THE RISK REPORT BY IAN BREMMER

What falling birth rates reveal about China's future

WHEN CHINA announced in January that its population fell in 2022 for the first time since the early 1960s, the search for solutions to a growing demographic crisis took on new urgency. Beijing knew this day was coming and that an aging population inside a country with a social safety net that remains a work in progress will force new thinking. Failure will stunt the country's economic growth and create social pressures by pushing millions of older people into poverty.

That's the backdrop for a decision by authorities in Sichuan province, with a population of more than 80 million, to allow unmarried citizens to register their children and receive state health benefits. So far, only two provinces have taken this road. The municipal government of Shanghai tried this for a few weeks in 2021 before reversing course but we can expect more Chinese provinces and cities to experiment with similar steps.

A nurse cares for a newborn at a maternity hospital in Fuyang in central China's Anhui province on Jan. 17

YET, CHINESE OFFICIALS should know these reforms won't solve China's demographic dilemma. After all, similar plans in Japan and South Korea, which face the same problems, haven't had any impact on their own declining birth rates. In all three countries, low salaries, long work hours, and the rising costs of child rearing make large families unaffordable.

In Japan, the population began to shrink in 2005. Nearly 29% of Japanese are now 65 or older, and the country's population is forecast to fall from 125 million now to 87 million by 2060. Prime Minister Fumio Kishida warned recently that a low birth rate puts Japan "on the brink of being unable to maintain social functions." His government will open a new state agency to oversee childcare policies, but it's hard to see why that plan can do more than the Minister already responsible for this problem.

Though South Korea's population didn't begin shrinking until 2020, its outlook is even darker than Japan's. According to the OECD, "assuming no net migration and unchanged mortality, a total fertility rate of 2.1 children per woman ensures a broadly stable population." South Korea's fertility rate now stands at just 0.8, and the share of its population ages 65 and older is expected to overtake that of Japan by 2045 and will account for half the population by 2070. The efforts of past South Korean governments to throw money at this problem—as Japan and now China have done—have accomplished little, and the county's birth rate is now the lowest in the world. That's why South Korea's President Yoon Suk-yeol recently fired the vice chair of the presidential committee on birth rates after she proposed a plan to offer loans of $32,000 to young married couples and forgive the loans after the birth of a second child. Similar financial incentives have failed too many times over too many years.

But South Korea has been more aggressive in managing its demographic crisis by moving beyond strategies to increase the birth rate toward plans to welcome a lot more tax-paying immigrants. The country's foreign-born population doubled in just over a decade to push past 2.5 million in 2019. That's still under 5% of the total population, but the number is expected to keep rising. Japan has focused mainly on creating opportunities for higher-skilled foreign workers, and South Korea has promised a fast-track path to citizenship for them. But Seoul has calculated that welcoming larger numbers of immigrants in lower-skilled jobs can help to broaden the tax base more quickly.

The lesson for Beijing is clear: it must welcome more foreign workers. That means accepting the risks that come with higher levels of outside influence inside the country, managing the social problems that more immigrants will create—and giving foreigners, high- and low-skilled, more good reasons to live long-term in China. ◻

SOCIETY

The secret tax on women's time

BY LAUREN C. HOWE, LINDSAY B. HOWE, AND ASHLEY V. WHILLANS

WHEN STUDIES REVEALED THE SO-CALLED PINK TAX, showing in 2015 that personal hygiene products "for her" cost 13% more than similar products for men, it caused outrage and action. But there is also an unaddressed pink tax on women's time: a global epidemic of women lacking time to conduct the activities of their everyday lives that men simply do not experience. In fact, men have on average five hours more leisure time per week than women—equivalent to 260 hours, or 10.8 full 24-hour days, each year.

Our own research found it's true everywhere. After a conversation with a mother of three from an upper-middle-class neighborhood of Johannesburg, our colleague Margot Rubin asked, "So you're saying that there's nothing outside of money, or time, that will make anything better?" She paused and said, "Yes." In interviews with working mothers in the crowded and poor Kibera settlement in Nairobi, one lamented, "I have so much to do at home and I still have to go to work."

Why is there this time inequality? At home, childcare and chores devour women's time. At work, women—even those who have the security of steady employment—face further unequal time demands.

Women are more often asked and expected to take on "office housework": necessary but nonpromotable tasks such as taking notes, helping new hires get up to speed, bringing in cake for colleagues, or getting coffee for the office. With results that aligned with gender-based stereotypes, one study found that women volunteer up to 50% more than men for these tasks. Women also negotiate for time at a lower rate than men—in another study, men were more than twice as likely as women to request an extension when their deadline was adjustable—perpetuating this time-poverty trap further.

SO HOW CAN WE REPEAL the pink tax on time? Time-saving incentives are one solution: giving women money or vouchers to pay someone else to complete daily tasks that erode their free time—cooking, shopping, laundry, bringing children to school, household maintenance—or to shorten the time spent on tasks, like providing money to take a taxi instead of a bus. Services such as backup childcare or prepared takeaway meals can also reduce time burdens.

Given that buying time is a luxury that few can afford, policy innovations are also needed—and could be particularly impactful if expanded and adapted to reach those with the lowest incomes around the globe. For example, in field research in Kibera, Kenya, women in informal settlements reported that meal and laundry services would be most helpful in saving time. The research team then worked with a local community center to offer these time-saving services, finding that they reduced women's perceived burden of unpaid labor by 7% and resulted in a 5% increase in well-being during the study.

Valuing leisure over work is related to greater fulfillment

Another hurdle is to get women to actually use time-saving services. Overturning social norms is key—both for women and for men. For example, 60% of women find workplace flexibility key to future jobs, but many believe that a risk to flexible work is that any time women gain will be consumed by domestic responsibilities. At the same time, men get criticized at work when taking on childcare responsibilities, even resulting in workplace penalties like demotion.

