

# SpooQySats

TESTING QUANTUM TECHNOLOGIES IN SPACE



**Robert Bedington, Rakhitha Chandrasekara & Alexander Ling**



# Overview

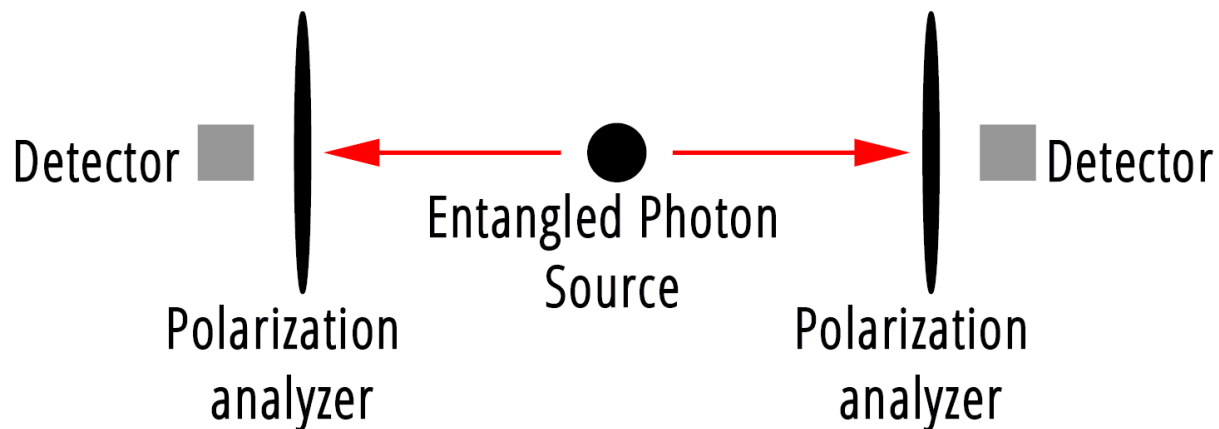
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- **The goal:** continental scale QKD – *Quantum Key Distribution*
- **The technology:** SPEQS – *a source of entangled photons*
- **The mission:** SpooQySats – *verifying SPEQS works in space*
- **The CubeSat:** GomX platform – *GomSpace satellite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

# Quantum Key Distribution

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- 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

