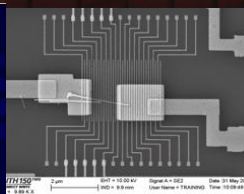




Airborne Demonstration of a Quantum Key Distribution Receiver Payload

Presented by: Chris Pugh, PhD Student
Supervisor: Dr. Thomas Jennewein
COST Action QTSpace, March 27-30, 2017



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Outline

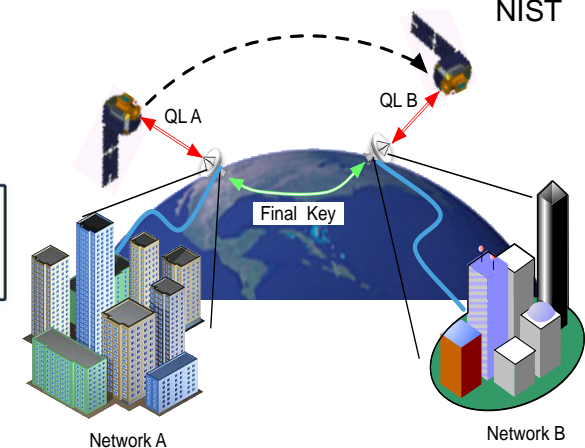
- **Motivation**
- Canadian Activities Towards QT in Space
- Airborne Demonstration of Payload
- Summary and Future Work

>> Motivation

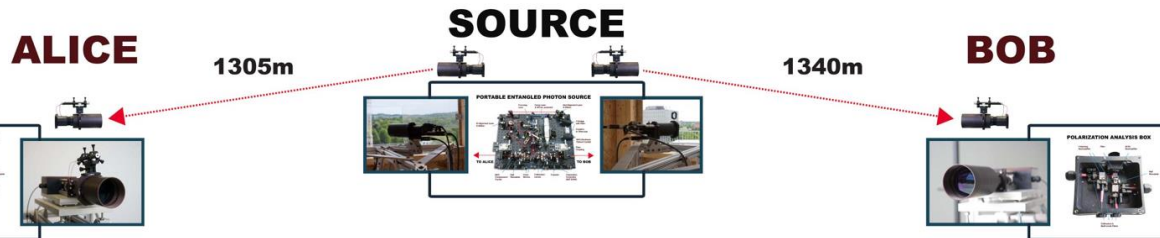
- Many current cryptographic schemes not safe from quantum computer attacks.
- Quantum Key Distribution (QKD) used as a symmetric key algorithm.
- Develop a satellite trusted node approach for long distance key generation.
- Fundamental entanglement tests in new regimes.



NIST



Proc. of SPIE Vol 9254 925402-1



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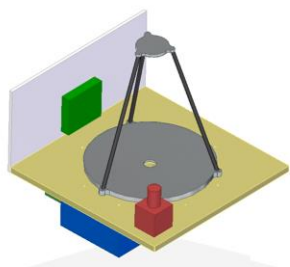
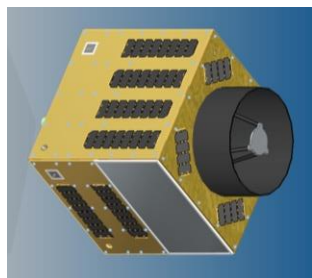
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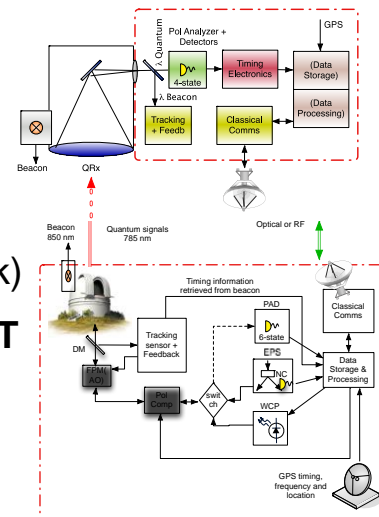
Studies towards a Canadian Quantum Satellite Mission



