design and testing needed for an ASIC, says Kumar. By starting with a standard microcontroller design, the process is simplified and cheaper.

It's like "a black box," says Kumar. "Input the app, and it outputs the processor design."

It might not be that simple, says Tom Hackenberg, principal analyst for embedded processors at market research firm IHS. Testing, validation, and other costs encountered on the road to putting out a new application-specific chip will still remain. If the technique can't reduce the cost of the design process enough, cheap microcontrollers—which average about US $1 but can be as little as 25 cents—will still be the winning solution.

Still, if the concept "can do what they're saying it can do, then it might be a much more simple process to design a very application-specific processor," says Hackenberg.

Research engineers at ARM, in Cambridge, England, are hoping it is that simple. They've been working hard on a project called Plastic ARM—an attempt to construct 1-cent disposable microcontrollers on plastic using printed electronics. Their first attempt occupied 7.5 square centimeters. It took a full year of hard design work to shrink it below their 1 cm^2 target and to customize it for their application, says the project's leader, James Myers. This summer, with the help of one of Sartori's students, they plan to use the bespoke processor technique to see if they can achieve the same or better results with a fraction of the effort.

"With printed electronics, there should be a lower barrier to entry" than to silicon, he says. "There should be more opportunity for application-specific designs, but not if the design costs stay the same. What I want is to reduce the design cost as well as the fabrication cost of these things. If you can automatically generate a bespoke version of the processor…then that's a huge benefit." —SAMUEL K. MOORE

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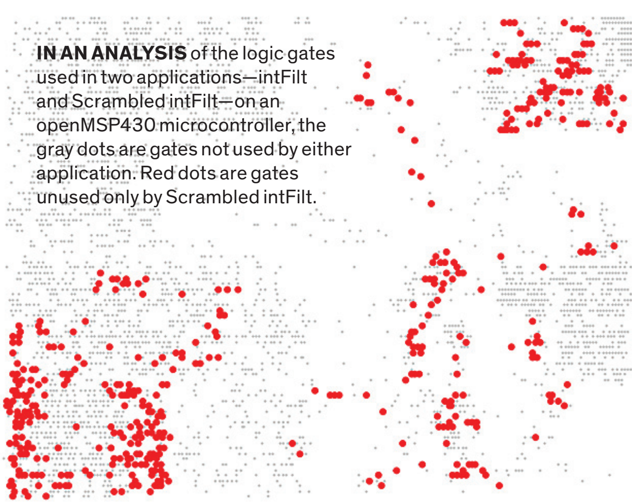

IN AN ANALYSIS of the logic gates used in two applications—intFilt and Scrambled intFilt—on an openMSP430 microcontroller, the gray dots are gates not used by either application. Red dots are gates unused only by Scrambled intFilt.

UNHACKABLE QUANTUM NETWORKS TAKE TO SPACE

In two new trials, satellites set distance records for beaming photons usable in quantum crypto

The dream of a space-based, nigh-unhackable quantum Internet may now be closer to reality, thanks to new experiments with Chinese and European satellites.

Quantum physics makes possible a strange phenomenon known as entanglement. Essentially, two or more particles such as photons that get linked or "entangled" can, in theory, influence each other simultaneously no matter how far apart they are. Entanglement is essential to the workings of quantum computers, the networks that would connect them, and the most sophisticated kinds of quantum cryptography—a theoretically unhackable means of information exchange.

Back in 2012, Pan Jianwei, a quantum physicist at the University of Science and Technology of China at Hefei, and his colleagues set the distance record for quantum entanglement. A particle on one side of China's Qinghai Lake influenced one on the other side, 101.8 kilometers away. However, entanglement gets easily disrupted by interference from the environment, and this fragility has stymied efforts at greater distance records on Earth.

Now, Pan and his colleagues have set a new record for entanglement by using a satellite to connect sites on Earth separated by up to 1,203 km. The main advantage of a space-based approach is that most of the interference that entangled photons face occurs in the 10 km or so of atmosphere closest to Earth's surface. Above that, the photons encounter virtually no problems, the researchers say.

The researchers launched the quantum science experiment satellite (nicknamed Micius) from Jiuquan, China, in 2016. It orbits the planet at a speed of roughly