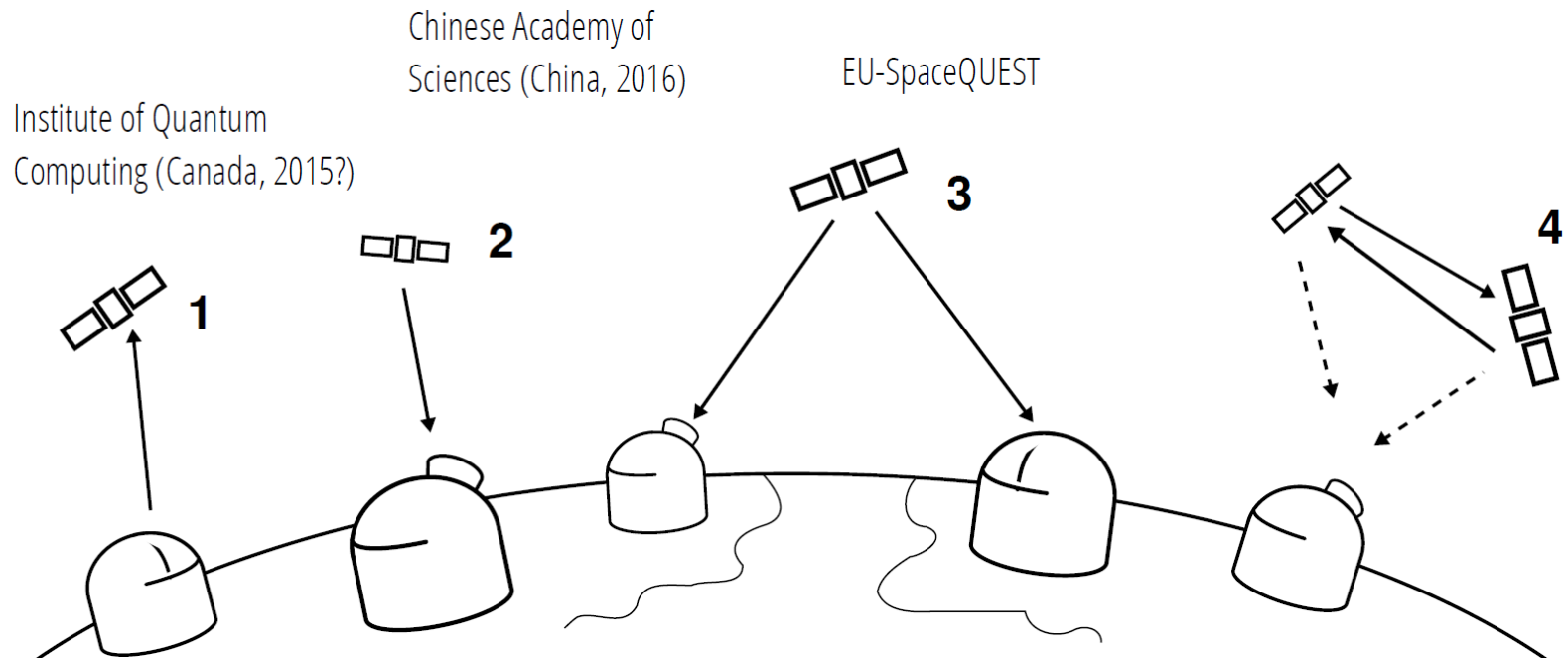
# Why Space

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- ❑ Secure control of satellites
- ❑ Enables continental scale communications
- ❑ Applications to fundamental physics research

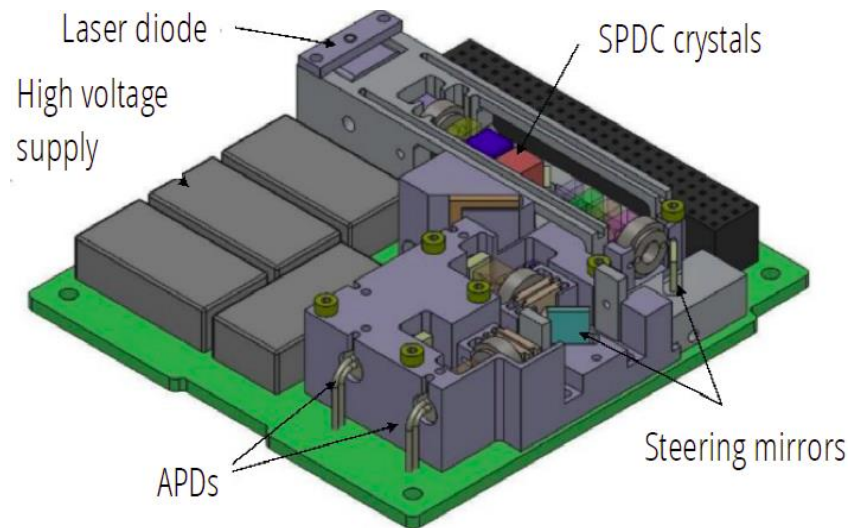


# Space based QKD experiments

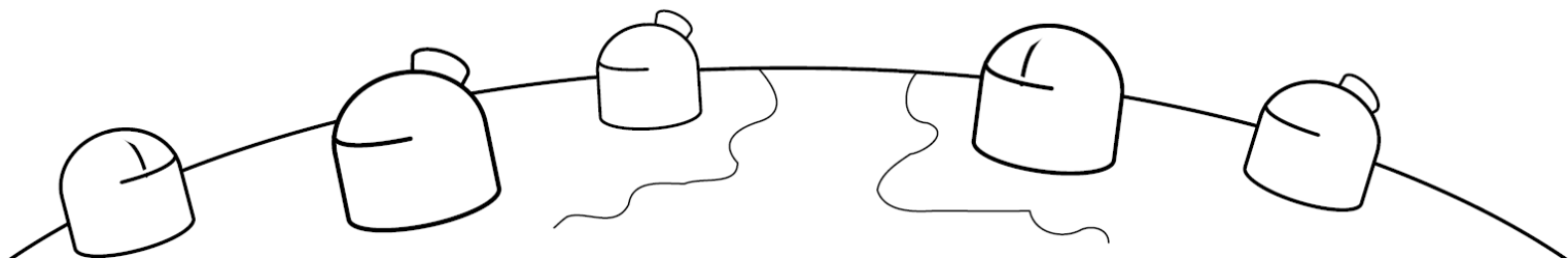


# SPEQS: *a QKD precursor*

**Small  
Photon  
Entangling  
Quantum  
System**



  
**SPEQS**



# SPEQS-1



## SPEQS specs

- 1/3U
- 300g
- 2W

## Testing

- Thermal testing (-10 to 40C)
- 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