- Mission objectives and mission science
- Link performance, turbulence, choice of wavelength, background signals, AO
- QKD transmission with high transmission losses
- QKD transmission with fluctuating free-space link
- Quantum source requirements
- Computational requirements on satellite

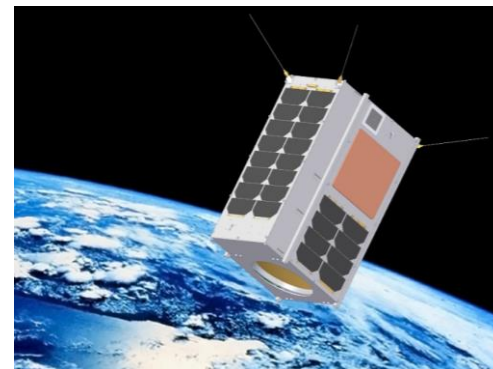
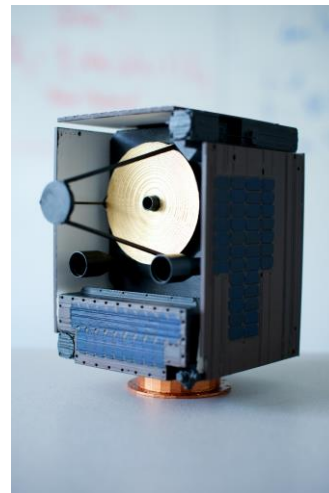


- Optical pointing requirements
- Study of tech demo roadmap, including Nanosat
- Integrated receiver prototype, radiation of components
- Fine pointing system
- Moving QKD receiver on (truck)
- **Airborne QKD with QEYSSAT prototype**
- Ground station equipment
- Phase-0 Micro Sat
- Prototype for Detectors

