside funding. This year Stitch Fix hired over 2,000 people and expanded into menswear and women's footwear. Look for a plus-size offering in 2017. Most admires: Reed Hastings.

24. CLAY BAVOR ³⁴

VICE PRESIDENT OF VIRTUAL REALITY, GOOGLE



A veteran Googler and Princeton computer science grad,

Bavor heads the search giant's ambitious new virtual-reality unit (motto: "VR for everyone"). Reporting directly to Google CEO Sundar Pichai, Bavor oversaw this year's launch of the company's new VR operating system along with the debut of its own headset, controller, and hardware blueprints for other manufacturers to build on. Now it falls on Bavor to make VR mainstream—and to beat out front-runners like Facebook's Oculus VR and HTC's Vive.

26. MORGAN VAWTER ³⁵

CHIEF OF ANALYTICS,
CATERPILLAR



As head of Caterpillar's analytics team, the former Accen-

ture consultant has been tasked with transforming the 91-year-old bulldozer and hydraulic mining shovelmaker into a "digital first," data-driven company. Her 120-person group has been overhauling internal processes and developing new, customer-facing software services, like a tool that uses sensor-based data to predict when equipment will wear out long before it does. The division is also experimenting with drone data to optimize large job sites.

28. TIM FERRISS ³⁹

AUTHOR AND HOST,
THE TIM FERRISS SHOW

ADAM GRANT ³⁵

PROFESSOR OF PSYCHOLOGY,
WHARTON SCHOOL,
UNIVERSITY OF PENNSYLVANIA



Ferriss turned his *4-Hour Workweek* into a mega-

franchise; now his podcast, with over 80 million downloads, drives sales of any product he mentions. Grant is the management consultant of the moment to the biggest names in tech and business. Both gurus are penning their next works: Grant, a book on resilience with Sheryl Sandberg; Ferriss's tome is *Tools of Titans*.

30. LIN-MANUEL MIRANDA ³⁶

COMPOSER, LYRICIST,
AND PERFORMER



The creator of the Broadway and pop-culture sensation

Hamilton: An American Musical thought it would be a hit only with history teachers. How wrong he was: The 2015 show about the life of Alexander Hamilton has grossed more than \$100 million in ticket sales and become the year's cultural sensation, including a soundtrack that hit the Billboard top 10, *Hamilton*-themed indoor cycling classes, and a book. That's on top of the awards: a Grammy, 11 Tonys—oh, and Miranda's Pulitzer. [See our interview in this issue.]

FUN FACTS

JOE ZADEH has no sense of smell. ▶ ALEX SKATELL admires FedEx founder and CEO Fred Smith.

KATRINA LAKE was a lifeguard in high school and college. ▶ JOEL GAY says politics will be the next arena he competes in.

31. VITALIK BUTERIN ²²

CREATOR, ETHEREUM

"MOXIE MARLINSPIKE"

30s, FOUNDER,
OPEN WHISPER SYSTEMS



Buterin, born outside Moscow, is a programmer whose billion-

dollar crypto-creation is Bitcoin's biggest rival (see the story in this issue). Marlinspike, a dreadlocked hacker and self-identified anarchist, is the ex-head of Twitter's security team. His coding crew has developed what many deem to be the best encryption tools on the planet, used by WhatsApp, Facebook Messenger, and Google's Allo.

32. PAYAL KADAKIA ³³

FOUNDER AND CEO,
CLASSPASS



With the launch of ClassPass in 2013, Kadakia created a

next-generation gym membership that let users book an unlimited number of fitness classes at a variety of studios for a flat, month-to-month fee. Now in 39 cities and armed with \$84 million in funding, the company is focused on profitability. In the past 15 months, ClassPass rolled out tiered packages and raised prices 50% in some markets. As Kadakia tries to balance the needs of partner studios and members, the classically trained dancer will have to show off her fanciest footwork yet.

33. PAUL JUDGE ³⁹

COFOUNDER AND CEO, LUMA;
COFOUNDER AND EXECUTIVE
CHAIRMAN, PINDROP SECURITY



The Atlanta-based entrepreneur and computer science Ph.D. got

his start as a spam email blocker. He joined junk-mail eradicator CipherTrust in 2000, rising to become chief technology officer. After the company's sale to Honeywell spinoff Secure Computing, Judge founded PureWire, an Internet traffic scrubber that Barracuda Networks scooped up in 2009. Two years later he cofounded phone-fraud-fighter Pindrop Security. Now he leads Wi-Fi device maker Luma—and invests in startups like Amazon-backed data shielder Ionic Security.

34. APRIL UNDERWOOD ³⁶

VICE PRESIDENT OF PRODUCT,
SLACK



This software developer's idea of a sab-

Starting an all-female investor group during the four-month gap between her previous job as Twitter's director of product and joining Slack, a \$3 billion hyper-hot corporate-messaging startup. During her first year heading product strategy, the number of active users relying on the service tripled to more than 3 million. Her latest project: an \$80 million fund for startups that buy into Underwood's vision of turning Slack into a hub for everyday business tasks like arranging transportation.



35

KATHERINE POWER ³⁶

COFOUNDER AND CEO, CLIQUE MEDIA GROUP

FOUNDED BY POWER in 2006, Clique Media Group (CMG) operates multiplatform women-focused media brands, including WhoWhatWear, Byrdie, Obsessee, and MyDomaine, and has quietly scaled up without the piles of venture capital common to new media startups. (It even turned down an offer to sell to Yahoo.) The profitable, L.A.-based company is set to grow revenue by nearly 100% this year after launching a clothing line with Target; a new app and a shoe line are in the works, too, and a Power-penned advice book came out this spring.

► **PAUL JUDGE** likes to brainstorm ideas on hotel notepads. ► **ADAM GRANT** is a fan of the Barenaked Ladies. ► **MARIE KONDO** doesn't own a television.

► **JOEY LEVIN** speaks to things around the house. ► **HOUI LING TAN** breaks out into "little jigs in the office" when she's happy.

36. MARIE KONDO ³¹

AUTHOR AND FOUNDER, THE KONMARI METHOD



Professional organizers have long preached the emotional benefits of decluttering the home, but it wasn't until Kondo that the subject became a global fixation. Her organizational advice comes with instructions as quirky as they are precise. You should hold your belongings one by one: If an item "sparks joy," keep it; if not, thank it for its service and let it go. Her KonMari Method has attracted legions of fans, and her breakout book, *The Life-Changing Magic of Tidying Up*, has been on the *New York Times* bestseller list for 99 weeks.

37. JACOB LIEF ³⁹

COFOUNDER AND CEO, UBUNTU EDUCATION FUND



Instead of helping a lot of people in one area, say, health care or education, Lief's Ubuntu is working with 2,000 children in one place—Port Elizabeth, South Africa—to help meet *all* their needs, from prenatal tests to education to medical care and counseling, from the womb to adulthood. That formula was novel enough to win Bill Clinton and Desmond Tutu as major supporters and attract a six-figure donation from Trevor Noah. Now, to scale the idea, Lief is building an institute in New York dedicated to helping other would-be do-gooders set up their own narrow-but-deep charities.

38. CARLY ZAKIN ³⁰

DANIELLE WEISBERG ³⁰

COFOUNDERS, "THE SKIMM"



Zakin and Weisberg have found a huge following for their millennial, women-focused daily email newsletter. Covering everything from the presidential election to North Korean nuclear developments in a cheeky, irreverent voice, "The Skimm" has amassed more than 3.5 million subscribers, and recently raised \$8 million in funding and launched its first product extension, a calendar app. Next up: a new video venture, Skimm Studios.

39. ALEX SKATELL ³⁰

FOUNDER AND CEO, IJR



You may not have heard yet of the IJReview, the conservative news site Skatell founded four years ago, but its traffic now rivals that of the right's most recognizable online news brands, including Drudge and Breitbart. Skatell is no stranger to the official Republican apparatus: He started out as the digital guru for the Republican Governors Association. And while he's a full-time entrepreneur now, as his party struggles through an identity crisis, he's building out a platform that could help it reach the younger voters who will be vital to its rebirth.

40

JAMES CORDEN ³⁸

HOST, THE LATE LATE SHOW WITH JAMES CORDEN

THE BRITISH-BORN star of CBS's *The Late Late Show With James Corden* catapulted to fame this year with the runaway success of "Carpool Karaoke," the addictive, happy-making series that features him driving around with A-list celebrities and musicians and singing along to their hits or favorite songs. His episode with Michelle Obama has garnered 43 million views. No wonder Apple bought the rights to the series. [While Corden is unlikely to star in the Apple shows, he will serve as producer.] As for his TV show? It just won two Emmys.



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SELFIE STATION



17 HODI LING TAN
GRAB

"My first three months at McKinsey, I felt like a fish out of water. Having trained as a mechanical engineer, I knew nothing about what it takes to be a consultant."

17 ANTHONY TAN
GRAB

"Never procrastinate. Just get it done right away. I don't wait until I get home—I take calls wherever I am. I execute on any feedback I get right away. That way, the work never piles up."



33 PAUL JUDGE LUMA

"Too often 'Fail fast' is used as an excuse to give up prematurely."



32 PAYAL KADAKIA
CLASSPASS

"Each one of our low moments was necessary to get where we are today, so I'm grateful for all of them."



38 DANIELLE WEISBERG AND CARLY ZAKIN
"THE SKIMM"

"Don't be so attached to your plans; enjoy the adventure." ZAKIN



8 SCOTT FARQUHAR
ATLASSIAN

"Most of the opportunities we've missed at Atlassian we missed because we were too cautious."



24 CLAY BAVOR
GOOGLE

"I love reading about big, complicated engineering projects and the people behind them: the Panama Canal, the Wright brothers' first aircraft, the Brooklyn Bridge."



13 JOEL GAY
ENERGY RECOVERY

"As with most hypercompetitive individuals, I struggle to embrace the virtue of patience."

FUN FACTS

ANTHONY TAN most admires Masayoshi Son, founder and CEO of SoftBank. > SOPHIE WATTS' first concert was George Michael.

DANIELLE WEISBERG eats peanut butter every day. > BRAD KATSUYAMA meditates on the train to work.

DRIVEN

IN

Kyle Vogt and Daniel Kan just sold **CRUISE AUTOMATION** to **GM** for \$1 billion.

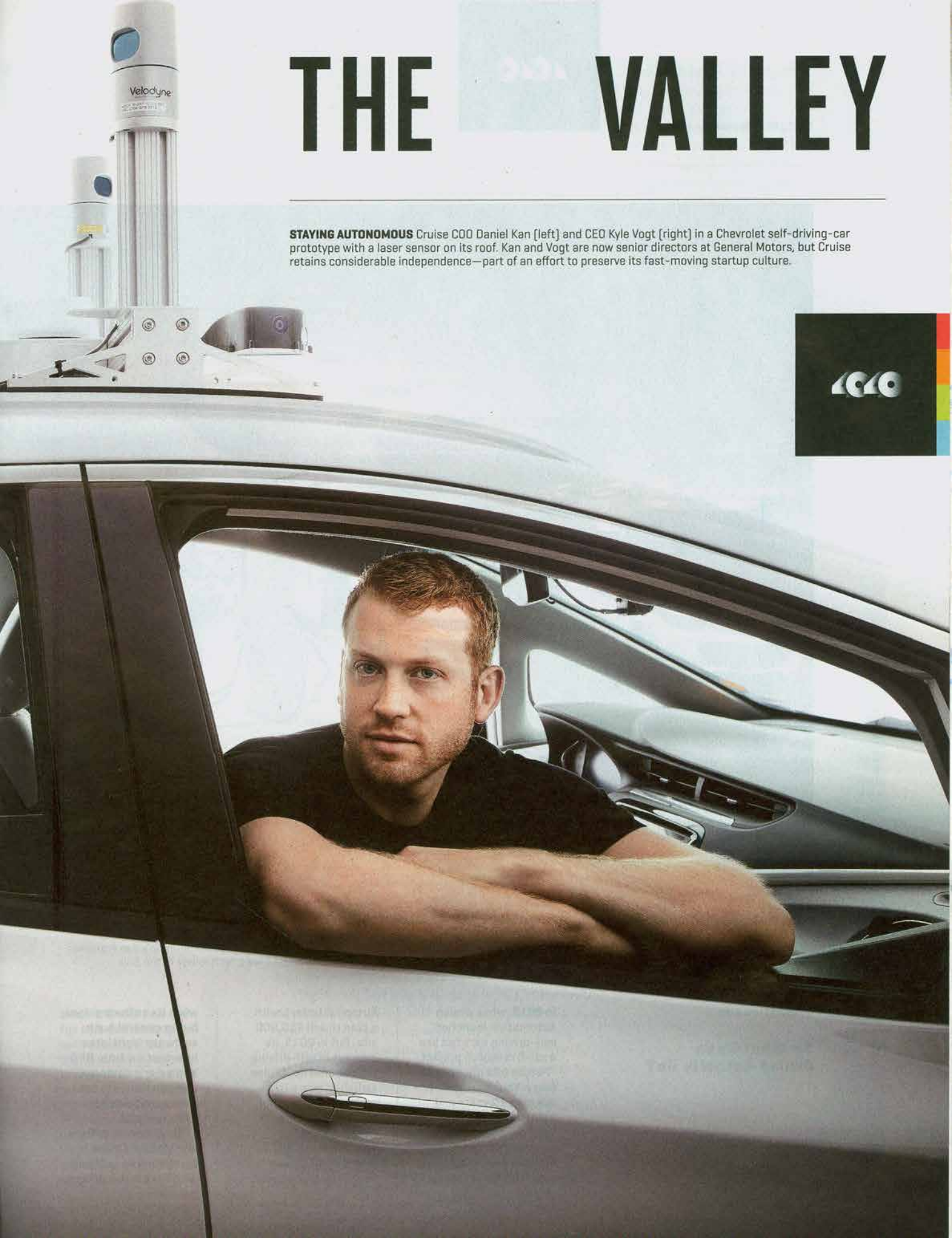
But there's no time to enjoy the windfall: They're under crazy pressure as they race to bring a self-driving car to the masses.