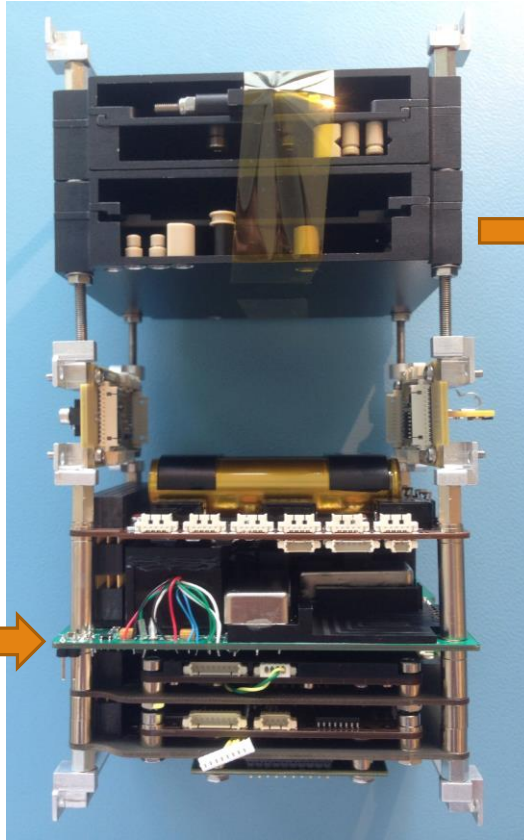


Photo by GomSpace



Photo by Steve Jurvetson

***Extreme environmental testing of a rugged correlated photon source***, Grieve et al.

arXiv:1504.00171v1 [quant-ph] 1 Apr 2015



# SPEQS-1 on GomX-2

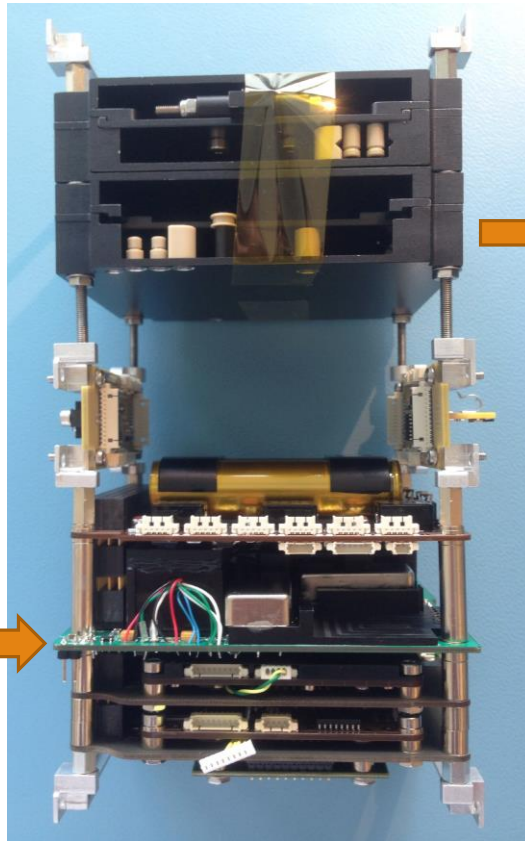
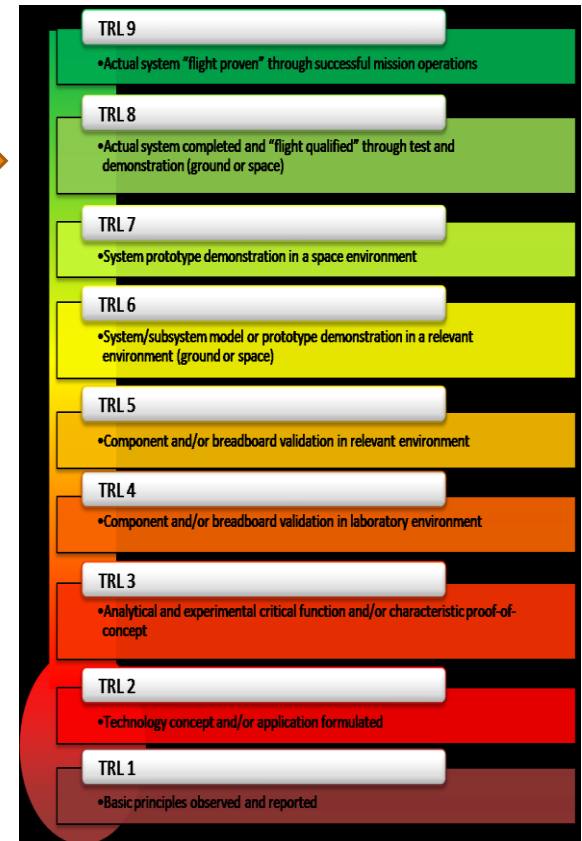


