FEB. 13 / FEB. 20, 2023

TIME

# THE QUANTUM LEAP

THIS MACHINE CAN SOLVE PROBLEMS IN SECONDS THAT USED TO TAKE YEARS

THE FUTURE OF COMPUTING IS HERE

*by* **CHARLIE CAMPBELL**

+

INTEL CEO PAT GELSINGER ON THE RISKS OF AI

免责申明：

1. 本附加与原报告无关；
2. 本资料来源互联网公开数据；
3. 本资料在“行业报告资源群”和“知识星球行业与管理资源”均免费获取；
4. 本资料仅限社群内部学习，如需它用请联系版权方

合作与沟通，
请联系客服

客服微信　　客服微信

## 行业报告资源群

微信扫码 长期有效

1. 进群即领福利《报告与资源合编》，内有近百行业、上万份行研、管理及其他学习资源免费下载；
2. 每日分享学习最新6+份精选行研资料；
3. 群友交流，群主免费提供相关领域行研资料。

微信扫码 行研无忧

知识星球 行业与管理资源 是投资、产业研究、运营管理、价值传播等专业知识库，已成为产业生态圈、企业经营者及数据研究者的智慧工具。

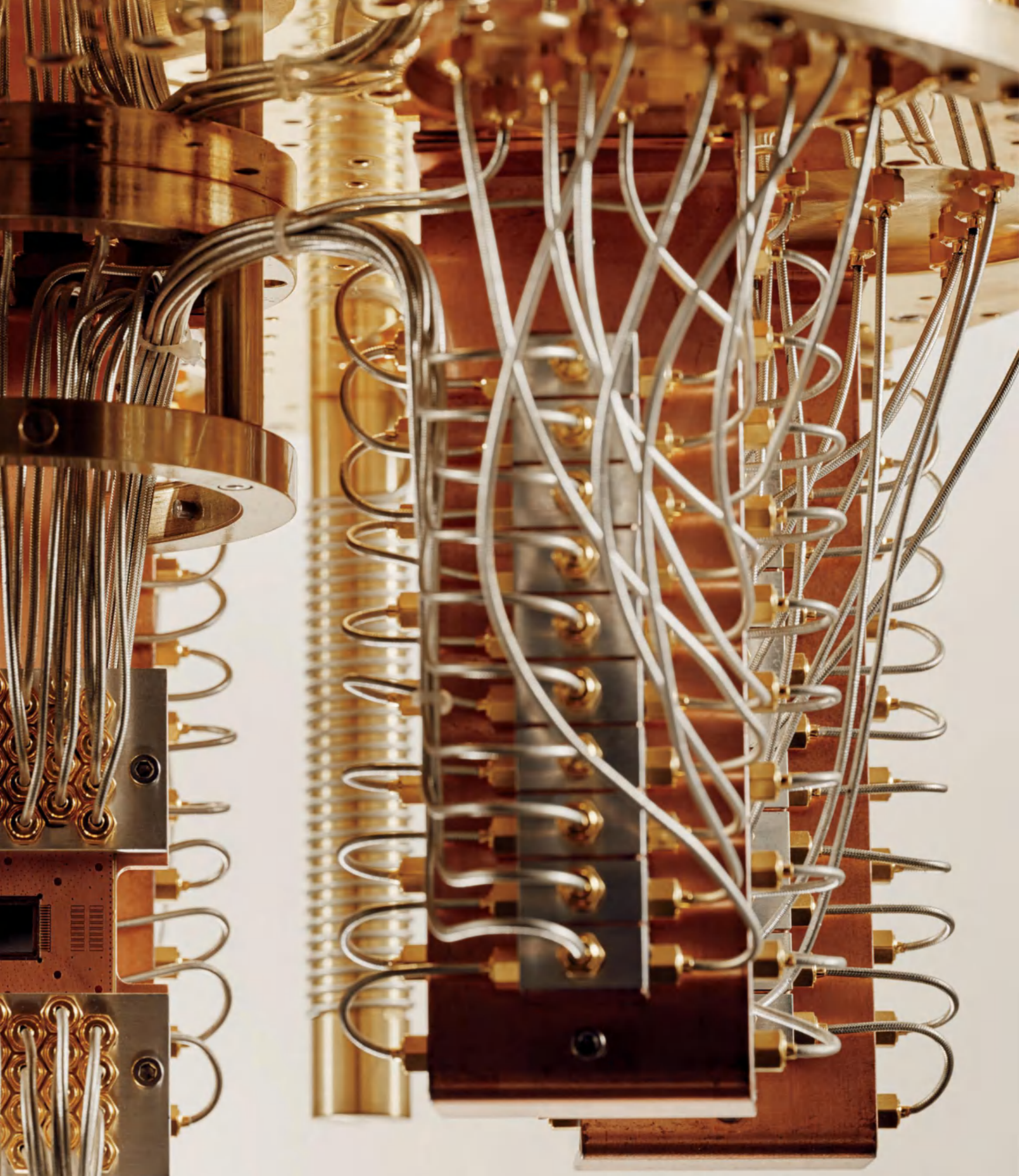
知识星球 行业与管理资源每月更新5000+份行业研究报告、商业计划、市场研究、企业运营及咨询管理方案等，涵盖科技、金融、教育、互联网、房地产、生物制药、医疗健康等；

