NanoBob
A Secure Quantum Communication CubeSat Concept for Quantum Key Distribution

Grenoble University Space Center
Centre Spatial Universitaire de Grenoble (CSUG)

IQOQI Vienna, Austria
Institute for Quantum Optics and Quantum Information

ESA, Scylight Meeting
February 8, 2017

IQOQI Quantum Communication Competition

hina (XD-2 QUantum Experiments at Space Scale) launched August 16, 2016, the 00-kg Mozi (or Micius) satellite, a collaboration between the Chinese and Austrian cademies of Sciences. It has on board a photon-pair source to establish quantum ownlinks to two far apart ground stations on Earth.

urope (Space-QUEST) consortium including the IQOQI (PI) and 42 international partners: undamental physics using downlink from the International Space Station (ISS)

nada, Institute for Quantum Computing, U of Waterloo (T. Jennewein) and U of Toronto Institute for Aerospace Stu EYSsat uplink ongoing feasibility study using COM DEV Ltd.'s AIM-class 70 kg microsatellite bus.

ngapore Center for Quantum Technologies (Alexander Ling): in-orbit demonstration of cubesat subsystem technolo

pan, QE, National Institute for Communications Technology, Tokyo: space-based quantum emulation experiment us e SOCRATES 50-kg class microsatellite.

SA, Los Alamos National Laboratory (Richard Hughes): ISS feasibility study and on-going proof-of-principle experime

IQI Motivations

ur society relies ever more on secure communication …

A number of actors willing to pay a premium to assure absolute security of selected information

- Intelligence and National Security Agencies
- Defense
- Telecom Operators and their end-customers (tech firms, hospitals, etc..)
- Blockchain technology: crypto-currencies (Bitcoin), high value supply chain, …

Europe lags behind the international competition in quantum communication

Cubesat is an ideal vehicle to demonstrate the QKD technology in Space

- Potentially a means to bring down costs
- Spatial and temporal coverage: constellations, short time-to-launch
- More and more optical communication in space : embarked optical source, optical inter-satellite links, ground stations links, satellite optical tracking know-how

Key Success Factors

- Instrumentation Miniaturization & Quantum Cryptography expertise

Mutual complementarity of proposed European partnersh
Instrumentation miniaturisation & cryptography expertise

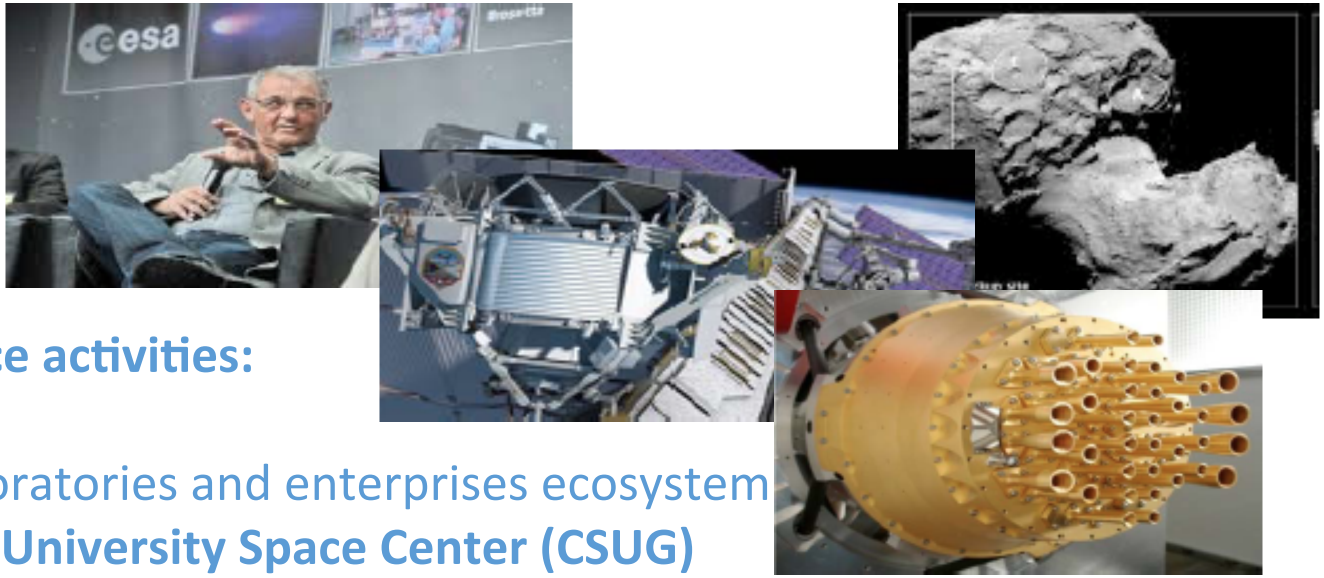
renoble space activities:

- History
- Local Laboratories and enterprises ecosystem
- **Grenoble University Space Center (CSUG)**
- Keywords: ***Miniaturized Instrumentation, Science and Data exploitation***

enna IQOQI (Zeilinger & Ursin groups):

- Internationally recognized leader in quantum communication
- Extensive experience with free-space demonstrations on Earth
- ***144-km record holder of free-space QKD***
- Optical Ground Station infrastructure, single photon sources

Mutual complementarity of proposed European partnersh
Instrumentation miniaturisation & cryptography expertise



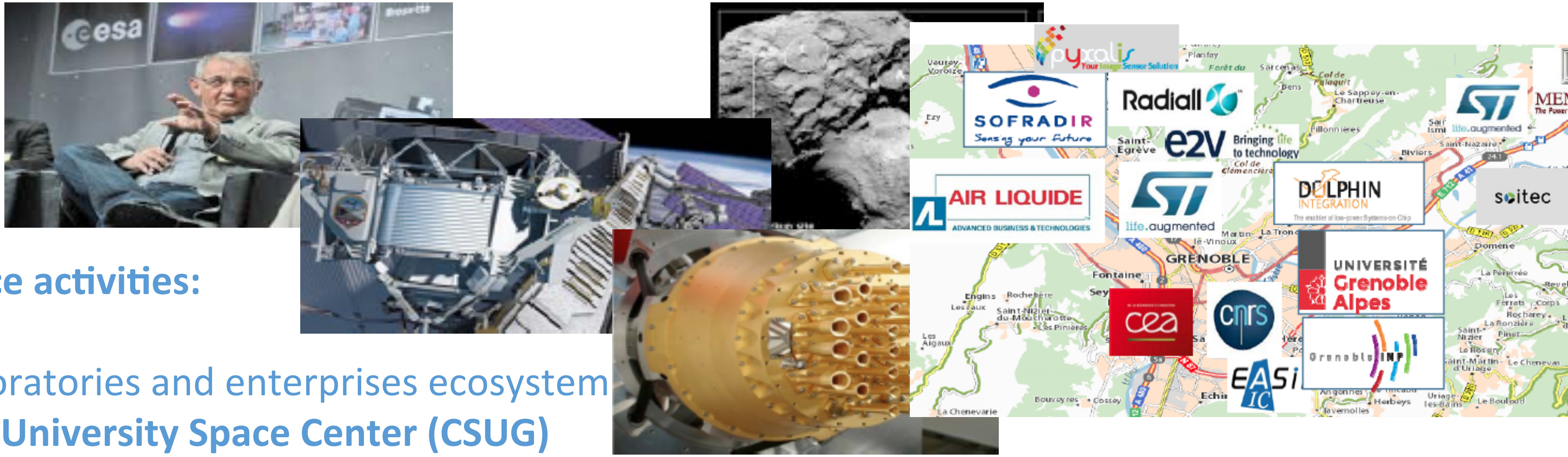
renoble space activities:

- History
- Local Laboratories and enterprises ecosystem
- **Grenoble University Space Center (CSUG)**
- Keywords: ***Miniaturized Instrumentation, Science and Data exploitation***

enna IQOQI (Zeilinger & Ursin groups):