Photo by GomSpace



# SPEQS development approach

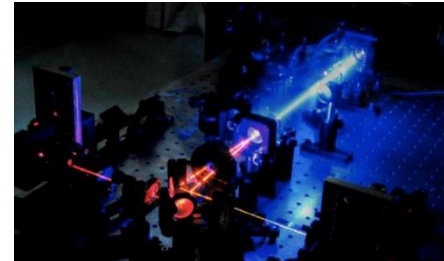
## SPEQS-1.x

- 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

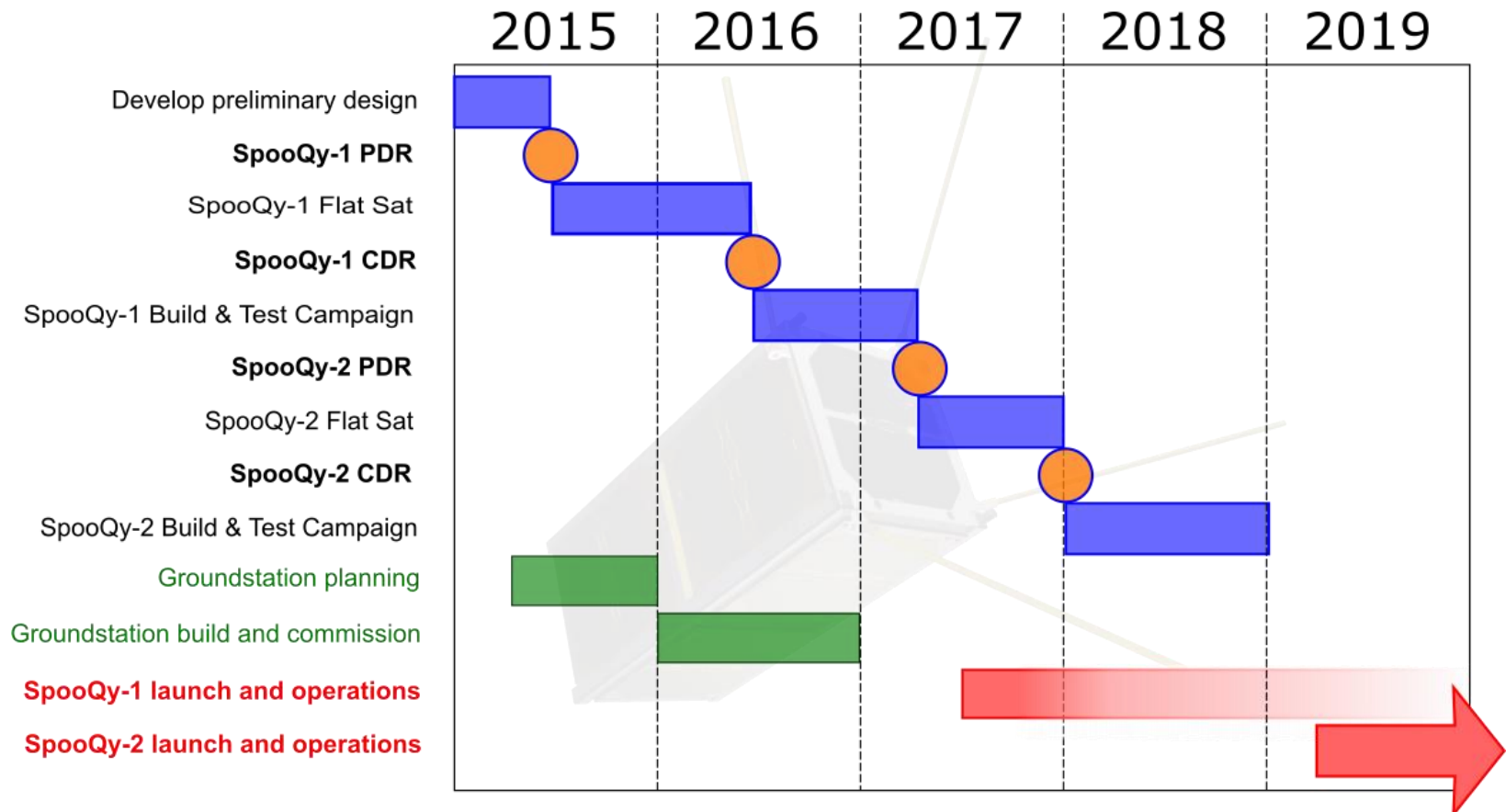
- *Space-to-ground QKD demos*
- *Under study for future projects*
- *Photons beamed to ground*



# SpooQySats – SPEQS-2 demos

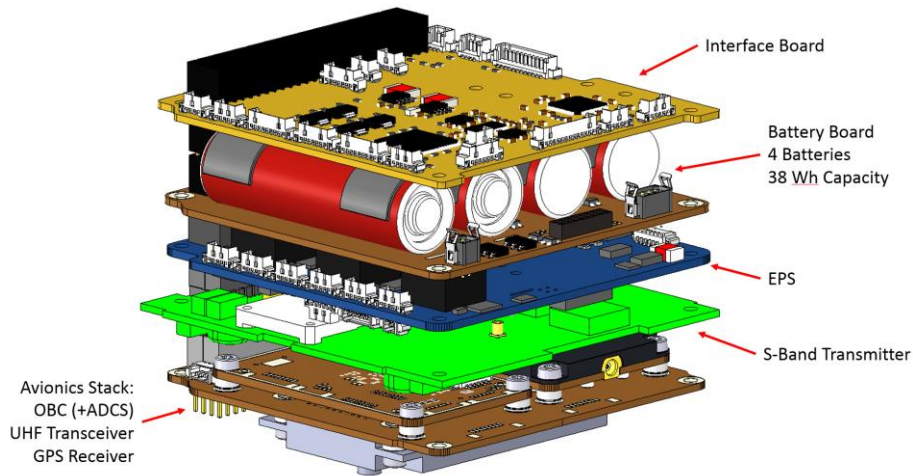
SpooQy-1 - engineering pathfinder;