Lastly, free time needs to be reframed as essential, rather than as unproductive and wasteful. Spending time on activities such as exercising, volunteering, or socializing predicts happiness, and valuing leisure over work is related to greater fulfillment. Mindsets must shift to view leisure as necessary, rather than nice to have.

Lauren Howe, Lindsay Howe, and Whillans study the future of work at, respectively, the University of Zurich, the University of Liechtenstein, and Harvard Business School

ILLUSTRATION BY SOL COTTI FOR TIME

ESSAY

Sleepwalking into a less secure future

BY KRISTALINA GEORGIEVA

EARLY IN THE PANDEMIC, EXPERTS PROJECTED THAT the world economy could shrink by almost 10% in 2020. Yet what played out was a contraction of 3.1%—still a huge loss of output, but not nearly as dire. To a large extent, this was due to international cooperation. Countries came together to diagnose the problem: a simultaneous shock to supply and demand. This meant that standard policy responses would not be sufficient. That's why policymakers took extraordinary fiscal and monetary measures to support businesses and households. Without this coordinated response, we would have faced another Great Depression. And without the global collaboration of scientists and health authorities, we would not have had effective vaccines in record time. When crisis strikes, as it has so often in the past three years, international cooperation can save lives and livelihoods, and lay the foundations for a faster recovery.

Both the financial response and the vaccines are representative of the broader benefits of decades of economic integration and cooperation, which also helped billions of people to become healthier, wealthier, and better educated. Over the past three decades, around 1.3 billion people were lifted out of extreme poverty. To get there, we had to reach across borders. Think of trade integration, spurred by lower trade barriers and the emergence of global supply chains. And think of the spread of new technologies and cross-border capital flows that have underpinned much-needed investment, especially in emerging and developing economies.

No country should face these challenges alone

BUT THIS IS only part of the story. The dislocations from trade and technological change have harmed some communities. Inward-looking policies and trade tensions have been on the rise for some years. And now geopolitical fragmentation is raising the specter of a "new cold war" that could see the world break into economic blocs at a cost of trillions of dollars in lost productivity.

In other words, unless we confront fragmentation, we are at risk of sleepwalking into a future that is poorer and less secure. And as we work to overcome these divisive forces, we must focus on the most vulnerable. This includes many countries in Africa and the Caribbean that are already bearing the brunt of climate change. Should they face this challenge alone, even though others contributed so much more to the climate crisis? Or consider the growing risk of a debt crisis in emerging and developing economies. Should they face this dire fiscal situation alone, even though most are being hit by external shocks rather than domestic policy missteps?

THE ANSWER MUST BE NO. The suffering of one country can easily affect others and threaten global growth. So it's in everyone's interest to urgently strengthen international cooperation on these vital issues. The IMF is founded on the principle that we are stronger together. Thanks to the collective will of our membership, we provided a record $650 billion allocation of Special Drawing Rights (SDRs), funds that allowed many vulnerable countries to maintain access to liquidity, freeing up resources to pay for vaccines and health care. And we are now helping countries with stronger reserves to channel their SDRs to countries whose need is greater.

For example, so far we have around $40 billion in pledges to support our new Resilience and Sustainability Trust, which will allow the IMF to provide long-term financing for the first time. Our goal is to help vulnerable low- and middle-income countries build resilience against structural challenges such as climate change and pandemics. While we cannot prevent new shocks, we can bolster the resilience of our people, our communities, and our societies.

One thing is clear: we must overcome diminished trust and growing fragmentation, because no country should face these challenges alone. The pandemic showed us that we can cooperate to harness human courage, compassion, and ingenuity. And this is exactly how we can help build a better future for all people. —*As told to* BELINDA LUSCOMBE

Georgieva is the managing director of the International Monetary Fund

WORLD

SHADOW NETWORK

Inside the clandestine effort to smuggle a free internet into Iran, one dish at a time

BY KARL VICK

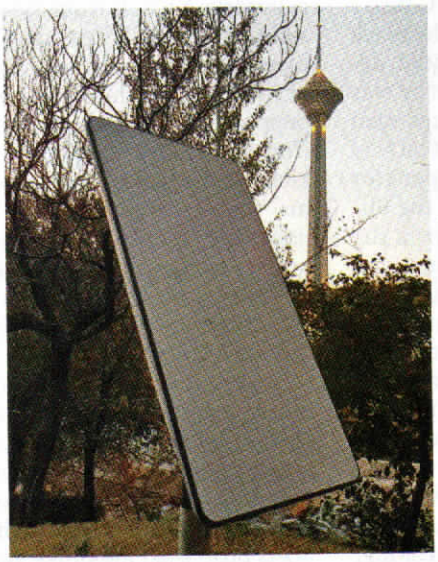
SOMEHOW, THE SATELLITE DISH ARrived in its original packaging, a gray cardboard box clearly labeled STARLINK, handed over in broad daylight in the middle of Tehran. "As if Elon Musk himself is delivering to me," Reza, the young Iranian who accepted the package, recalls with a laugh. He took the delivery not from Musk, who owns the satellite internet company, but from a visibly nervous and irate professional smuggler. The man wanted the $300 he'd been promised, and an explanation of why the device he'd just risked his life sneaking into the Islamic Republic was so important.

"They kept me like five hours at the border for that," the smuggler told him.

What the Iranian border guards had finally, and foolishly, allowed into the country may well be the means to sustain the rebellion there. Now in its fifth month, the slow-motion uprising depends first on the zeal of protesters—but at least as much on being able to show the world what is happening. "The most important thing," says Reza, who asked not to be further identified for fear of arrest, "is to have the protests on the internet. It's crucial."

Iran's authoritarian government not only controls the internet in the country, it also uses that control as a weapon—slowing service to a crawl when protesters go into the streets, and shutting it down altogether when the decision is made to slaughter them. The last time spontaneous protests erupted across Iran—over a fuel-price hike in November 2019—the regime responded by cutting off all external web portals and opening fire. Reuters reported that, all told, some 1,500 people were killed.

