Using Satellites to Create a Quantum Internet

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LEADERS IN IDEAS AND SOLUTIONS

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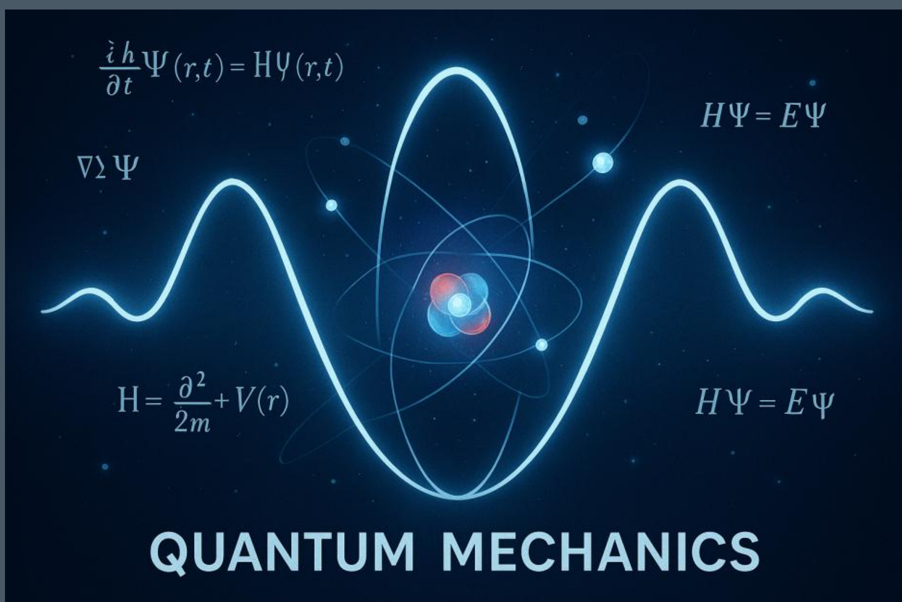
Bio

Using Satellites to Create a Quantum Internet

- What is quantum (and why is it useful)?
- What is the quantum internet?
- Why do we want to do it using satellites?
- How will this impact me (The tax-payer who funds all this research)?

What is quantum (and why is it useful)?



AI understanding of Quantum

> If you aren't confused by quantum mechanics, you haven't really understood it.
>
> — Niels Bohr —

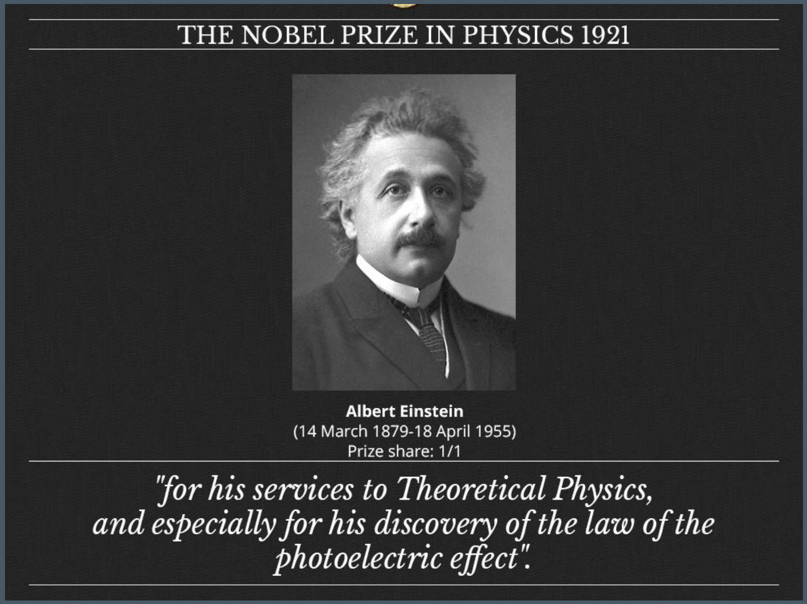
> GOD DOESN'T PLAY DICE.
>
> - ALBERT EINSTEIN

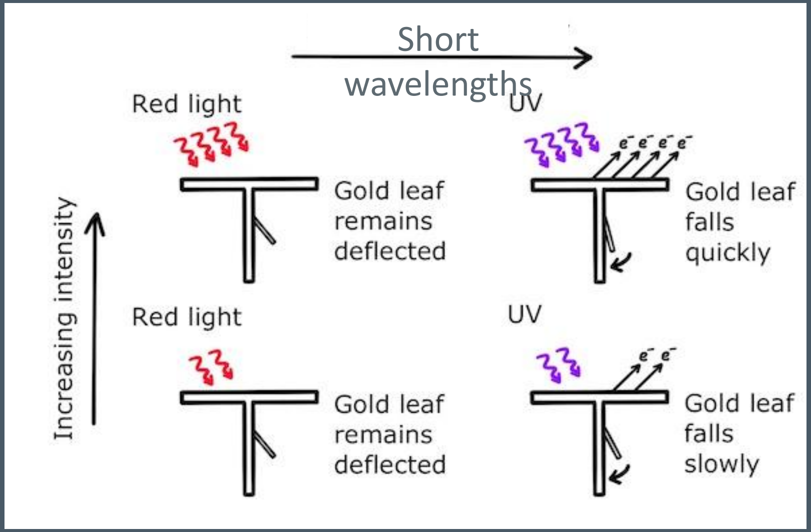
> If you think you understand quantum mechanics, you don't understand quantum mechanics.
>
> — Richard P. Feynman —

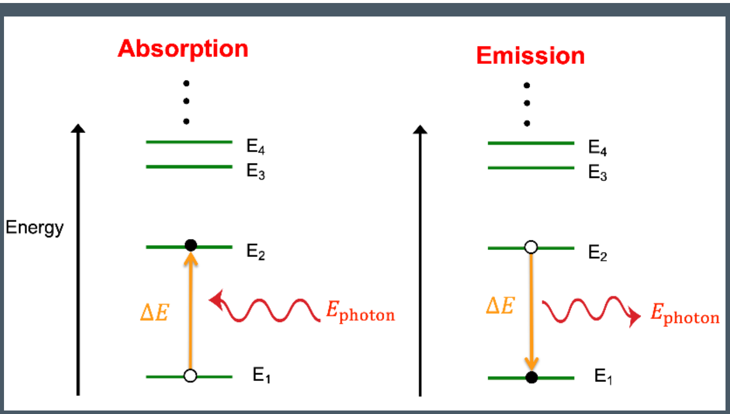
~~*Academic snobbery*~~

Dated quotes

What is quantum (and why is it useful)?







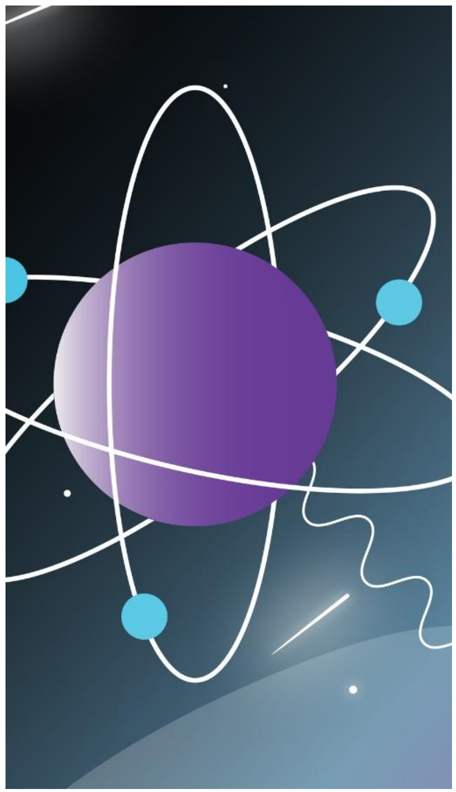
Discretized energy levels
“**Quanta**”

Gen I quantum technologies

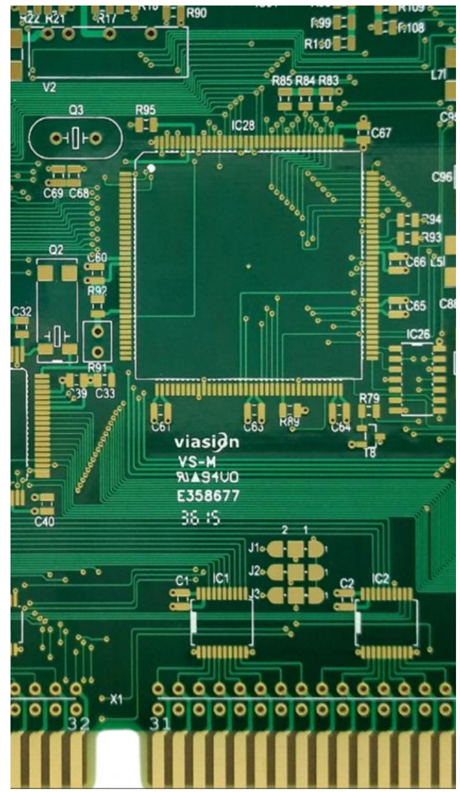
Things we use today!