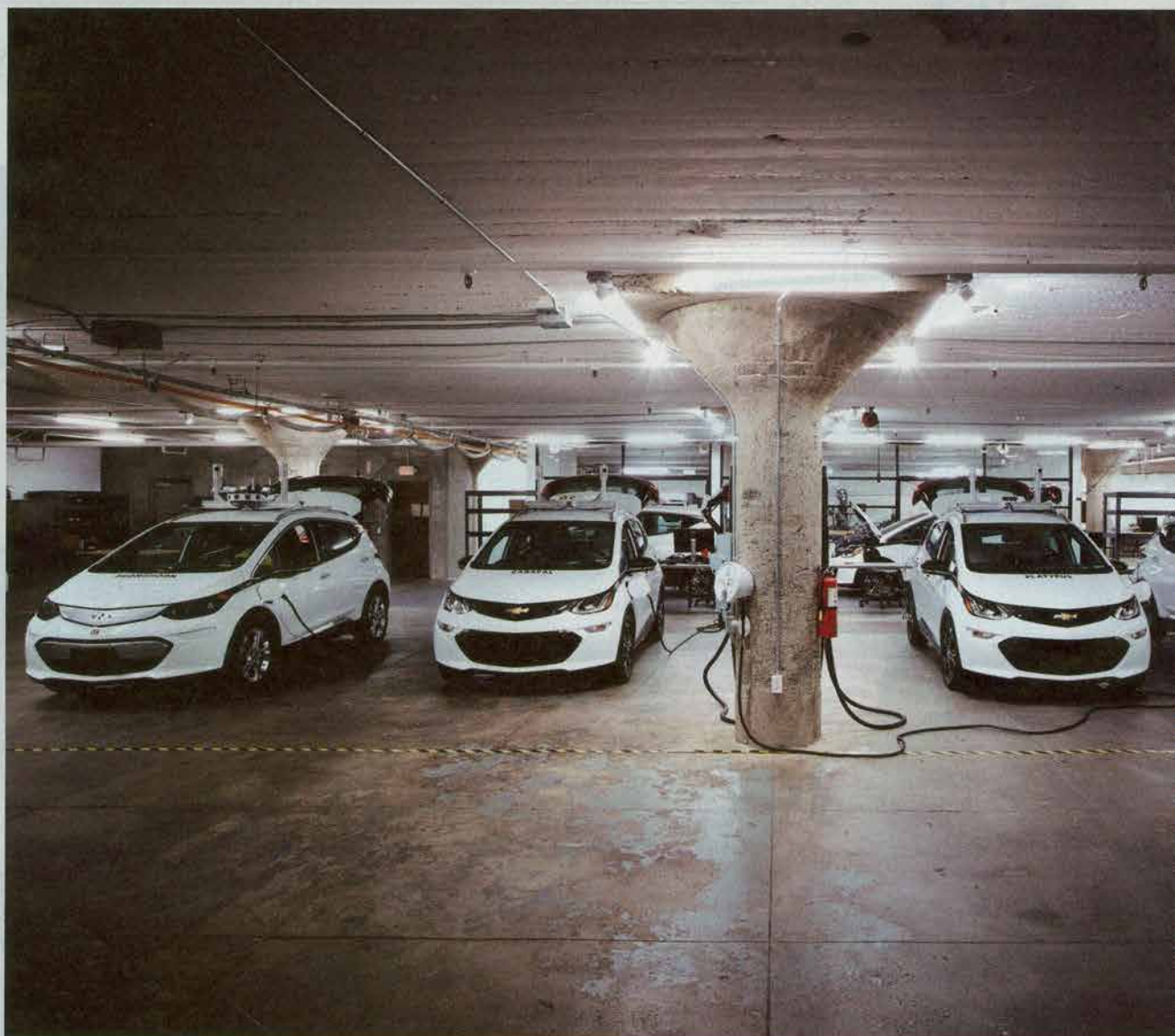
by **ERIN GRIFFITH**



THE VALLEY

STAYING AUTONOMOUS Cruise COO Daniel Kan (left) and CEO Kyle Vogt (right) in a Chevrolet self-driving-car prototype with a laser sensor on its roof. Kan and Vogt are now senior directors at General Motors, but Cruise retains considerable independence—part of an effort to preserve its fast-moving startup culture.





DRIVERS NOT REQUIRED Electric-powered Chevrolet Bolts in Cruise Automation's San Francisco garage. Cruise is working with GM to add autonomous-driving technology to the Bolt.

● AUTOMATION 101

So What Does Cruise Actually Do?

40 FORTUNE.COM

In 2013, when Cruise Automation launched, self-driving cars felt like a sci-fi research project. "People told me, 'You're crazy. You're an idiot. It will take 10 years and \$100 million,'" CEO Kyle Vogt says. So he devised a system to retrofit any car with partial autonomy [similar to Tesla's

Autopilot today], with a plan to sell \$10,000 kits. But in 2015, as interest in self-driving tech heated up, Cruise switched gears to a more audacious goal: building software for fully autonomous vehicles. For competitive reasons Cruise won't say much about

what its software does, but in general such software translates information from GPS and a car's cameras and sensors into data the car can use to self-navigate.

Now, as part of General Motors, Cruise is combining its software with GM's forthcoming



electric Chevy Bolt and the Lyft ride-hailing network. Together they'll launch a robotaxi service—a possible predecessor to a mass-market driverless car. Of course, they've got competition: Google, Uber, Ford, and others are aiming at similar targets.

STATISTICALLY SPEAKING, most of us will never build a billion-dollar company. We definitely won't build two of them. If any of us did pull that off, we'd most likely feel pretty satisfied with ourselves. We'd retire. Travel the world, maybe. Do a TED Talk, definitely.

Most of us are not like Kyle Vogt, who at the age of 31 has already built two startups that sold for \$1 billion. He and Daniel Kan, his cofounder and COO at Cruise Automation, have recently become the youngest senior directors at General Motors, a role most auto-industry lifers would have to toil for three decades to get a shot at. Vogt and Kan got there in just three years because Vogt built self-driving car software so compelling that GM had to have it. In May the country's largest automaker shelled out \$1 billion (including incentives for performance) for Cruise, a 40-person startup, before it even launched a product. And before Cruise, Vogt cofounded Justin.tv, a pioneering live-streaming business that eventually evolved into Twitch, a videogame-streaming site that was sold to Amazon for \$970 million in 2014.

One of those accomplishments might be enough for a normal human being, but Vogt operates in Silicon Valley, the land of insatiable ambition. Success by normal standards wasn't enough for Elon Musk or Steve Jobs or Larry Page. And it isn't enough for Vogt, Kan, and the guys (yes, all guys) in their tight-knit crew of equally accomplished, equally young friends from Justin.tv.

Vogt won't feel like a success until Cruise fulfills its mission: making self-driving cars a reality. Not just a prototype or a few cars in a test market, but fully autonomous vehicles, out in the world, by the millions, in a way that increases access to transportation, reduces congestion and pollution, and, most important, saves lives. To put it in Silicon Valley-speak: He wants to make the world a better place.

Sitting in a conference room at Cruise's warehouse-style office in San Francisco's SoMa

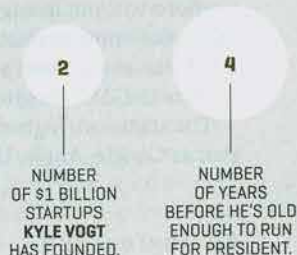
neighborhood, Kan, sporting the startup uniform of jeans, T-shirt, and hoodie, matches that Valley platitude with another. "I've always heard, 'The first time you start a company, you want to get rich. The second time you start a company, you want to build a legacy.'"

"That's going to be quoted," Vogt warns from across the table. (Yep!) Vogt quickly clarifies that Cruise isn't Kan's first startup either. "It's not the get-rich one."

The startup game has made millionaires out of the people in Vogt and Kan's network of friends and colleagues, but they'd never say they're in it for the money. "Your startup should be what you want the first line in your Wikipedia entry to be," says Michael Seibel, a Justin.tv cofounder who is now CEO of the famous startup accelerator program at Y Combinator (YC). "It's your life's work."

Vogt, a reserved, media-shy Midwesterner, does not have a Wikipedia page yet, but self-driving cars are clearly his life's work. He's been passionate about them since participating in the 2004 DARPA Grand Challenge as an undergrad at MIT. At Cruise's office, he rattles off the ways self-driving cars will improve society, alongside auto fatality stats (35,000 deaths last year in the U.S.). Now, under the umbrella of GM, his

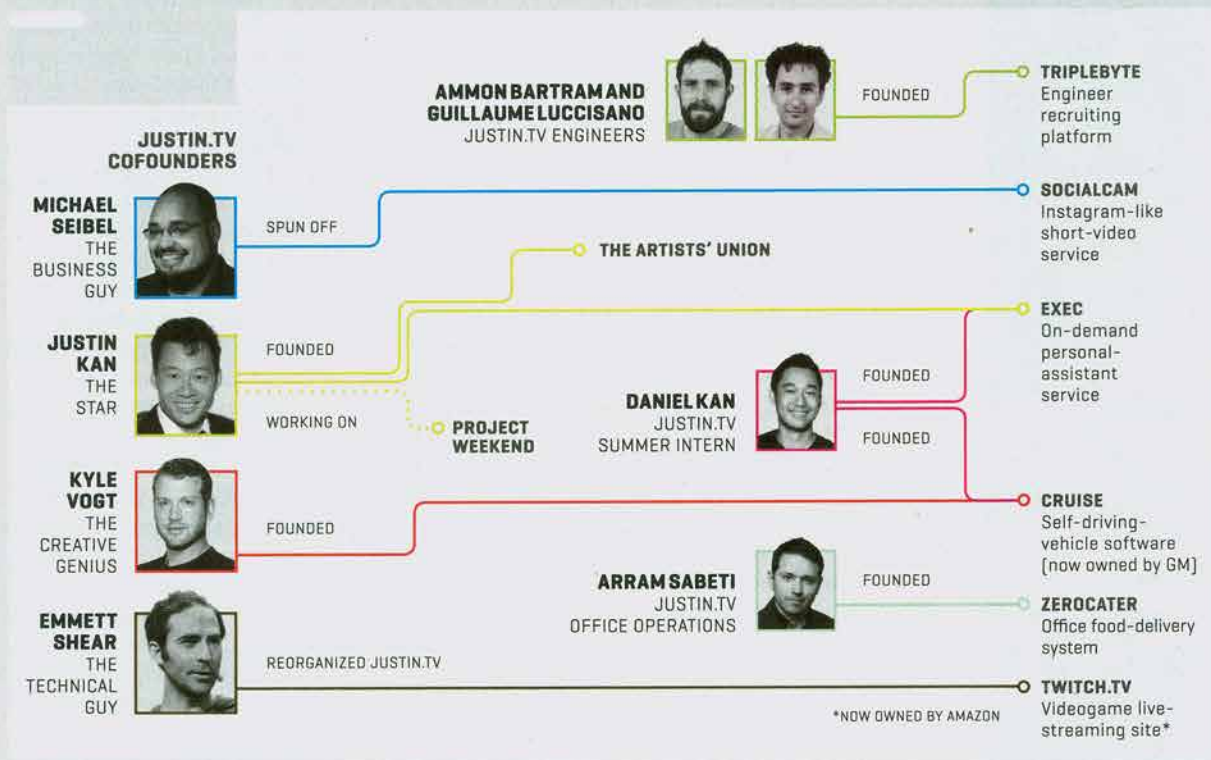
INFO BUBBLE



FAMILY TREE

How the "Justin.tv Mafia" Got Made

The live-streaming video site Justin.tv never quite succeeded as a business. But it attained near-mythic status thanks to the achievements of its cofounders and early employees, the "Justin.tv mafia." Not coincidentally, two of those founders, Justin Kan and Michael Seibel, are top-ranking figures at Y Combinator, a startup accelerator that mentors entrepreneurs—and which funded most of the gang's later projects.



tiny software company has a chance to vastly expand its impact.

But to cement his legacy, he must pull off an even rarer feat—a startup acquisition that actually works. Bright-burning startups tend to fizzle after selling to larger companies. Vogt and Kan must figure out how to navigate the politics and red tape of their new corporate overlord without losing any of the fast-moving startup DNA that made them so attractive to GM to begin with.

The stakes are higher than ever as Google, Apple, Uber,

Tesla, Ford, and myriad startups sprint to bring the first self-driving car to market. The resources of a car-building leviathan that's in dire need of software expertise could give Vogt and Kan the fuel they need to win that race—or weigh them down with baggage that turns them into an also-ran.

KYLE VOGT planned to spend the evening of March 18, 2007, putting the finishing touches on Justin.tv, the live-streaming video site he had cofounded. But at midnight, TechCrunch accidentally published a story announcing the site's launch, nine hours before it was supposed to go up. An audience of hundreds, maybe thousands, of people flooded onto the not-yet-ready site, causing it to crash. Vogt, the company's head of engineering, and Emmett Shear, its chief technology officer, "grinded through the night and for two more days," scrambling to get their site to function properly, says Seibel, a third cofounder. Shear has no memory of the event beyond a photo

of himself typing furiously on a laptop from his bed. "It's all a giant blank spot," he says. "I hear that happens sometimes with trauma."