- Internationally recognized leader in quantum communication
- Extensive experience with free-space demonstrations on Earth
- ***144-km record holder of free-space QKD***
- Optical Ground Station infrastructure, single photon sources

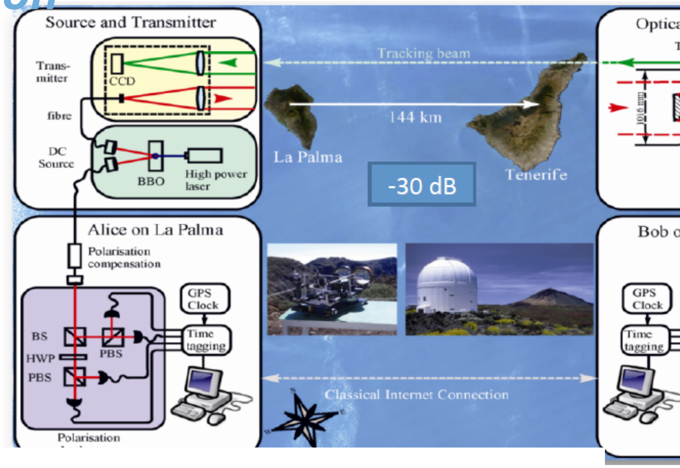
Mutual complementarity of proposed European partnersh
Instrumentation miniaturisation & cryptography expertise



renoble space activities:

- History
- Local Laboratories and enterprises ecosystem
- **Grenoble University Space Center (CSUG)**

Keywords: ***Miniaturized Instrumentation, Science and Data exploitation***

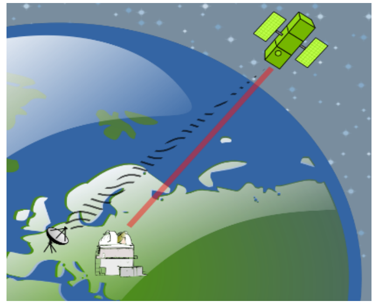


enna IQOQI (Zeilinger & Ursin groups):

- Internationally recognized leader in quantum communication
- Extensive experience with free-space demonstrations on Earth
- ***144-km record holder of free-space QKD***
- Optical Ground Station infrastructure, single photon sources

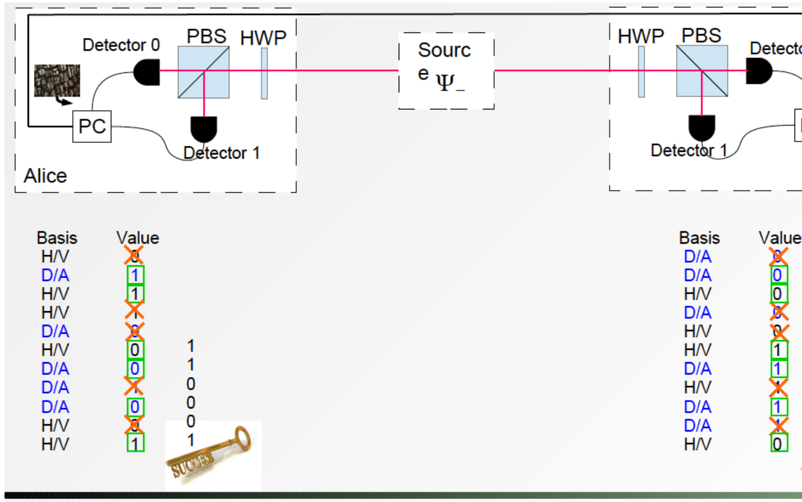
Air Liquide creative oxygen · e2V Bringing life to technology · life.augmented · cnrs · cnes · UNIVERSITÉ Grenoble Alpes · Grenoble INP · FONDATION UNIVERSITÉ Grenoble Alpes