Based on discrete energy levels

Laser/LEDs



Atomic clocks

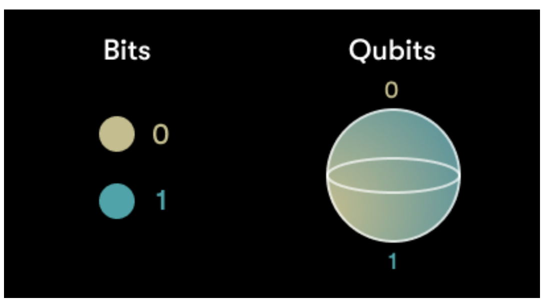


Electronics

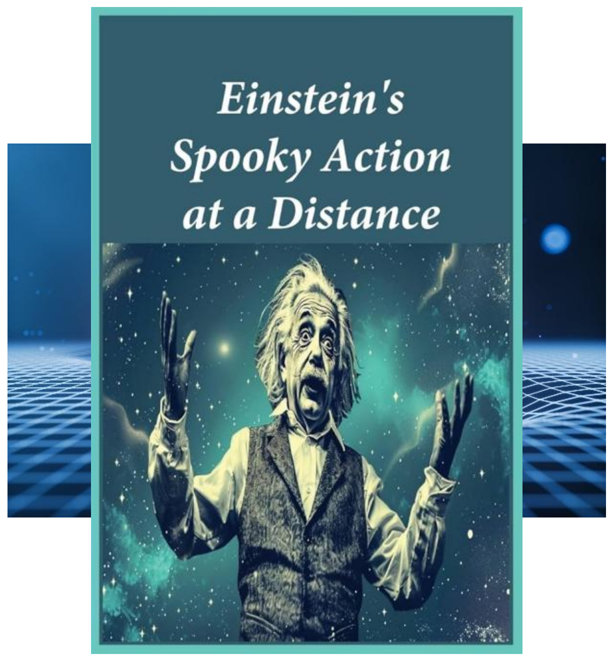
Medical imaging/sensing (MRI)

Gen II quantum technologies?

Things we don’t think about everyday (why it is thought of counterintuitive)



Qubits



Entanglement

Superposition

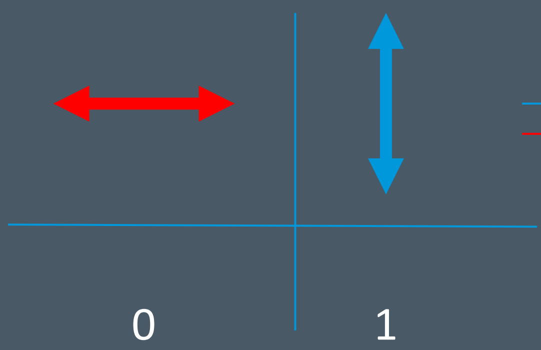
How do we share “quantum information”?

“Light quantum”

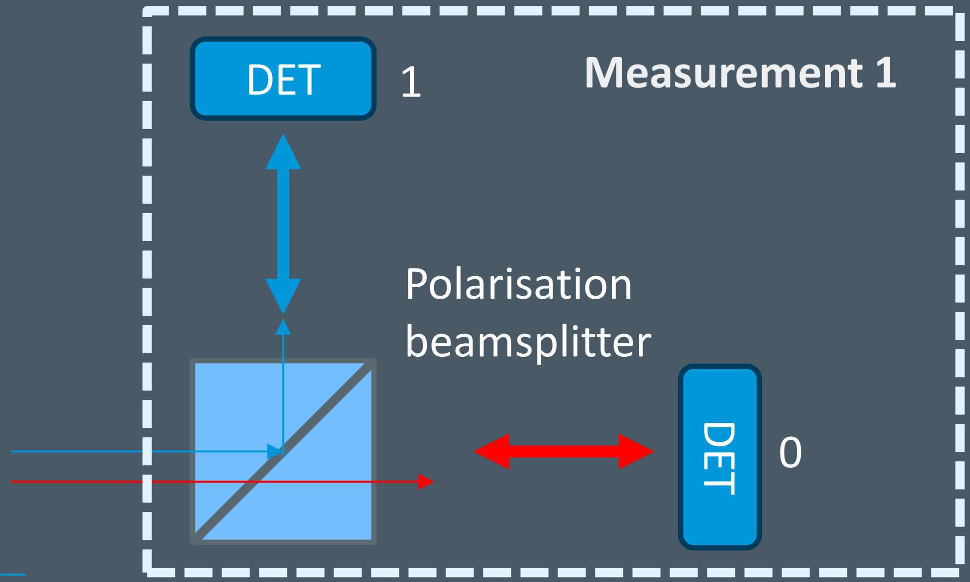
Using superposition?

In terms of Qubits?

Light can be polarised



Can apply an encoding
“bit value”



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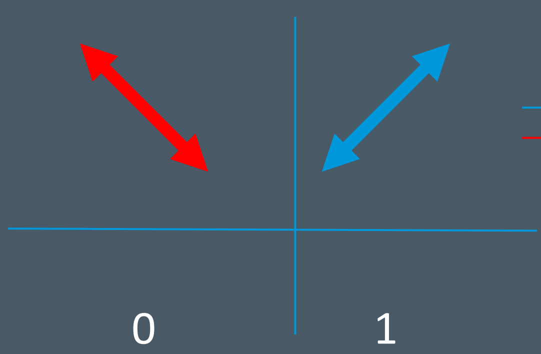
“Light quantum”

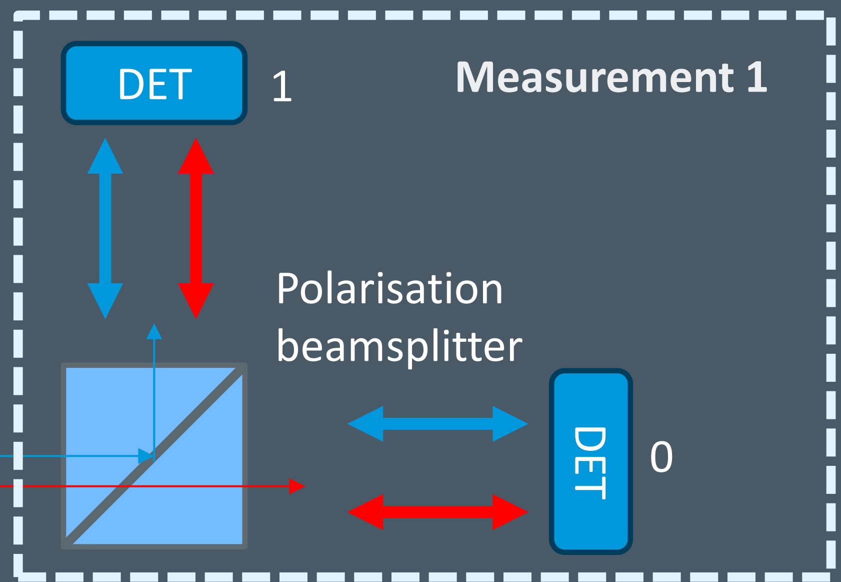
Using superposition?

In terms of Qubits?

Light can be polarised



Can apply an encoding
“bit value”

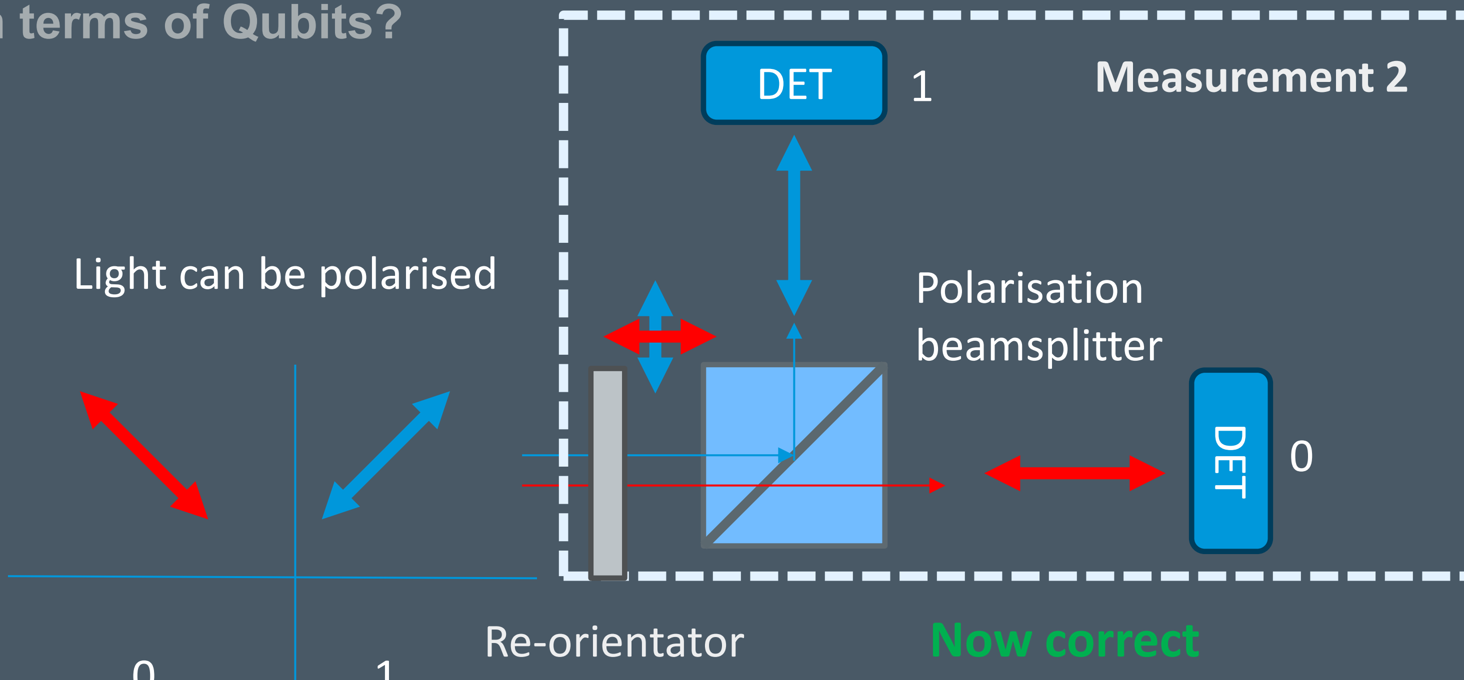


The measurement is wrong 50%

“Light quantum”

Using superposition?

