Space based QKD at ESA

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WE ARE ESA

EUROPE'S GATEWAY TO SPACE

WHAT	22 Member States, 5000 employees
WHY	Exploration and use of space for exclusively peaceful purposes
WHERE	HQ in Paris, 7 sites across Europe and a spaceport in French Guiana
HOW MUCH	€5.72 billion = €12 per European per year

QKD Activities at ESA

2003 Accommodation of a Quantum Communication Transceiver in an Optical Terminal
2004 Quantum Information and Quantum Physics in Space: Experimental Evaluation
2008 Photonic Transceiver for Secure Space Communications
2009 Entangled Photon Source For Quantum Communication 1
2009 Entangled Photon Source For Quantum Communication 2
2010 Introduction of Quantum Communication in Satellite Communication Networks
2011 Experimental Evaluation of Quantum Teleportation for Space Systems
2012 Applications of Optical-Quantum Links to GNSS
2014 Photonic Transceiver for Secure Space Communications: New Space Suitable Entangled Photon Source
2015 Ground Segment Development for LEO to Ground Quantum Communication
2017 Space Quest Phase A/B
2018 QUARTZ: Quantum Cryptography Telecommunication System
2018 Use of secure optical communication technologies to protect European critical infrastructure 1
2018 Use of secure optical communication technologies to protect European critical infrastructure 2
2018 QKDSAT
2019 Quantum key distribution protocols for space applications
2020 High performance entangled photon source 1
2020 High performance entangled photon source 2
2020 SAGA Phase A 1
2020 SAGA Phase A 2
2020 SAGA Phase A 3
+ internal studies and activities

Why do we need QKD satellites?

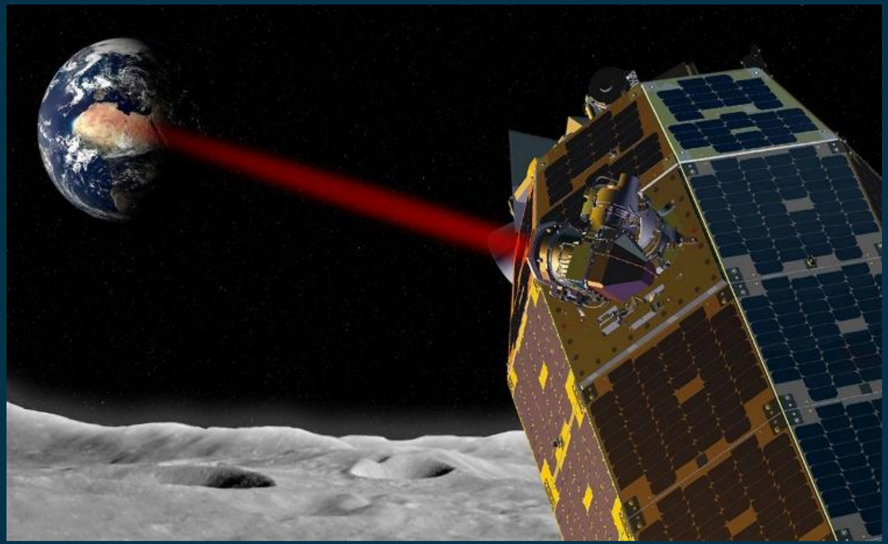
Attenuation of light in fibers and in free space:

Optical fibers:

Exponential loss, 0.3 dB/km
no amplification for quantum
(example: 80 dB for 270 km)