So when new protests erupted in September—sparked by the death of 22-year-old Mahsa Amini, who had been arrested by the loathed "morality police"—human-rights activists outside the country were primed. Within days, efforts got under way to provide a nationwide but leaderless movement with an alternate internet. The most ambitious of the efforts operates largely underground and on private funds; it spans continents, communicates on encrypted messaging platforms, and involves about a dozen activists, five of whom spoke to TIME.



A Starlink receiver and Tehran's Milad Tower, photographed in early November

Their secret campaign, they say, began with two public announcements: on Sept. 23, the Biden Administration cleared the way for U.S. communications companies to operate in Iran while keeping other sanctions in place. Later the same day, Musk announced, "Starlink is now activated in Iran." That was the good news. But his message continued: "It requires the use of terminals in-country, which I suspect the government will not support, but if anyone can get terminals into Iran, they will work."

Musk suspected correctly. In addition to the 500 protesters killed and estimated 18,000 arrested inside the country since September, the regime also stalks critics overseas. U.S. Attorney General Merrick Garland announced on Jan. 27 that the man on Masih Alinejad's Brooklyn doorstep in July 2021 was an assassin hired to silence a critic with 8 million Instagram followers. "I don't have any weapon," says Alinejad, who escaped out the back. "I'm a threat for the regime just because of my social media platform."

The Iranian regime is now challenged by a nonviolent rebellion with a slogan, "Woman, life, freedom," and an anthem, "Because Of," a ballad that took its lyrics

A Tehran street on Sept. 22, 2022, six days after the death of Mahsa Amini in police custody

STARLINK DISH: COURTESY; PROTEST IN TEHRAN: IRANWIRE/MIDDLE EAST IMAGES/REDUX

from tweets listing the ways life in Iran had become intolerable. Like word of the protests, the song spread across the country online. "For those living under dictatorships like the Islamic Republic," says Karim Sadjadpour, a fellow at the Carnegie Endowment for International Peace, "unfettered internet access is like oxygen."

HERE'S HOW STARLINK WORKS: Several thousand small satellites in low orbit around the globe beam broadband internet down to earth. The signal can be picked up only by a Starlink dish, which works only with a subscription that runs $110 a month—but pretty much anywhere in the world. Though other companies have explored the model, Starlink is essentially the only option for locations remote or under siege—and, at a time when its founder is more likely to be associated with the fight over "free speech" on social media platforms, the company has played a significant role in preserving open information in some of the places it is most at risk. In Ukraine, Starlink effectively replaced the internet taken down during Russia's invasion. There, the U.S. government and its allies purchased nearly 20,000 Starlink dishes. Musk's privately owned SpaceX, which operates Starlink, contributed 3,667. Further, in Ukraine, Musk waived the subscription fee.

The same largesse has not been extended in Iran.

"Each one is $700 … so 100 devices is almost $70,000," notes an activist involved in organizing the largest effort to secure them, which is supported by private contributions. Adding the cost of smuggling them into the country, "it can easily come to $200,000."

And 100 devices is not nearly enough. Organizers estimate that a shadow web could be effective in Iran with about 5,000 Starlink dishes. "The main goal is not really equipping all Iranians with satellites," one organizer says, "but basically sending a few thousand devices and getting them to the right people, so

an internet shutdown is not a problem."

But how to get them there? "The biggest challenge is the logistics," says an activist who traveled to western Asia to arrange passage of the receivers.

Fortunately, the region has a rich culture of smuggling. Iran shares a land border with seven countries and has been a trading crossroads for millennia. "So far, I'd say we have six separate channels that we are trying," one organizer tells TIME. "We are not just relying on one channel. We try to diversify and see if we can get the job done."

Some routes are more treacherous than others. Dubai, for instance, is fraught because of all the smuggling done there by members of the Islamic Revolutionary Guard Corps (IRGC). "A lot of what I do is vetting," says the activist tasked with logistics. The IRGC also poses a danger inside Iran, where it has deployed mechanized divisions in the Kurdish region from which Amini hailed. "There are a lot of checkpoints at Kurdistan and Kermanshah, and they are specifically looking for guns and Starlink," one organizer said. "But there are different routes. They can't stop every car. So far we've been lucky that no one has been harmed in this operation."

The professional smuggler who brought Reza the still packaged dish was on a test run, organizers said, and not used again. The goal is to use only people committed to the mission, trustworthy, and willing to accept the risk.

"It's simply life and death," says an activist. "You get caught, there's no middle ground. Maybe they throw you from the 20th floor instead of the 40th floor, that's the middle ground. Like, 'moderate beheading.'"

ONCE INSIDE IRAN, the dishes amount to a new front on the dangerous battlefield that is communications. Early in the protests, the regime took down gaming platforms, with their chat channels teeming with young people. And although VPNs and encrypted messaging platforms like Signal may circumvent government surveillance, protesters rightly regard their phones as loaded guns. Reza says his most terrifying moment came when, at a demonstration, an undercover agent wrapped him in a bear hug and pulled him toward a waiting car. "Unfortunately, I had my phone with me." He thought of a friend sentenced to five years in prison after authorities found messages "cursing the regime" on an encrypted chat with his father. Reza managed to avoid a similar fate but a month later was still mortified: "If they capture my phone, the information on it…"

Locations of Starlink satellites on Jan. 25, 2 p.m. E.T.

Starlink likely brings its own dangers. "Any novel new technology has the promise of moving faster than the regime trying to track it down," notes John Scott-Railton, a senior researcher at the University of Toronto's Citizen Lab project. "At the same time, novel technologies come with risks … Some we won't know until the risks are translated to people getting arrested."