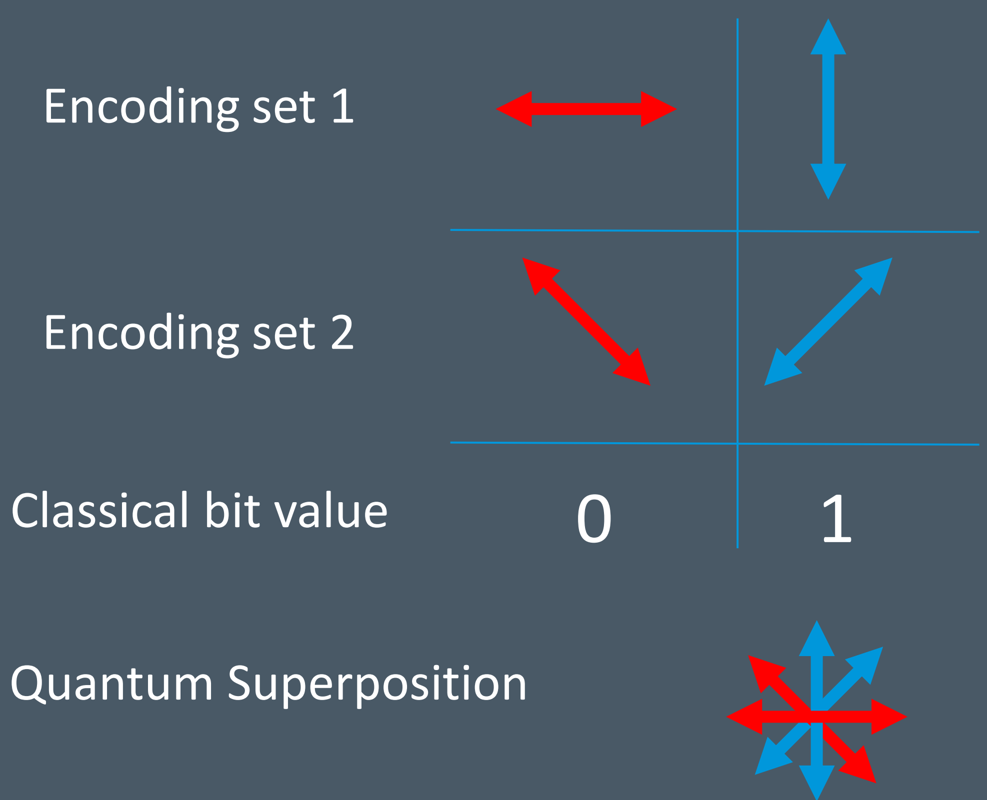
In terms of Qubits?

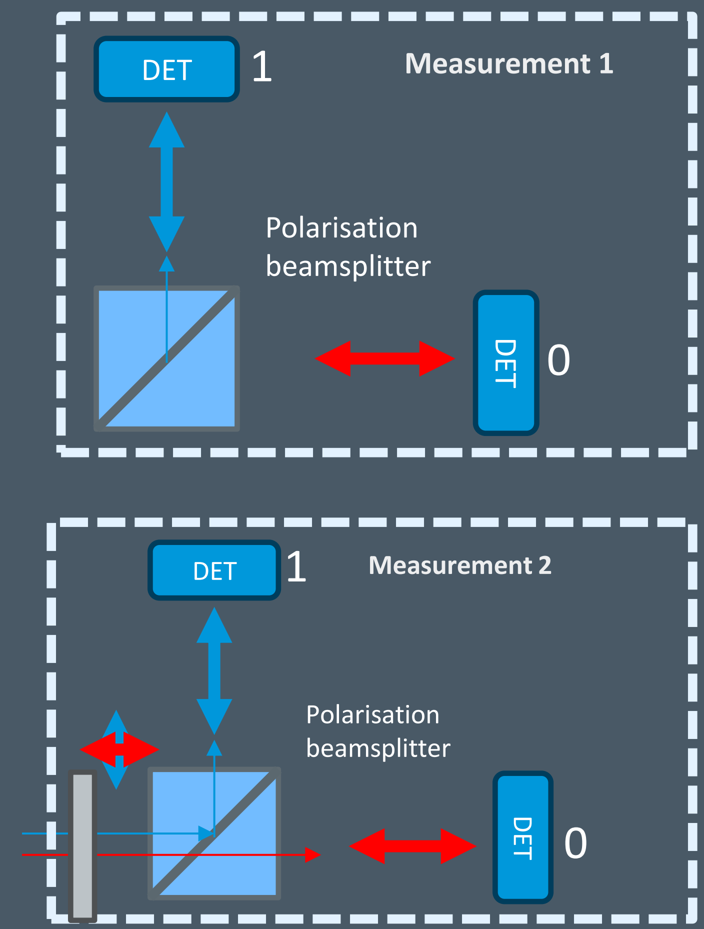


Can apply an encoding
“bit value”

Using superposition?

In terms of Qubits?





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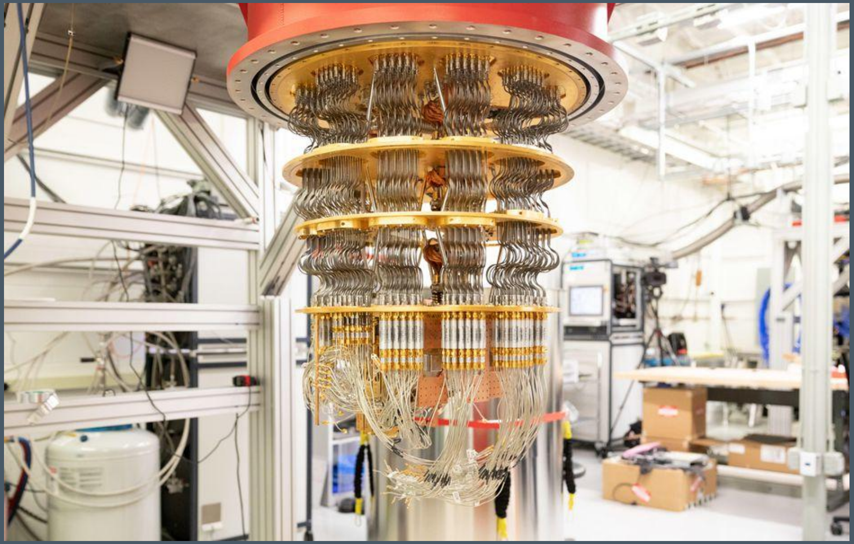
Quantum key distribution (QKD)



Believed that *universal* quantum computers, with a sufficient number of qubits and low error, could run quantum algorithms that can break encryption faster than conventional computers.

(Shor's algorithm and Grover's algorithm)

Faster factorisation — Faster searching of databases

Quantum key distribution (QKD)

Quantum states

States sent

Basis set reconciliation

Sifted key

Conventional communications

Quantum bit error rate (QBER) check

Sacrifice a small amount of shared key to check for errors

Error correction codes

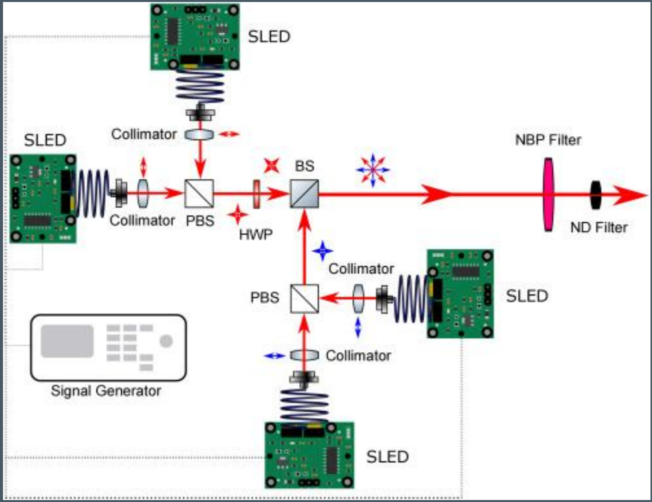
Algorithms to reduce errors in shared key (efficiency is not 100%)

Privacy amplification

Reduce possible information held by eavesdropper

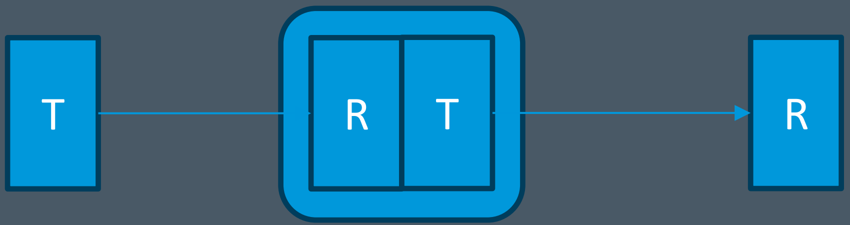
Using superposition?