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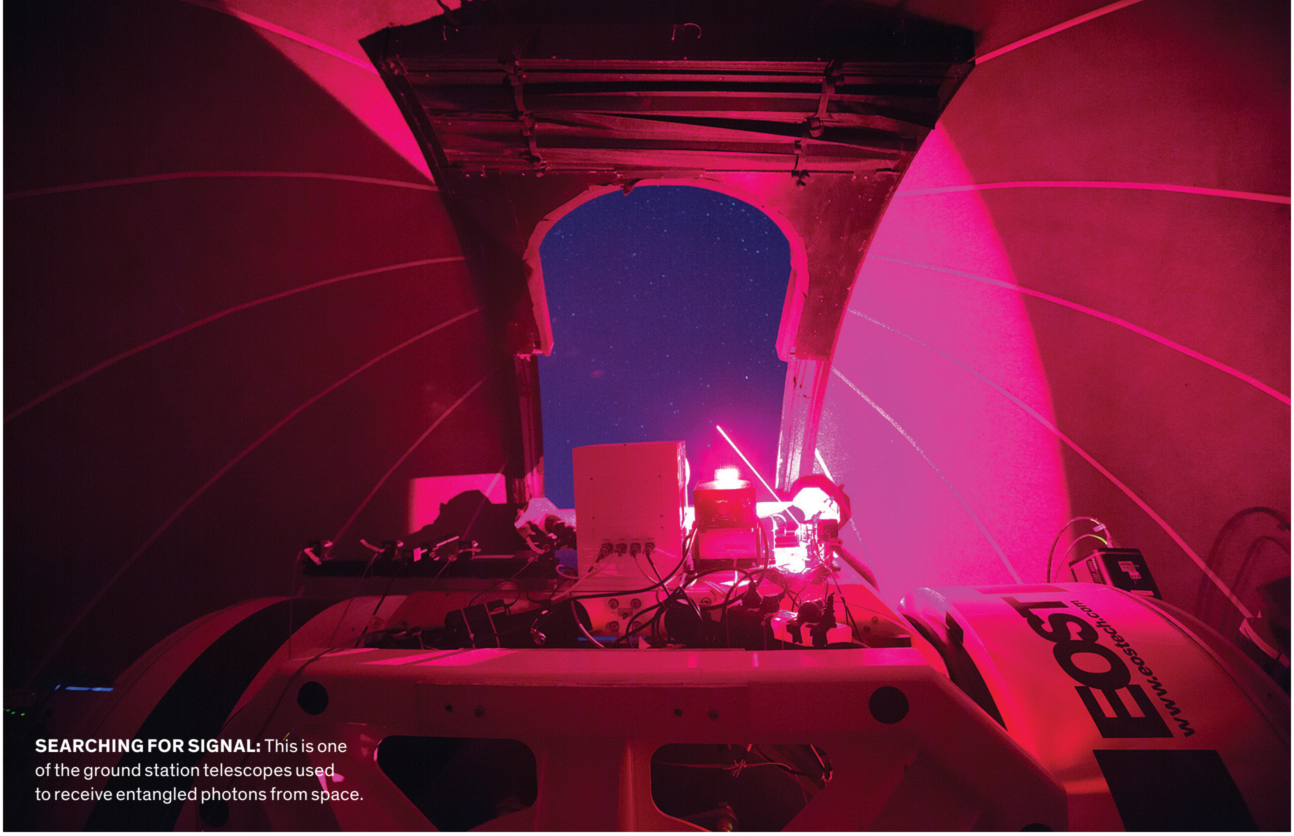

SEARCHING FOR SIGNAL: This is one of the ground station telescopes used to receive entangled photons from space.

JIN LIWANG/XINHUA/GETTY IMAGES

28,800 km per hour and an altitude of roughly 500 km. "Through ground-based feasibility studies, we gradually developed the necessary toolbox for the quantum science satellite," Pan says.

The experiments involved communications between Micius and three ground stations across China. Beacon lasers on both the transmitters and receivers helped them lock onto each other.

Micius generated entangled pairs of photons and then split them up, beaming the members of a pair to separate ground stations. The distance between the satellite and the ground stations varied from 500 to 2,000 km.

The record distance involved photons beamed from Micius to stations in the cities of Delingha and Lijiang. The experiments transmitted entangled photons with a 10^{17} greater efficiency than the best optical fibers can achieve. "We have finally sent entanglement into space and established a much, much larger quantum optics laboratory, which provides us a new platform for quantum networks as well as for probing the interaction of quantum mechanics with gravity," Pan says.

Although these experiments generated roughly 5.9 million entangled pairs of photons every second, the researchers were able to detect only about one pair per second. Pan's team expects a thousandfold improvement in this rate "in the next five years," he says. He also notes that the current transmission rate for entangled pairs is close to what's necessary to provide quantum cryptography for very brief texts; five years from now, networks of satellites and ground stations could successfully transmit at megahertz rates.

In another study, researchers in Germany found they could measure the quantum features of laser signals transmitted by a satellite a record 38,600 km away. These findings suggest that satellites could play a role in quantum networks that use less sophisticated forms of quantum cryptography that do not rely on entanglement.

Quantum physicist Christoph Marquardt from the Max Planck Institute for the Science of Light, in Erlangen, Germany, and his colleagues experimented with the Alphasat I-XL satellite, which is in geostationary orbit. Alphasat used laser signals to communicate with a ground station at the Teide Observatory in Tenerife, Spain.

Marquardt notes that the laser communications technology they experimented with is already used commercially in space. That, combined with the success of his and his colleagues' experiments, suggests that quantum networks that do not rely on entanglement could be set up "as soon as five years from now," he says.

Marquardt acknowledges that entanglement enables more-sophisticated strategies for foiling eavesdroppers. But "our approach only needs relatively small upgrades to proven technology," he says.

The German scientists are now working with satellite telecommunications company Tesat-Spacecom and others to design a quantum network. Though it will be based on hardware already employed in space, it will require upgrades such as adding a quantum random number generator, Marquardt says.
—CHARLES Q. CHOI

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