微信扫码加入后无限制搜索下载。

*The chandelier inside a quantum computer cools its processing chip*

2030 | TECHNOLOGY

# 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.

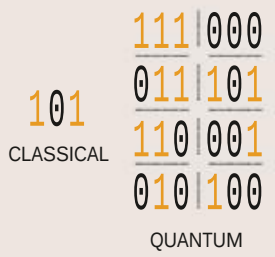
While the world's biggest companies, alongside hundreds of startups, are clamoring to harness quantum, IBM has emerged in recent years as the industry leader. Today, the firm has over 60 functioning quantum computers—more than the rest of the world combined—and a roster of collaborators that include 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

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 ◻

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

Q&A

# KEEPING AI IN CHECK

*Why ChatGPT's creator is pro-regulation*

BY JOHN SIMONS


SOMEHOW, MIRA MURATI CAN forthrightly discuss the dangers of AI while making you feel like it's all going to be OK.

Murati is chief technology officer at OpenAI, leading the teams behind DALL-E, which uses AI to create artwork based on prompts, and ChatGPT, the wildly popular AI chatbot that can answer complex questions with eerily humanlike skill.

ChatGPT captured the public imagination upon its release in late November. While some schools are banning it, Microsoft announced a $10 billion investment in the company and Google issued a "code red," fretting that the technology could disrupt its search business. "As with other revolutions that we've gone through, there will be new jobs and some jobs will be lost…" Murati told Trevor Noah last fall of the impact of AI, "but I'm optimistic."

For most of January, *ChatGPT* surpassed *Bitcoin* among popular search terms, according to Google Trends. All the attention has meant the privately held San Francisco–based startup—with 375 employees and little in the way of revenue—now has a valuation of roughly $30 billion. Murati spoke to TIME about ChatGPT's biggest weakness, the software's untapped potential, and why it's time to move toward regulating AI.

**First, I want to congratulate you and your team on the recent news that ChatGPT scored a passing grade on a U.S. medical-licensing exam, a Wharton Business School MBA exam, and four major university law-school exams. Does it feel like you have a brilliant child?**
We weren't anticipating this level of excitement from putting our child in the world. We, in fact, even had some trepidation about putting it out there. I'm curious to see the areas where it'll start generating utility for people and not just novelty and pure curiosity.

**I asked ChatGPT for a good question to ask you. Here's what it said: "What are some of the limitations or challenges you have encountered while working with ChatGPT and how have you overcome them?"**
That is a good question. ChatGPT is essentially a large conversational model—a big neural net that's been trained to predict the next word—and the challenges with it are similar challenges we see with the base large language models: it may make up facts.

**In a very confident way too!**
Yes. This is actually a core challenge. We picked dialogue specifically because dialogue is a way to interact with a model and give it feedback. If we think that the answer of the model is incorrect, we can say, "Are you sure? I think actually…" And then the model has an opportunity to go back and forth with you, similar to how we would converse with another human.

'THIS IS A UNIQUE MOMENT IN TIME WHERE WE DO HAVE AGENCY IN HOW [AI] SHAPES SOCIETY.'
—OPENAI'S MIRA MURATI

**Truly groundbreaking technologies solve a problem. What problem is ChatGPT solving?**
Right now, it's in the research review stage, so I don't want to speak with high confidence on what problems it is solving. But I think that we can see that it has the potential to really revolutionize the way we learn. People are in classrooms of, say, 30 people. Everyone has different backgrounds, ways of learning, and everyone is getting basically the same curriculum. With tools like ChatGPT, you can endlessly converse with a model to understand a concept in a way that is catered to your level of understanding. It has immense potential to help us with personalized education.

**But some schools are banning ChatGPT. Does this surprise you?**
When we're developing these technologies, we're really pushing toward general intelligence, general capabilities with high reliability—and doing so safely. But when you open it up to as many people as possible with different backgrounds and domain expertise, you'll definitely get surprised by the kinds of things that they do with the technology, both on the positive front and on the negative front.