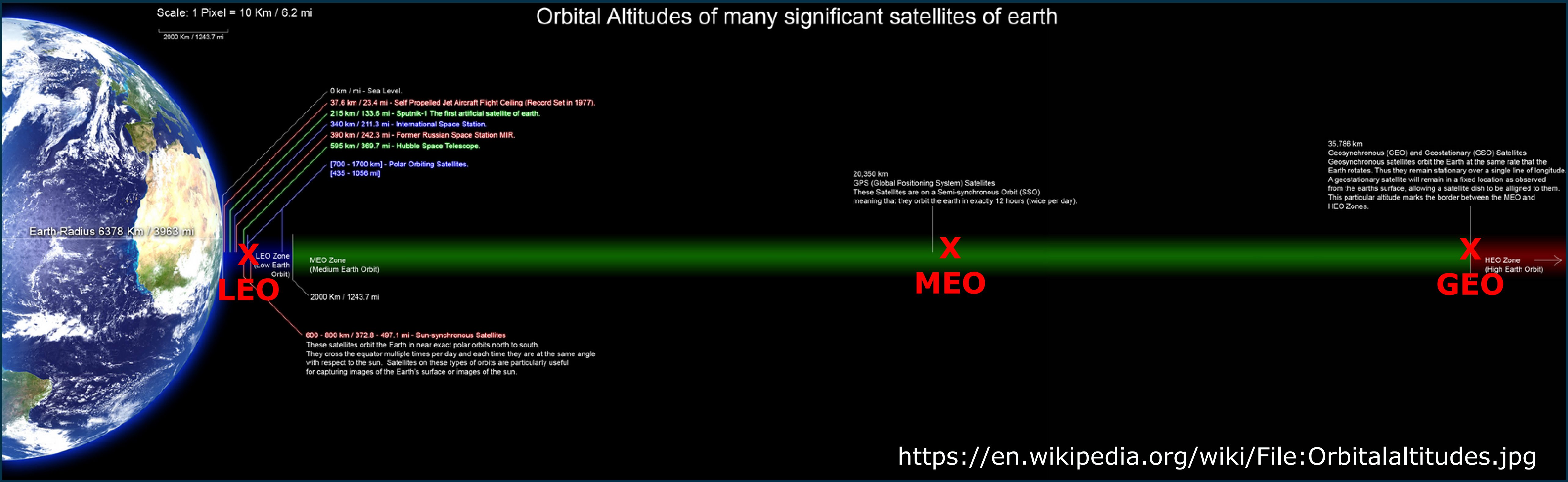
(QKD record: 421 km, PRL 121, 190502 (2018))

Free space:



Quadratic loss, depends on telescope size
(example: 80 dB for 400000 km)
(moon-earth, 10 cm transmitter, 1 m receiver, 1550 nm)