IQI NanoBob Mission Objectives



emonstrate Quantum Key Distribution > 500 km with a CubeSat

- Demonstrate the first cubesat, full quantum uplink using entangled photons
- 100% European Project
- Miniaturized Implementation, demo at 808 nm, or at 1550 nm
- Cubesat launch 2020
- Low cost (secure key demo ~k€/Mb, forecast <100 €/Mb)



Ekert, Artur K., „Quantum cryptography based on Bell's theorem“

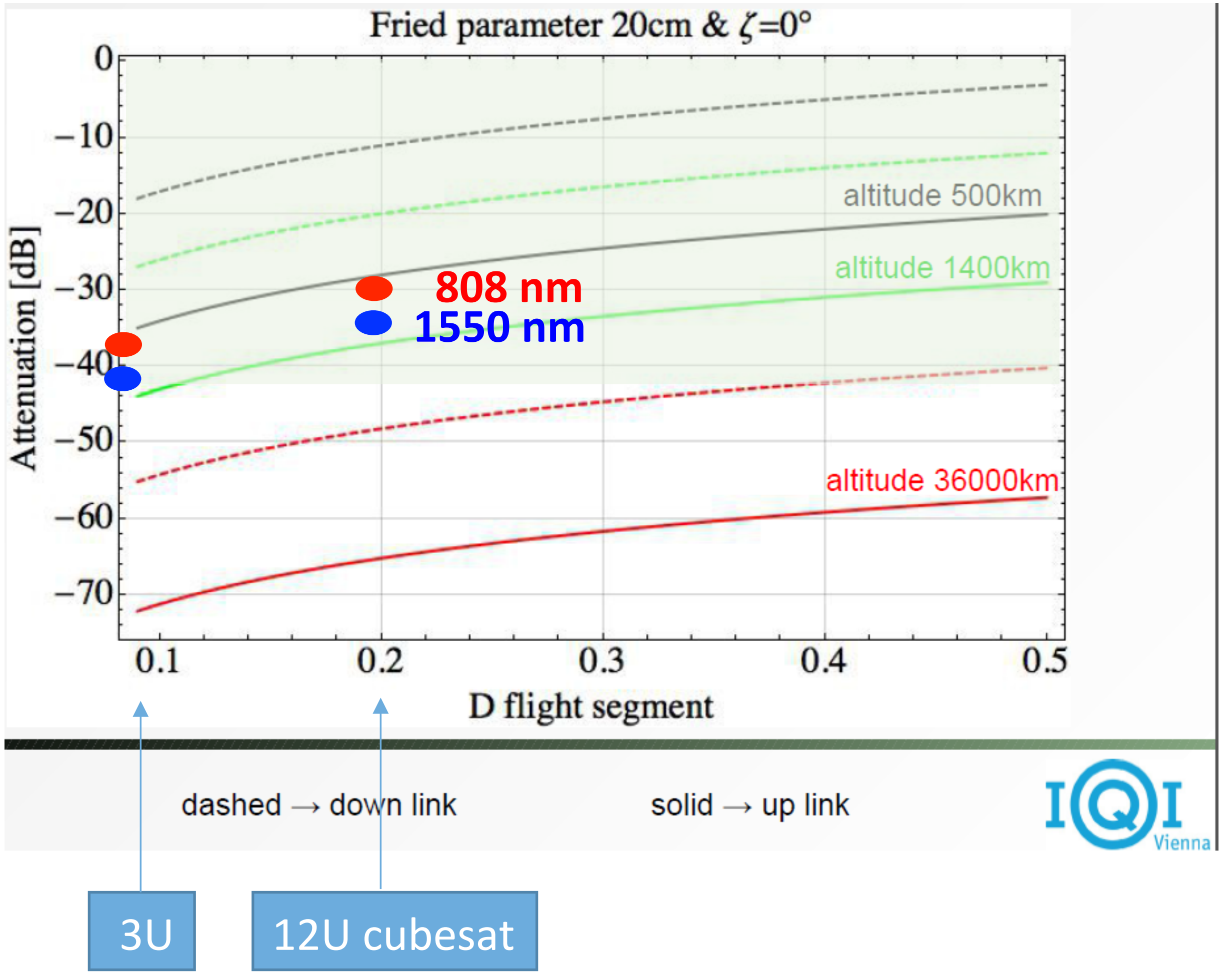
emonstrate fast classical optical communication ~500 km·Gb/s