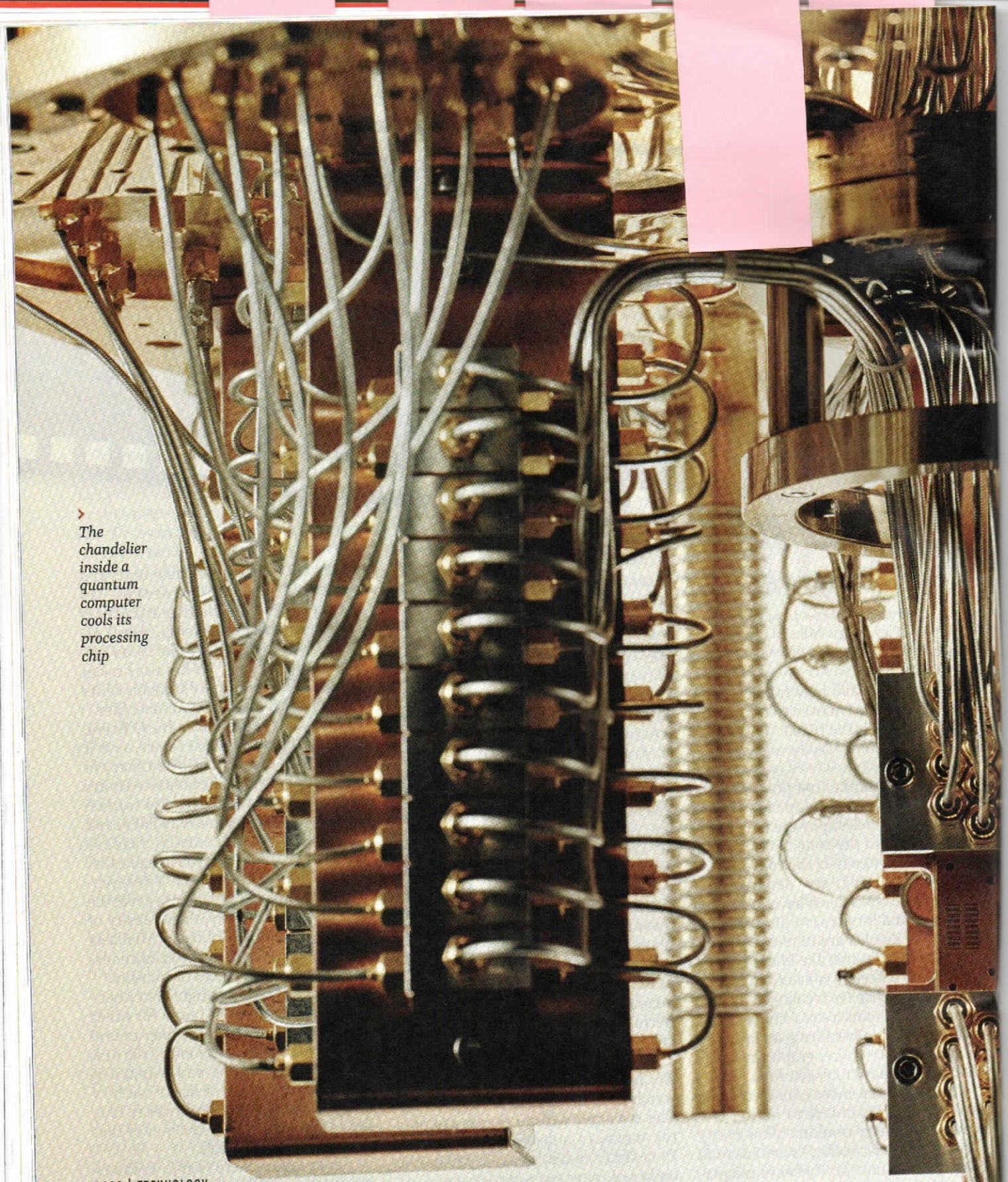
But public opinion is an important weapon. With foreign journalists barred by the Iranian government, "citizen journalism is a big thing," says Saman Arbabi, a New Yorker who posts cellphone videos from the protests to his 700,000 Instagram followers. A day when a protester is hanged, as four have been so far, will bring thousands of submissions. "They understand that they are the people who are communicating with the outside world, and they're very important," he says of the senders. "It's very significant, to get reaction from governments and also powerful and influential people in the West."

Ukraine has restored much of its internet thanks to 22,000 Starlink dishes, and there are 10,000 more on the way. Asked by TIME if the company would lift its fees in Iran or donate dishes, a SpaceX spokesman declined comment. He also demurred on whether the company is working with the U.S. government to bring Starlink to Iran. A senior State Department official declared, "We're not going to get into the details of what tools or partners we may or may not be working with."

The coy replies dismay the activists, who state flatly that the U.S. government has offered only rhetorical support. But they also note that, in time, every technology previously banned by the Islamic Republic inevitably became available inside its borders.

