SpooQySats

TESTING QUANTUM TECHNOLOGIES IN SPACE

Robert Bedington, Rakhitha Chandrasekara & Alexander Ling
Overview

- **The goal:** continental scale QKD – *Quantum Key Distribution*
- **The technology:** SPEQS – *a source of entangled photons*
- **The mission:** SpooQySats – *verifying SPEQS works in space*
- **The CubeSat:** GomX platform – *GomSpace satellite bus*
- **Future:** QKD demo – *beam entangled photon pairs from space to ground*
Quantum Key Distribution

- The main motivation for this work *(there are others..)*
- Using quantum mechanics to achieve communication that is greatly more secure than conventional, classical methods.
- Nice to have now, essential for future-proof encryption
Why Space

- Secure control of satellites
- Enables continental scale communications
- Applications to fundamental physics research
Space based QKD experiments

Institute of Quantum Computing (Canada, 2015?)

Chinese Academy of Sciences (China, 2016)

EU-SpaceQUEST

Diagram showing the setup of space-based QKD experiments with satellites and ground stations.
SPEQS: a QKD precursor

Small
Photon
Entangling
Quantum
System
SPEQS specs
• 1/3U
• 300g
• 2W

Testing
• Thermal testing (-10 to 40°C)
• Vacuum testing (10e-6 mbar)
• Vibration testing
• Radiation testing
• Balloon launch (35km)

MORE INFO
5PM Wednesday
Rakhitha Chandrasekara’s talk
SPEQS-1 on GomX-2

Extreme environmental testing of a rugged correlated photon source, Grieve et al.
SPEQS-1 on GomX-2

Photo by GomSpace

TRL 9
• Actual system “flight proven” through successful mission operations

TRL 8
• Actual system completed and “flight qualified” through test and demonstration (ground or space)

TRL 7
• System/subsystem demonstration in a space environment

TRL 6
• System/subsystem model or prototype demonstration in a relevant environment (ground or space)

TRL 5
• Component and/or breadboard validation in relevant environment

TRL 4
• Component and/or breadboard validation in laboratory environment

TRL 3
• Analytical and experimental critical function and/or characteristic proof-of-concept

TRL 2
• Technology concept and/or application formulated

TRL 1
• Basic principles observed and reported
SPEQS development approach

SPEQS-1.x
- Low brightness, proofs of concepts
- Balloons, shared CubeSats, TEXUS
- Photons all detected on board

SPEQS-2
- Full QKD-strength, tech demo
- Under development for SpooQySat
- Photons all detected on board

... 
SPEQS-n
- Space-to-ground QKD demos
- Under study for future projects
- Photons beamed to ground
SpooQySats – SPEQS-2 demos

SpooQy-1 - engineering pathfinder;

- Develop preliminary design
- SpooQy-1 PDR
- SpooQy-1 Flat Sat
- SpooQy-1 CDR
- SpooQy-1 Build & Test Campaign

SpooQy-2 – science demonstration

- SpooQy-2 PDR
- SpooQy-2 Flat Sat
- SpooQy-2 CDR
- SpooQy-2 Build & Test Campaign

- Groundstation planning
- Groundstation build and commission
- SpooQy-1 launch and operations
- SpooQy-2 launch and operations
Satellite bus – GomX platform

Limited flight heritage but most components slated to fly Q3 this year on GomX-3.

Interfaces in order of preference
Serial
CAN
I2C

Total mass:
With 4 batteries - 2.2kg
With 8 batteries - 2.4kg
+ 2kg Payload allowance
Design capability studies

**SpooQyLite**
- Minimum configuration producing useful results.

**SpooQySat**
- PDR SpooQySat without secondary payloads and s-band

**SpooQyMAX**
- Low complexity options for redundancy?
- Main cubesat Failure Modes?
Current design work - SpooQyLite

- Minimum configuration.
- Reduces duty cycle of experiments as power limited.

<table>
<thead>
<tr>
<th>SpooQy-Lite: 2U</th>
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<tbody>
<tr>
<td>1.17kg</td>
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<tr>
<td>1 (or 2)x SPEQS-2.0</td>
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<tr>
<td>1x AX100 UHF</td>
</tr>
<tr>
<td>1x A3200 OBC</td>
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<tr>
<td>4x batteries</td>
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<tr>
<td>10x panels</td>
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<tr>
<td>3x magnetorquers</td>
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<td>1x antenna</td>
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Current design work - SpooQyMAX

- Two-in-one satellite
- FMEA ongoing

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<td>2x SPEQS-2.0</td>
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<td>2x AX100 UHF radios</td>
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<tr>
<td><strong>2x A3200 OBC</strong></td>
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<tr>
<td>8x batteries</td>
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<tr>
<td>14x panels</td>
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<tr>
<td>6-14x magnetorquers</td>
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<td>2x antennae</td>
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Current design work - SpooQyMAX

- Two-in-one option enabled by new nanodock
- But value of identical redundant components is questionable

**SpooQy-MAX: 3U**
- 2.72kg (*without payload*)
- 2x SPEQS-2.0
- 2x AX100 UHF radios
- **2x A3200 OBC**
- 8x batteries
- 14x panels
- 6-14x magnetorquers
- 2x antennae

*GomSpace Nanodock*
Current design work - SpooQyMAX

- Two-in-one option enabled by new nanodock
- But value of identical redundant components is questionable

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Current design work

- ADCS maturity also questioned. Use passive ADCS?
- Varying payload resources, but all meet nominal minimums.

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<th>SpooQySat</th>
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<tbody>
<tr>
<td>+0.47kg</td>
<td>2.25kg (without payload)</td>
<td>-1.08kg (-1U)</td>
</tr>
<tr>
<td>2x SPEQS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+1</td>
<td>1x UHF</td>
<td></td>
</tr>
<tr>
<td>+1</td>
<td>1x OBC</td>
<td></td>
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<tr>
<td>8x batteries</td>
<td></td>
<td>-4</td>
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<tr>
<td>14 x solar panels</td>
<td></td>
<td>-4</td>
</tr>
<tr>
<td>+3 to 11</td>
<td>3x magnetorquers</td>
<td></td>
</tr>
<tr>
<td>+1</td>
<td>1x antenna</td>
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Ground stations

**Current:**

**UHF** – *at CQT*
- GomSpace NanoCom GS100
- Plus collaborators

**Nearer term:**

**S-band** – *at CQT*
- OSAGS network
- 2.3m parabolic dish, full RF chain with SDR processing

**Longer term:**

**Optical**
- Repurposed laser ranging groundstations

Photo by Jörg Weingrill
Possible future payloads

Nearer term
- Alternative SPEQS sources
- GNSS tests
- CCR – corner cube reflector
- Miniature pressure sensor

Longer term
- Micro-radian ADCS
- Advanced CCRs
- Beam steering optics
- Detector cooling systems

-collaborators welcomed!
Future applications for SPEQS

**Fundamental physics**
- Long baseline entanglement tests
  *gravitational effects on entanglement*

**Commercial**
- Device-independent, Quantum random number generators
- Ground-based (optical fibre) / UAV drone-based / portable QKD

*Collaborators welcomed!*
Summary

- Proof of Concept
- CQT’s first space payload
- Tested on Balloons
- Integrated onto 3rd party, 2U CubeSats

SPEQS-1:
- CQT’s first satellites
- Dedicated for SPEQS-2
- Training and assistance from GomSpace, UCL MSSL, TU Delft

SpooQySats:
- Space-to-ground QKD
- Long-baseline entanglement tests
- Commercial applications

Future:

See Also:
5pm Wednesday
Rakhitha Chandrasekara’s talk