onstruct an accurate background light pollution map VIS and/or IR

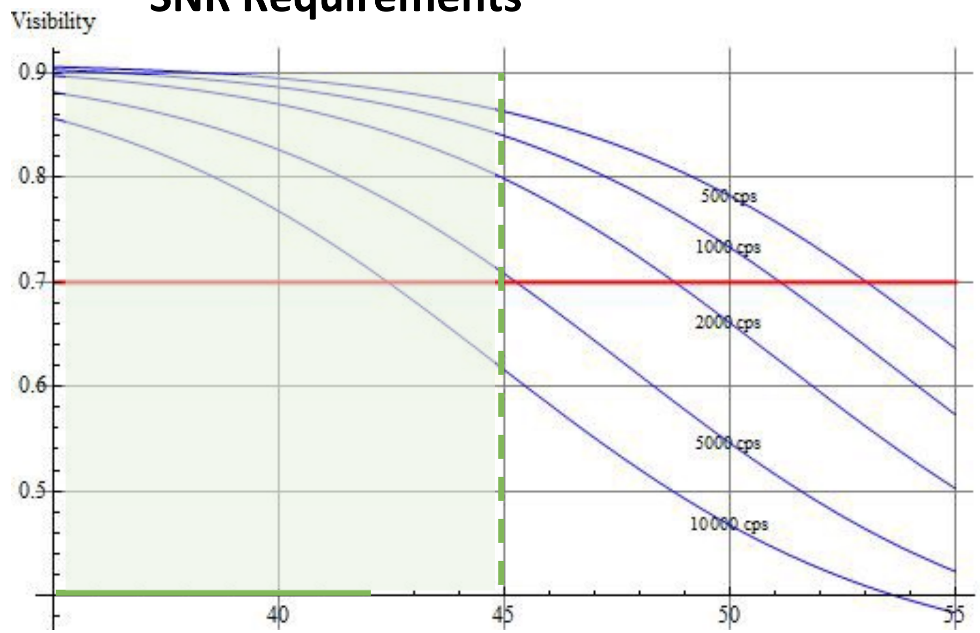
- Using the high spatial resolution and single photon counting near urban areas