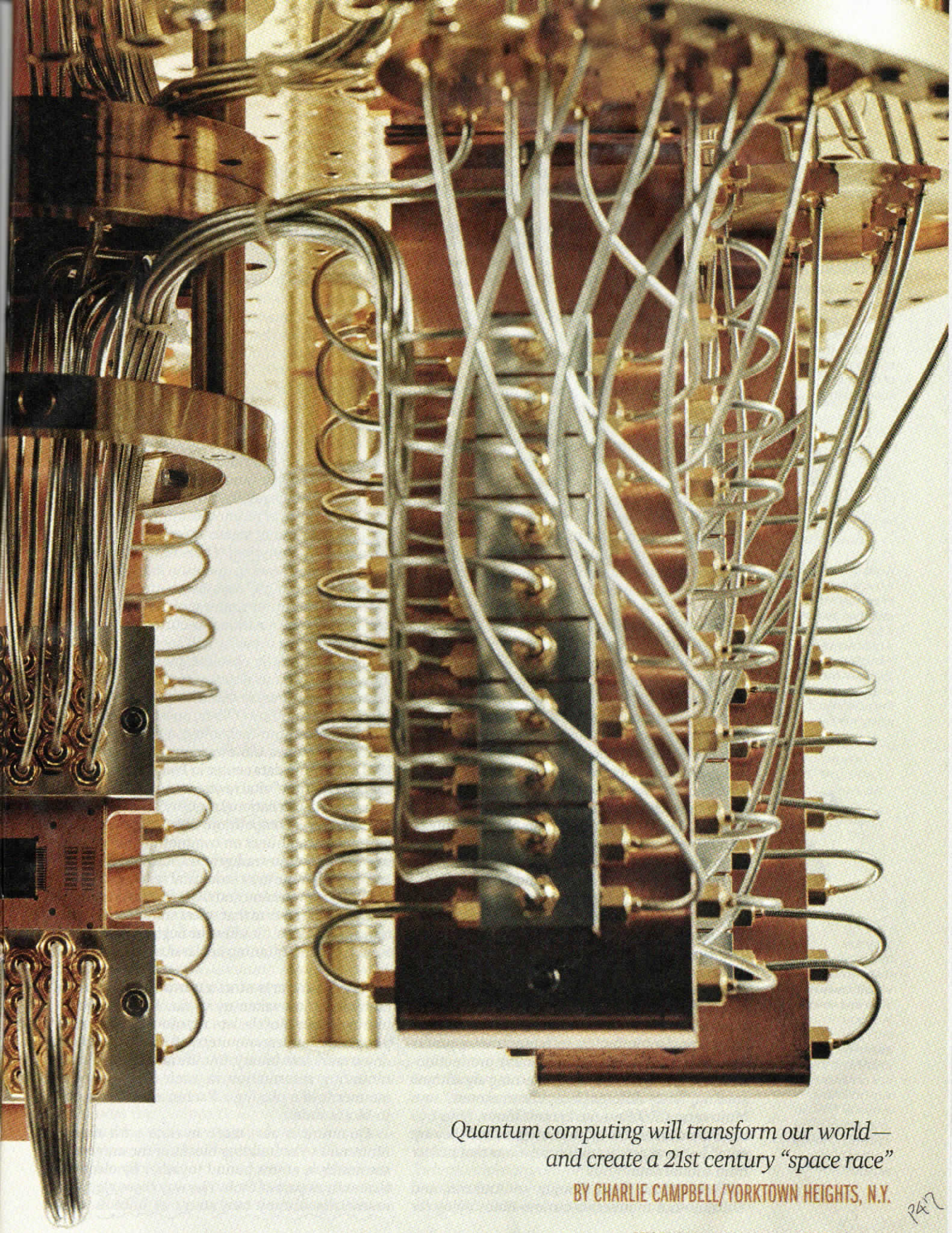
Reza says that when a Starlink dish arrived without a tripod, he got one from a local vendor who installs satellite TV, also once illegal in Iran. He set up the dish on the roof of his apartment building, but after noticing that it stood out from other satellite dishes, he asked his mother for one of her chadors—the billowing black cloaks favored by devoutly religious women, of which his mother is one. She chooses hijab, her son explained, but opposes a regime that thinks it can make the choice for her or anyone else. Reza draped the fabric over the Starlink dish. It still worked fine.

"For sure I'm worried and I'm scared," he says, but adds, "I don't see any value in this life without standing with people, standing up against the cruelty of this regime." —*With reporting by* MARIAH ESPADA



The chandelier inside a quantum computer cools its processing chip

THE QUANTUM LEAP



Quantum computing will transform our world—and create a 21st century "space race"

BY CHARLIE CAMPBELL/YORKTOWN HEIGHTS, N.Y.

PHOTOGRAPHS BY THOMAS PRIOR FOR TIME

THE THEORY

Erwin Schrödinger created the famous thought experiment that illustrates the strangeness of quantum superposition

A **cat** is sealed in a box with a **flask of poison** and a **radiation source.** If the source emits a radioactive particle—a 50-50 chance—the flask shatters, releasing the poison and killing the cat

Quantum mechanics implies that the cat is **simultaneously alive and dead—** in superposition—until it is **observed.** The act of opening the box collapses the superposition, returning the cat to a classical state and making it either alive or dead

ONE OF THE SECRETS TO BUILDING THE WORLD'S most powerful computer is probably perched by your bathroom sink.

At IBM's Thomas J. Watson Research Center in New York State's Westchester County, scientists always keep a box of dental floss—Reach is the preferred brand—close by in case they need to tinker with their oil-drum-size quantum computers, the latest of which can complete certain tasks millions of times as fast as your laptop.

Inside the shimmering aluminum canister of IBM's System One, which sits shielded by the same kind of protective glass as the *Mona Lisa*, are three cylinders of diminishing circumference, rather like a set of Russian dolls. Together, these encase a chandelier of looping silver wires that cascade through chunky gold plates to a quantum chip in the base. To work properly, this chip requires supercooling to 0.015 kelvins—a smidgen above absolute zero and colder than outer space. Most materials contract or grow brittle and snap under such intense chill. But ordinary dental floss, it turns out, maintains its integrity remarkably well if you need to secure wayward wires.

"But only the unwaxed, unflavored kind," says Jay Gambetta, IBM's vice president of quantum. "Otherwise, released vapors mess everything up."

It's a curiously homespun facet of a technology that is set to transform pretty much everything. Quantum's unique ability to crunch stacks of data is already optimizing the routes of thousands of fuel tankers traversing the globe, helping decide which ICU patients require the most urgent care, and mimicking chemical processes at the atomic level to better design new materials. It also promises to supercharge artificial intelligence, with the power to better train algorithms that can finally turn driverless cars and drone taxis into a reality. Quantum AI simulations exhibit a "degree of effectiveness and efficiency that is mind-boggling," U.S. National Cyber Director Chris Inglis tells TIME.