In terms of Qubits?



Superposition (for me)
Is typically performed by encoding systems.
Requires additional hardware.

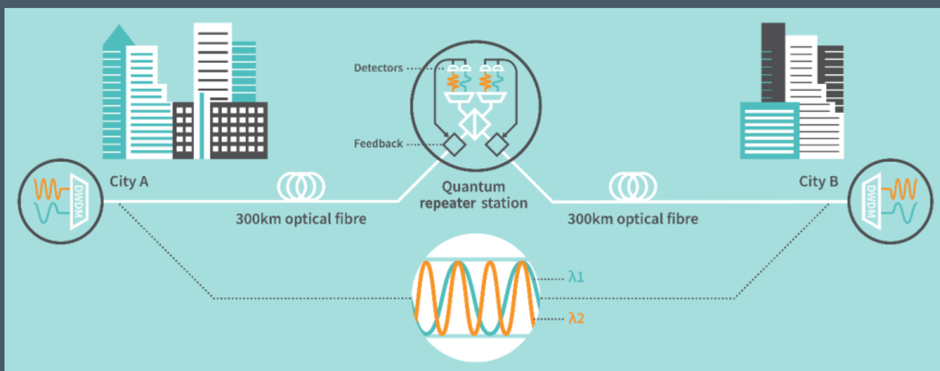
Quantum Key Distribution (QKD)



Trusted node
Key management etc.

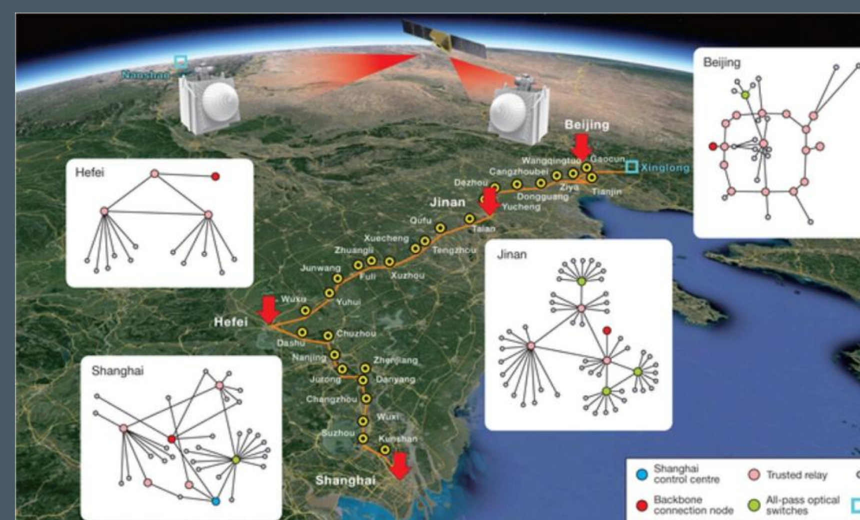
National Cyber Security Centre
a part of GCHQ

State of the art superposition QKD



- Measurement-device QKD
  - Removes detector side-channels
  - Interferes two sources
  - Typically time/phase
  - Demonstrated up to 1,000 km in fibre.

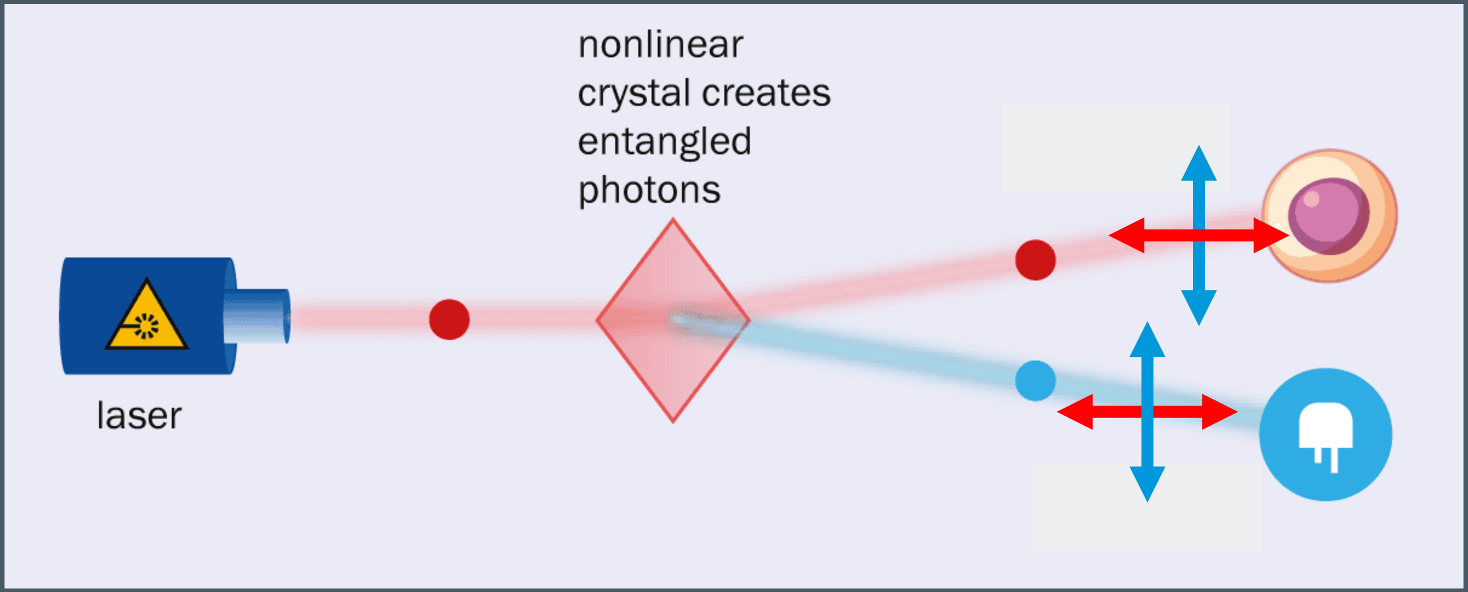
- QKD networking
  - Chinese network
  - Optical ground stations
  - Metro networks
  - 2,400 km backbone
  - Plans for MEO and GEO satellites



Using entanglement?

In terms of Qubits?

There is some inherent linked properties at creation

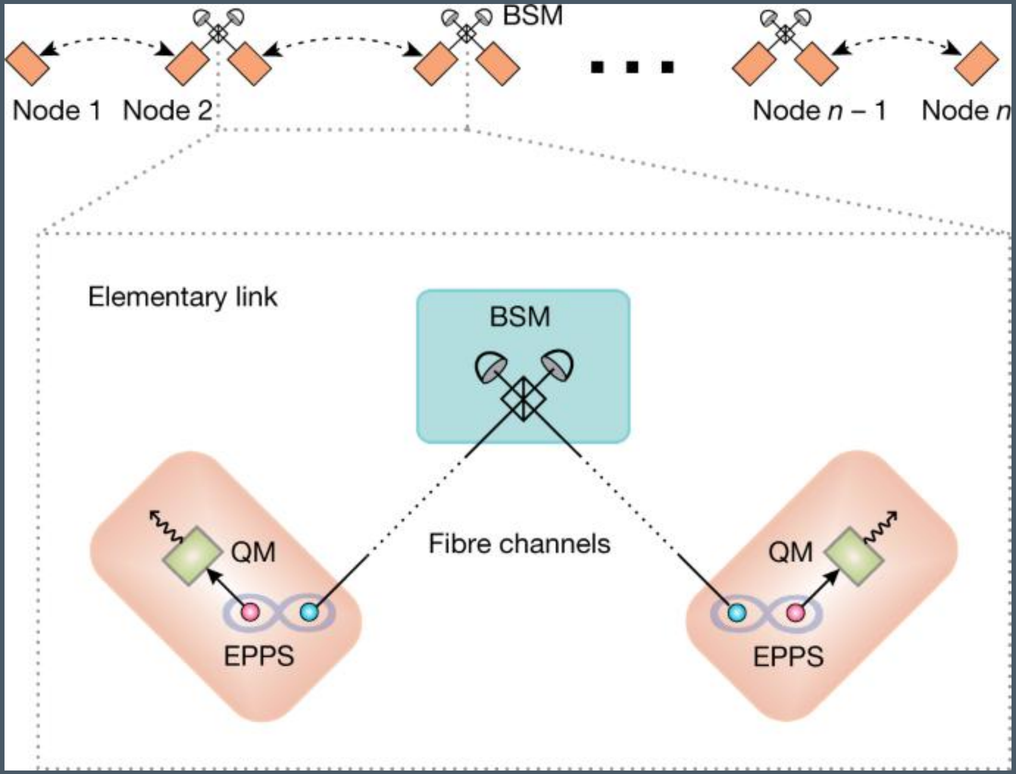


Quantum entanglement is the key link between Gen II quantum technologies

The architecture of
Device independent QKD

Using entanglement?