SpooQy-2 – science demonstration



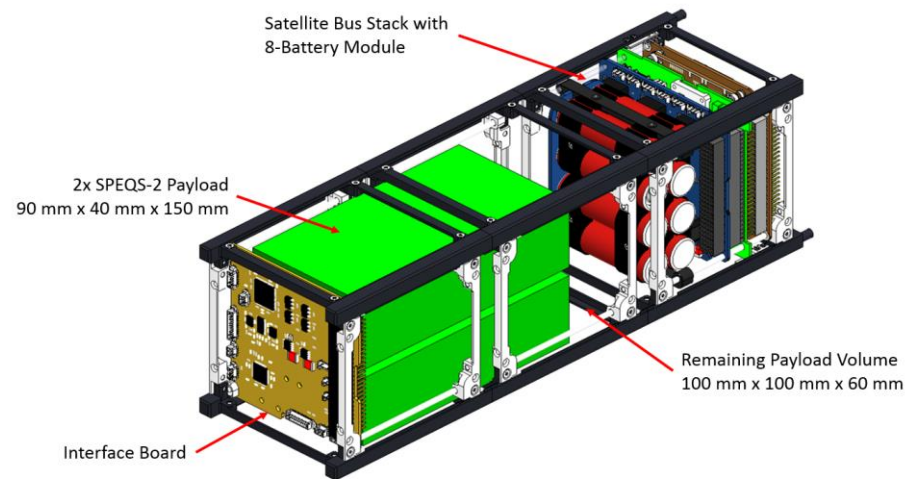
# Satellite bus – GomX platform

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



## Interfaces in order of preference

Serial  
CAN  
I2C



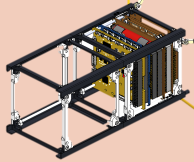
## Total mass:

With 4 batteries - 2.2kg

With 8 batteries - 2.4kg

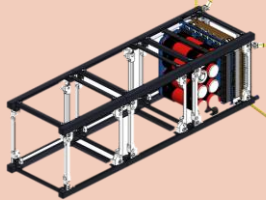
**+ 2kg Payload allowance**

# Design capability studies



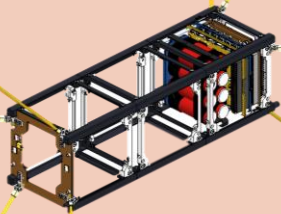
## *SpooQyLite*

- Minimum configuration producing useful results.



## SpooQySat

- PDR SpooQySat without secondary payloads and s-band

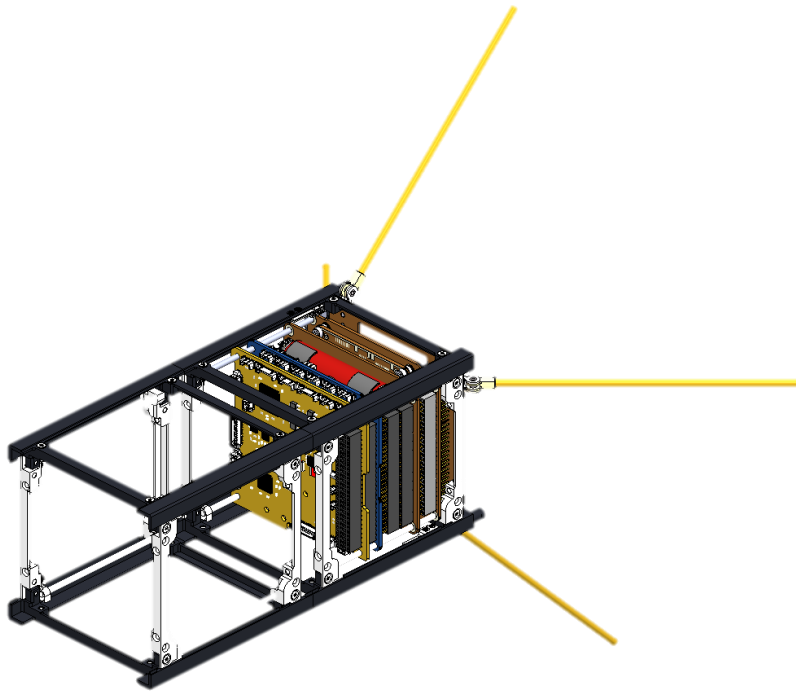


## SpooQyMAX

- Low complexity options for redundancy?
  - Main cubesat Failure Modes?

