QUANTUM KEY DISTRIBUTION:

What is the opportunity in Space?

Quantum Key Distribution (QKD) is an ultra-secure way of encrypting information, which one day could underpin the world's digital communications. To deliver QKD-secured communication between continents, we need to develop techniques to transfer quantum keys between ground stations and satellites, and between satellites. This represents a huge opportunity for the space industry.

Why does QKD matter to the Space sector?
There is growing international interest and investment around Satellite QKD, creating global market opportunities.

Early large-scale QKD deployment will be over optical fibre. But quantum keys cannot be transmitted through undersea cables over long distances as photons are lost and cannot pass through the optical amplifiers used in underwater cables. The only way to create global QKD-secured communications will be with satellites.

Although there is some photon loss in the atmosphere, it is low enough that we can send quantum light signals between satellites and ground stations.

To make this work, we need to collaborate with the space industry to develop new technology and infrastructure to transmit and receive quantum keys between ground stations, satellites and other aerial vehicles. As the technology advances, the space sector will become relied upon to launch and manage the QKD satellites that will become an integral part of the world's future communications infrastructure.

Where are we now and where are we going?
There are two approaches to satellite QKD. The first involves a ground station sharing a quantum encoded key with a satellite, which then shares it with another ground station. This is needed where ground stations are on opposite sides of the earth, and requires that satellites be trusted by the users. The second approach shares entangled photons between two ground stations simultaneously, which can use the entanglement to create a shared key. This has the advantage that the satellite cannot steal the key so need not be trusted, but it is only viable where a satellite can see two ground stations at the same time.

In 2017, the Chinese satellite MICIUS demonstrated that photons – single and entangled – could be transmitted between satellite and ground stations, proving the concept of satellite QKD. In Phase 2 of the UK Quantum Technologies Programme, starting December 2019, the Quantum Communications Hub will undertake a significant programme of work on satellite QKD.

The aim is that within five years the UK will have demonstrated single photon QKD from Low Earth Orbit and interoperability with the ground QKD network. Within a decade we hope to have improved photon sources for high key transmission rates and demonstrate inter-satellite QKD. Beyond that we hope to develop a constellation for global QKD commercial service.

WHAT IS QKD?

In conventional encryption, data is encrypted using an algorithm, making it unintelligible to anyone who steals it. The algorithm also generates a key – a long string of random numbers – which allows the intended receiver to decrypt the data. This is secure for now, but such algorithms could be cracked in future by quantum computers.

In QKD, this key is physically distributed using a sequence of photons, whose quantum state is assigned randomly to represent a 0 or a 1. The physical approach means the key cannot be cracked mathematically. It is also impossible to copy or steal the key in transit, since quantum mechanics dictates that any observation will change the quantum state – which can be detected by the receiver.

WHAT'S HAPPENING IN THE SPACE SECTOR?

There are various missions and supporting projects worldwide, aimed at developing satellite quantum key exchange technology.

These include:

- An ESA-supported satellite QKD mission led by ArQit Ltd.
- A £10 million joint UK-Singapore "QKD QubeSat" mission to demonstrate satellite-to-ground key exchange over the UK and Singapore, using the trusted satellite approach.
- As part of the UK Quantum Technologies Programme, an ISCF-supported project to develop modular QKD receivers for communication with satellites.

The EU is also expected to announce multiple space QKD calls over the coming years.

How the space sector can get involved

Quantum communications in space opens up new opportunities for the UK space sector in areas including:

- Satellite hosts: delivery platform options, dedicated or shared (for hosted payloads)
- Satellite systems and sub-systems: acquisition, pointing and tracking, fine steering mirrors, system and flight software
- Quantum payloads: photonics components: lasers, non-linear crystals, detectors
- Optimisation of size, weight and power constraints on small satellites
- Optical Ground Stations: telescopes and mounts, tracking systems

The Quantum Communications Hub can help UK space companies get involved with such opportunities. We are running a significant satellite work programme which will include launching a research satellite to explore QKD approaches, including single photon, entangled photons, and continuous quantum light signals. The consortium includes RAL Space alongside academic and industrial partners, and is seeking additional commercial partners.

The Hub also provides access to cutting edge facilities and expertise to develop and test QKD technology, which has already supported many technical advances during Phase 1 in partnership with established companies, start-ups and spinouts. We look forward to working more closely with the space industry during Phase 2.

Those interested in being involved in these projects, receiving updates, or finding out more should contact:

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