RSIS — S. Rajaratnam School of International Studies, Nanyang Technological University

RSIS COMMENTARY

www.rsis.edu.sg No. 223 – 5 September 2016

China's Quantum Satellite Experiments: Strategic and Military Implications

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Synopsis

While China's quantum science satellite (QSS) project is part of the Strategic Priority Programme on Space Science, the country's first space exploration programme intended purely for scientific research, its experiments have significant military implications.

Commentary

ON 16 AUGUST 2016 China launched the world's first quantum communications experiment satellite into orbit from the Jiuquan Satellite Launch Centre in the Gobi Desert. The small satellite, recently named Micius after an ancient Chinese philosopher, is tasked to establish a hack-proof communication line - a quantum key distribution network, while performing a series of quantum entanglement experiments in space for the first time.

The quantum science satellite (QSS) programme is the third mission of the 2011 Strategic Priority Programme on Space Science that includes a series of satellite launches between 2015 and 2030 to explore black holes, dark matter, and cosmic background radiation. Research on quantum technology is also a key priority, including in the 13th Five-Year Plan, China's latest economic blueprint for research and development released in March 2016. The QSS is sponsored and managed by the China Academy of Sciences (CAS), and led by chief scientist Pan Jianwei. Its mission payload was developed jointly by the CAS's Shanghai Institute of Technical Physics (SITP) and the University of Science and Technology of China (USTC).

"Quantum Internet" and Communication Experiments

While the QSS will advance research on “quantum internet” – i.e. secure communications and a distributed computational power that greatly exceeds that of the classical Internet, Micius’ experiments will also advance quantum cryptography, communications systems, and cyber capabilities that the China’s military (PLA) requires for its sensors and future strike systems.

Micius’ experiments are designed to advance communication between space and Earth using quantum information technology, which relies on transmitting photons, or tiny particles of light. In particular, rather than using radio waves by traditional communications satellites, a quantum communication uses a crystal that produces a pair of entangled photons whose properties can be manipulated to perform cryptographic tasks.

For example, one can encode cryptographic keys in the discrete properties of a pulse of light, such as its polarisation state, or the continuous aspects of an electromagnetic wave, such as the intensity and phase of the wave's electric field. In doing so, the complex quantum properties cannot be measured or reverse engineered without destroying the particle’s original quantum states, so the embedded cryptographic keys, in theory, cannot be copied, stolen, or manipulated.

In this context, Micius will conduct three rounds of experiments in the next two years. The first phase includes testing a secure transmission of data to targeted areas on Earth, including three ground receiving stations located at Miyun (Beijing), Sanya (Hainan), and Kashgar (Xinjiang), and processed by the National Space Science Centre (NSSC) of the China Academy of Sciences (CAS) in Beijing. These ground stations will then beam the photon chains with cryptographic keys back to Micius, which the satellite will then relay to other ground stations to decode the message.

More Ambitious Goal

The second and third round of experiments are more ambitious, focusing on complex challenges related to particle entanglement – i.e. if two quantum particles are entangled, a change of quantum state of one particle triggers a counter-change on the other, even for systems that are too far apart to physically interact. Particle entanglement is theoretically possible across any distance, however, the fragile state of entanglement currently limits that distance to around 100 kilometres. With the QSS, Chinese researchers hope to increase that distance to more than 1,000 km.

If this phase succeeds, the QSS third round of experiments will attempt to implement the idea of teleportation of quantum information, a phenomenon described by Albert Einstein as “a spooky action at a distance”. Scientists will generate a pair of entangled photons at a ground station; one photon will be transmitted to Micius, while the other will remain on the ground.

Altering the quantum state of the particle on the ground – such as a clockwise spin – may simultaneously trigger a counter-clockwise spin in space. While theoretically possible, such ‘teleportation’ carries significant challenges, including compensating for atmospheric turbulence and movement on the ground. It also requires advanced precision technologies to synchronise both ends.

Strategic and Military Implications

China plans a network of quantum satellites by 2030, which will augment a ground-based quantum computer network, which will likely be extended from the currently operational 2,000 km link between Beijing and Shanghai. If successful, China's quantum communication network will serve as a dual-use strategic asset that may advance PLA's capacity for power projection through a constellation of space-based intelligence, surveillance, and reconnaissance platforms, tactical warning and attack assessment; command, control, and communications; navigation and positioning, and environmental monitoring.

In the PLA terms, establishing *"space dominance" ("zhi tian quan")* is an essential enabler for "information dominance" *(zhi xinxi quan)* – a key prerequisite for allowing the PLA to seize air and naval superiority in contested areas. To this end, the PLA and civilian-defence R&D community have been developing multiple types of satellites to enhance PLA's military effectiveness: electro-optical (EO), synthetic aperture radar (SAR), electronic intelligence (ELINT), Beidou navigation satellites, microsatellites, and also quantum communication satellites. In the PLA's strategic thought, as reflected in the 2013 *Science of Military Strategy*, the ability to enter, control, and exploit space serves not only as a force enhancement, but also as a deterrent factor.

Specifically, integrated space-based electronic reconnaissance and secure communications enables PLA's long-range precision strike capabilities, including its anti-ship ballistic missiles such as DF-21D. An SAR satellite uses a microwave transmission to create an image of maritime and ground-based targets in real time and in all weather conditions. Quantum communication satellites could be then used as data relay satellites to securely transmit targeting data to and from command centres, while evading cyber interceptions. These capabilities may in turn shape the direction and character of US carrier strike group operations at sea.

China, however, does not have a monopoly on quantum technologies. Both Russia and the US have large-scale cryptologic quantum computing development programmes, attempting to exploit the potential of quantum computing in future warfare. Military space operations together with quantum computing and cyber warfare will likely shape the contours of strategic competition as well as competitive strategies between great powers and their allies.

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