Justin.tv's goal was to build the first network of live-streaming broadcasters. That sounds a lot less complicated now than it was in 2007, when iPhones were brand-new, bandwidth was expensive, and online video streaming was glitchy. To do what live-streamers can do today with a smartphone, the site's early broadcasters had to wear elaborate backpacks and baseball hats rigged with camera systems designed by Vogt. Justin Kan, the site's namesake

(and older brother of Cruise's Daniel Kan), was the site's first "lifecaster," capturing himself doing 23-year-old guy stuff: hanging out, wasting time, going to parties, meeting girls.

That chaotic, sleepless first 72 hours foreshadowed the entire seven years of Justin.tv's existence. Startup life is prone to drama and dysfunction, but Justin.tv's failings were so uniquely turbulent that a Hollywood production company optioned the rights for a feature film about it.

There was the first monthly bandwidth bill for \$20,000, double the startup's cash in the bank. There was the time Seibel had to defend the company at a House Judiciary Committee hearing because users were sharing pirated sports content. The site crashed anytime the Jonas Brothers tried to go live. A teenager live-streamed his suicide. And most famously, in a prank by viewers, a SWAT team kicked down the door of the two-bedroom apartment where Justin.tv's four founders lived and worked. (The North Beach apartment tower was known as the Y-Scraper because so many Y Combinator founders lived there.)

If Kan was Justin.tv's star, Seibel was the business guy, Shear was the technical guy, and Vogt was the creative genius. (And for a summer, Daniel Kan was the intern.) Vogt became known for "hero coding" the company out of problems, Justin Kan says. "He'd just, like, lock himself in a room for three days and code away and then emerge with something that worked."

No amount of hero coding could make Justin.tv

into a viable business; 24-hour lifecasting wasn't compelling enough for a mass audience. But while most failed startups are quickly forgotten, Justin.tv's legacy is traceable throughout the Valley. Young entrepreneurs revel in the mythology of the "Justin.tv mafia," in part because Seibel and Justin Kan are now leaders at YC. As thirtysomething startup sages, they dispense advice from their time in the trenches to dozens of hopeful founders who come to YC for mentorship, introductions to investors and powerful alumni, and a small seed investment.

And unlike most of Silicon Valley's graveyard of dead startups, Justin.tv produced a return for its investors. When the original site began to stumble, Seibel spun out Socialcam, a side project focused on short, Instagram-like videos, eventually selling it to software giant Autodesk in 2012 for \$60 million. Meanwhile, Shear shifted the remaining

ADVICE

Road Rules for Merging With a Giant

KEEP YOUR CULTURE.

Under their merger deal, Cruise operates as an independent GM subsidiary. Its staff also works out of its own office, where it's easier to maintain a startup's pace.

MAKE THE BIG NAME MATTER.

Cruise can expand its impact because of GM's expertise in building at scale. And GM's relationships and brand recognition help Cruise get faster responses from suppliers.

GIVE YOURSELF A REASON TO STAY.

Cruise's mission of bringing self-driving cars to market ASAP motivates its team to make the deal work. Their pact also includes financial incentives that kick in only if the project succeeds.

team's focus to videogames, one area of Justin.tv where traffic was booming. Branded Twitch.tv, the site quickly ballooned to 55 million users who spent an average of 20 hours a week watching other people play videogames. Twitch even turned a profit on ads and monthly subscriptions. In 2014, Amazon acquired Twitch for \$970 million including incentives—10 times the company's private market valuation at the time. YC has funded 10 companies that rose to billion-dollar valuations, including Airbnb and Dropbox, but Twitch and Cruise are its two largest exits to date—which just reinforces the Justin.tv mafia's legacy.

So many of Justin.tv founders' Y-Scraper pals became successful that Seibel once said to Justin Kan (in Kan's words), "Man, we knew so many geniuses." In reality, timing and grit played a bigger role than IQ. "We're not like Mozart or something," Kan says. "We were just in the right place at the right time and we didn't give up."

Nor did they dream small. Recently Kan's cousin, a professor, asked him if he wanted to

retire. After all, he's Twitch-Rich. He told her, "I want to build a billion-dollar company. I want to build a \$10 billion company." The answer surprised his cousin. "I've never heard anyone say that," she said. But though it often feels as if everyone in the Bay Area is swimming in startup cash, the money is beside the point. What matters is what the money symbolizes: Your outsize, possibly irrational ambitions. Kan repeats what I've heard from just about everyone in the Justin.tv crew: Every person is the average of their five closest friends. People come to Silicon Valley to be around ambition, he explains. Wanting to build a \$10 billion company? Kan throws up his hands. "I've *only* heard people say that."

THE LESSON from Justin.tv, according to the founders of Justin.tv, is don't repeat the mistakes of Justin.tv. And yet, on March 24, 2014, Vogt found himself pulling another last-minute almost-all-nighter to save his new startup, Cruise Automation, from a total meltdown. This time it was literal—the polylactic acid parts he had 3D-printed for his prototype car had melted in the California sun after the first day of YC's high-profile "demo day" event.

Demo days are like beauty pageants for startups, where founders use big numbers, snazzy pitch decks, and a healthy dollop of snake oil to coax seven-figure checks out of an audience of influential investors. Now Cruise's star player—Vogt's black Audi S4, rigged with sensors that enabled it to steer and brake on its own—was a dud. Vogt

and his two engineers, Ian Rust and Rita Ciaravino, worked through the night reprinting the parts (they had to buy three new printers to get the job done in time) and rebuilding the prototype from scratch.

The next morning Vogt, looking just barely presentable, drove Justin Kan to day two of the event. For a few miles on Highway 101, Vogt let the car take over. Kan had already invested \$25,000 in Cruise “because it’s Kyle,” he says; he immediately invested more. He couldn’t believe they had built a car that drives itself in just three months (and then again, overnight). “Kyle had basically hero coded it once again,” he says.

Cruise emerged from demo day with \$4.3 million in convertible debt funding. At the time, Cruise planned to sell \$10,000 kits that would retrofit any car to drive itself on highways, similar to Tesla’s autopilot feature today. Daniel Kan, who joined the company just after demo day to run operations, remembers thinking, “This might be one of the craziest things, but it will at least be a good story.” But not long after the demo day, the founders recognized a major roadblock: Cruise would need to customize its kits to accommodate hundreds of vehicle makes and models. In 2015, Cruise abandoned the kits to build software for fully autonomous vehicles.

By then, self-driving cars were feeling less like one of the craziest things. Google was showing off its fleet of jelly bean pod cars, Uber’s CEO predicted an end to

human cabdrivers, and Detroit automakers were taking a closer look at the up-and-coming self-driving-car startups.

It’s common for large corporations to get friendly with potential competitors at vague “business development” meetings. Cruise used the meetings with *Fortune* 500 automakers and suppliers to set ambitious development targets for itself. Startups with no demanding customers can lose their urgency, with development cycles dragging on for years, says Rust, who worked at Google’s experimental research factory before joining Cruise. “We tried to accomplish what one of the most talented teams at Google did in two years and compress that into six months,” Vogt says.

One of the stalwarts, GM, was visiting so frequently that Cruise had to expand its city road testing beyond a single fixed route in San Francisco. “You do that once, and the next time GM comes back, you can’t demo that route again,” Rust says. “You don’t want them thinking, Does this car run on rails?”

“We used it as internal motivation,” Daniel Kan says. “If we impress them, there is potential opportunity; if we don’t, who cares?”

They impressed them. “Every time we went there they’d moved along another nine steps,” says Dan Ammann, president of GM. “We were super excited with what the guys there had achieved already technically, but also the caliber of the talent and speed of development.” In March, GM and Cruise announced the deal, which closed after Cruise settled a spat with an estranged cofounder.

The billion-dollar price tag alone makes the deal seem like a no-brainer for Cruise—but remember, this is the legacy startup, not the get-rich one. Vogt believes selling to GM will help Cruise fulfill its lifesaving mission faster. “If we truly want to do what brought us to work on autonomous vehicles in the first place, we need to do something that is going to achieve scale,” he says. “With GM we can build and deploy it at scale. We want to have the highest possible social impact.”

I T’S BECOME A CLICHÉ, when a startup sells to a large corporation, for the founders to spout hopeful phrases about “perfect alignment” and “inspiring commitments.” The company is the founders’ baby, and they’ve barely grasped the reality of letting it go. They take the team out for a big celebratory dinner as the congratulations pile up in their smartphone notifications. They take their first vacation in years. They tell themselves the commitments really are inspiring.

It’s also a startup cliché that within a year, the jig is up. The founders realize that the grinding,

slogging, against-all-odds hero’s journey of cold calling and pitching and building and hustling and eating glass and staring into the abyss is finally over. Their metabolism doesn’t adapt well to the politics of slow-moving, risk-averse corporations. Once their life’s work begins to feel like a job, a switch goes off in their brains. Some leave to start their next company. Others “vest in peace.” Whatever innovative thing they built gets lost inside a giant corporate overlord. Startups have a 90% failure rate, according to studies. The failure rate for mergers and acquisitions—at least when it comes to meeting expectations—is just as high.

Already Vogt and Kan are being pulled into more tedious corporate meetings, where committees of executives are required to sign off on decisions and budgets that they’re used to handling themselves. It won’t be simple to combine Cruise, a three-year-old upstart that has yet to launch a product, with General Motors, a 108-year-old, 216,000-person company that shipped 9.8 million vehicles last year to the tune of \$152.4 billion. The stakes are high: GM can’t afford to fall behind as the auto industry transforms itself from the business of manufacturing and selling cars to the business of “mobility.”

Vogt and Kan do not intend to become clichés. While negotiating the deal, Vogt turned to his former cofounder, Emmett Shear, for advice. Twitch has thrived under Amazon’s ownership—doubling its users with very little executive turnover—because it has maintained its indepen-



SCALING UP The Cruise automation team in the garage at their San Francisco headquarters. Cruise's staff has doubled since the GM acquisition closed, adding person power (and headaches) for Vogt and Kan.

FEATURE: CRUISE



dence, with Shear staying on as CEO of Twitch. “[Shear] made it clear to Amazon that it was important for it to be this way if you want to keep the people that made it what it is,” Vogt says. He mimicked Twitch’s deal structure: Cruise operates as an independent subsidiary of GM, and its executives are incentivized to stick around. Cruise’s \$1 billion price tag included just \$300 million in cash, with another \$300 million in GM stock and the rest hinging on Cruise’s ability to retain key employees—mainly Kan and Vogt—and hit technological milestones. “By design, we wanted it to succeed post-acquisition,” Vogt says.

Still, there’s a natural culture clash between Cruise’s focus on speed and GM’s focus on durability. Doug Parks, GM’s vice president for autonomous technology and vehicle execution, and Kan and Vogt’s new boss, calls it a “give-and-take.” “They’re

focused on getting two to three cars to work, and we’re focused on getting 20,000 to 30,000 cars to work,” he says. “They don’t have expertise on what it takes to make a vehicle durable over many miles.” (The Cruise guys won’t argue there. Vogt’s first assembly-plant tour was “jaw-dropping in its scale,” he says.)

Likewise, GM doesn’t have much experience in the art of “move fast and break things,” but it’s starting to learn. Since acquiring Cruise, Parks’ team has ditched its daily staff meeting where everyone reviews projects, in favor of a Cruise-style daily 15-minute phone call to discuss the biggest issue holding the team back. “It doesn’t allow people to say, ‘We’re going to go off for a week and work on a proposal,’” Parks says. “Now it’s, ‘Take the next 23 hours and answer the question.’”

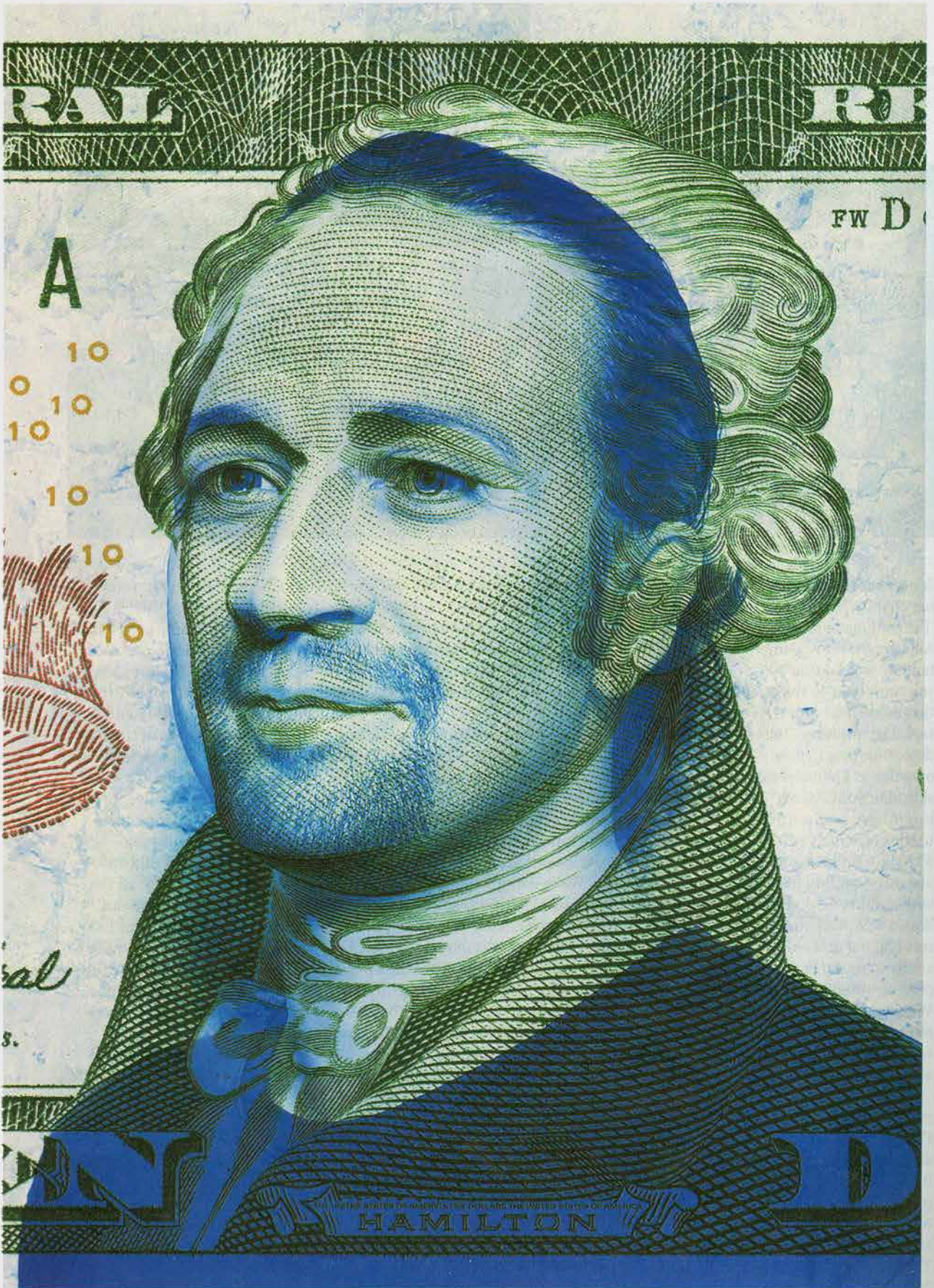
Meanwhile, Cruise gets to enjoy the perks of a large, powerful parent company. The startup has access to GM’s testing and validation facilities in Warren, Mich. When something breaks on one of Cruise’s modified Chevy Bolts, Cruise staffers can call the GM team that designed that exact part, rather than spend hours trying to figure out what went wrong. And GM’s brand carries weight. “Suppliers pay attention to us,” Kan says. “You email from your GM email, and it opens all the doors.”