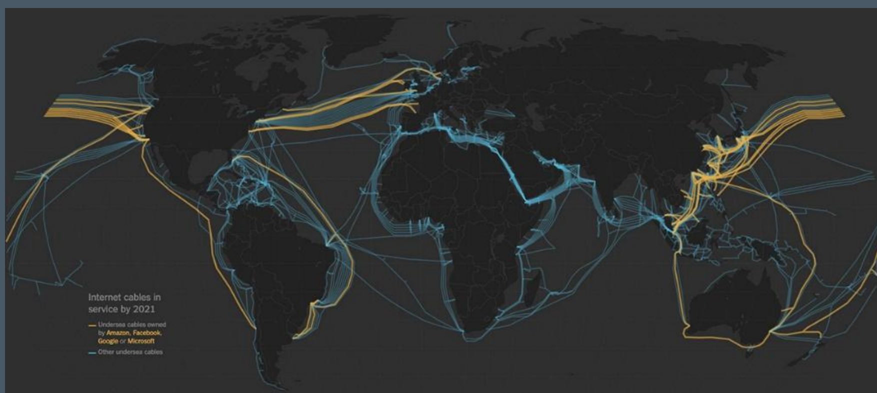
In terms of Qubits?



This entanglement swapping process allows quantum technologies to be linked and create a network

Towards a global quantum internet

Our internet today?



Optical fibre networks are critical to global connectivity today

Emergence of satellite networks growing to overcome:

- Connectivity to nomadic platforms
- Reduce latency
- Harder to disrupt infrastructure

What makes the quantum internet different?

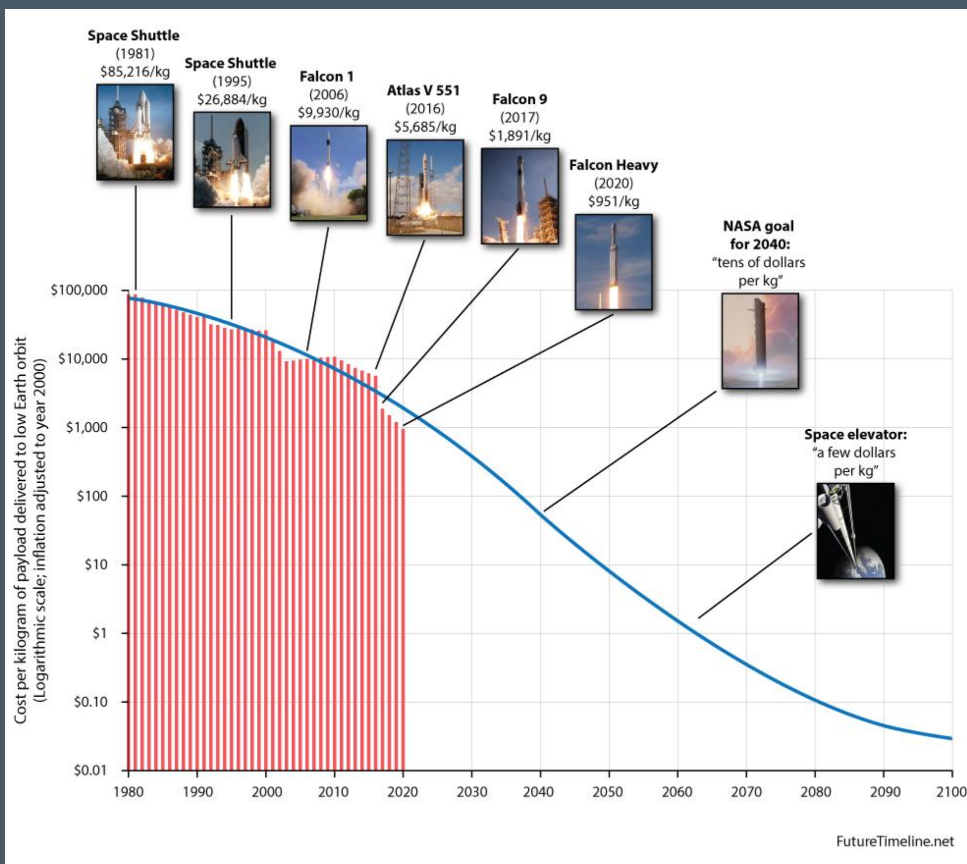
Spectrum

Precision to point and track

Sensitivity

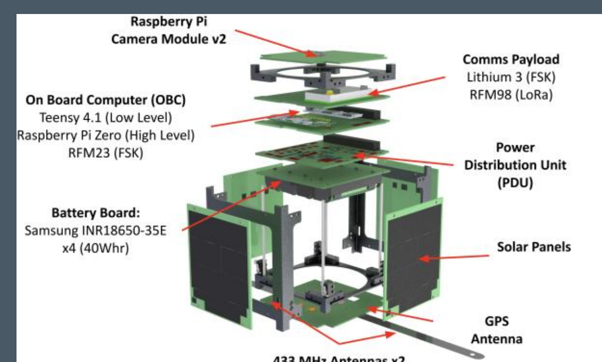
Hardware

Changes to the space sector over time?



Access to space has become cheaper!

Space qualification in space

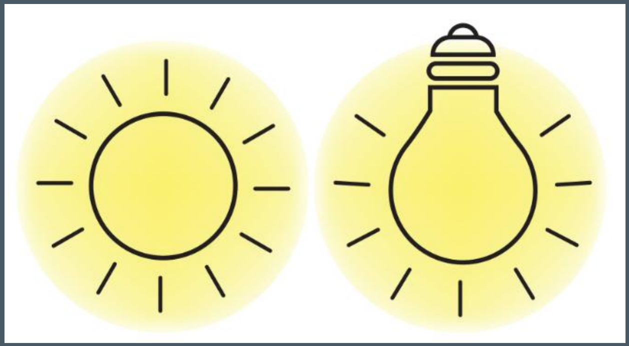


Consumer electronics in space

Accessibility

Challenges?

Environmental conditions



Natural and artificial noise

Maintaining quantum properties

Nae cloning/copying

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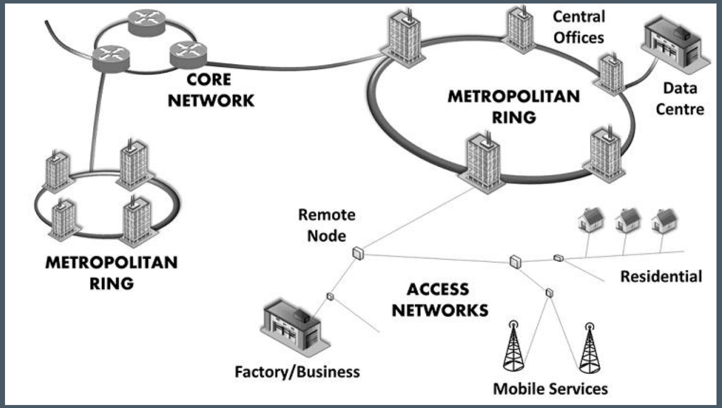
So how do we create the quantum internet?

Satellites

Supporting local networks



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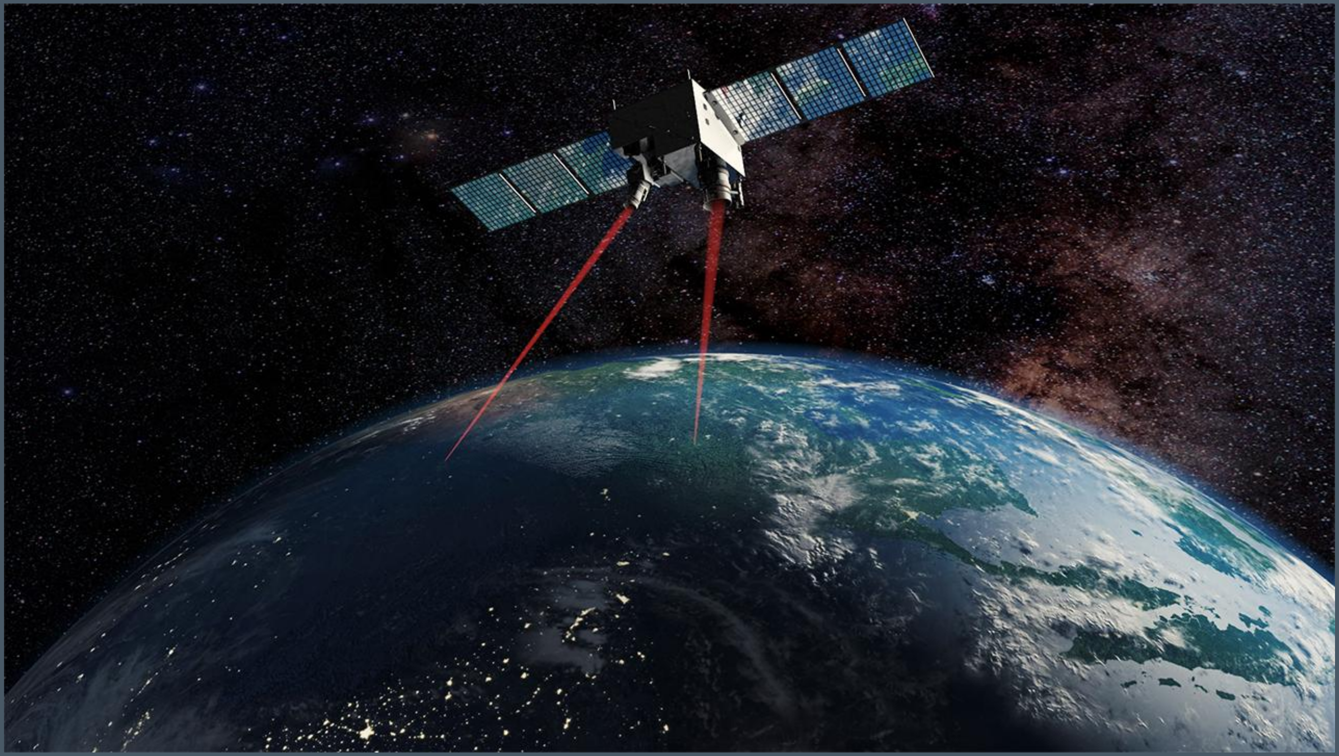
Where are we globally?