Credit: Istituto di Scienza e Tecn
dell'Inquinamento Luminoso (Fa

NanoBob link budget & background counts



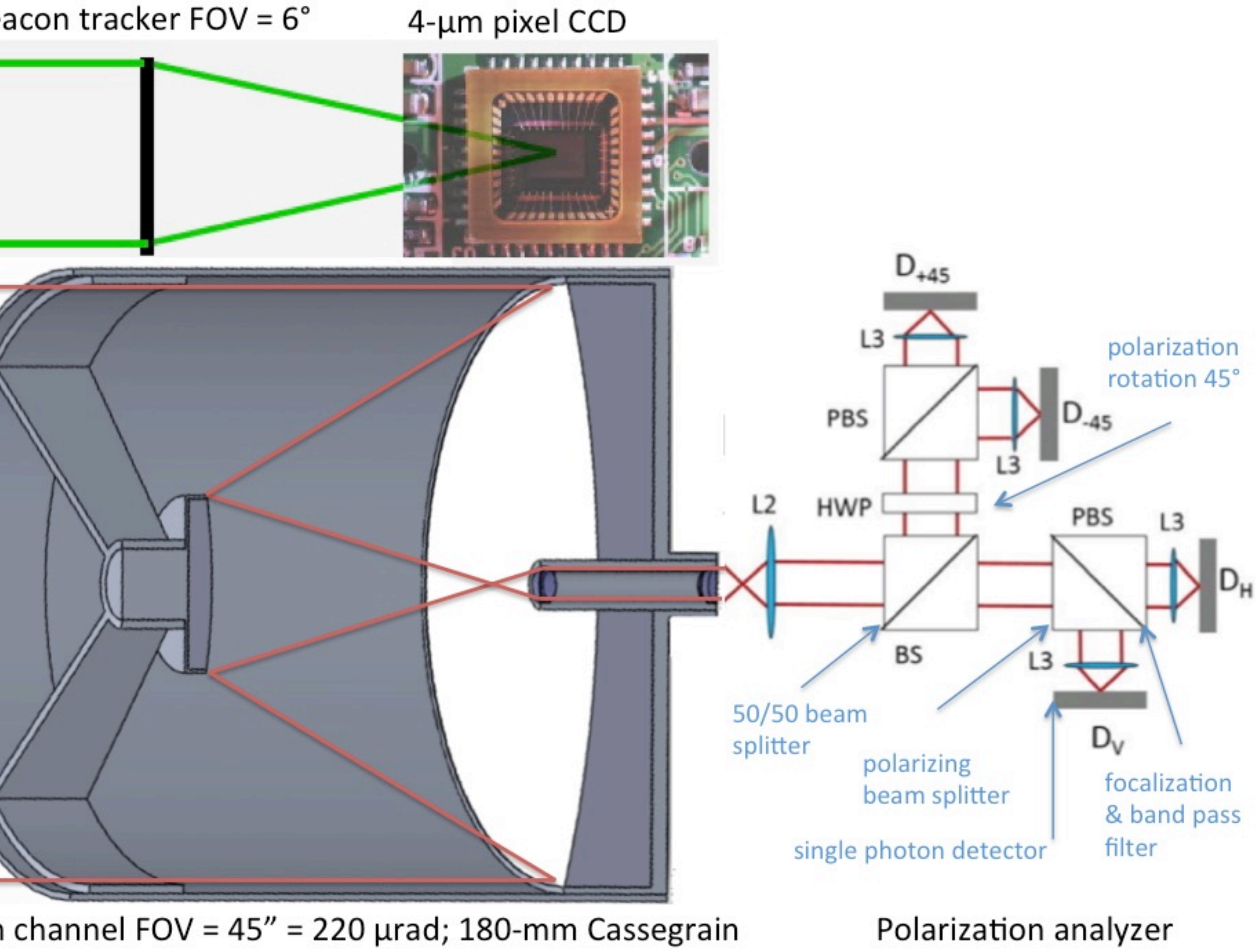
SNR Requirements



Visibility (polarization correlation) vs. Link atten
for different values of background counts

To generate a secret key a Visibility (SNR) > 0.7 i
needed --> red line (45 dB / background < 5000

NanoBob key mission specifications



12U Cubesat working hypothesis

Orbit

- altitude 500 km – 700 km, 2-year mission duration
- OGS-satellite tracking from at least -60° to 60° from
  experiment duration ≥ 240 s

Bell-test (security verification)

