NUS National University of Singapore

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SpooQy-1 being ejected from the Japanese Small Satellite Orbital Deployer past the International Space Station's (ISS) solar arrays. This Nasa photograph was taken by an astronaut on the ISS. PHOTO: CENTRE FOR QUANTUM TECHNOLOGIES

ScienceTalk

Unlocking the quantum Internet from space

Singapore in race for secure communication through network of tiny satellites

Artur Ekert and Alexander Ling
For The Straits Times

SpooQy-1 is Singapore's technological marvel.

A tiny satellite with a state-of-the-art quantum payload, cruising 400km above our heads, it is quietly heralding the dawn of the quantum age.

Our colleagues in Europe call this new era the second quantum revolution.

The first quantum revolution unleashed the power of atomic energy, streamlined photons in our ubiquitous lasers, delivered a range of medical scanners and computer chips, and equipped us with mobile phones, to mention but a few of its outcomes.

This second revolution will be more important, for it will fundamentally affect the way we process information.

The newly developed quantum technologies, based on phenomena known as quantum interference and quantum entanglement, can do much more than cram ever more bits onto silicon chips and multiply the clock speed of microprocessors.

They can support entirely new kinds of computations with qualitatively new algorithms and new forms of secure communication based on quantum principles.

In years to come, satellites such as the Singaporean SpooQy-1, or the Chinese Micius, will become part of a global network supporting quantum communication between any two points on Earth. Call it a quantum Internet.

Last month, the teams that launched SpooQy-1 and Micius both published data from their satellites that can fire the ambitions of the quantum revolutionaries.

Micius, a 630kg satellite launched in 2016, created a secure communication link between two ground stations more than 1,000km apart in China.

It did this by beaming light with the powerful property of quantum entanglement to Earth from its orbit 500km from the planet.

SpooQy-1, meanwhile, carries a source of quantum entanglement that scientists at the Centre for Quantum Technologies (CQT) at the National University of Singapore (NUS) have miniaturised, through exhaustive examination of every component, to fly in a satellite that weighs only 2.6kg.

SpooQy-1 celebrated its first birthday in orbit last month.

Down on the ground, there is growing effort in testing and building quantum communication networks.

Two countries with the most advanced networks at the moment are China and South Korea. They aim to use quantum communication to secure data traffic, such as in 5G networks that require long-term security.

In Singapore, too, quantum networks are being considered, with Singtel and ST Engineering both working on projects with researchers at NUS.

A challenge for the bigger countries is that networks become too large for quantum signals to reach all users. Quantum communication needs direct, point-to-point links.

One solution is to add intermediate "trusted nodes" where the information carried by the quantum signals is read out and stored in conventional computers before being relayed farther.

For example, in China, the link between Beijing and Shanghai requires dozens of trusted nodes. But trusted nodes represent potential intrusion points for hackers, requiring costly protection, and may be impossible when crossing international borders and jurisdictions.

This is where quantum communication satellites provide a solution.

In the most basic concept, an orbiting satellite acts as a single trusted node that can connect any two ground networks. This is appealing because now the number of trusted nodes has been dramatically reduced.

Furthermore, the satellite's distant location and difficulty of access make it harder to break into for stealing secrets.

A satellite equipped with entangled light sources, like Micius or SpooQy-1, can avoid the need for trust by sending its signals without ever reading the quantum information.

That, in fact, is what was reported from Micius in a paper published on June 15 in the leading international journal Nature.

People are still working out the best concept for deploying quantum communication satellites.

The research team at CQT recently studied how a small constellation of satellites in low-Earth orbit could best serve the Indo-Asean region.

We studied how much quantum signal constellations of six or 16 satellites in different orbits could deliver to 11 regional cities.

Despite tropical weather and monsoon seasons, we calculated that over the course of a year, it would be possible to ensure secure communications.

Constellations are a very hot topic for the space industry at the moment, with large companies like Amazon and SpaceX planning constellations with thousands of satellites, some of which will be equipped with laser links like the type needed in quantum communication.

The big issue is cost – these satellites would require replacing every few years, because anything launched into low-Earth orbit gradually gets dragged down into the atmosphere, where it burns up.

Smaller satellites are attractive because they are cheaper to build and deploy.

That is what drove the team at CQT to develop our quantum technology to fit into the smallest standard satellite, called a CubeSat.

Our scientific data published on June 25 in Optica, The Optical Society's journal for high-impact research, proves our miniaturised entanglement source works.

So far, it has survived almost 6,000 orbits of Earth, swinging through the bright sun-side and the cold of Earth's shadow.

CubeSats are stackable units of 10cm cubes. SpooQy-1 is a three-cube satellite.

These satellites are so portable that our team sometimes carries them as hand luggage when travelling overseas to exhibitions and conferences.

Our project was funded by Singapore's National Research Foundation. Now quantum satellites are picking up commercial interest, too.

Seeing the potential, several former research staff from CQT have set up a spin-off company called SpeQtral with seed funding to explore commercial-use cases.

In the next few years, scientists at CQT will be working with partners at the RAL Space laboratory in the United Kingdom to equip a similar-sized satellite with a telescope so that in our next mission, we can demonstrate quantum signals from the small satellite to ground-based users.

Over the next decade, we anticipate progress from these solo satellites towards constellations.

We will enjoy the benefits of secure communication first, and further applications of quantum communication as the quantum revolution delivers on its promise.

We may one day run our heaviest calculations in a quantum cloud, formed of quantum computers around the world connected via satellites above the clouds.

To be sure, we are only at the very beginning, but things can happen fast.

Just look at the history of computers. The theory of classical universal computation was laid down in 1936, was implemented within a decade, became commercial within another decade, and dominated the world's economy half a century later.

Quantum information technology, a fundamentally new way of harnessing nature, will be no different, and it may arrive sooner than we expect.

Remember that you read about it here.

> **The newly developed quantum technologies, based on phenomena known as quantum interference and quantum entanglement, can do much more than cram ever more bits onto silicon chips and multiply the clock speed of microprocessors.**
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