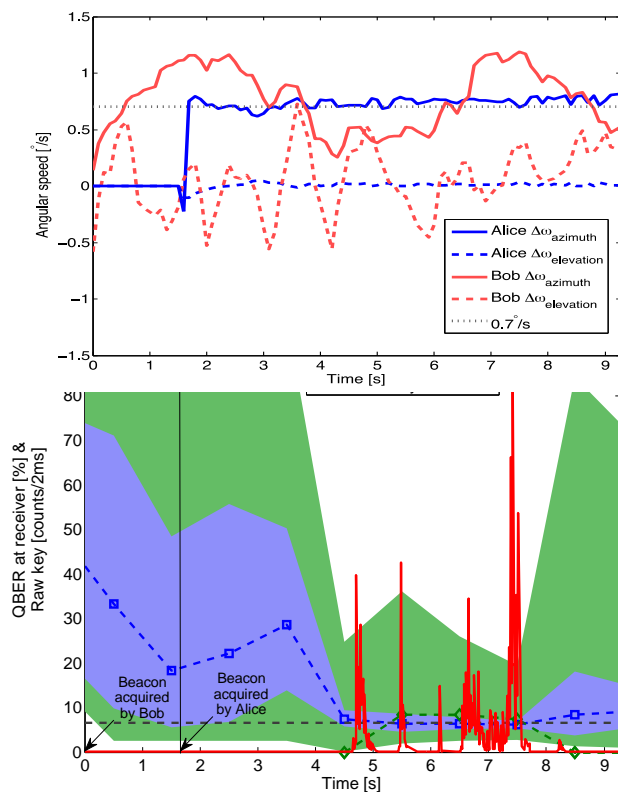


>> Canadian space QKD

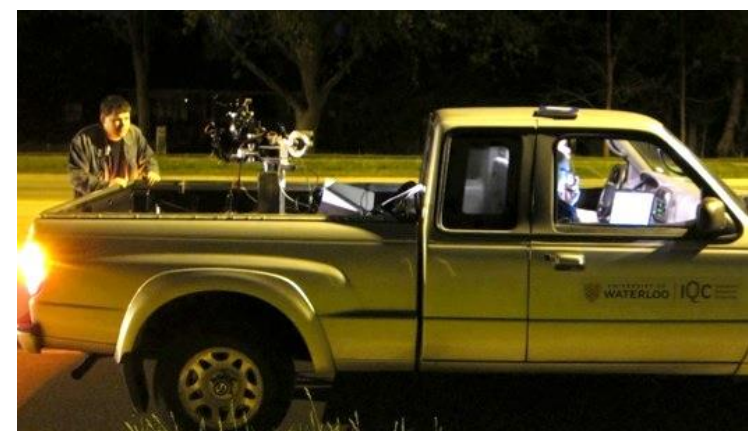
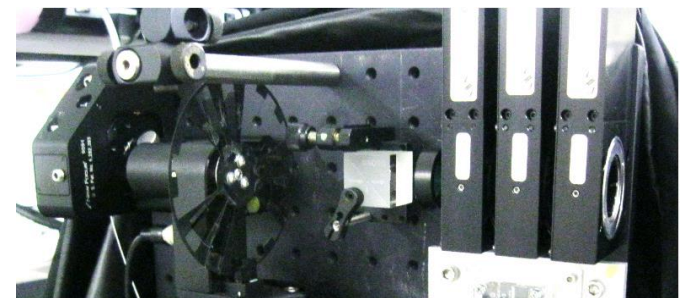
- Mission proposal: QEYSSAT (Quantum EncrYption and Science SATellite)
- Uplink of photons for QKD and for fundamental science experiments
- Jennewein *et. al.* Proc. SPIE, 8997, 89970A, 2014 (QEYSSat)
- Jennewein *et. al.* Proc. SPIE, 9254, 925402, 2014 (NanoQEY)



>>> 2014: QKD demonstration on Truck

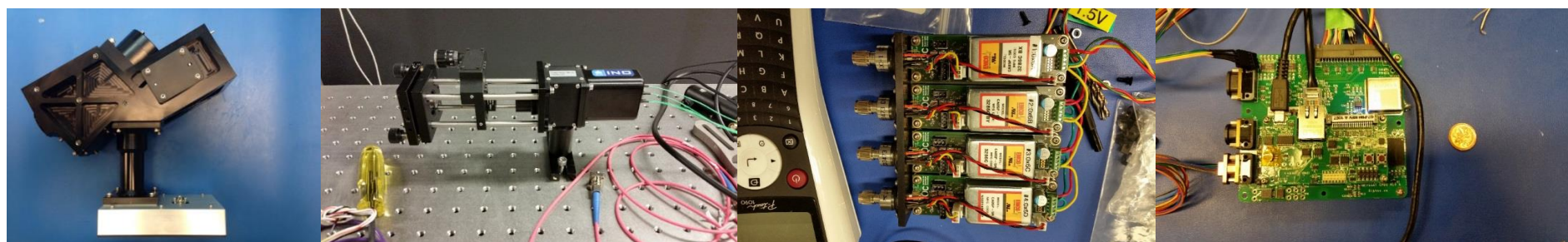
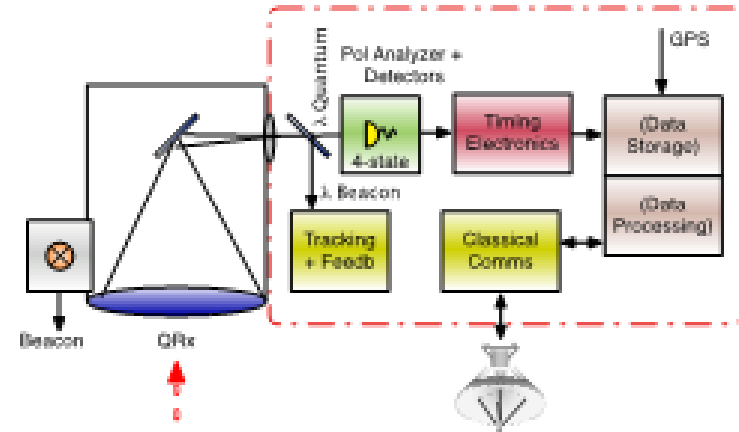


- 1st generation system
- Quantum transmission range 650 m
- Quantum receiver truck driving 30 km/h
- Generated 160 bit secure key
- Real-time compensation of pointing, polarization and timing
- Bourgoïn *et. al.* Opt. Exp. **23**, 26, 33437-33447, 2015