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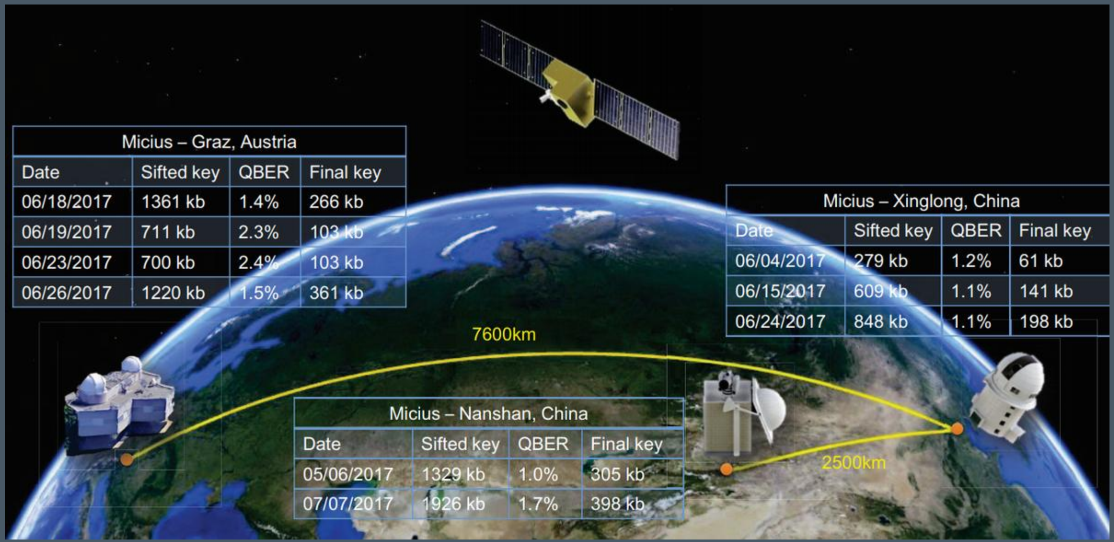
China?

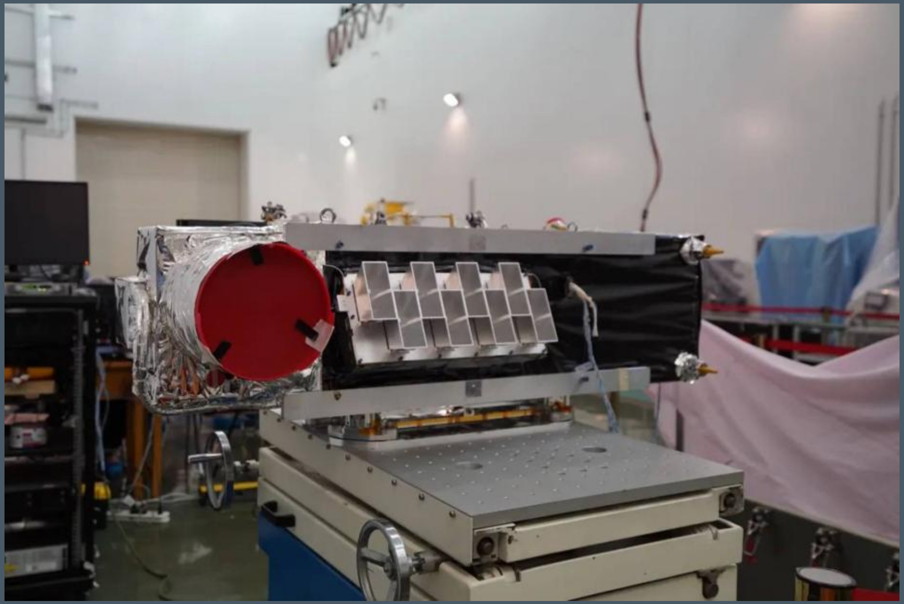


Micius – Graz, Austria			
Date	Sifted key	QBER	Final key
06/18/2017	1361 kb	1.4%	266 kb
06/19/2017	711 kb	2.3%	103 kb
06/23/2017	700 kb	2.4%	103 kb
06/26/2017	1220 kb	1.5%	361 kb

Micius – Xinglong, China			
Date	Sifted key	QBER	Final key
06/04/2017	279 kb	1.2%	61 kb
06/15/2017	609 kb	1.1%	141 kb
06/24/2017	848 kb	1.1%	198 kb

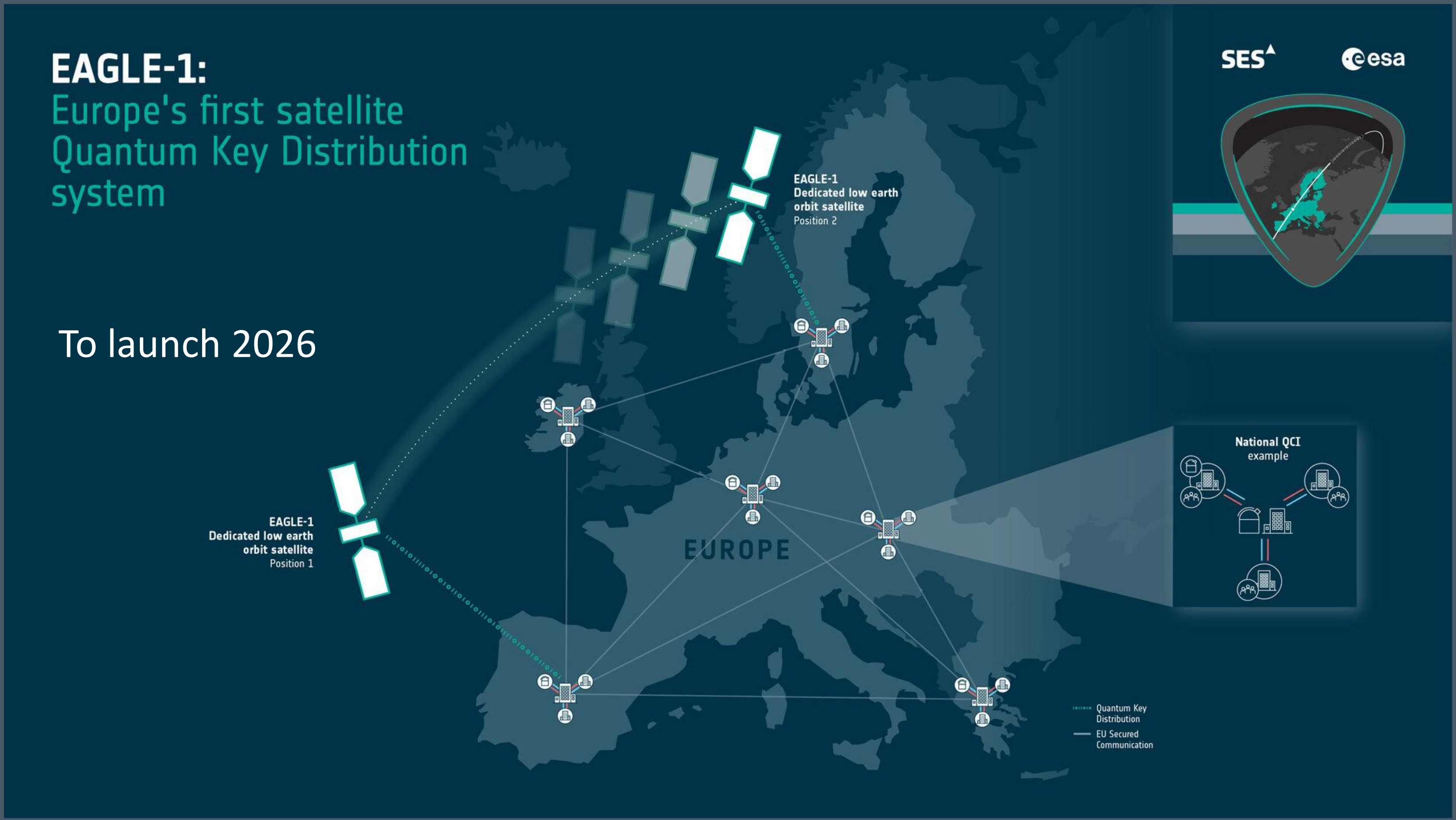
Micius – Nanshan, China			
Date	Sifted key	QBER	Final key
05/06/2017	1329 kb	1.0%	305 kb
07/07/2017	1926 kb	1.7%	398 kb

Micius – launched 2016



Jinan-1 – launched 2022

Europe?



EAGLE-1:
Europe's first satellite Quantum Key Distribution system
To launch 2026
SES
esa
EAGLE-1
Dedicated low earth orbit satellite
Position 2
EAGLE-1
Dedicated low earth orbit satellite
Position 1
EUROPE
National QCI example
Quantum Key Distribution
EU Secured Communication

Europe?