Since the deal closed, Cruise has more than doubled its staff. The company’s office is filling up quickly, something that makes Kan nervous. Office space in San Francisco is already scarce and pricey, and Cruise has a unique challenge: It needs to drive cars in and out of the office. Beneath Cruise’s barnlike warehouse is a fleet of

Chevy Bolts with names emblazoned on their hoods (Platypus, Narwhal, Charlie, after Vogt’s dog), each outfitted with lidar laser sensors that look like old-timey sirens. There’s only one ramp in and out of the basement. The cars are starting to feel crowded too.

Cruise could solve its problem by moving its operations to the suburban sprawl of Silicon Valley proper. Like all the automakers, GM has an innovation outpost in Palo Alto. But no one at Cruise has even visited it. Staying independent is too important—and besides, they’re busy. Vogt and Kan can barely spare an hour for a reporter. As I scan my list of questions, Vogt is antsy to get back to his desk. “Is that good for you?” he asks. “I think we’ve given you quite a bit of color.” The clock is ticking, and their legacy is on the line. **■**

FEEDBACK:
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ONE DOLLAR
ALEXANDER HAMILTON
THE UNITED STATES OF AMERICA

AMERICAN WATER MURKIN - BETTMANN

ILLUSTRATION BY JAVIER JAÉN



HAMILTON, NONSTOP

LIN-MANUEL MIRANDA, the 36-year-old creator of the hit musical, talks about trusting his instincts, the value of a vacation, and how he accidentally married the oldest form of entertainment with the newest form of social media.

Edited interview by **KIA KOKALITCHEVA**

What surprised you most about the *Hamilton* phenomenon?

Um, everything. Honestly. I knew we'd be a hit with history teachers. Everything else has been sort of a surprise.

Do you have a process, a formula, for your creative work?

Not really. One of the best things about the success of *Hamilton* is that this is an idea that sounds crazy when you say it in one sentence. I had that experience over and over again. When I performed the first song at the White House, on that YouTube video in 2009, I said, "Someone who embodies hip-hop, Treasury Secretary Alexander Hamilton," and the room laughed. Then by the end of the song they're in it because they're sucked into the story. Which is what happened to me. I picked up Ron Chernow's [biography of Hamilton] and I got sucked into the story. I had the idea when I grabbed Ron's book to read on vacation.

What are the lessons there?

One: You can have good ideas when you take a break from what you're normally

doing and don't just go 100 miles an hour. Two: really trusting my gut. I won a Tony with *In the Heights*. I got offered movie adaptations of musicals. I got offered a lot of Latin-theme stuff. But I had faith that the idea I was chasing with *Hamilton* would be worthwhile.

It takes years to make a musical. So I've got to choose projects knowing that even if they open and close in a day, I will not regret the time I spent on them. And so you can't choose on what you think is going to be a financial success. You've got to pick the idea that excites you and inspires you to write.

That was actually my next question: How much does the commercial potential influence you?

Exactly zero percent. Honestly. Look at the field in which I work. One in five shows that go to Broadway make their money back. If you invest in Broadway musicals, it has to be because you love the things, because, you know, four out of five times you're not going to make your money back.

How have digital media like Spotify affected your approach?

What's been interesting is that *Hamilton* has proliferated in the age of social media. I believe the magic of theater is that we are all in the same room having the same experience. I think people really crave that communal experience. But I also saw what happened when the cast album came out. It was first streamed for free on NPR, and people started freaking out when they heard it then, and then it was on sale later that week. And streaming it for free didn't hurt the sales at all—it whetted people's appetite. So that was fascinating.

Then there was the #Ham4Ham experience. Our plan was always to have a lottery outside the theater for the front row, sell the front row seats for \$10. Ham for Ham: You pay a Hamilton to see *Hamilton*. And 700 people showed up to our first lottery drawing—that is an insane amount of people. I was there watching this crowd grow. I got a megaphone and said, "Thank you so much for coming, I love you very much, goodbye." And my collaborator Tommy Kail said, "There's 20 people

who got the tickets and 680 people who are just going to be sent disappointed into the streets of New York. You should grab the megaphone before every lottery drawing." That became the #Ham4Ham show and this de facto talent show. I brought in actors from other theaters and some of my musical theater heroes. It could be anything from Jonathan Groff and I singing songs we sang in middle school to dancers from the New York City Ballet doing a solo in the streets of New York. And then as people filmed that, and that went online, that became this extra experience for fans.

What we created almost by accident is this community of people who are very invested in the show and invested in the people who work on the show, and also the sort of "only in New York" moments that we create outside the box office.

What would Hamilton think of the current election season?

I think he would have been very comfortable with the rough-and-tumble of it. I mean, read some of the things he wrote about Jefferson; they're every bit as mean-spirited as anything you see in today's politics. The other answer I give is I think he would be freaking out over computers and how they work and the speed of information. In the election of 1800, a group of Federalists sent out a paper saying Jefferson was dead, hoping to suppress his support and just hoping word would travel slow that he wasn't dead. That is dirty f---ing politics. You wouldn't get away with that now. And the fact that the election changes at the speed of one of Donald Trump's tweets, I don't know what Hamilton would say about that! ■

MEET ACTIVISM'S

NEW FACE

DIANNE MCKEEVER'S hedge fund won its first fight, against Boingo Wireless. Now she's going after her next targets. CEOs, beware Ides Capital.

by **JEN WIECZNER**

DIANNE MCKEEVER doesn't like to talk about the fact that she's a woman. But her gender has made her a groundbreaker on Wall Street: The moment she launched Ides Capital last year, the 38-year-old became the only woman running an activist hedge fund shaking up U.S. companies. And her firm, which takes its name from the day of each month on the Roman calendar thought to portend dramatic change (made famous by Julius Caesar's assassination on the Ides of March), is already showing companies that they ignore her at their peril.

Shares of Boingo Wireless, a provider of Wi-Fi hotspots (you've likely used it at airports) have risen

more than 20% since McKeever revealed her campaign to amplify the company's value in March. For Ides, the rewards have been even greater: Its investment has returned more than 55% since the firm began buying the stock in late 2015.

McKeever has made corporate governance a pillar of her strategy, and in doing so she has become known as a champion of boardroom gender diversity. After Boingo's stock price lost nearly half its value since going public in 2011, McKeever sought to replace two members of the company's board, which she criticized as "stale, pale, and male." (On the cover of her presentation about the company, she quoted Cicero: "The Ides changed everything.")

Pushing to right society's wrongs is not Ides' goal. "We're there first and last to make money," McKeever says. Still, Ides' efforts set it apart from its peers. In the past five years the top five activist hedge funds nominated women for just 4% of the board seats they targeted, according to Bloomberg. That's despite evidence that gender diversity correlates with financial performance: Companies in the MSCI World index with at least three women on their board posted an annual return on equity of 10.1% over a six-year period through last summer, compared with 7.4% for companies without.

McKeever's initial challenge was getting others to take her seriously. When she approached Boingo with her new-director nominees, the company said it "had never heard of Ides Capital." McKeever and her cofounder, Rob Longnecker, owned just 0.18% of Boingo's stock at the time, far less than the stakes of 5% or more that activist investors often buy to gain leverage over a company. "Normally, a holder of that size you don't really need to listen to or negotiate with; her chances of winning were exceedingly low," says Karen Finerman, CEO of Metropolitan Capital Advisors and one of McKeever's nominees to Boingo's board. "And she did."

In June, Boingo settled. Ides had gained the upper hand



INVESTING'S MS. PAC-MAN: Dianne McKeever got her start arbitraging candy bars in seventh grade and is an avid videogamer. Her activist fund, Ides Capital, is now shaking up small-cap companies.

PHOTOGRAPH BY
REBECCA GREENFIELD

FEEDBACK:
LETTERS@FORTUNE.COM



when Institutional Shareholder Services, a proxy advisory firm that holds enormous sway in board contests, sided with McKeever and recommended that investors vote in favor of her slate. Boingo agreed to appoint three new independent directors—including its first woman—though not Ides'

nominees. "For a little group to win a somewhat contentious nomination process was huge for us," says Brad Stewart, CEO of XOJet and Ides' second nominee. (Boingo says it "had a very positive growth story before Ides became involved" and that it was already trying to recruit women to its board.)

While relatively unknown on Wall Street, McKeever is no rookie. Growing up in Indianapolis, she bought her first stock at age 10 and soon started her first business, arbitraging candy bars: As a seventh-grader taking high school classes, she would buy \$20 worth of premium chocolate at the high school, then sell it at a markup to her middle school

classmates. "It was what the market could bear," she says.

After graduating from college in 2001 (with dual degrees in chemistry and chemical engineering at New York University and the Stevens Institute of Technology), she got a job at New York hedge fund Barington Capital Group. By age 25, she had become the youngest person to make partner. "She's analytical and very smart," recalls James Mitarotonda, Barington's chairman and CEO.

At the time, Barington was becoming a pioneer in the current generation of investor activism, and it was there that McKeever got to know Starboard Value activist Jeff Smith, whose hedge fund was then part of Ramius Capital. Smith partnered with McKeever in many of Barington's campaigns.

But McKeever yearned to make a bigger impact. So she went to law school—not to be a lawyer, but to study up on corporate governance. She launched Ides in the summer of 2015, renting a desk at a swanky coworking space a block from Central Park. She's now looking for new office space, and she has set her sights on several more small-company targets.

In the meantime, McKeever, who describes herself as a "hard-core videogamer," blows off steam playing *Ms. Pac-Man*. Her Twitter picture is the game's avatar; her bio just says, "Eatin' ghosts."

Just as in *Ms. Pac-Man*, McKeever is likely to face greater challenges as she levels up with new campaigns. But she's equal to the task. "The next time that some board sees her filing," says Finerman, "they do need to worry about it." ■

CAN THIS 22-YEAR-OLD CODER

BRIGHT FUTURE Buterin on a street in Shanghai on Sept. 13, days before he hosted an Ethereum conference.

PHOTOGRAPHS BY **JULIE GLASSBERG**



A photograph of Vitalik Buterin, the creator of Ethereum, standing in a city street. He is wearing a green t-shirt with the Ethereum logo and the text 'Ethereum core' on it. He is also wearing sunglasses and a watch. The background shows a busy city street with buildings and a red sign that says 'AIR CONDITION'.

OUT-BITCOIN BITCOIN?

Russian-born wunderkind **VITALIK BUTERIN** is the creator of **ETHEREUM**, a fast-growing new cryptocurrency network. His audacious goal? To unleash the power of the technology behind his creation and spur radical change in finance, social networks, and even government.

by **ROBERT HACKETT**

THE CHAOS STARTED in the morning hours of Friday, June 17. At 8:15 a.m. Berlin time, Griff Green, a community organizer for Slock.it, a German tech firm, blared an alarm: “EMERGENCY ALERT!” he wrote in a public chat channel.

“PLEASE DM A SLOCK.IT MEMBER ASAP!!!” he continued, addressing stakeholders in a blockbuster venture codeveloped by the company, the DAO (pronounced like the Chinese philosophical tenet), which had been hailed as the most successful crowdfunded project of all time. Three people replied immediately: “Uh oh.” “What is going on?” “Oh shit.”

Green waited another half-hour before adding, “We aren’t sure what is happening but the DAO is in an emergency situation.”

The letters in DAO stood for decentralized autonomous organization, and the idea was that the startup would be a new type of corporation—built on the technology that powers cryptocurrencies, such as Bitcoin—with algorithms executing the strategy instead of human managers. Specifically, its coders intended the DAO to function like a venture capital firm—a kind of Kickstarter-like Kleiner Perkins.