>> Quantum Key Distribution Receiver Payload

- Fine Pointing Unit
- Integrated Optical Assembly
- Single Photon Detectors
- Control and Data Processing Unit



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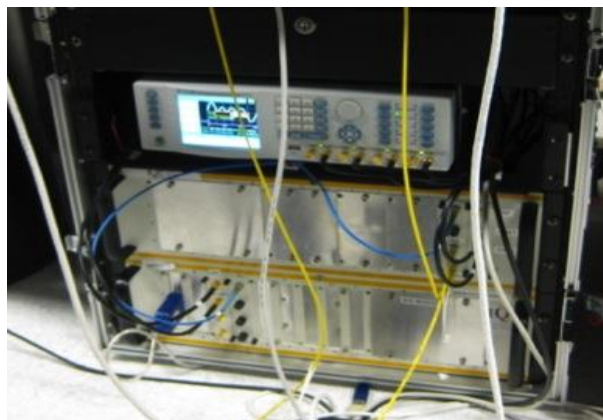
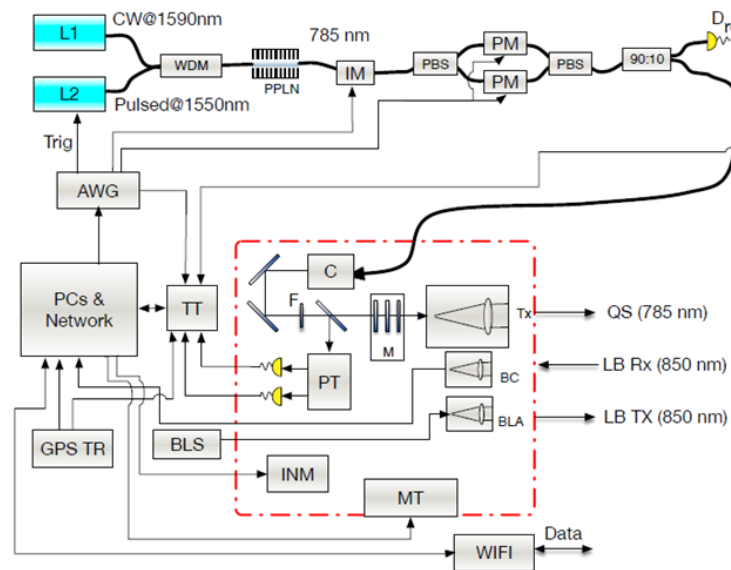
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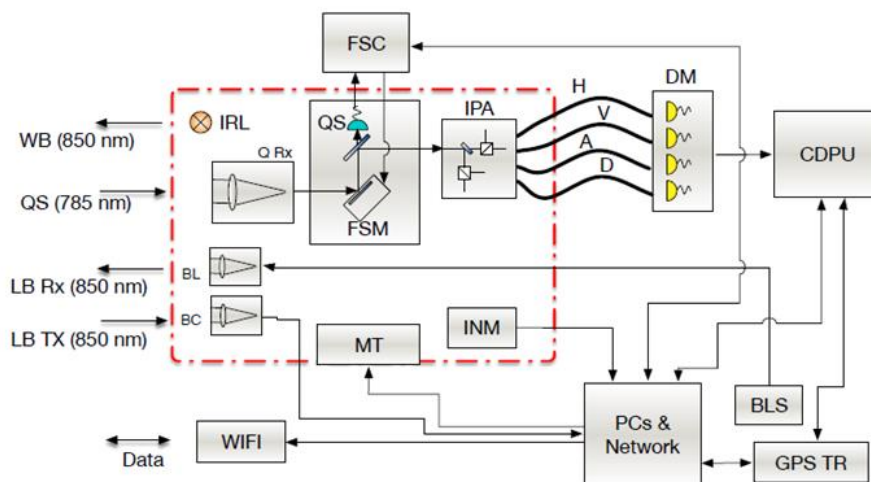
Quantum Ground Station

- Telescope (12 cm, refractor)
 - Mount ASA
- WCP source: 400 MHz, Decoy State, Polarization encoding, 785 nm
- Real-time polarization compensation
- Mock receiver for alignment