TeQuants or SAGA 2027

Hispasat QKD-GEO - 2028

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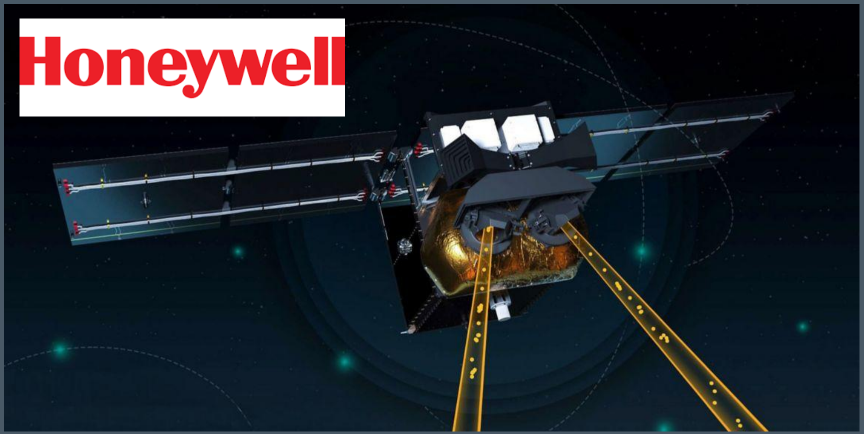
UK?

ESA-VOLT - 2027

>19M Euros value being led by Scottish team

Honeywell QKDSAT – mid-2026



>100M Euros value being led by Scottish team

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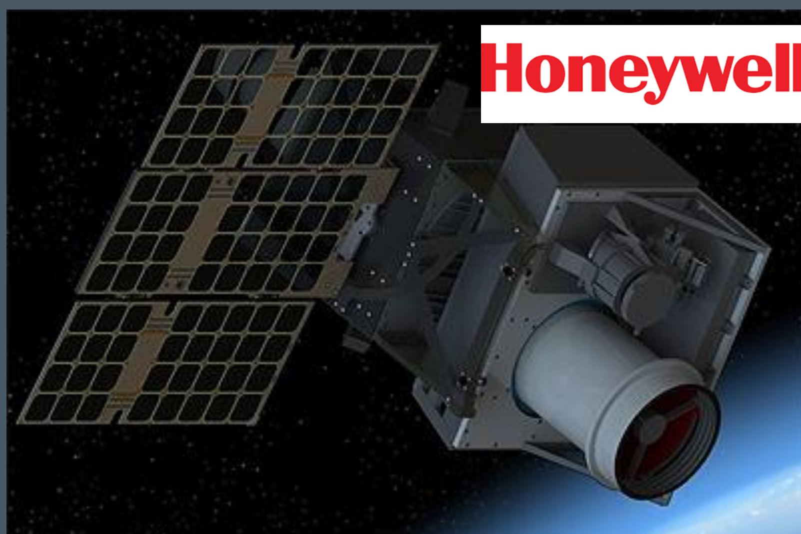
Rest of the world?



Canadian QEYSSAT - 2026

Ambitions from USA and other countries

HERIOT WATT UNIVERSITY International Scientific Team

Current mission engagement:

Quantum Communications Hub

QUANTUM COMMUNICATIONS HUB

To accelerate the translation of terrestrial quantum key distribution technology to satellite platforms.

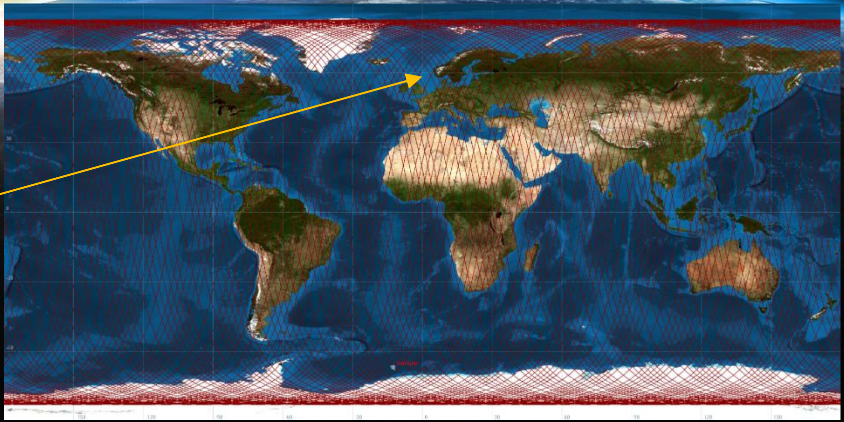
- Funded CubeSat in-orbit demonstrator (IOD) in LEO.
- Quantum payloads developed within the work package.
- Optical ground station with a quantum receiver payload.
- Launch 2025.

12U CubeSat

SATELLITE PLATFORM FOR OPTICAL QUANTUM COMMUNICATIONS (SPOQC)

UKRI Science and Technology Facilities Council RAL Space; University of York; Heriot Watt University; University of Bristol; University of Strathclyde Glasgow

Hub Optical Ground Station



Example of the Sun synchronous orbit @ 550km

Priority – one pass over the UK between 1-2 am – but global collaboration possible

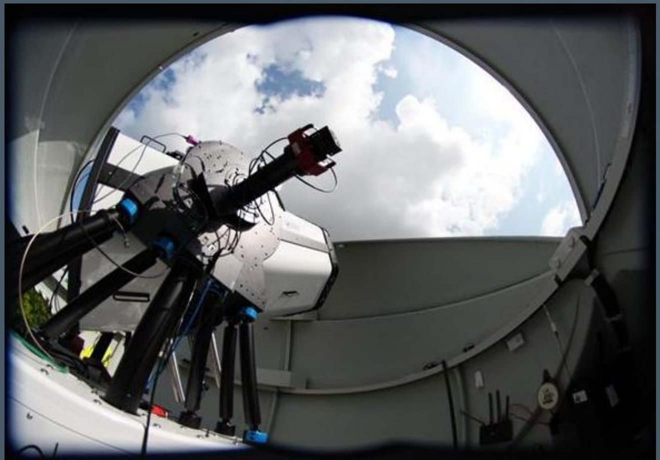
Image credit: ISIS & SPECTRE

Hub Optical Ground Station (HOGS)

A flexible optical ground station to support a broad range of research communities.

Infrastructure:

- Main equipment – telescope and dome.
- Upgrades:
  - Piggyback telescope,
  - Adaptive optics,
  - Beacon laser(s) / tracking sensors,
    - (400-1,700 nm).
- Portacabin space.
- Monitoring – turbulence monitor.



Site photo – December 2024

Planewave - RC700

Multifunctional telescope
Uses in astronomy, laser communications, and space situational awareness

Funders
QUANTUM COMMUNICATIONS HUB
UKRI Engineering and Physical Sciences Research Council
Royal Academy of Engineering

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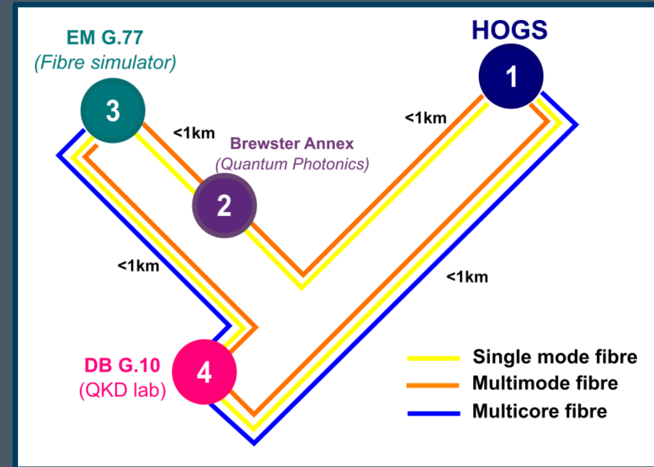
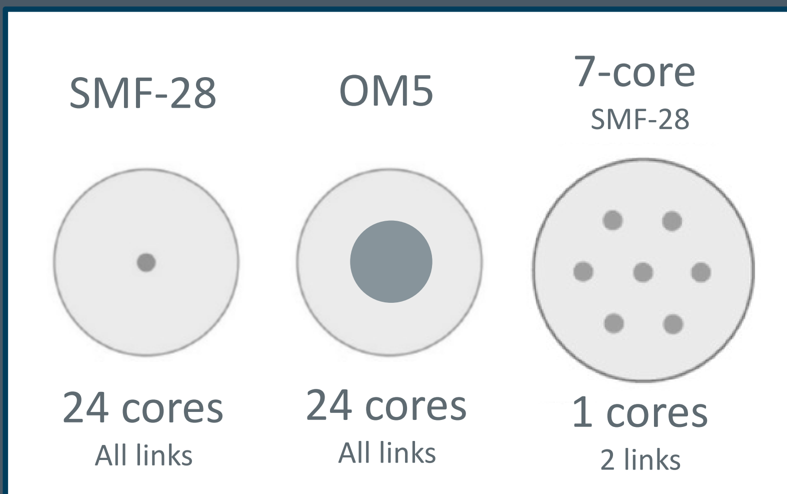
Dark fibre network



Deployed (ducted) fibre network



Hybrid network:

- Deployed ~1 km links in underground ducting
- QuTech lab connectivity
- Access to fibre simulator
- Speciality fibre – 7-core multicore.

Fibre simulator:

- SMF-28:
  - Up to 200 km link.
  - Shorter links – 10, 20, 30, 50 km.
- OM5 – 5km.