Quantum's earliest adopters are asset-management firms—for which incorporating quantum calculations involves few increased overhead costs—but commercial uses aren't far behind. Spanish firm Multiverse Computing has run successful pilot projects with multinational clients like BASF and Bosch that show its quantum algorithms can double foreign-exchange trading profits and catch almost four times as many production-line defects. "Quantum deep-learning algorithms are completely different from classical ones," says Multiverse CEO Enrique Lizaso Olmos. "You can train them faster, try more strategies, and they are much better at getting the correlations that matter from a lot of data."

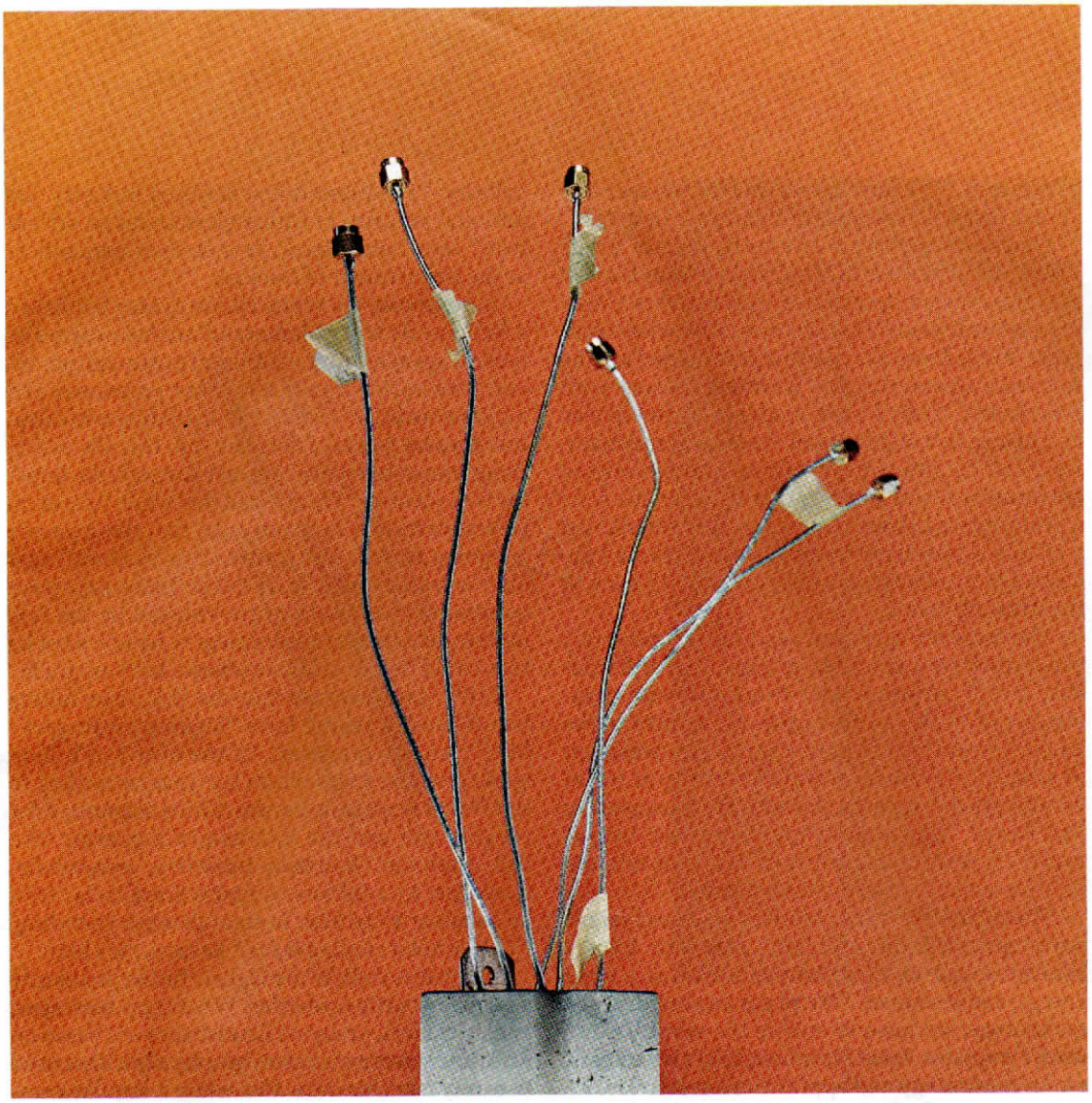
Tech giants from Google to Amazon and Alibaba—not to mention nation-states vying for technological supremacy—are racing to dominate this space. The global quantum-computing industry is projected to grow from $412 million in 2020 to $8.6 billion in 2027, according to an International Data Corp. analysis.

Whereas traditional computers rely on binary "bits"—switches either on or off, denoted as 1s and 0s—to process information, the "qubits" that underpin quantum computing are tiny subatomic particles that can exist in some percentage of both states simultaneously, rather like a coin spinning in midair. This leap from dual to multivariate processing exponentially boosts computing power. Complex problems that currently take the most powerful supercomputer several years could potentially be solved in seconds. Future quantum computers could open hitherto unfathomable frontiers in mathematics and science, helping to solve existential challenges like climate change and food security. A flurry of recent breakthroughs and government investment means we now sit on the cusp of a quantum revolution. "I believe we will do more in the next five years in quantum innovation than we did in the last 30," says Gambetta.

But any disrupter comes with risks, and quantum has become a national-security migraine. Its problem-solving capacity will soon render all existing cryptography obsolete, jeopardizing communications, financial transactions, and even military defenses. "People describe quantum as a new space race," says Dan O'Shea, operations manager for Inside Quantum Technology, an industry publication. In October, U.S. President Joe Biden toured IBM's quantum data center in Poughkeepsie, N.Y., calling quantum "vital to our economy and equally important to our national security." In this new era of great-power competition, China and the U.S. are particularly hell-bent on conquering the technology lest they lose vital ground. "This technology is going to be the next industrial revolution," says Tony Uttley, president and COO for Quantinuum, a Colorado-based firm that offers commercial quantum applications. "It's like the beginning of the internet, or the beginning of classical computing."