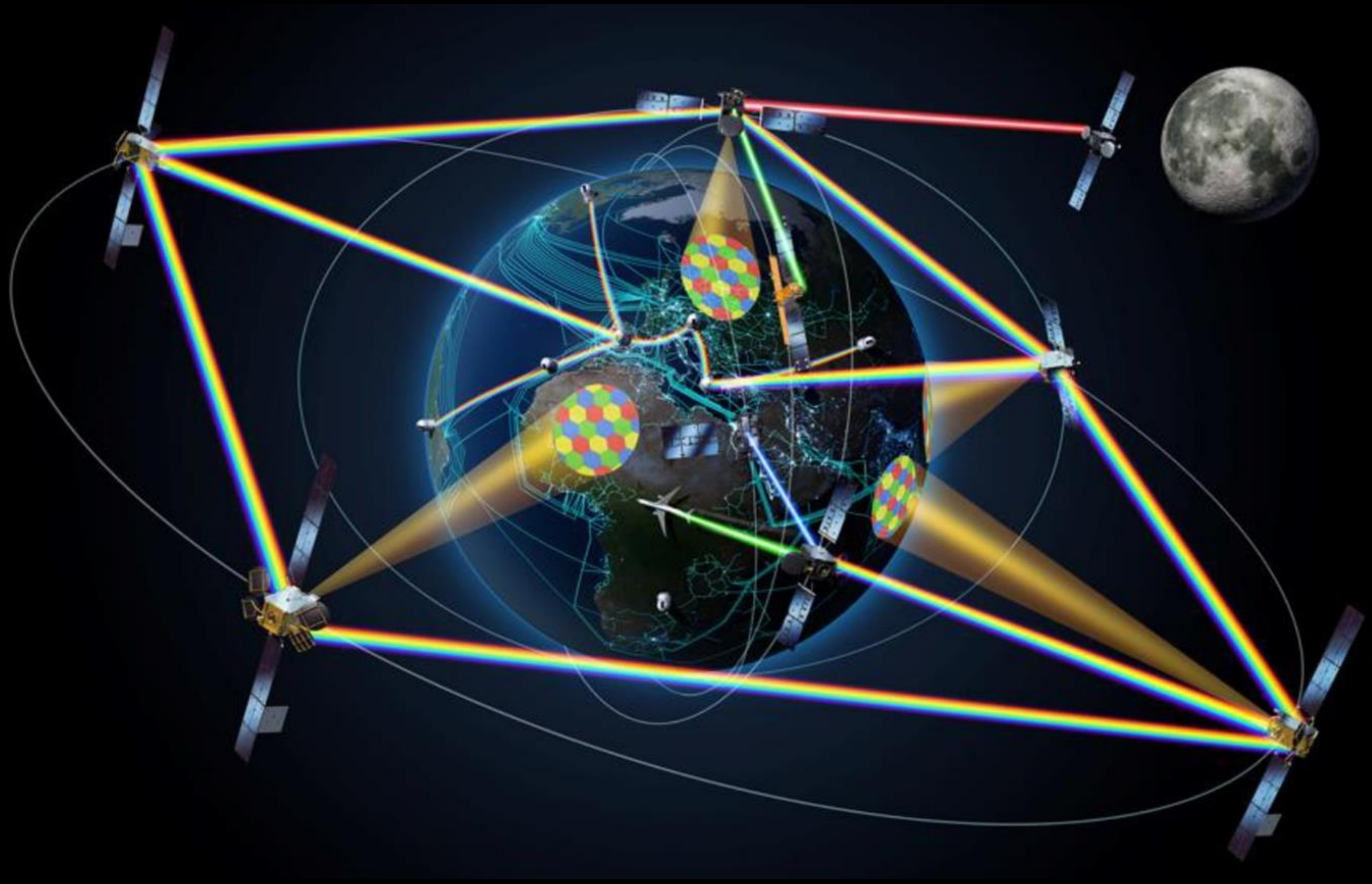
Different orbits for QKD



https://en.wikipedia.org/wiki/File:Orbitalaltitudes.jpg

Pass durations:		
	Low Earth Orbit (LEO)	3-10 min
	Medium Earth Orbit (MEO)	~250 min
	Geostationary Orbit (GEO)	infinite

Laser links in space



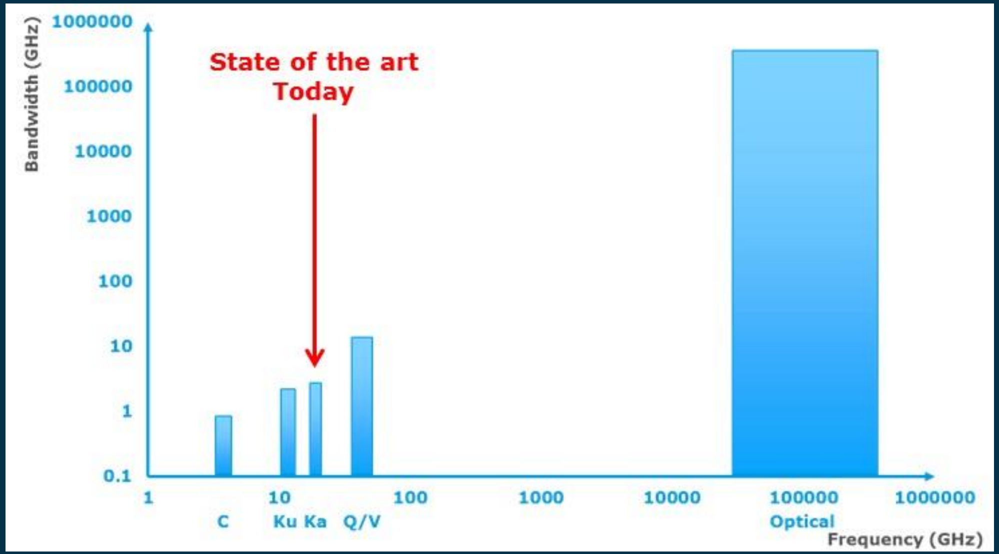
Classical Optical Communication in Space

