Quantum Research CubeSat (QUARC)

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Abstract

The Quantum Research CubeSat (QUARC) is a proposal to offer secure quantum key distribution (QKD) communication from a 6U nanosatellite platform. Due to the relatively low cost for CubeSats compared to traditional, large satellite platforms, the scope to deploy a large number of platforms and offer greater coverage, would mitigate some of the risk associated with poor performance due to cloud cover. In this work, we present the results of our analysis in terms of key provision and the results of a preliminary hardware development to support future in-orbit demonstration.

Quantum communication from space overcomes the range limitations of fibre-based and free space-based methods and enable intercontinental distribution of secure keys. Satellites may also allow the distribution of entanglement for more general quantum communication and networking tasks that will form the backbone for a global quantum internet [1]. However, developing such systems can be expensive, requiring extended development and risk minimization, especially using traditional space engineering approaches as for the recent Micius mission [2] and [3]. The recent NewSpace revolution offers an alternative path to developing and deploying space systems that is characterized by rapid and iterative design cycles, easier access to space (through rideshare or microlaunch), and enhanced capability of small satellite platforms, nanosatellites in the 1-10 kg range of which the most popular is the CubeSat. The CubeSats standard, established 20 years ago, enjoys large and growing commercial support with more than a thousand successful launch a large component supplier and launch services ecosystem with advanced systems becoming increasingly available.

CubeSats can play two main roles in satellite QKD [4], [5] and [6]. The first is the rapid test and in-orbit demonstration of components and technologies. This has previously been shown with the CQT SPEQS payload on the NUS Galassia CubeSat, soon to be joined by a follow-up SpooqySat mission [6]. Secondly, with advanced in both quantum optical payloads and platform systems, CubeSats may themselves be able to provide user services. A large constellation of many CubeSats could provide low-latency, wide-area coverage for low data rate secure applications, potentially augmenting or complementing the services of larger satellite systems.

Here, we describe recent UK efforts to utilise CubeSats for the development of space quantum communications components, sub-systems, and eventually services and present results from the QUARC (Quantum Research CubeSat) project to develop a downlink QKD system based on a 6U CubeSat. Main development priorities include low size, mass, and power (SWaP) acquisition, pointing, and tracking (APT) systems engineering and mission analysis, and performance characterization. An APT system based on conventional off-the-shelf (COTS) components, including a MEMS micromirror, CMOS camera, and microcontrollers has been demonstrated that will be compatible with the stringent SWaP constraints of a CubeSat. This has been integrated into the payload design incorporating a compact transmission telescope and high speed quantum signal source. Mission analysis of a QKD CubeSat constellation has also been conducted for securing national critical infrastructure. We have estimated the monthly key rates incorporating meteorological data, hardware characterization and orbital parameters. We are also developing network models for optimization of key delivery.

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