A month earlier thousands of investors had plowed some \$160 million into the experimental company. Their contributions were made in Ether, a year-old digital currency (and rival to Bitcoin) that they had exchanged for virtual tokens. The DAO’s creators had designed the software to execute the will of its token holders, based on a tally of their collectively computed votes.

The investors had been assured the money was safe when they deposited it in the DAO. The network powering it was “more secure than every bank put together,” Stephan Tual, one of the DAO’s originators as well as a cofounder and the chief operating officer of Slock.it, had boasted during the project’s funding campaign.

But now a hacker had broken in and was in the process of pilfering their funds. Green recommended that constituents spam the network—clogging its pipes—to slow down the thief. “Yeah sorry guys, this is not a drill,” Green added lamely.

In the chatroom, emotions ran high. “Are we fckd?” one person asked. “Man what a epic failure,” ranted another. “I’m in the bathtub, about to throw a toaster in!” said a third. Another person summarized: “:fire: :fire: :fire: :fire: NOBODY PANIC :fire: :fire: :fire: :fire:” Many drew comparisons to Mt. Gox, a Japanese virtual-currency exchange—once the largest of its kind—that had collapsed in a catastrophic \$460 million hack two years prior. Were they now watching the DAO implode too?

By the time Slock.it had regained control the next day, the hacker (or hackers) had stolen more than \$50 million—nearly a third of the DAO’s funds. As people scrambled to make sense of the calamity, one name rang out in the forum. “Where is Vitalik?” asked one. “Wake up vitalik,” pleaded another. “Vitalik, our alien overlord, please save us.”

“Calm down,” came a reply. “Vitalik is working on it.”

A MONTH AFTER the hack—and mere days after presiding over a controversial vote to initiate a “hard fork” process that would recover the DAO’s stolen funds and make whole its backers—Vitalik Buterin is listening impassively to a guy wearing a beanie cap shaped like a Pokémon dragon. “This is a really tricky game,” says the man in the hat, an assistant professor of computer engineering, as he excitedly begins to lay out a complicated logic puzzle. But before he can get too far, Buterin quietly interrupts



BOLD VISION Buterin wants to use his technology to radically re-architect the web, upending the current power structure. In the near future, he believes, entire companies could be controlled by crowdsourced algorithms rather than executives.

**ETHEREUM,
SAYS ONE VENTURE
CAPITALIST, IS
"PROBABLY THE
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HAPPENED" IN
DIGITAL CURRENCY
IN A COUPLE
OF YEARS.**

with a clever solution. "Oh," says the Pokémon prof, crestfallen. "That's actually pretty cool."

Buterin, a 22-year-old coder, is visiting the Cornell University campus for a boot camp organized by IC3, or the Initiative for Cryptocurrencies & Contracts, an academic consortium that researches peer-to-peer payment systems. Roughly two-dozen programmers are gathered around a long conference table inside Gates Hall (as in Bill and Melinda), the brand-new, steel-plated home to Cornell's computing and information science departments. The air is thick with talk of "stochastic dominance," "Merkle trees," and "zk-SNARKs."

Although he's among the youngest in the room, Buterin is indisputably the star of the group. He is, after all, the wunderkind creator of Ethereum, the network on which Ether runs. And Ether is now the biggest rival to Bitcoin, the \$10 billion cryptocurrency that mysteriously burst onto the scene less than a decade ago.

Since its launch last year, the total value of Ether has rocketed from nothing to nearly \$1 bil-

lion, easily outpacing every other virtual-coin contender. (There are hundreds.) Yet the promise of the technology Buterin has built extends far beyond its possibilities as a speculative digital currency. Ethereum's boosters believe the network could someday power a host of decentralized applications—censorship-free social networks, public utility ride-hailing apps, crowdsourced prediction markets and investment firms, even governments.

Buterin's creation is already making inroads beyond the coder set. *Fortune* 500 companies have begun trials with the technology. Last year Samsung and IBM launched a project to coordinate Internet-connected devices, like washing machines and lightbulbs, over an Ethereum-based network. At the beginning of this year 11 banks—including Wells Fargo, Barclays, UBS, Credit Suisse, and HSBC—ran a financial services pilot program using Ethereum. Microsoft and Deloitte have been facilitating experiments on the network too.

"I'm very excited about Ethereum," says Chris Dixon, a general partner at Andreessen Horowitz, a venture capital firm in Silicon Valley that got into the Bitcoin game early on. "It's probably the most exciting thing that's happened in the whole space in a couple of years."

Mark Russinovich, chief technology officer of Microsoft Azure, the tech giant's cloud arm, echoes Dixon's enthusiasm. "What's great

about Ethereum is that it is open, flexible, and can be customized to meet a customer's needs," he says.

If it sounds as if Ethereum is destined to be Silicon Valley's latest billion-dollar startup, however, think again. Because Buterin isn't your typical entrepreneur. He isn't backed by VC money and he isn't even based in the Valley—in fact, he's a vagabond who more or less lives out of a backpack and crashes on couches wherever he happens to be coding. Rather than setting himself up for an IPO payday in the future, he has structured his "startup" as a nonprofit foundation based in Zug, Switzerland. In his role as Ethereum's chief scientist, Buterin looks to Linus Torvalds, the firebrand inventor of Linux, an open-source computing system that powers many operating systems today, as inspiration.

In that sense, Buterin represents a challenging archetype for the banks and investors lining up to invest in the potentially world-altering technology underlying cryptocurrencies: the unprogrammable programmer.

He certainly doesn't come across as Wall Street's ideal business partner. On the day I meet him, Buterin, tall and skeletally thin, is wearing a wrinkled T-shirt promoting open-source software and a pink-and-purple-striped Swatch wristwatch with a smirking Cheshire cat on its face. He tends to reply to questions in a voice so measured that it almost sounds computer generated.

But if his affect is flat, Buterin's ambition is any-



● DIGITAL DIVIDE

New Coin on the Blockchain

Bitcoin remains the biggest digital currency by far, but the fast-rising Ether is easily its biggest rival. Buterin's creation reached \$1 billion in market value in just over a year.

thing but muted. He says his ultimate goal is to use Ethereum to radically re-architect the web—taking power away from traditional brokers and delivering it to the masses. Of course, if his revolution succeeds and Buterin's technology achieves mass adoption, his plan will have the added benefit of enriching him and other Ether holders.

Before he can upset the world order, though, Buterin must prove that developers can use his technology securely—a legitimate question in the wake of the hack of the DAO, which was constructed on his network. Much of the excitement in the tech community has been shifting toward Ether in recent months and away from other digital monies, like Bitcoin. But in the volatile, idealistic world of cryptocurrencies and their creators, allegiances can change rapidly.

THE DIGITAL CURRENCY movement achieved liftoff at a moment when the global financial system appeared to be on the verge of collapse. On Nov. 1, 2008, just weeks after Lehman Brothers went under and kicked off a worldwide market crisis,

a bulletin appeared on an esoteric mailing list that was a favorite haunt of cryptography enthusiasts. "I've been working on a new electronic cash system that's fully peer-to-peer, with no trusted third party," wrote a newcomer to the thread alongside an abstract and a link to a nine-page academic paper. He called the creation Bitcoin.

The shadowy persona, who signed off as "Satoshi Nakamoto," had solved a long-standing conundrum in computer science known as the Byzantine Generals Problem. Building on the work of others, he proposed a decentralized system in which effectively no one could cheat. Nakamoto's genius was to use a blend of cryptography, mathematics, and game theory to keep everyone honest. Instead of trusting the curator of some monolithic database to approve an all-knowing, all-seeing record of every payment transaction, why not distribute a copy of that ledger across everyone's machine? Easier said than done—but Nakamoto's system accomplished the feat.

Nakamoto's prime innovation was the so-called blockchain—a new system for structuring data. As the name suggests, a blockchain consists of a series of linked blocks, or lists. Each block contains a record of time-stamped transactions—who paid whom, how much, and when. Everyone agrees upon the order, thanks to a clever combination of mathematics and economic incentives, and all transactions are mirrored publicly across its open network. Like the Internet, a blockchain aims to eliminate single points of failure; any



one node could explode and the system would survive, accurately and intact.

Early on, Bitcoin had attracted a following of ardent cryptoanarchists, libertarians, and curiosity-driven technologists drawn to the separatist framework. By 2011, Nakamoto himself had mysteriously evaporated into the fogs of cyberspace. (He has yet to be identified despite a global media manhunt in recent years.) But interest in his creation was about to explode and attract the attention of a computer-obsessed teenager living in Toronto.

ONE DAY IN

February of 2011, Dmitry Buterin introduced his

son to an intriguing development he had come across online: Bitcoin. Initially Vitalik didn't show much interest. The idea of digital money sounded boring compared to *World of Warcraft*. And he didn't share the same stringently libertarian values as his father. But after doing a little research on cryptocurrencies, Buterin adjusted his thinking. Maybe the math appealed to him.

Numbers had captivated Vitalik Buterin at an early age. As a child, Buterin didn't spend much time socializing with other children. He stayed home with his grandparents while his father and mother studied computer science at a university in Moscow in the years following the Soviet Union's collapse. Given Legos to play with, Buterin didn't assemble miniature towers, animals, or people. Instead, he made numerals. When Dmitry bought his

• SMART MONEY

Six Startups Building the Tech Future

The number of cryptocurrency and blockchain companies is exploding. So much so that many investors compare it to the heady days of the early commercial Internet. Here are a half-dozen of the most important ones. —R.H.



BLOCKSTREAM

This San Francisco company has a stranglehold on Bitcoin brawn. The startup employs many of the developers closest to the open-source project. Led by Adam Back, a cryptographer who created Hashcash, a precursor to Bitcoin, Blockstream is working to bolster the network through "sidechains," a technology that allows different blockchains to talk to one another.

◀ **R3 CEV**

More than 50 top financial companies—including JPMorgan Chase, Deutsche Bank, Morgan Stanley, and Goldman Sachs—have teamed up to test out blockchain tools as part of this banking consortium. R3's star coder is **Mike Hearn**, formerly one of the most-high profile core developers of Bitcoin.



◀ **CHAIN**

Founded by **Adam Ludwin**, an angel investor in stratospheric startups Uber and Slack, the company has built "private" blockchains for financial customers such as Visa and Capital One. Unlike its rivals, Chain is based in Silicon Valley.

COINBASE

Cofounded in 2012 by an ex-Goldman Sachs trader and an early Airbnb software engineer, Coinbase has raised more than \$100 million in venture capital funding. It added the ability to trade Ether through its exchanges earlier this year.



◀ **DIGITAL ASSET HOLDINGS**

Run by **Blythe Masters**, an ex-commodities honcho at JPMorgan Chase credited with devising the credit default swap, the startup is developing a blockchain trade-settlement system for the Australian stock exchange.

CONSENSYS

Founded by Joseph Lubin, a onetime hedge fund manager and a cofounder of the Ethereum Foundation, the Brooklyn-based incubator aims to foster startups built on the technology that powers the cryptocurrency Ether.

son his first computer at age 4, Buterin took to it instantly. "Excel was his favorite toy," says Dmitry.

Dmitry, who had divorced Vitalik's mother, moved to Toronto in 1999. Buterin followed a few months later. As time went on, things got easier for Buterin. He began coming out of his shell in high school, joining a debate team. But computers remained a central part of his life.

Once he understood Bitcoin's potential, Buterin started looking for ways to earn some of the currency himself. He first wrote posts about the subject for a website in exchange for a meager sum

of 5 Bitcoins apiece (then about \$4 per blog post), but the site went belly-up. So he began writing two articles a week on aspects of the technology and its potential social impact, publishing a teaser paragraph on Bitcoin forums. He would put up his Bitcoin address—sort of like bank account information—and announce that



**BOY'S
BEST FRIEND**

Growing up near Moscow, Buterin, the son of two programmers, was obsessed with numbers and was hooked on computers by age 4. "Excel was his favorite toy," says his father.

he would release an article if he received enough donations. Steadily, the Bitcoin began rolling in.

Then, improbably, he launched his own magazine. In September 2011, a Romanian programmer named Mihai Alisie, then 23, suggested that he and Buterin, then 17, start their own publication. They founded *Bitcoin Magazine*, a print and online publication that has claimed, in the years since, a total readership of 1.5 million. Buterin wrote most of the articles. (The magazine is still published but by different owners.)

Buterin's timing was perfect. Interest in Bitcoin began exploding. To take advantage of the opportunity, Buterin decided to drop out of school during his freshman year at the University of Waterloo. (He later received a fellowship from PayPal cofounder Peter Thiel.) The value of Bitcoin spiked along with the currency's hype—rocketing from less than \$1 in 2011 to nearly \$1,000 in 2013. Entrepreneurs and

venture capitalists began to see it as an opportunity to upend the entrenched financial sector. Banks began secretly exploring the technology too.

Funded by the surging value of his Bitcoin earnings, Buterin went on a world tour. He began living a peripatetic lifestyle, dabbling in projects here or there. For a while he stayed with a band of cryptoanarchists in an abandoned flat in Barcelona. "I actually got more skeptical of left-wing anarchism after spending two months there," Buterin says. Everyone in the commune was responsible for collectively cooking dinner and lunch. But over time, says Buterin, people got lazy and blew off their assigned duties. "It made me realize that if you don't have economic incentives or rules forcing people to do basic chores, then they're not going to get done," he says.

Buterin also began to recognize limitations in Bitcoin. As more people began using the currency, a problem became abundantly clear: The network didn't scale. It could handle only seven transactions per second—far from what would be required if the system ever were to go mainstream. Visa, by contrast, processes thousands of transactions per second.

Aspiring developers also had to deal with an unfortunate reality: It's pretty difficult to build an app on Bitcoin. The system's primary role is being a secure means of transferring value, not being a system to create software. Nakamoto had deliberately constrained Bitcoin to make it less vulnerable. And its most influential core coders seemed uninterested in deploying quick fixes to the underlying problems.