免责申明：

1. 本附加与原报告无关；
2. 本资料来源互联网公开数据；
3. 本资料在“行业报告资源群”和“知识星球行业与管理资源”均免费获取；
4. 本资料仅限社群内部学习，如需它用请联系版权方

合作与沟通，
请联系客服

客服微信　　客服微信

## 行业报告资源群

微信扫码 长期有效

1. 进群即领福利《报告与资源合编》，内有近百行业、上万份行研、管理及其他学习资源免费下载；
2. 每日分享学习最新6+份精选行研资料；
3. 群友交流，群主免费提供相关领域行研资料。

微信扫码 行研无忧

知识星球 行业与管理资源 是投资、产业研究、运营管理、价值传播等专业知识库，已成为产业生态圈、企业经营者及数据研究者的智慧工具。

知识星球 行业与管理资源每月更新5000+份行业研究报告、商业计划、市场研究、企业运营及咨询管理方案等，涵盖科技、金融、教育、互联网、房地产、生物制药、医疗健康等；

微信扫码加入后无限制搜索下载。

**A growing number of leaders in the field are warning of the dangers of AI. Do you have any misgivings about the technology?**
This is a unique moment in time where we do have agency in how it shapes society. And it goes both ways: the technology shapes us and we shape it. There are a lot of hard problems to figure out. How do you get the model to do the thing that you want it to do, and how you make sure it's aligned with human intention and ultimately in service of humanity? There are also a ton of questions around societal impact, and there are a lot of ethical and philosophical questions that we need to consider. And it's important that we bring in different voices, like philosophers, social scientists, artists, and people from the humanities.

**What's the key ethical or philosophical question that we still need to figure out?**
[AI] can be misused, or it can be used by bad actors. So, then there are questions about how you govern the use of this technology globally. How do you govern the use of AI in a way that's aligned with human values?

**Do you think these questions should be left to companies like yours, or should governments get involved in creating regulations?**
It's important for OpenAI and companies like ours to bring this into the public consciousness in a way that's controlled and responsible. But we're a small group of people and we need a ton more input in this system and a lot more input that goes beyond the technologies—definitely regulators and governments and everyone else.

**There's always a fear that government involvement can slow innovation. You don't think it's too early for policymakers and regulators to get involved?**
It's not too early. It's very important for everyone to start getting involved, given the impact these technologies are going to have.



VIEWPOINT

# PROGRESS HAS ITS RISKS

*We must not blindly follow innovation*

BY PAT GELSINGER

Fifty-five years ago, a sentient supercomputer struck fear into millions of moviegoers with a chilling phrase:

"I'm sorry, Dave. I'm afraid I can't do that."

The trope of artificial intelligence (AI) as the plot twist in Stanley Kubrick's futuristic dystopia *2001: A Space Odyssey* is entertaining; the reality is far more mundane, yet crucial. We must ensure AI technology advances responsibly. Industries and global leaders must work together to shape our technological future while advancements are in early development by coming together to create new possibilities that bring out the best in our human selves.

AI has already created global change and provided us with powerful tools. It has the potential to enable a responsible, inclusive, and sustainable future. We harness the power of AI to tackle critical global challenges like pandemics, natural disasters, and global public health. And we are developing AI capabilities and solutions to amplify human potential, enhance inclusion, and improve accessibility for people with disabilities.

When we create something new, it is incumbent upon us to ask, "Have I made society better—or worse?" If the technology cannot be proved to be good, the engineering remains incomplete. Only when it's demonstrably and repeatedly better than any non-AI experience can it become a new standard.

There must always be a scientific and data-driven basis for the introduction of technology, specifically AI, and governance that guides the journey. Neutral is akin to negative in the early phases. We have experienced some darkness amid the tumult of the past couple of years, showing us how simple it is to find our world teetering on the edge of pervasive tech for bad. We cannot let ourselves blindly follow economic and algorithmic innovations run amok; we cannot chase metrics like click-through rates or time on websites. Technology must consistently demonstrate outcomes superior to existing human results and provide an improved experience.

When it comes to innovation, the question is no longer if something can be done, but why. AI is already performing human tasks that used to be difficult to achieve with traditional computing. Machines will soon make more decisions than humans. Our role as humans is to make sure those decisions are better and more ethical by utilizing rigorous, collaborative, multidisciplinary peer-review processes throughout the development life cycle, establishing diverse development teams to reduce biases. We must also acknowledge potential ethical and human-rights risks associated with the development of AI technology, and we are constantly in a race between positive and negative outcomes. We can mitigate potentially harmful uses of AI while also anticipating the law of unanticipated consequences for when technology is both a problem and a solution.

THE QUESTION IS NO LONGER IF SOMETHING CAN BE DONE, BUT WHY

Technology itself is inherently neutral; we must constantly shape it as a force for good. The technology industry must serve as the role model for companies across all industries making breakthroughs using systems enhanced with AI technology. When built and used responsibly, AI will create prosperity and enrich lives.

Tomorrow will be the better for it.

*Gelsinger is chief executive officer of Intel*