# Current design work - SpooQyLite

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



SpooQy-Lite: 2U
1.17kg
1 (or 2)x SPEQS-2.0
1x AX100 UHF
1x A3200 OBC
4x batteries
10x panels
3x magnetorquers
1x antenna

# Current design work - SpooQyMAX

- ❑ Two-in-one satellite
- ❑ FMEA ongoing

## SpooQy-MAX: 3U

2.72kg (*without payload*)

2x SPEQS-2.0

2x AX100 UHF radios

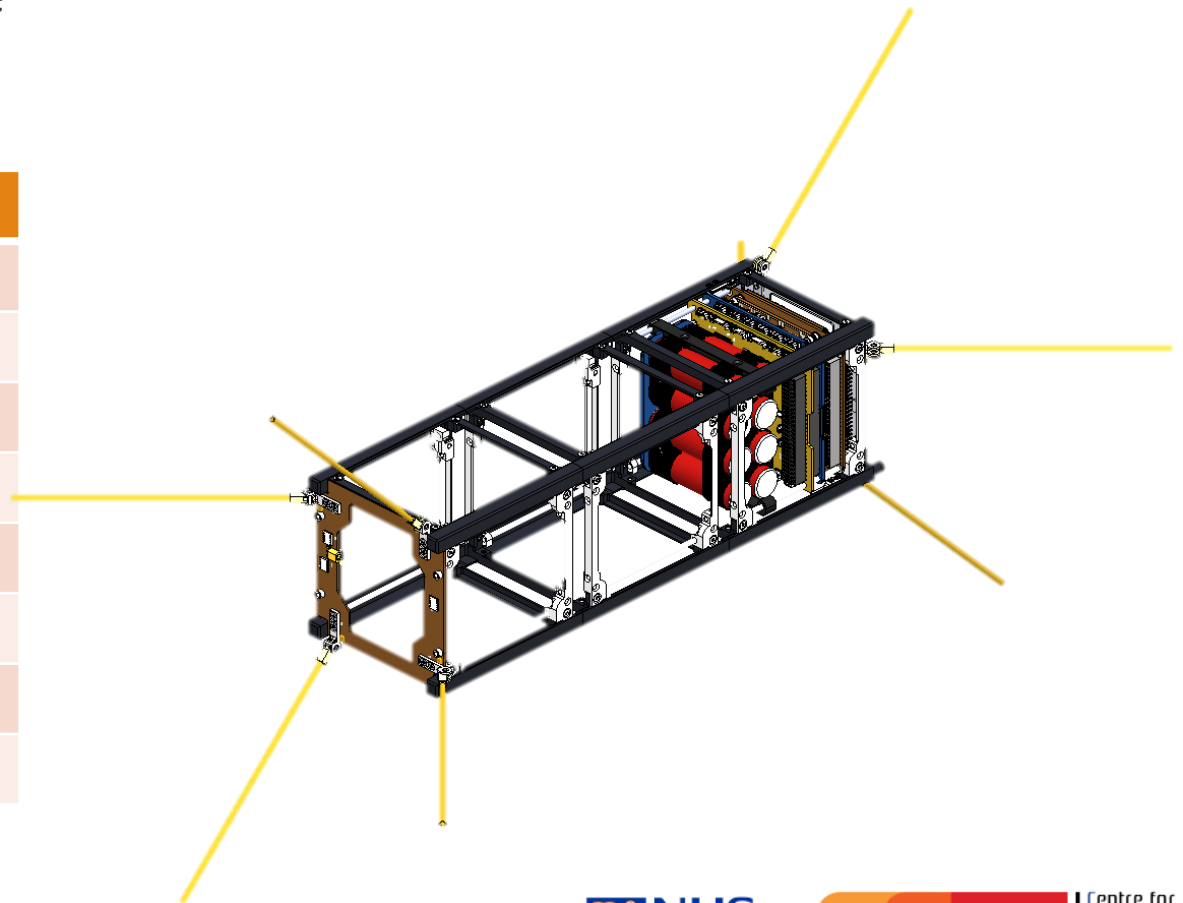
**2x A3200 OBC**

8x batteries

14x panels

6-14x magnetorquers

2x antennae



# Current design work - SpooQyMAX

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