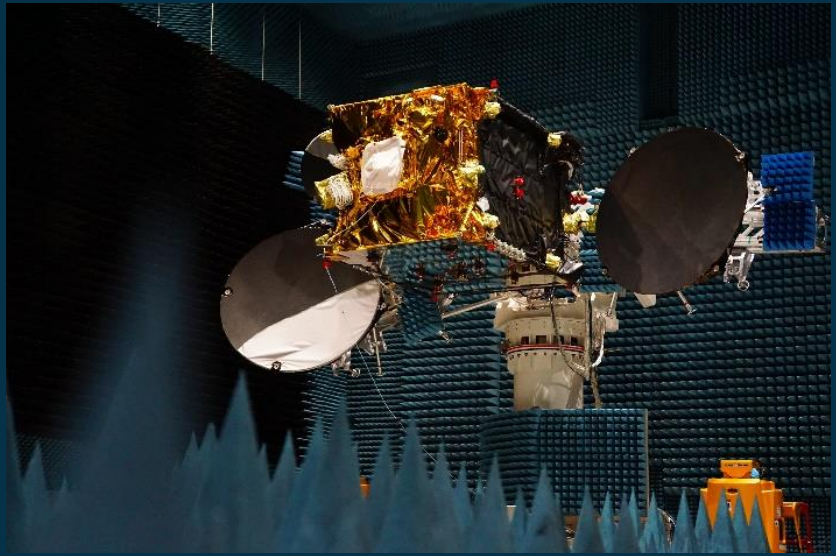
Advantages:

- Bandwidth: The radio frequency spectrum is becoming scarce, while the optical spectrum is not regulated and bandwidth (= data that can be transmitted) is available in abundance.
- Security: Optical communication is safer against jamming, interference and eavesdropping.

Disadvantages:

- Availability: Cloud coverage
- New technology with little heritage (EDRS is the first commercial application).





EDRS-A: 2016
EDRS-C: 2019
Relays for Sentinels 1+2
>25,000 successful links
>99.5 % reliability