An idea began to crystallize for Buterin. What if someone made a more generalized platform—one on top of which you could build any kind of financial derivative? He proposed the project to a group of coders he was working with, but they put him

off. Says Buterin: "I remember thinking, 'Screw that. I'll do it myself.'"

So he put his ideas into an email and sent it to a small circle of confidants. By early 2014, he and a group of acolytes had begun building Ethereum.

FROM THE

F outside, the office of ConsenSys looks more like

a rehearsal space than a high-tech startup studio. Nestled between an organic-food market and a sushi restaurant in the hip Bushwick neighborhood of Brooklyn, the door is plastered with peeling stickers for obscure punk and indie rock bands. Upstairs, the open office space is packed with Ethereum application developers.

The incubator is the brainchild of Joseph Lubin, a software expert and onetime hedge fund manager. Lubin was crucial to helping get Ethereum off the ground. He provided some initial funding for the foundation. Lubin created ConsenSys earlier this year as a for-profit tech foundry operating in much the same vein as Betaworks and IdeaLab, except that it's entirely Ethereum-focused.

Lubin says he caught the cryptocurrency bug for "existential reasons" after the 2008 economic meltdown. "I was pretty depressed about the state of the global economy," says Lubin, who studied computer science and electrical engineering at Princeton. "When I read the Bitcoin paper, it seemed like we had a way to build an alternative system."

Now he's busy recruiting

would-be bankers to help him and Buterin reinvent the architecture of industries ranging from finance to energy to health care. "Our goal is not to create a hierarchical command-and-control structure, but to stand up startups that stand on their own," Lubin says.

ConsenSys is one of many companies working on Ethereum projects. Lubin's organization has set up trials for automatic music royalty payments, persistent identity records, and solar energy trading tokens over a blockchain. Elsewhere, a startup called Augur is building an Ether-powered prediction market. And Santander Bank is collaborating with a company called Ether.camp on a new digitized form of cash.

Ethereum's power lies in its ability to automate complex relationships encoded in so-called smart contracts. The contracts function like software programs that encapsulate business logic—rules about money transfers, equity stake transfers, and other types of binding obligations—based on predetermined conditions. Ethereum also has a built-in programming language, called Solidity, which lets anyone build apps easily on top of it.

Buterin's allies say these features make Ethereum superior to Bitcoin. "Currency alone doesn't buy you the ability to create new social structures," says Vinay Gupta, an Ethereum project manager best known for inventing the hexayurt, a makeshift shelter that dots the landscape at the Burning Man festival each year. "Once you add smart contracts, you get the ability to

organize the world in new ways, and that's where things get more interesting."

Bitcoin loyalists argue that Ethereum's fatal tradeoff is that it's not as secure, and they point to the DAO hack as Exhibit A. Even in the Bitcoin community, though, there's some envy for the flexibility of Buterin's creation. "Ether is getting a lot of attention because we're not being allowed to scale fast enough," says Roger Ver, nicknamed "Bitcoin Jesus" for being one of the cryptocurrency's earliest and most vocal promoters. "The same thing happened with Friendster and MySpace. They had a bad user experience, weren't able to upgrade the servers and software fast enough, and everyone migrated to the next thing."

"It hurts me to say that," Ver adds.

THE HACK of the DAO was potentially a major setback for Ethereum. But Buterin says he didn't get too worked up at the time. He was in China and was engrossed in trying to fix things. "I personally, generally, don't really feel much emotion if there's some problem and I'm actively solving it," he says.

The fallout from the cybertheft is ongoing, however. And the solution that Buterin ultimately implemented has caused a bizarre schism in the Ethereum community.

After much debate, Buterin and his team proposed that Ethereum deal with the DAO theft by conducting the so-called hard fork. Essentially, they would rewrite the code in the transaction ledger and electronically retrieve the stolen DAO tokens. The hacker would be unable to exchange his purloined stake, and DAO investors could get their money back in Ether. When it was put to a vote, the hard fork passed. And some 85% of the Ethereum network implemented it.

But the other 15% rebelled. They decided to break away from the Ethereum network on principle and form their own, new version of the blockchain, calling it "Ethereum Classic." In pulling off the hard-fork fix, these purists argued, Buterin and the other stewards of Ethereum had contravened a fundamental blockchain tenet: the sanctity and irrevocability of the public ledger.


In their view, the hacker had rightfully succeeded by way of a "legal loophole" in the DAO's buggy software. So on the Ethereum Classic blockchain, the hacker has retained his or her riches. (Although the value of the haul is much less than at the time of the hack. Ethereum Classic recently traded at about \$1, vs. \$12 for regular Ethereum.)

This is all confusing to say the least. And the feud has the potential to scare off potential partners at a crucial stage of Ethereum's development.

"I think the fact now that there is Ethereum and Ethereum Classic, and that people continue to mine both, is unfortunate," says David Treat, global head of Accenture's capital markets blockchain unit, whose team continues to use the Ethereum code base in their work with clients, like big banks. Yet Treat doesn't hold the tenet of blockchain immutability dear. From his perspective, clients will one day need to correct potential mistakes on blockchain ledgers. "If and when something goes wrong, who has the right and ability to make a change? How does that change get made?" he asks. These are questions that should be addressed well ahead of time, he argues.

Buterin is working on solutions that he believes will prevent major hacks in the future—like software debuggers. He describes the DAO attack as a "rite of passage" for Ethereum. As was a second major attack on the network in late September, on the eve of an Ethereum conference in Shanghai.

Given the breaches, it's fair to wonder: Will Ethereum and other blockchain networks ever be trusted enough to replace our current financial system? Buterin believes it will take a few years, but he's patient. "The main advantage of blockchain technology is supposed to be that it's more secure, but new technologies are generally hard for people to trust, and this paradox can't really be avoided," he wrote in an email from China. "We have to just live through it." ■



**THE
DEEP-LEARNING
REVOLUTION**

Why decades-old discoveries are suddenly changing your life and electrifying the computing industry, and why they'll soon transform corporate America.

BY ROGER PARLOFF

ILLUSTRATION BY JUSTIN METZ



A CONCEPTION OF HOW DEEP LEARNING MIGHT BE USED TO IDENTIFY A FACE.

Over the past four years, readers have doubtlessly noticed quantum leaps in the quality of a wide range of everyday technologies.

Most obviously, the speech-recognition functions on our smartphones work much better than they used to. When we use a voice command to call our spouses, we reach them now. We aren't connected to Amtrak or an angry ex.

In fact, we are increasingly interacting with our computers by just talking to them, whether it's Amazon's Alexa, Apple's Siri, Microsoft's Cortana, or the many voice-responsive features of Google. Chinese search giant Baidu says customers have tripled their use of its speech interfaces in the past 18 months.

Machine translation and other forms of language processing have also become far more convincing, with Google, Microsoft, Facebook, and Baidu unveiling new tricks every month. Google Translate now renders spoken sentences in one language into spoken sentences in another for 32 pairs of languages, while offering text translations for 103 tongues, including Cebuano, Igbo, and

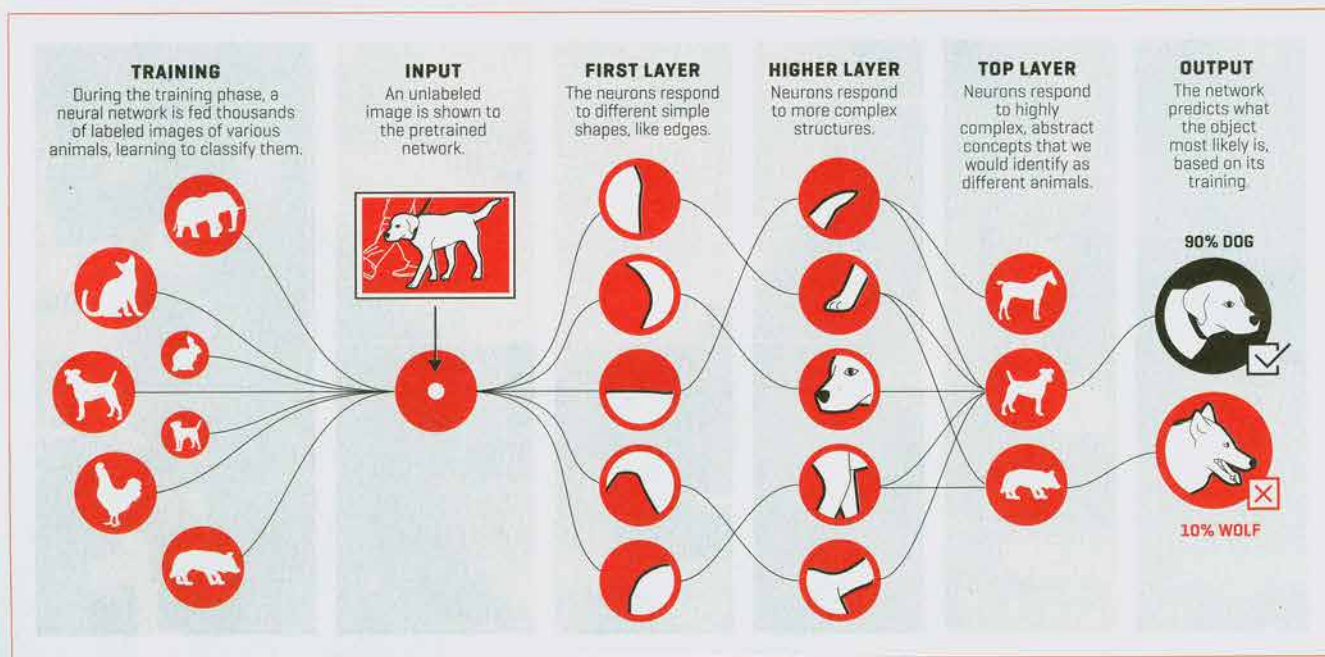
Zulu. Google's Inbox app offers three ready-made replies for many incoming emails.

Then there are the advances in image recognition. The same four companies all have features that let you search or automatically organize collections of photos with no identifying tags. You can ask to be shown, say, all the ones that have dogs in them, or snow, or even something fairly abstract like hugs. The companies all have prototypes in the works that generate sentence-long descriptions for the photos in seconds.

Think about that. To gather up dog pictures, the app must identify anything from a Chihuahua to a German shepherd and not be tripped up if the pup is upside down or partially obscured, at the right of the frame or the left, in fog or snow, sun or shade. At the same time it needs to exclude wolves and cats. Using pixels alone. How is that possible?

The advances in image recognition extend far beyond cool social apps. Medical startups claim

HOW NEURAL NETWORKS RECOGNIZE A DOG IN A PHOTO



they'll soon be able to use computers to read X-rays, MRIs, and CT scans more rapidly and accurately than radiologists, to diagnose cancer earlier and less invasively, and to accelerate the search for life-saving pharmaceuticals. Better image recognition is crucial to unleashing improvements in robotics, autonomous drones, and, of course, self-driving cars—a development so momentous that we made it a cover story in June. Ford, Tesla, Uber, Baidu, and Google parent Alphabet are all testing prototypes of self-piloting vehicles on public roads today.

But what most people don't realize is that all these breakthroughs are, in essence, the same breakthrough. They've all been made possible by a family of artificial intelligence (AI) techniques popularly known as deep learning, though most scientists still prefer to call them by their original academic designation: deep neural networks.

The most remarkable thing about neural nets is that no human being has programmed a computer to perform any of the stunts described above. In fact, no human could. Programmers have, rather, fed the computer a learning algorithm, exposed it to terabytes of data—hundreds of thousands of images or years' worth of speech samples—to train it, and have then allowed the computer to figure out for itself how to recognize the desired objects, words, or sentences.

In short, such computers can now teach themselves. "You essentially have software writing software," says Jen-Hsun Huang, CEO of graphics processing leader Nvidia, which began placing a massive bet on deep learning about five years ago.

Neural nets aren't new. The concept dates back to the 1950s, and many of the key algorithmic breakthroughs occurred in the 1980s and 1990s. What's changed is that today computer scientists have finally harnessed both the vast computational power and the enormous storehouses of data—images, video, audio, and text files strewn across the Internet—that, it turns out, are essential to making neural nets work well. "This is deep learning's Cambrian explosion," says Frank Chen, a partner at the Andreessen Horowitz venture capital firm, alluding to the geological era when most higher animal species suddenly burst onto the scene.

That dramatic progress has sparked a burst of activity. In the first quarter of 2016 there were 27 acquisitions or funding rounds of AI startups, compared with four in the equivalent quarter in 2011, according to the CB Insights research firm.

More than \$1 billion in investments were made during that stretch—with \$600 million coming in the past 18 months.

Google had two deep-learning projects underway in 2012. Today it is pursuing more than 1,000, according to a spokesperson, in all its major product sectors, including search, Android, Gmail, translation, maps, YouTube, and self-driving cars. IBM's Watson system used AI, but not deep learning, when it beat two *Jeopardy* champions in 2011. Now, though, almost all of Watson's 30 component services have been augmented by deep learning, according to Watson CTO Rob High.

Venture capitalists, who didn't even know what deep learning was five years ago, today are wary of startups that don't have it. "We're now living in an age," Chen observes, "where it's going to be mandatory for people building sophisticated software applications." People will soon demand, he says, "Where's your natural-language processing version? 'How do I talk to your app? Because I don't want to have to click through menus.'"

Some companies are already integrating deep learning into their own day-to-day processes. Says Peter Lee, cohead of Microsoft Research: "Our sales teams are using neural nets to recommend which prospects to contact next or what kinds of product offerings to recommend."