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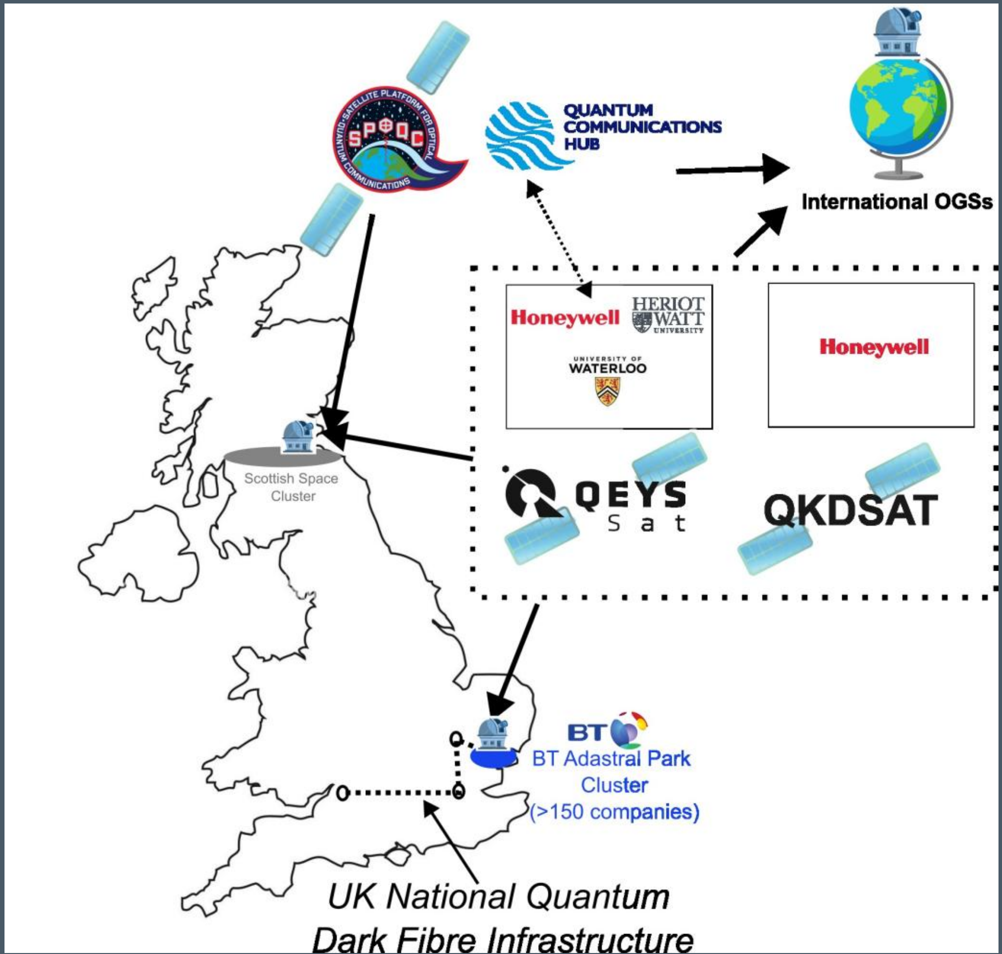
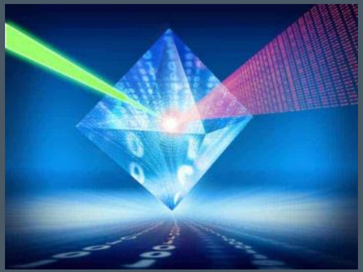
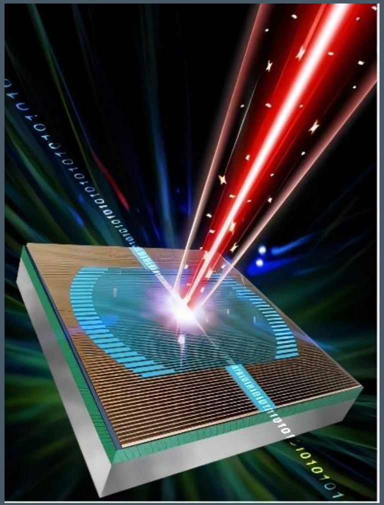
Beyond the first mission



Quantum memories





Alternative sensors

Alternative wavelengths

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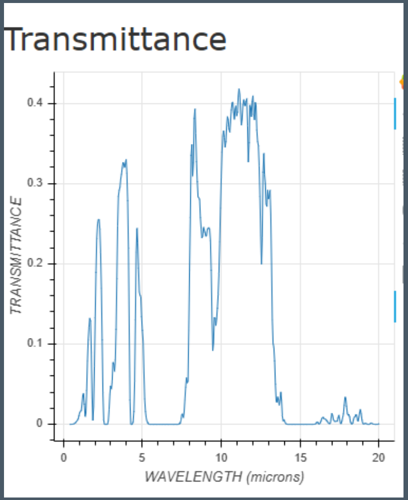
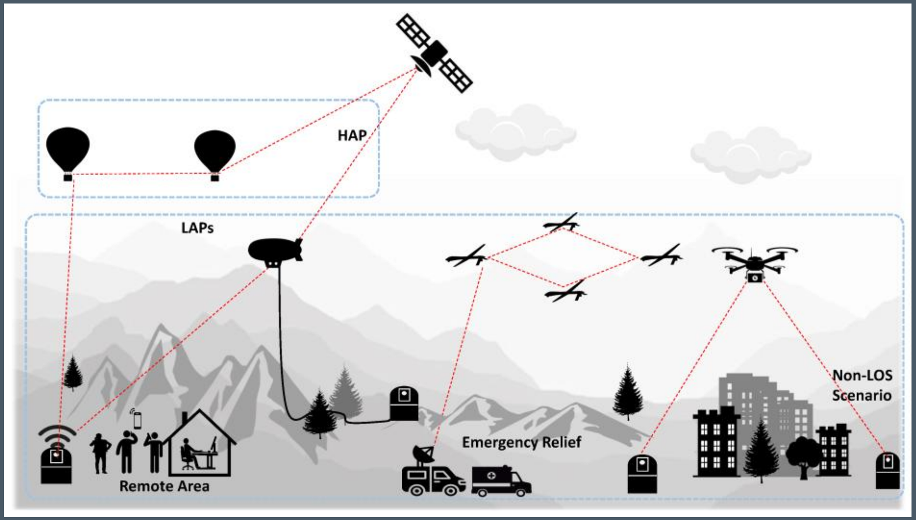
Next gen research?

Overcoming obscuration





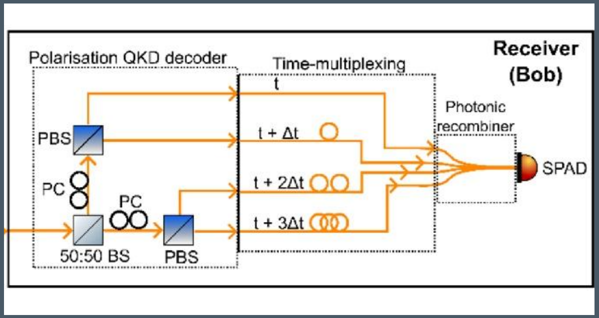
Exploration of further network architecture

Ultimate goal:
Connection of quantum devices globally

Towards commercialisation

UK Research and Innovation

Return on Investment is £3.40 per £1 spend on R&I

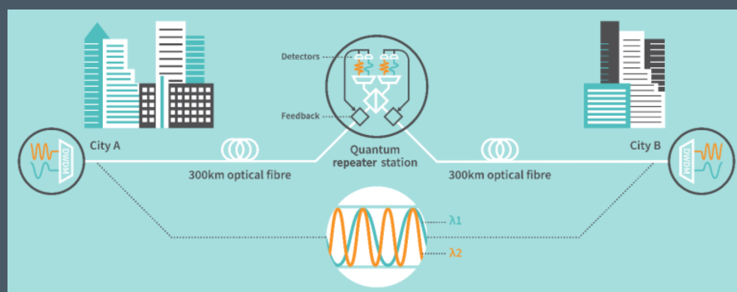


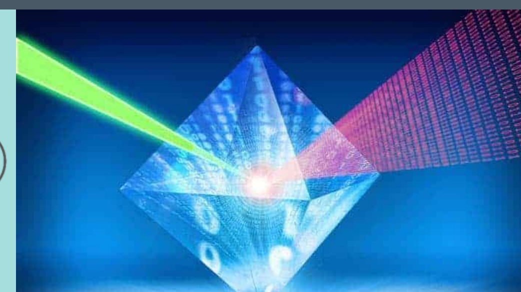
Patented receiver technology

Key partners

BT
vodafone
LUMINO TECHNOLOGIES
TOSHIBA
Honeywell
INTEGRATED QUANTUM NETWORKS HUB

Summary


Detectors
Feedback
City A
Quantum
repeater station
300km optical fibre
300km optical fibre
City B
λ1
λ2



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Heriot-Watt University Team

(OGS team – Oct 2025)

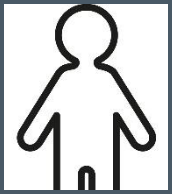
Academic

Ross Donaldson
(Free-space quantum communications and applications of advanced photonic tech)

Email: R.Donaldson@hw.ac.uk

SINGLE-PHOTON GROUP

Research staff and students



Brandon Reade
Robust quantum communications

Cameron Simmons
(Free-space optical and quantum communications)

Andrew Green
(Free-space optics and detection)