IF ANYTHING, IT'S SURPRISING that traditional computing has taken us so far. From the trailblazing Apple II of the late 1970s to today's smartphones and supercomputers, all processors break down tasks into binary. But life is so complex that rendering information in such a rudimentary manner is like playing a Rachmaninoff concerto in Morse code.

Quantum is also more in tune with nature. Molecules—the building blocks of the universe—are multiple atoms bound together by electrons that exist as part of each. The way these electrons essentially occupy two states at once is what



This IBM quantum processor dates back more than a decade

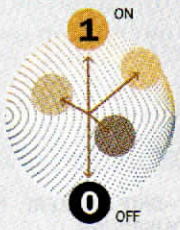
quantum particles replicate, presenting applications for natural and material sciences by predicting how drugs interact with the human body, or substances perform under corrosion. Traditional manufacturing takes calculated guesses to make breakthroughs through trial and error; by mirroring the natural world, quantum should allow advances to be purposefully designed.

While the world's biggest companies, alongside hundreds of startups, are clamoring to harness quantum, IBM has emerged in recent years as the industry leader. Today, the firm has over 60 functioning quantum computers—more than the rest of the world combined—and a roster of collaborators that include titans of practically every industry from ExxonMobil to Sony. It's a welcome return to technology's zenith for the storied firm, founded over a century ago to produce tabulating machines fed with punch cards. In recent years, IBM had fallen behind rivals like Apple and Microsoft by not seizing the initiative with cloud computing and AI. Quantum offers some redemption. "It's great to be back at the top again," says one executive. "It's no secret that we let things slip by not jumping on cloud."

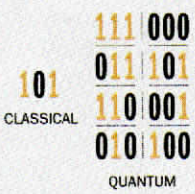
In November, IBM unveiled its new 433-qubit Osprey chip—the world's most powerful quantum processor, the speed of which, if represented in traditional bits, would far exceed the total number of atoms in the known universe. IBM has more than 20 quantum computers available on its open-source quantum tool kit Qiskit, which has been downloaded more than 450,000 times to date. In order to build an industry around quantum, some machines are free to use, while paying clients such as startups and scholars can access more powerful ones remotely on a lease basis. IBM has a bold road map to launch a 1,121-qubit processor this year and, by 2025, surpass 4,000 qubits by creating modular quantum circuits that link multiple processor chips in the same computer. "Modularity is a big inflection point," says Dario Gil, IBM senior vice president and director

THE COMPUTER

Classical computers process data in **bits**—single units of information that can be either 1 or 0. This is the building block of all digital computation



Quantum computers rely on **qubits,** which because of quantum superposition can be 1 and 0 at the same time



Because its data can exist in multiple states, a quantum computer can **perform multiple operations simultaneously** instead of one by one

of research. "We now have a way to engineer machines that will have tens of thousands of qubits."

Quantum's industrial uses are boundless. Inside BMW's headquarters in Munich there stands a wall that gives vehicle designers sleepless nights. Creating a new car model from scratch takes at least four years. First, designers use computer-aided styling to sketch an exterior that combines beauty with practicality. Next, a scale model is carved in clay and placed in a wind tunnel to assess aerodynamics. After countless decisions on interior, engine performance, and so on comes the ultimate test: a prototype is driven at 35 m.p.h. into that fabled wall to test how it performs in a crash. Should the car fail to meet various safety criteria, it's back to the drawing board.

This is where quantum can help by accurately predicting how complex materials of different shapes will perform under stress. "Robust simulated crash tests can save up to six months in the whole process," says Carsten Sapia, vice president of strategy, governance, and IT security at BMW Group, which has partnered with French quantum firm Pasqal. "Quantum computing will also help us find the new optimum between design, maximum interior space, and best aerodynamics."

That's just the start. Modern business teems with optimization problems that are ideally suited to quantum algorithms and could save time, energy, and resources. "We're not just building the technology, we have to enable the workforce to use it," explains Katie Pizzolato, IBM's director of quantum strategy and applications research.

Sapia says finding uses for the technology is easy; the challenge will be ensuring that all divisions of BMW are able to utilize it. Already, BMW is unable to communicate from Europe to its cars in China for driving software maintenance and monitoring because of increasingly strict curbs on the transfer of data across borders. "In the future, we will rely on everywhere in the world having access to quantum technology to run our business," Sapia says. "So how can we set it up so no matter what happens on a geopolitical scale that we still have access to this technology?"

'PEOPLE ARE GOING TO WEAPONIZE THESE SYSTEMS.'
—SKIP SANZERI, QUSECURE

OVER THE PAST FEW YEARS quantum has moved from a footnote to the top of the global security agenda. To date, 17 countries have national quantum strategies and four more are developing them. China has invested an estimated $25 billion in quantum research since the mid-1980s, according to Quantum Computing Report. Its top quantum scientist, Pan Jianwei, led the launch of the world's first quantum satellite in 2016 and in 2021 unveiled a then record-breaking 56-qubit quantum computer. China's 14th Five-Year Plan, published in March 2021, made mastery of quantum a policy priority. "The blurred line between industry and national security in China gives them an advantage," says David Spirk, former chief data officer at the Department of Defense.