The hardware world is feeling the tremors. The increased computational power that is making all this possible derives not only from Moore's law but also from the realization in the late 2000s that graphics processing units (GPUs) made by Nvidia—the powerful chips that were first designed to give gamers rich, 3D visual experiences—were 20 to 50 times more efficient than traditional central processing units (CPUs) for deep-learning computations. This past August, Nvidia announced that quarterly revenue for its data center segment had more than doubled year over year, to \$151 million. Its chief financial officer told investors that "the vast majority of the growth comes from deep learning by far." The term "deep learning" came up 81 times during the 83-minute earnings call.

Chip giant Intel isn't standing still. In the past two months it has purchased Nervana Systems (for more than \$400 million) and Movius (price undisclosed), two startups that make technology tailored for different phases of deep-learning computations.

For its part, Google revealed in May that for over a year it had been secretly using its own

**KEY
MOMENTS IN
DEEP-LEARNING
HISTORY**



1958
Cornell psychologist Frank Rosenblatt unveils the Perceptron, a single-layer neural network on a room-size computer.



1969
AI giant Marvin Minsky of MIT cowrites a book casting doubt on the viability of neural networks. They fall out of favor.

1986
Neural nets pioneer Geoffrey Hinton and others find a way to train multilayer neural networks to correct mistakes. A flurry of activity ensues.



1989

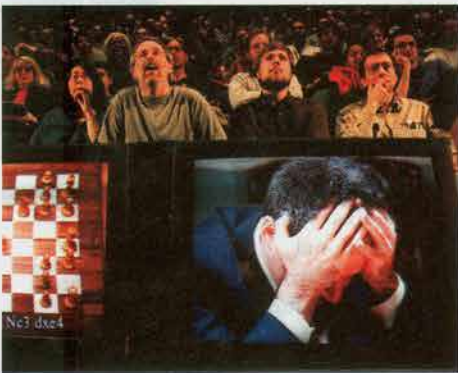
French researcher Yann LeCun, then at Bell Labs, begins foundational work on a type of neural net that becomes crucial for image recognition.

1991

German researchers Sepp Hochreiter and Jürgen Schmidhuber pioneer a neural net with memory features, which eventually proves superior for natural-language processing.

1997

IBM's Deep Blue beats world champion Garry Kasparov (below) in chess using traditional AI techniques.



Mid-1990s

Neural nets fall into disfavor again, eclipsed by other machine-learning techniques.

tailor-made chips, called tensor processing units, or TPUs, to implement applications trained by deep learning. (Tensors are arrays of numbers, like matrices, which are often multiplied against one another in deep-learning computations.)

Indeed, corporations just may have reached another inflection point. "In the past," says Andrew Ng, chief scientist at Baidu Research, "a lot of S&P 500 CEOs wished they had started thinking sooner than they did about their Internet strategy. I think five years from now there will be a number of S&P 500 CEOs that will wish they'd started thinking earlier about their AI strategy."

Even the Internet metaphor doesn't do justice to what AI with deep learning will mean, in Ng's view. "AI is the new electricity," he says. "Just as 100 years ago electricity transformed industry after industry, AI will now do the same."



THINK OF DEEP LEARNING as a subset of a subset. "Artificial intelligence" encompasses a vast range of technologies—like traditional logic and rules-based systems—that enable

computers and robots to solve problems in ways that at least superficially resemble thinking. Within that realm is a smaller category called machine learning, which is the name for a whole toolbox of arcane but important mathematical techniques that enable computers to improve at performing tasks with experience. Finally, within machine learning is the smaller subcategory called deep learning.

One way to think of what deep learning does is as "A to B mappings," says Baidu's Ng. "You can input an audio clip and output the transcript. That's speech recognition." As long as you have data to train the software, the possibilities are endless, he maintains. "You can input email, and the output could be: Is this spam or not?" Input loan applications, he says, and the output might be the likelihood a customer will repay it. Input usage patterns on a fleet of cars, and the output could advise where to send a car next.

Deep learning, in that vision, could transform almost any industry. "There are fundamental changes that will happen now that computer vision really works," says Jeff Dean, who leads the Google Brain project. Or, as he unsettlingly rephrases his own sentence, "now that computers have opened their eyes."

Does that mean it's time to brace for "the singularity"—the hypothesized moment when superintelligent machines start improving themselves without human involvement, triggering a runaway cycle that leaves lowly humans ever further in the dust, with terrifying consequences?

Not just yet. Neural nets are good at recognizing patterns—sometimes as good as or better than we are at it. But they can't reason.

THE FIRST SPARKS of the impending revolution began flickering in 2009. That summer Microsoft's Lee invited neural nets pioneer Geoffrey Hinton, of the University of Toronto, to visit. Impressed with his research, Lee's group experimented with neural nets for speech recognition. "We were shocked by the results," Lee says. "We were achieving more than 30% improvements in accuracy with the very first prototypes."

In 2011, Microsoft introduced deep-learning technology into its commercial speech-recognition products, according to Lee. Google followed suit in August 2012.

But the real turning point came in October 2012. At a workshop in Florence, Italy, Fei-Fei Li, the head of the Stanford AI Lab and the founder of the prominent annual ImageNet computer-vision contest, announced that two of Hinton's students had invented software that identified objects with almost twice the accuracy of the nearest competitor. "It was a spectacular result," recounts Hinton, "and convinced lots and lots of people who had been very skeptical before." (In last year's contest a deep-learning entrant surpassed human performance.)

Cracking image recognition was the starting gun, and it kicked off a hiring race. Google landed Hinton and the two students who had won that contest. Facebook signed up French deep learning innovator Yann LeCun, who, in the 1980s and 1990s, had pioneered the type of algorithm that won the ImageNet contest. And Baidu snatched up Ng, a former head of the Stanford AI Lab, who had helped launch and lead the deep-learning-focused Google Brain project in 2010.

A GLOSSARY
OF ARTIFICIAL-
INTELLIGENCE
TERMS

■ **ARTIFICIAL INTELLIGENCE**

AI is the broadest term, applying to any technique that enables computers to mimic human intelligence, using logic, if-then rules, decision trees, and machine learning (including deep learning).

■ **MACHINE LEARNING**

The subset of AI that includes abstruse statistical techniques that enable machines to improve at tasks with experience. The category includes deep learning.

■ **DEEP LEARNING**

The subset of machine learning composed of algorithms that permit software to train itself to perform tasks, like speech and image recognition, by exposing multi-layered neural networks to vast amounts of data.

The hiring binge has only intensified since then. Today, says Microsoft's Lee, there's a "bloody war for talent in this space." He says top-flight minds command offers "along the lines of NFL football players."

6

EDDREY HINTON, 68, first heard of neural networks in 1972 when he started his graduate work in artificial intelligence at the University of Edinburgh. Having studied experi-

mental psychology as an undergraduate at Cambridge, Hinton was enthusiastic about neural nets, which were software constructs that took their inspiration from the way networks of neurons in the brain were thought to work. At the time, neural nets were out of favor. "Everybody thought they were crazy," he recounts. But Hinton soldiered on.

Neural nets offered the prospect of computers' learning the way children do—from experience—rather than through laborious instruction by programs tailor-made by humans. "Most of AI was inspired by logic back then," he recalls. "But logic is something people do very late in life. Kids of 2 and 3 aren't doing logic. So it seemed to me that neural nets were a much better paradigm for how intelligence would work than logic was." (Logic, as it happens, is one of the Hinton family trades. He comes from a long line of eminent scientists and is the great-great-grandson of 19th-century mathematician George Boole, after whom Boolean searches, logic, and algebra are named.)

During the 1950s and '60s, neural networks were in vogue among computer scientists. In 1958, Cornell research psychologist Frank Rosenblatt, in a Navy-backed project, built a prototype neural net, which he called the Perceptron, at a lab in Buffalo. It used a punch-card computer that filled an entire room. After 50 trials it learned to distinguish

between cards marked on the left and cards marked on the right. Reporting on the event, the *New York Times* wrote, "The Navy revealed the embryo of an electronic computer today that it expects will be able to walk, talk, see, write, reproduce itself and be conscious of its existence."

The Perceptron, whose software had only one layer of neuron-like nodes, proved limited. But researchers believed that more could be accomplished with multilayer—or deep—neural networks.

Hinton explains the basic idea this way. Suppose a neural net is interpreting photographic images, some of which show birds. "So the input would come in, say, pixels, and then the first layer of units would detect little edges. Dark one side, bright the other side." The next level of neurons, analyzing data sent from the first layer, would learn to detect "things like corners, where two edges join at an angle," he says. One of these neurons might respond strongly to the angle of a bird's beak, for instance.

The next level "might find more complicated configurations, like a bunch of edges arranged in a circle." A neuron at this level might respond to the head of the bird. At a still higher level a neuron might detect the recurring juxtaposition of beaklike angles near headlike circles. "And that's a pretty good cue that it might be the head of a bird," says Hinton. The neurons of each higher layer respond to concepts of greater complexity and abstraction, until one at the top level corresponds to our concept of "bird."



2007
Fei-Fei Li founds ImageNet and begins assembling a database of 14 million labeled images that can be used for machine-learning research.

2011
Microsoft introduces neural nets into its speech-recognition features.

2011
IBM's Watson beats two champions at *Jeopardy!* using traditional AI techniques.



To learn, however, a deep neural net needed to do more than just send messages up through the layers in this fashion. It also needed a way to see if it was getting the right results at the top layer and, if not, send messages back down so that all the lower neuron-like units could retune their activations to improve the results. That's where the learning would occur.

In the early 1980s, Hinton was working on this problem. So was a French researcher named Yann LeCun, who was just starting his graduate work in Paris. LeCun stumbled on a 1983 paper by Hinton, which talked about multilayer neural nets. "It was not formulated in those terms," LeCun recalls, "because it was very difficult at that time actually to publish a paper if you mentioned

**FOUR TECH
GIANTS GET
SERIOUS ABOUT
DEEP LEARNING**



GOOGLE

GOOGLE LAUNCHED the deep-learning-focused Google Brain project in 2011, introduced neural nets into its speech-recognition products in mid-2012, and retained neural nets pioneer Geoffrey Hinton in March 2013. It now has more than 1,000 deep-learning projects underway, it says, extending across search, Android, Gmail, photo, maps, translate, YouTube, and self-driving cars. In 2014 it bought DeepMind, whose deep reinforcement learning project, **AlphaGo, defeated the world's go champion, Lee Sedol (above)**, in March, achieving an artificial intelligence landmark.

MICROSOFT

MICROSOFT INTRODUCED deep learning into its commercial speech-recognition products, including Bing voice search and X-Box voice commands, during the first half of 2011. The company now uses neural nets for its search rankings, photo search, translation systems, and more. "It's hard to convey the pervasive impact this has had," says Lee. Last year it won the key image-recognition contest, and in September it scored a record low error rate on a speech-recognition benchmark: 6.3%.

FACEBOOK

IN DECEMBER 2013, Facebook hired French neural nets innovator Yann LeCun to direct its new AI research lab. Facebook uses neural nets to translate about 2 billion user posts per day in more than 40 languages, and says its translations are seen by 800 million users a day. [About half its community does not speak English.] Facebook also uses neural nets for photo search and photo organization, and it's working on a feature that would generate spoken captions for untagged photos that could be used by the visually impaired.

BAIDU

IN MAY 2014, Baidu hired Andrew Ng, who had earlier helped launch and lead the Google Brain project, to lead its research lab. China's leading search and web services site, Baidu uses neural nets for speech recognition, translation, photo search, and a self-driving car project, among others. Speech recognition is key in China, a mobile-first society whose main language, Mandarin, is difficult to type into a device. The number of customers interfacing by speech has tripled in the past 18 months, Baidu says.

LEE JIN-MAK—AP PHOTO

the word 'neurons' or 'neural nets.' So he wrote this paper in an obfuscated manner so it would pass the reviewers. But I thought the paper was super-interesting." The two met two years later and hit it off.

In 1986, Hinton and two colleagues wrote a seminal paper offering an algorithmic solution to the error-correction problem. "His paper was basically the foundation of the second wave of neural nets," says LeCun. It reignited interest in the field.

After a post-doc stint with Hinton, LeCun moved to AT&T's Bell Labs in 1988, where during the next decade he did foundational work that is still being used today for most image-recognition tasks. In the 1990s, NCR, which was then a Bell Labs subsidiary, commercialized a neural-nets-powered device, widely used by banks, which could read handwritten digits on checks, according to LeCun. At the same time, two German researchers—Sepp Hochreiter, now at the University of Linz, and Jürgen Schmidhuber, codirector of a Swiss AI lab in Lugano—were independently pioneering a different type of algorithm that today, 20 years later, has become crucial for natural-language processing applications.

Despite all the strides, in the mid-1990s neural nets fell into disfavor again, eclipsed by what were, given the computational power of the times, more effective machine-learning tools. That situation persisted for almost a decade, until computing power increased another three to four orders of magnitude and researchers discovered GPU acceleration.

But one piece was still missing: data. Although the Internet was awash in it, most data—especially when it came to images—wasn't labeled, and that's what you needed to train neural nets. That's where Fei-Fei Li, a Stanford AI professor, stepped in. "Our vision was that big data would change the way machine learning works," she explains in an interview. "Data drives learning."

In 2007 she launched ImageNet, assembling a free database of more than 14 million labeled images. It went live in 2009, and the next year she set up an annual contest to incentivize and publish computer-vision breakthroughs.

In October 2012, when two of Hinton's students won that competition, it became clear to all that deep learning had arrived.

By then the general public had also heard about deep learning, though due to a different event. In June 2012, Google Brain published the results

of a quirky project now known colloquially as the "cat experiment." It struck a comic chord and went viral on social networks.