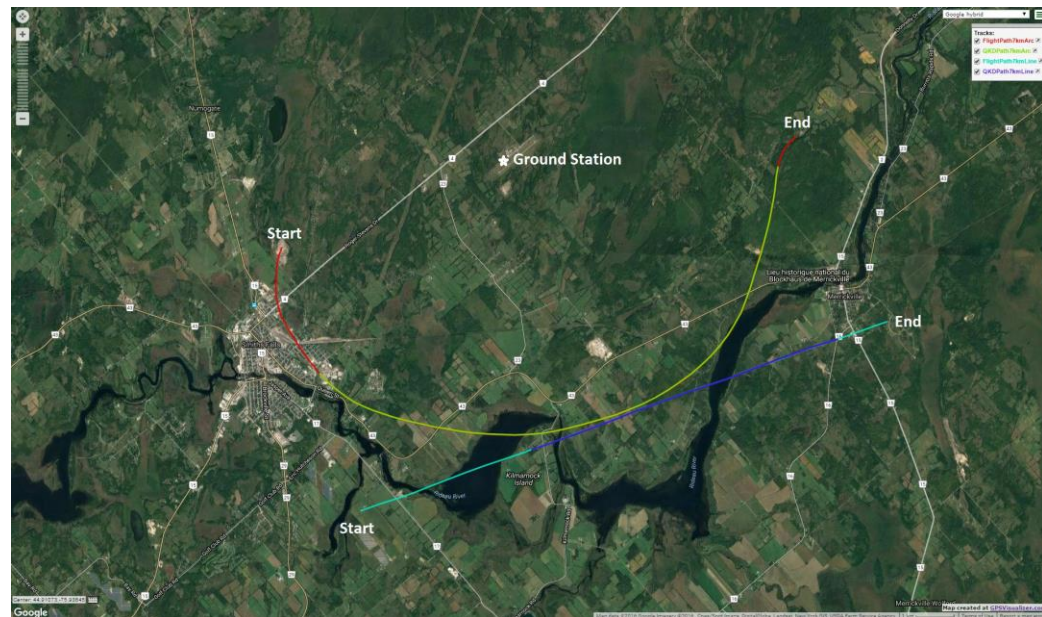
>> Airplane QKD Receiver

- NRC Twin Otter Research Aircraft
- Receiver pointing out rear door
- 10 cm commercial telescope and motor mount (coarse pointing)
- Signal 785 nm, Beacon 850 nm