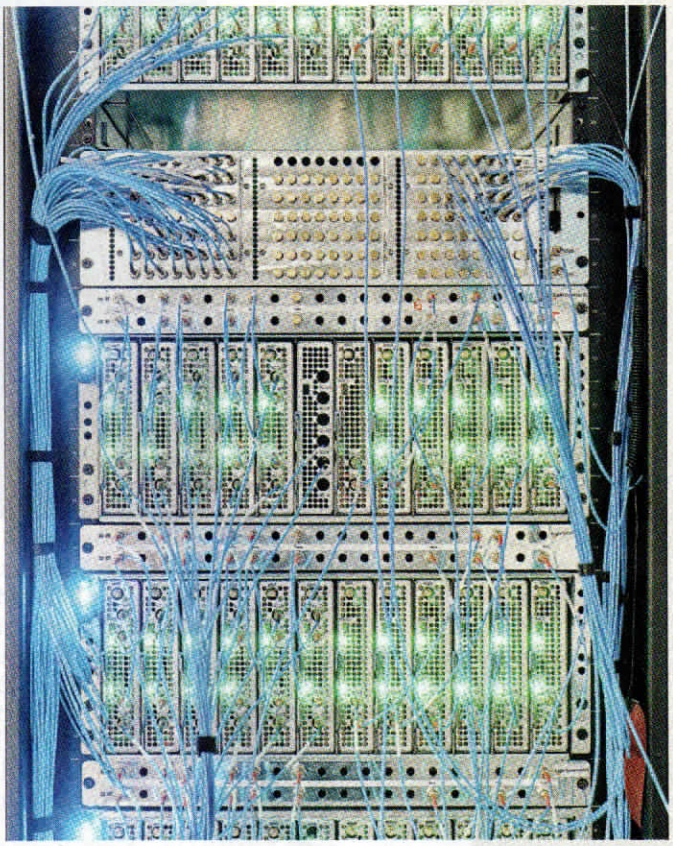
In response, the White House in May published a National Security Memorandum that ordered all federal agencies to transition to postquantum security owing to "significant risks to economic and national security." Given that upgrading critical infrastructure can take decades, and literally everything connected to the internet is at risk, the impetus is to act now. "We realized that while [quantum is] wonderful for humanity, the first thing people are going to do is weaponize these systems," says Skip Sanzeri, founder and COO of QuSecure, a postquantum cybersecurity firm enlisted by the U.S. military and federal government to handle what he says could be a $1 trillion cybersecurity upgrade.

Still, Spirk worries that the U.S. risks falling behind and is calling for a "Manhattan Project–like" focus on quantum. Of the over $30 billion spent globally on quantum last year, according to the World Economic Forum, China accounted for roughly half and the E.U. almost a quarter. The U.S. National Quantum Initiative, meanwhile, spent just $1.2 billion—a figure Spirk calls "trivial" against $1 trillion in total defense spending. "This is not a coming wave," he says, "it's here."

The stakes couldn't be higher. Today, practically all cybersecurity—whether WhatsApp messages, bank transfers, or digital handshakes—is based on RSA, an asymmetric cryptography algorithm used to safely transfer data. But while a regular computer needs billions of years to crack RSA, a fast quantum computer would take just hours. In December, a team of scientists in China published a paper that claimed it had a quantum algorithm that could break RSA with a 372-qubit computer (though its conclusions are hotly debated). The race is now on to devise postquantum security—a job that falls to the U.S. National Institute of Standards and Technology, or NIST. In 2016, NIST announced a competition for programmers to propose new postquantum encryption algorithms. The results were mixed: one of the finalists announced on July 5, 2022, has since been cracked by a regular laptop in a little over an hour.

In some ways, it's already too late. Even though quantum computers powerful enough to crack RSA are a few years away from being openly available, hackers are already seizing and storing sensitive data in the knowledge that they will be able to access it via quantum very soon. "Every day that you don't convert to a quantum-safe protocol, there's no recovery plan," Gil says.

The war in Ukraine has also served as a wake-up call. It is history's first hot conflict to begin with cyberattacks, as Russia targeted vital



Left, flexible cabling designed to deliver signals; right, a rack of classical control electronics

communications and infrastructure to lay the groundwork for its military assault. Public services, energy grids, media, banks, businesses, and nonprofit organizations were subjected to a cyberblitzkrieg, impacting the distribution of medicines, food, and relief supplies. Modern warfare and national-security mechanisms are grounded in the speed and precision of decisionmaking. "If your computer is faster than theirs, you win, it's pretty simple," says Spirk. "Quantum is that next leap."

But malign intentions are just one hazard. With the U.S. embroiled in a new Cold War, it's also unclear if China and Russia would adopt new NIST protocols, not least since in the past, RSA cryptography has allegedly been breached by the U.S. National Security Agency. In September, National Security Adviser Jake Sullivan said quantum would have "an outsized importance over the coming decade," adding that export controls could be used to maintain U.S. advantage. Competing postquantum security standards across Washington's and Beijing's spheres of influence have the potential to cleave the world into divergent blocs, with grave implications for global trade. "[The] balkanization of what we know today as a free and open internet is distinctly possible," Inglis says.

The trepidation surrounding quantum doesn't stem solely from security risks. We trust classical computers in part because we can verify their computations with pen and paper. But quantum computers involve such arcane physics, and deal with such complex problems, that traditional verification is extremely tricky. For now, it's possible to simulate many quantum calculations on a traditional supercomputer to check the outcome. But soon will come a time when trusting a quantum computer will require a leap of faith. "Trust building across the entire ecosystem right now is really important," says Uttley.

Boeing, for one, has been working with IBM's quantum team since 2020 on designing new materials for its next generation of aircraft. But given the colossal reputational stakes, the firm is in no rush. "The modeling tools that we use to design our airplanes are closely monitored," says Jay Lowell, chief engineer for disruptive computing and networks at Boeing. "To turn [quantum] into an operational code is a huge, huge hurdle."

One that IBM knows only too well. But by making its quantum computers open source, and welcoming academics and entrepreneurs from all over, the firm hopes to mitigate the hesitancy. As Gil puts it, "this is a new frontier of humanity."

—*With reporting by* LESLIE DICKSTEIN