The project actually explored an important unsolved problem in deep learning called "unsupervised learning." Almost every deep-learning product in commercial use today uses "supervised learning," meaning that the neural net is trained with labeled data (like the images assembled by ImageNet). With "unsupervised learning," by contrast, a neural net is shown unlabeled data and asked simply to look for recurring patterns. Researchers would love to master unsupervised learning one day because then machines could teach themselves about the world from vast stores of data that are unusable today—making sense of the world almost totally on their own, like infants.

In the cat experiment, researchers exposed a vast neural net—spread across 1,000 computers—to 10 million unlabeled images randomly taken from YouTube videos, and then just let the software do its thing. When the dust cleared, they checked the neurons of the highest layer and found, sure enough, that one of them responded powerfully to images of cats. "We also found a neuron that responded very strongly to human faces," says Ng, who led the project while at Google Brain.

Yet the results were puzzling too. "We did not find a neuron that responded strongly to cars," for instance, and "there were a lot of other neurons we couldn't assign an English word to. So it's difficult."

The experiment created a sensation. But unsupervised learning remains uncracked—a challenge for the future.

NOT SURPRISINGLY, most of the deep-learning applications that have been commercially deployed so far involve companies like Google, Microsoft, Facebook, Baidu, and Amazon—the companies with the vast stores of data needed for deep-learning computations. Many companies are trying to develop more realistic and helpful "chatbots"—automated



2012
JUNE

Google Brain publishes the "cat experiment." A neural net, shown 10 million unlabeled YouTube images, has trained itself to recognize cats.

AUGUST

Google introduces neural nets into its speech-recognition features.

OCTOBER

A neural net designed by two of Hinton's students wins the annual ImageNet contest by a wide margin.

2013

MAY

Google improves photo search using neural nets.

2014

JANUARY

Google acquires DeepMind, a startup specializing in combining deep learning and reinforcement learning, for \$600 million.



2015
DECEMBER
A team from Microsoft, using neural nets, outperforms a human on the ImageNet challenge.

2016
MARCH
DeepMind's AlphaGo, using deep learning, defeats world champion Lee Sedol in the Chinese game of go, four games to one.

DEEP
LEARNING AND
MEDICINE

customer-service representatives.

Companies like IBM and Microsoft are also helping business customers adapt deep-learning-powered applications—like speech-recognition interfaces and translation services—for their own businesses, while cloud services like Amazon Web Services provide cheap, GPU-driven deep-learning computation services for those who want to develop their own software. Plentiful open-source software—like Caffe, Google's TensorFlow, and Amazon's DSSTNE—have greased the innovation process, as has an open-publication ethic, whereby many researchers publish their results immediately on one database without awaiting peer-review approval.

Many of the most exciting new attempts to apply deep learning are in the medical realm (see sidebar). We already know that neural nets work well for image recognition, observes Vijay Pande, a Stanford professor who heads Andreesen Horowitz's biological investments unit, and "so much of what doctors do is image recognition, whether we're talking about radiology, dermatology, ophthalmology, or so many other '-ologies.'"

While a radiologist might see thousands of images in his life, a computer can be shown millions. "It's not crazy to imagine that this image problem could be solved better by computers," Pande says, "just because they can plow through so much more data than a human could ever do."

The potential advantages are not just greater accuracy and faster analysis, but democratization of services. As the technology becomes standard, eventually every patient will benefit.

The greatest impacts of deep learning may well be felt when it is integrated into the whole toolbox of other artificial intelligence techniques in ways that haven't been thought of yet. Google's DeepMind, for instance, has already been accomplishing startling things by combining deep learning with a related technique called reinforcement learning. Using the two, it created AlphaGo, the system that, this past March, defeated the champion player of the ancient Chinese game of go—widely considered a landmark AI achievement. Unlike IBM's Deep Blue, which defeated chess champion Garry Kasparov in 1997, AlphaGo was not programmed with decision trees, or equations on how to evaluate board positions, or with if-then rules. "AlphaGo learned how to play go essentially from self-play and from observing big professional games," says Demis Hassabis, DeepMind's CEO. (During training, AlphaGo played a million go games against itself.)

A game might seem like an artificial setting. But Hassabis thinks the same techniques can be applied to real-world problems. In July, in fact, Google reported that, by using approaches similar to those used by AlphaGo, DeepMind was able to

increase the energy efficiency of Google's data centers by 15%. "In the data centers there are maybe 120 different variables," says Hassabis. "You can change the fans, open the windows, alter the computer systems, where the power goes. You've got data from the sensors, the temperature gauges, and all that. It's like the go board. Through trial and error, you learn what the right moves are."

"So it's great," he continues. "You could save, say, tens of millions of dollars a year, and it's also great for the environment. Data centers use a lot of power around the world. We'd like to roll it out on a bigger scale now. Even the national grid level."

Chatbots are all well and good. But that would be a cool app. **13**

■ Startup **Enlitic** uses deep learning to analyze radiographs and CT and MRI scans. CEO Igor Barani, formerly a professor of radiation oncology at the University of California in San Francisco, says Enlitic's algorithms outperformed four radiologists in detecting and classifying lung nodules as benign or malignant. [The work has not been peer reviewed, and the technology has

not yet obtained FDA approval.] **Merck** is trying to use deep learning to accelerate drug discovery, as is a San Francisco startup called **Atomwise**. Neural networks examine 3D images—thousands of molecules that might serve as drug candidates—and predict their suitability for blocking the mechanism of a pathogen. Such companies are using neural nets to

try to improve what humans already do; others are trying to do things humans can't do at all. Gabriel Otte, 27, who has a Ph.D. in computational biology, started **Freenome**, which aims to diagnose cancer from blood samples. It examines DNA fragments in the bloodstream that are spewed out by cells as they die. Using deep learning, he asks computers to find correlations be-

tween cell-free DNA and some cancers. "We're seeing novel signatures that haven't even been characterized by cancer biologists yet," says Otte. When Andreesen Horowitz was mulling an investment in Freenome, AH's Pande sent Otte five blind samples—two normal and three cancerous. Otte got all five right, says Pande, whose firm decided to invest.

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WHILE YOU WERE OUT

THIS IS THE LAST COLUMN

I'll be writing for this magazine. After 21 years and tens of thousands of words under the banner While You Were Out, I'll be the one who is out and about. Now, now, Virginia. Don't cry. These things happen. The world has changed. How?

My first column, back in 1995, was about something funny. I disremember what. But my editors at the time thought it would be amusing to slap the following headline on it: "You're in Deep Kim-chi." This offended some people of Korean extraction, and rightly so, since it compared their national condiment to something marginally less pleasant.

Several wrote letters of complaint to the magazine. I believe they received polite replies. And that was that.

But oh, my, Virginia, just think of the flap that little incident would engender in today's Twitterverse. A national day of outrage would be initiated on social media. The blogs would pick up on it, then the mainstream media. I'd be petitioned for an immediate apology. If I did express remorse, bang! Public shaming ceremonies would begin. For a decade the incident would remain the top result if you Googled my name. Meanwhile the digital space has become a breeding ground for the worst kinds of hate speech since Hitler. No outrage about that to speak of.

I'll be out there trying to make it on that platform from here on in. Got to be digital if you want to remain in business. Look for me there.

Speaking of business, the trends that disguise things have mutated, but the core remains the same. Bosses make big money and have nice office spaces. Workers make small money and don't. The bullwinkies that dress up these underlying principles are still laughable, thank goodness. Back in the day, it was all about Quality and Excellence, which transitioned nicely into Greed for



BYE-BYE, BING

After two decades here, your fearless columnist is setting off for the digital frontier.

BY STANLEY BING

boondoggles that cost the company a lot of money. Everybody in middle management got to go. Now we have conferences where the elite chuckle in each other's faces. On the bright side, there are fewer neckties around. And we are allowed to wear more comfortable shoes.

Some things are still the same, of course. Russia still sucks.

When I started this gig a long time ago, I was a tiny tadpole—amazed, fascinated, and sometimes repelled by the nonsense that attended this supposedly rational, serious occupation we all engage in every day. I saw things from the bottom up. After all these years, I still do. Since I'm an outsider now, I might as well keep scrounging around to find out what it is that's wrong, and see if there isn't something that can be done about it.

So I'll be around, somewhere, in the digital morass. Where there's a fight for people trying to keep their jobs, I'll be there. Wherever there's a mass hazing going on, or a bully swaggering beneath his fake hair, I'll be there. I'll be standing with the folks who want to yell when they're mad. I'll be there in the way that folks laugh when they're hungry and they know the corporate buffet is about to open. And where people get to take pride in the companies they've built without disruption, I'll be there too.

See you around, my friends. I'll look for your clicks. **FB**

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a while, and now it's Disruption and Innovation, but it's all the same stuff on a different day. Some have power. Some don't. It's better to be in the first group, even if it means you're probably more obnoxious than the people in the second group, who are almost certainly reading this in their cubicles right now. They say workers really love these open offices! I do note that those who say this are often the executives who initiated the new floor plan and have a place they can go to take a nap.

A lot has changed, though. I miss drinking at lunch. Business was better, and we had more fun. I also miss



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**THE MASTER STRATEGISTS:
GEORGE W. BUSH
AND BARACK OBAMA**

Nov 5: 09:10, 23:10 (r)

Nov 6: 17:10 (r)

PREMIERES OCTOBER



**THE MAVERICKS:
SHIRLEY CHISHOLM AND
JOHN MCCAIN**

15 Oct: 12:10, 23:10 (r)

16 Oct: 17:10 (r)



**THE INDEPENDENTS:
ROSS PEROT AND RALPH NADER**

22 Oct: 12:10, 23:10 (r)

23 Oct: 17:10 (r)



**THE TRAILBLAZERS:
GERALDINE FERRARO
AND SARAH PALIN**

29 Oct: 12:10, 23:10 (r)

30 Oct: 17:10 (r)

Timings in HKT.

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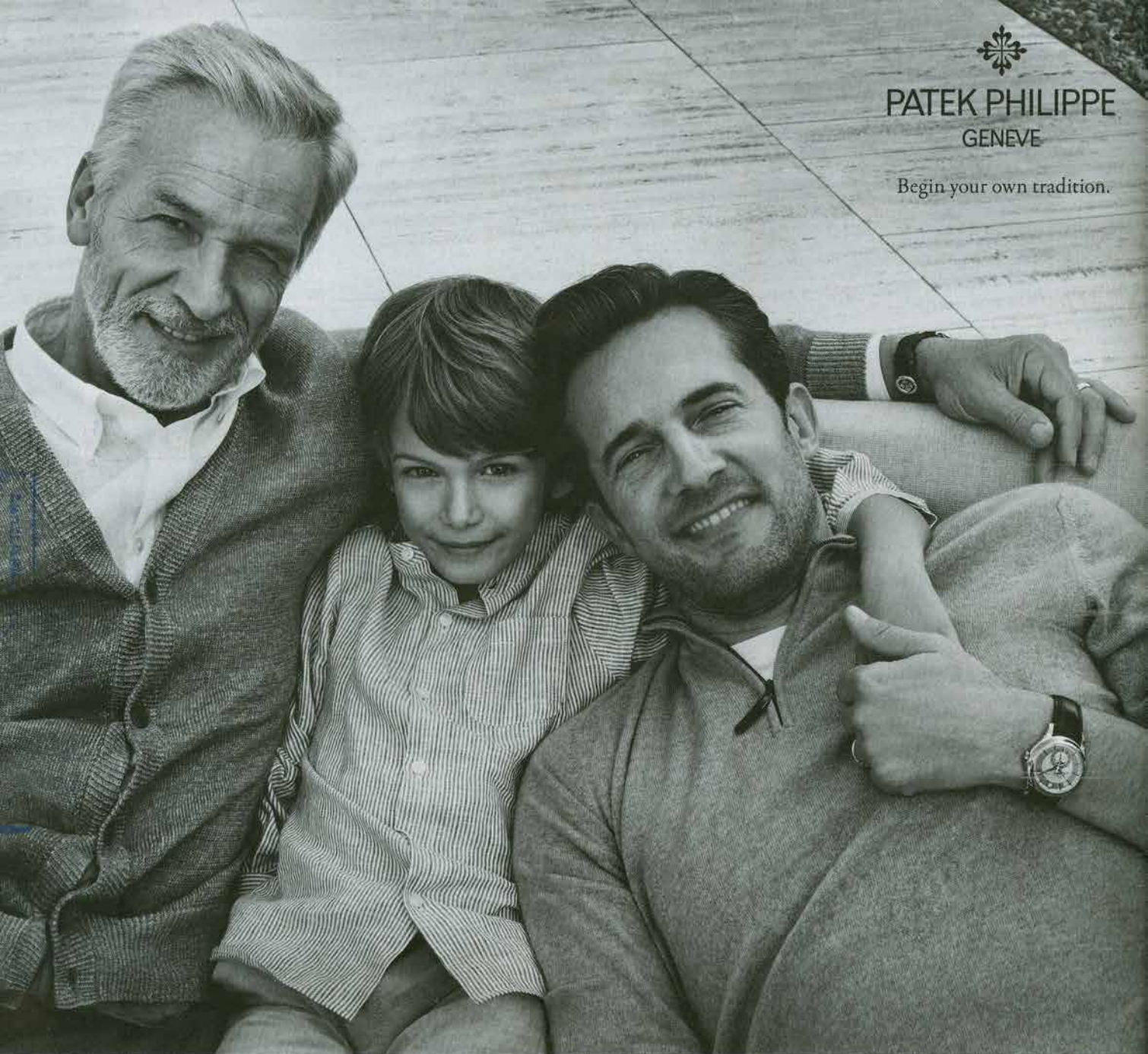
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