1000 coincident counts to assure 3-sigma verification

QKD: minimum key length per passage > 10^5 (< 43 dB li

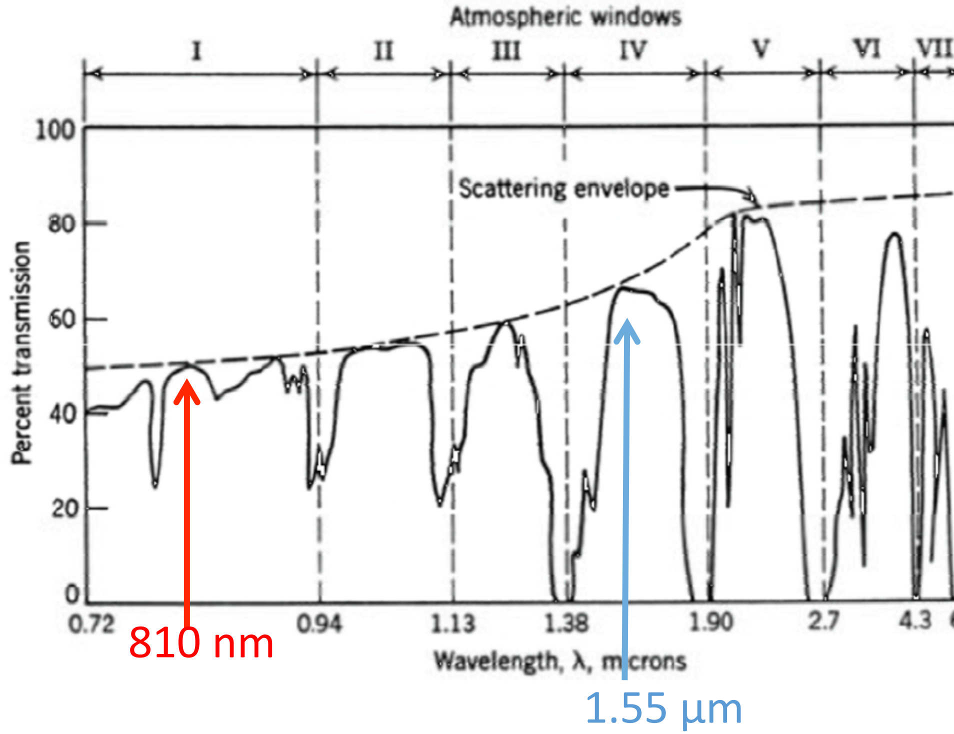
Air Liquide creative oxygen · e2v Bringing life to technology · ST life.augmented · cnrs · cnes · Université Grenoble Alpes · Grenoble INP · Fondation Université Grenoble Alpes

IQI NanoBob detectors

ellite payload: 4 Si-AP @ 0.8 µm, InGaAs or MCT @ 1.55 µm

photon detection efficiency > 40%
dark count rate < 1000 cps
Timing jitter < 1 ns
After pulsing <3%
Count rate > 10 MHz
Radiation studies performed by Singapore and Canada groups

velength range	VIS (800 nm)	NIR (1550 nm)	NIR (1550 nm)
hnology	Si-APD	InGaAs/InP-APD	MCT
ve area diameter)	500	fiber coupled	160
rating temperature	-30	-90	-120
k count rate (Hz)	< 200	200	1000 ?
ntum efficiency	75%	< 25%	> 60%
ing resolution (ps)	400	200	< 100 ps
se width (ns)	25	100	0.3
d time (µs)	1	> 2 (up to 100)	< 1
nufacturer/ del	IDQuantique/ ID120	IDQuantique/ ID230	CEA-Sofradir