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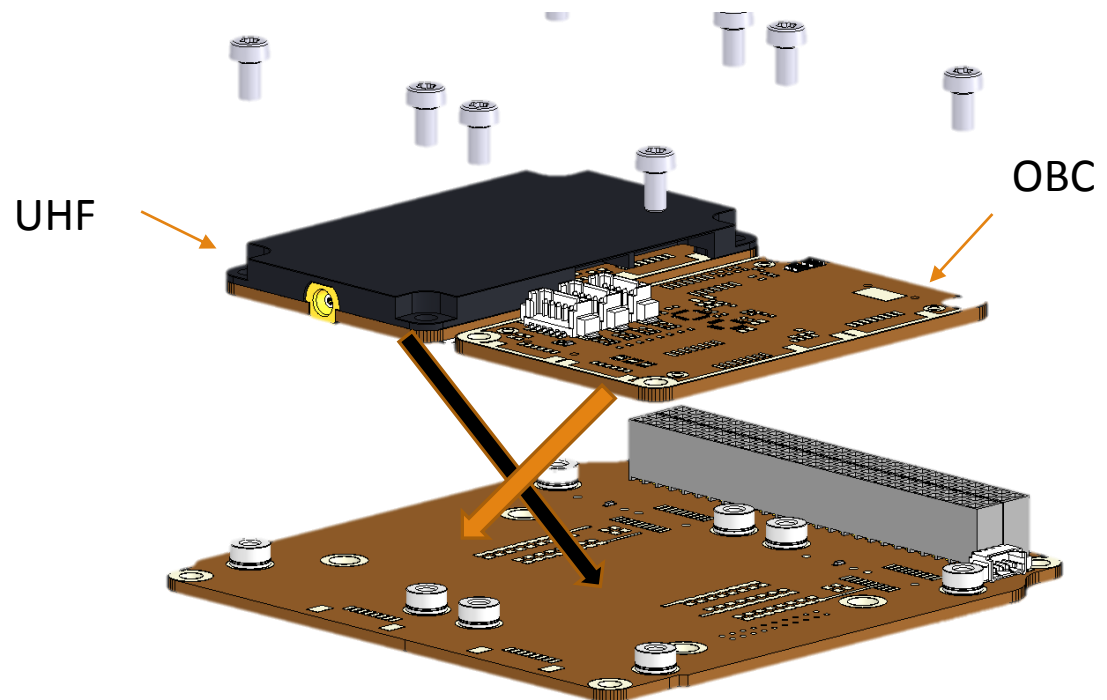
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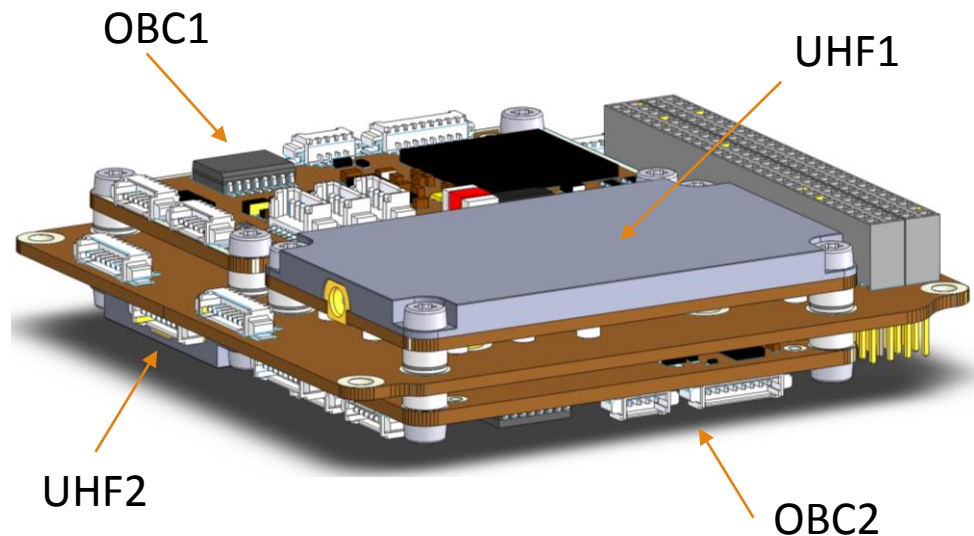
**2x A3200 OBC**

8x batteries

14x panels

6-14x magnetorquers

2x antennae



# Current design work

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

SpooQy-MAX: 3U	<i>SpooQySat</i>	SpooQy-Lite: 2U
<b>+0.47kg</b>	<b>2.25kg (without payload)</b>	<b>-1.08kg (-1U)</b>
	<b>2x SPEQS</b>	
<b>+1</b>	<b>1x UHF</b>	
<b>+1</b>	<b>1x OBC</b>	
	<b>8x batteries</b>	<b>-4</b>
	<b>14 x solar panels</b>	<b>-4</b>
<b>+3 to 11</b>	<b>3x magnetorquers</b>	
<b>+1</b>	<b>1x antenna</b>	