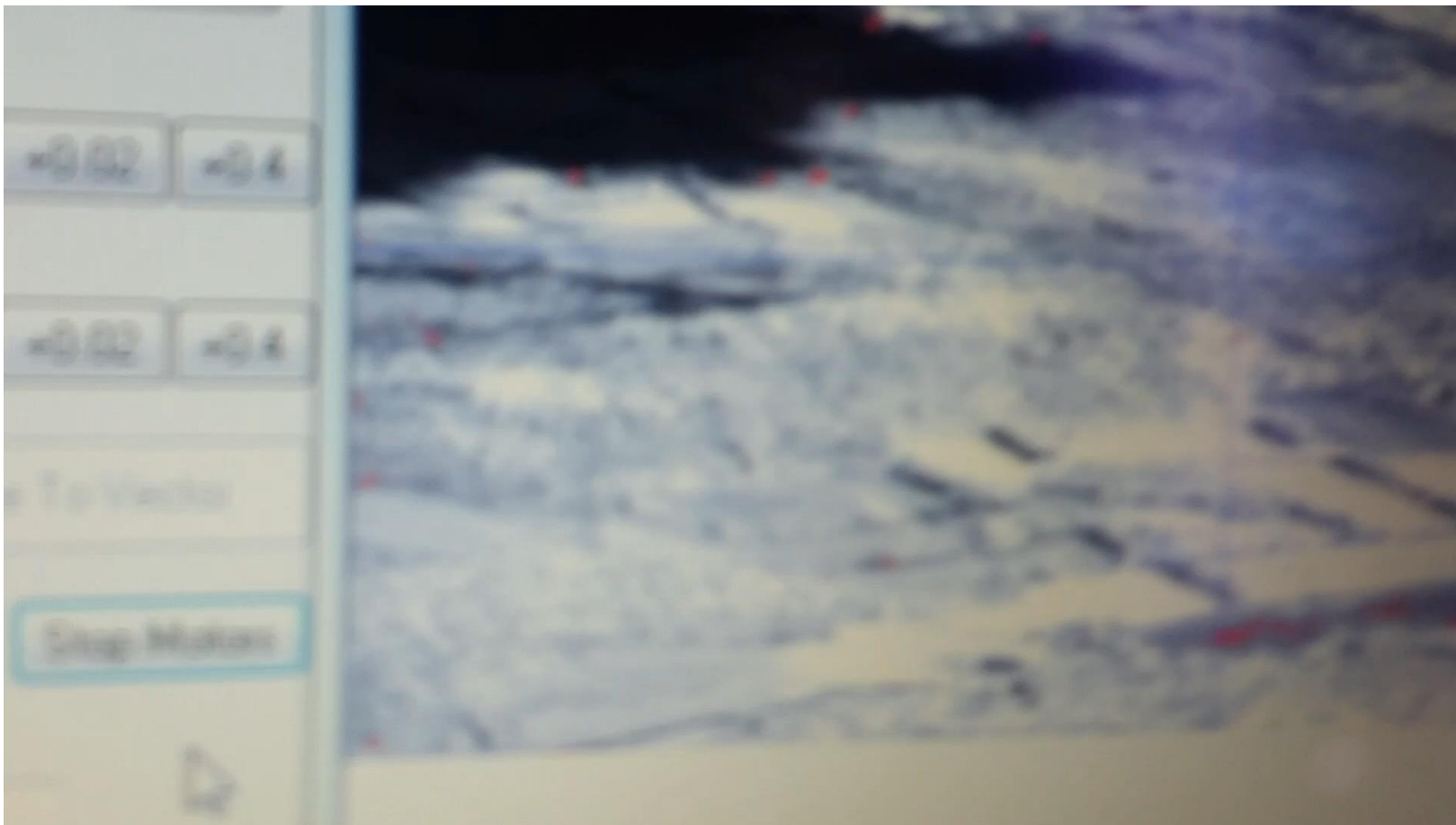


>> Flights

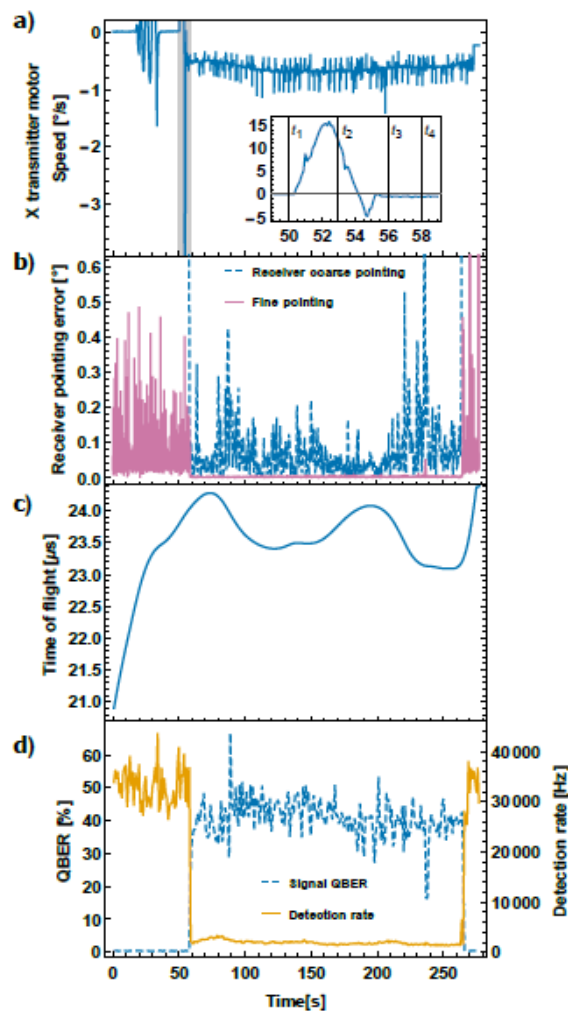
- Both Line and Arc passes
- 3 km to 10 km
- 90 knot to 130 knot
- 1.5 km altitude