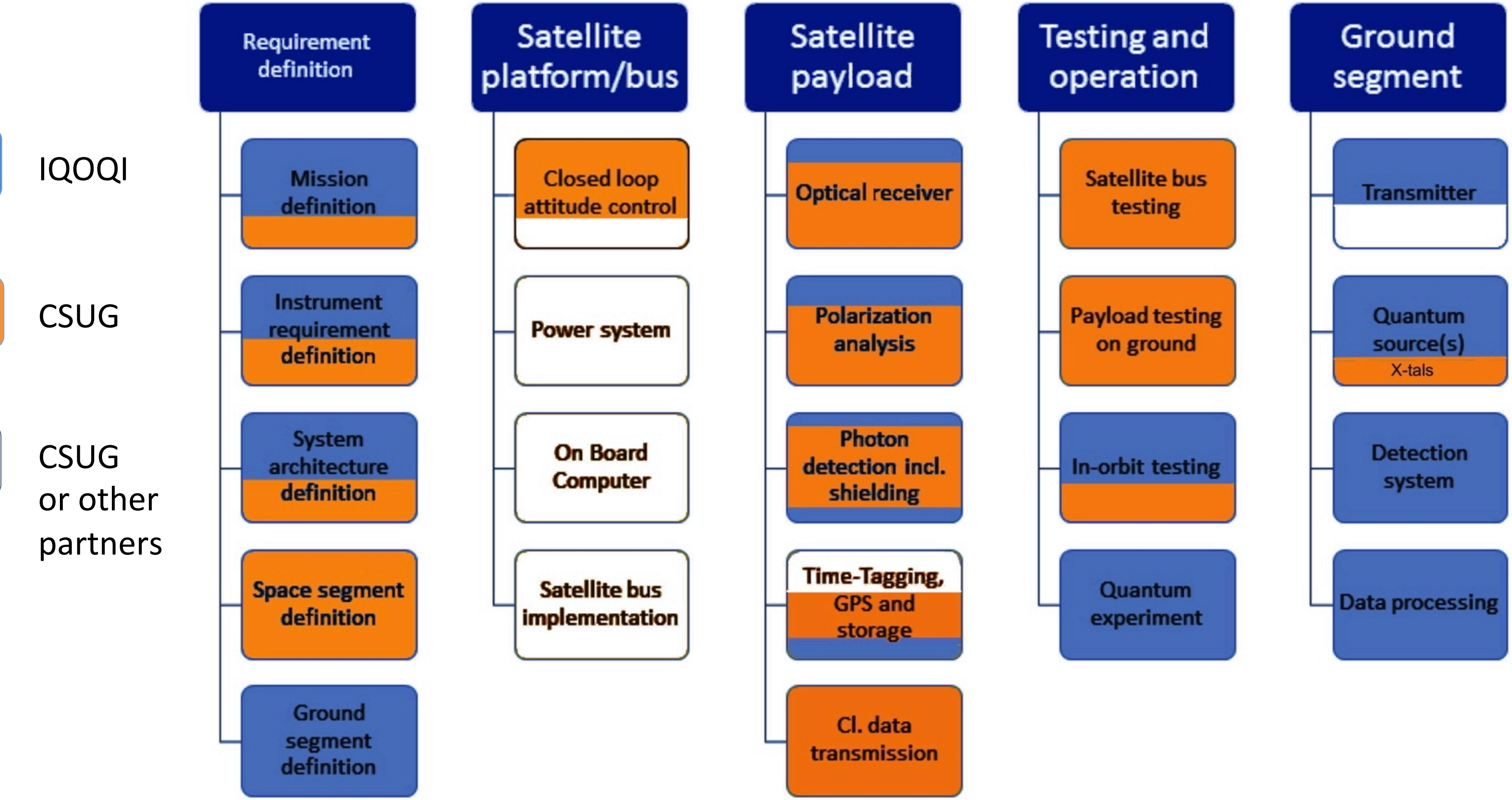


1550 nm versus 808 nm

More difficult at 1550 nm (diffraction, cooling)
but compatible with standard telecomm blocks
Additional link losses ~11 dB to be compensated
Source improvement and/or adaptive optics.

Air Liquide creative oxygen · e2v Bringing life to technology · ST life.augmented · cnrs · cnes · Université Grenoble Alpes · Grenoble INP · Fondation Université Grenoble Alpes

IQOQI NanoBob functional chart / WP partitioning



NanoBob project key take-aways

- Optical secure link : the next BIG THING in space ?

- The NanoBob project is a European project focusing on the use of entangled photons for very first European QKD demonstration using a CubeSat platform

- Compatible with existing 808-nm experience and translatable to 1550-nm (challenges to move from 808 nm to 1550 nm well understood and solutions identified)

- Timely and cost-effective space demonstration (4 to 5 M€ consolidated cost, including launch)

- Promising IQOQI – CSUG partnership with complementary skills

- Open to strengthening the consortium with more partners

- Paving the way to near-term (very) secure telecommunication

Air Liquide creative oxygen · e2v Bringing life to technology · ST life.augmented · cnrs · cnes · Université Grenoble Alpes · Grenoble INP · Fondation Université Grenoble Alpes

Q&A's