# 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

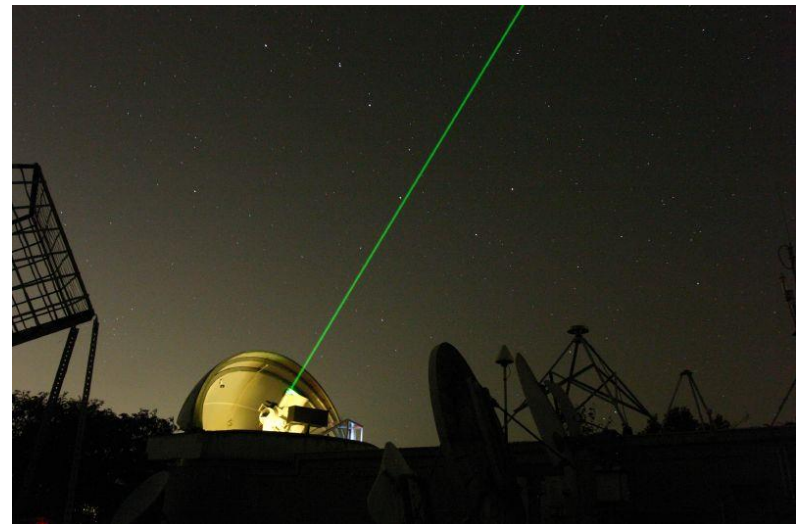
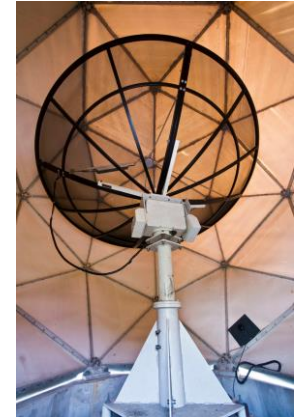


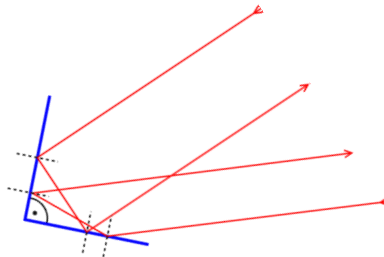
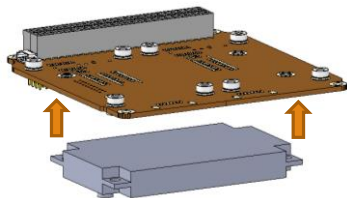
Photo by Jörg Weingrill

# Possible future payloads

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## 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

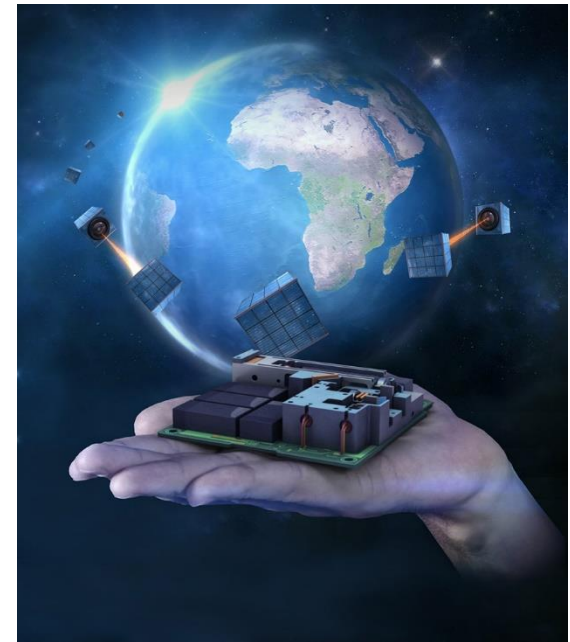
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## *Fundamental physics*

- 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 3<sup>rd</sup> party, 2U CubeSats

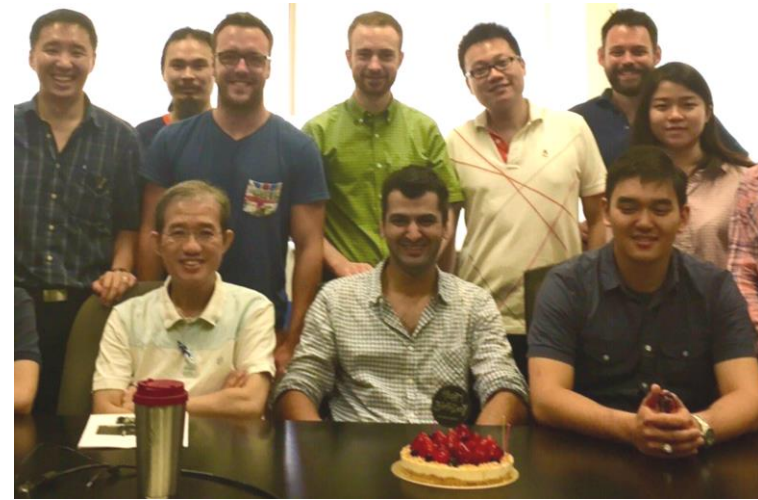
## **SPEQS-1:**

- 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:**



*The team*

**See Also:**  
**5pm Wednesday**  
**Rakhitha Chandrasekara's talk**