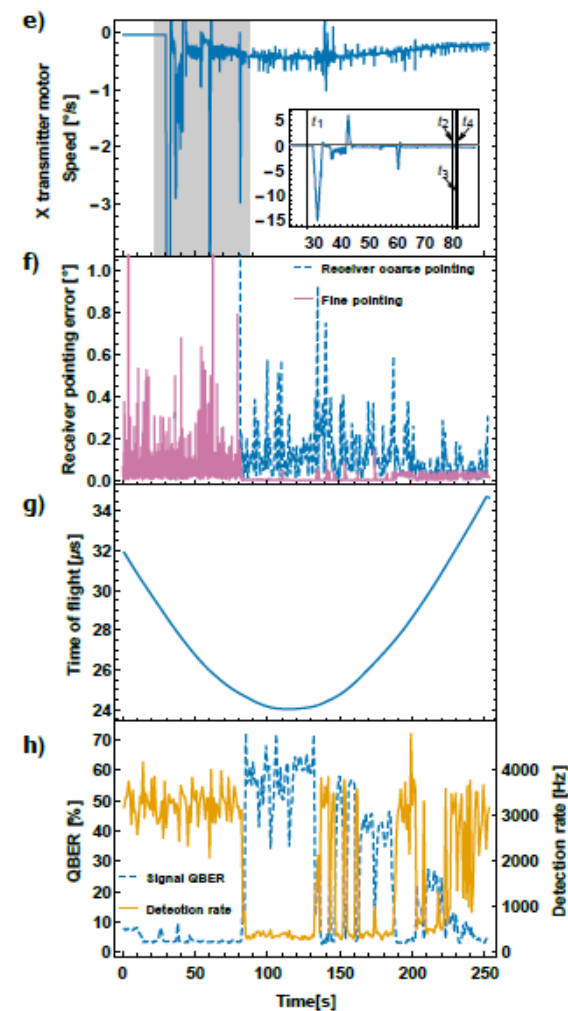
>> GPS Pointing Video



>>> Performance



7 km Arc



7 km Line



Highlights

- Link acquired in <10 s, some links lasting >250 s
- Max angular rate achieved during link of $\approx 1.28^\circ/\text{s}$
- Receiver Pointing Error $\approx 0.05^\circ$, $873\ \mu\text{rad}$, 180 arc seconds
- Fine Pointing Error $\approx 0.003^\circ$, $52\ \mu\text{rad}$, 11 arc seconds
- Transmitter Pointing Error $\approx 0.003^\circ$, $52\ \mu\text{rad}$, 11 arc seconds
- Able to get finite size secure key in multiple passes (one pass with $>800\text{kb}$ with full post processing)
- Maximum rate of ≈ 3 kbps of secure key (5km Arc Second Night)

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>> Summary

- The viability of the quantum satellite mission "QEYSSat" was demonstrated
- The core payload components have been demonstrated to operated under outdoor conditions
- C J Pugh *et. al.*
[arXiv:1612.06396](https://arxiv.org/abs/1612.06396)
- Further environmental testing and increasing TRL of components.
- Satellite Mission?



Support and partnerships:



>> Team

IQC Team Members:

PI: Dr. Thomas Jennewein

Project Lead: Christopher Pugh

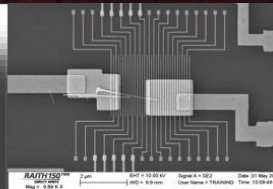
Project Support: Dr. Jean-Philippe Bourgoin, Dr. Brendon Higgins

Experimental and Component Support: Sascha Agne, Elena Anisimova, Eric Choi, Jeongwan Jin, Dr. Sarah Kaiser, Dr. Vadim Makarov, Nigar Sultana, Ramy Tannous





Thank you



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