Example: EDRS Laser Terminal

Optical Ground Stations

Optical ground stations: examples

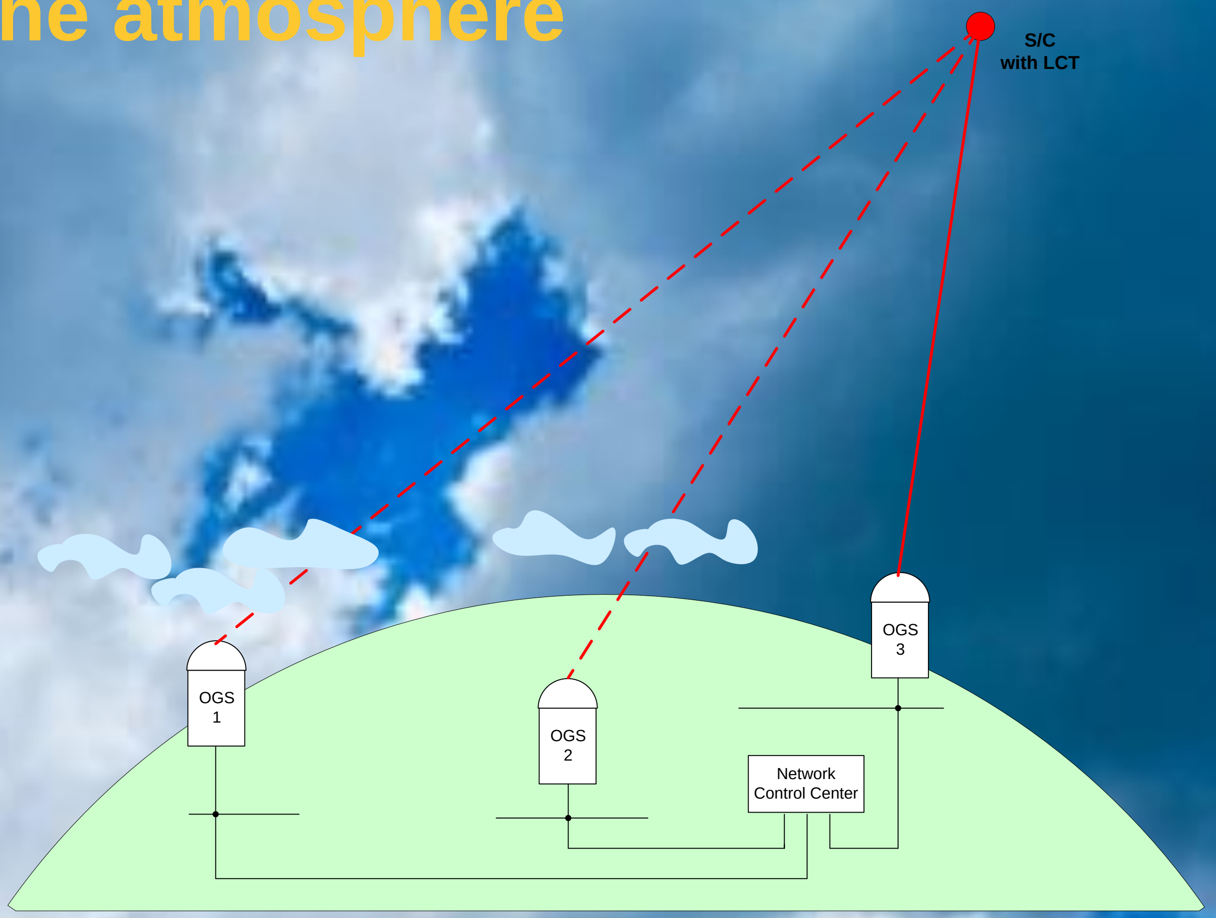
Diameters

ESA: 1 m
DLR: 0.6 m
NASA: 4x 0.4 m
ZHAW: 0.6 m

Optical communication through the atmosphere

Cloud coverage

No	Location	CFLOS
1	Maspalomas	76.6%
2	Marseille	66.6%
3	Granada	67.5%
4	Athens	68.8%
5	Heraklion	56.7%
6	Madrid	63.7%
7	Oslo	32.2%
8	Rome	62.0%
9	Oviedo	43.3%
10	Birmingham	28.2%
11	Bucharest	47.5%
12	Gibraltar	57.9%
	Cumulative	**99.9%**



A cloud free line of sight is needed for the optical link to establish QKD. In case of local cloud coverage another (cloud free) customer can be targeted. During times without links, a sufficiently full buffer needs to provide keys for the service.

Different QKD Space Systems

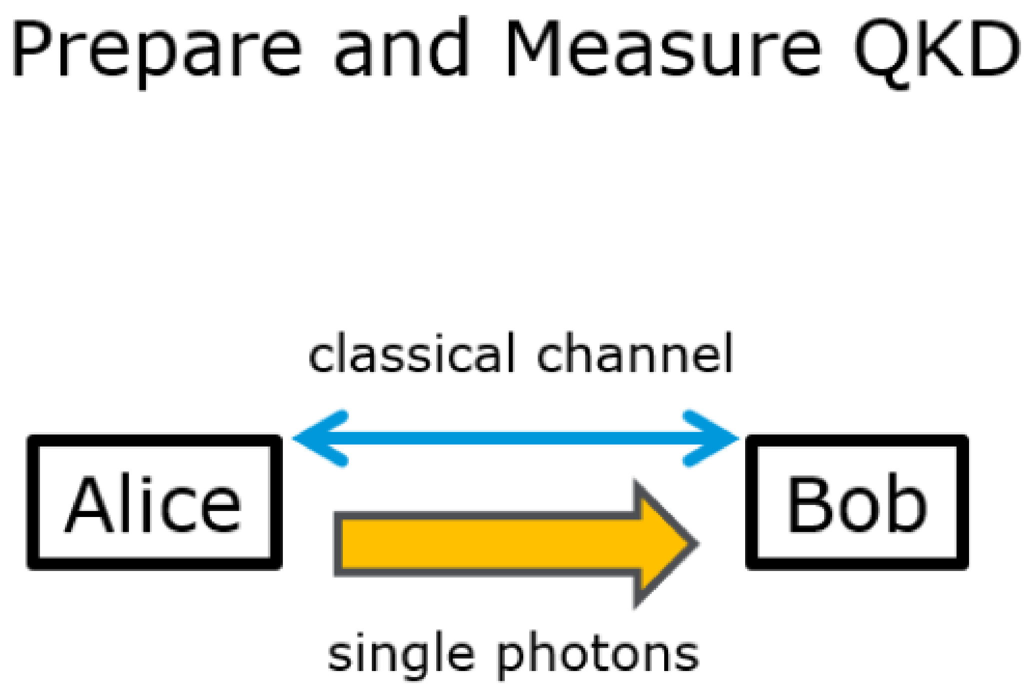
MEO
operational
service
E91
trusted node
1550nm
science
BB84
ISS
hosted payload
LEO
GEO
entanglement
BIG
orbit
cubesat
wavelength
small
technology demonstration
800nm
uplink
prepare&measure
certification
downlink

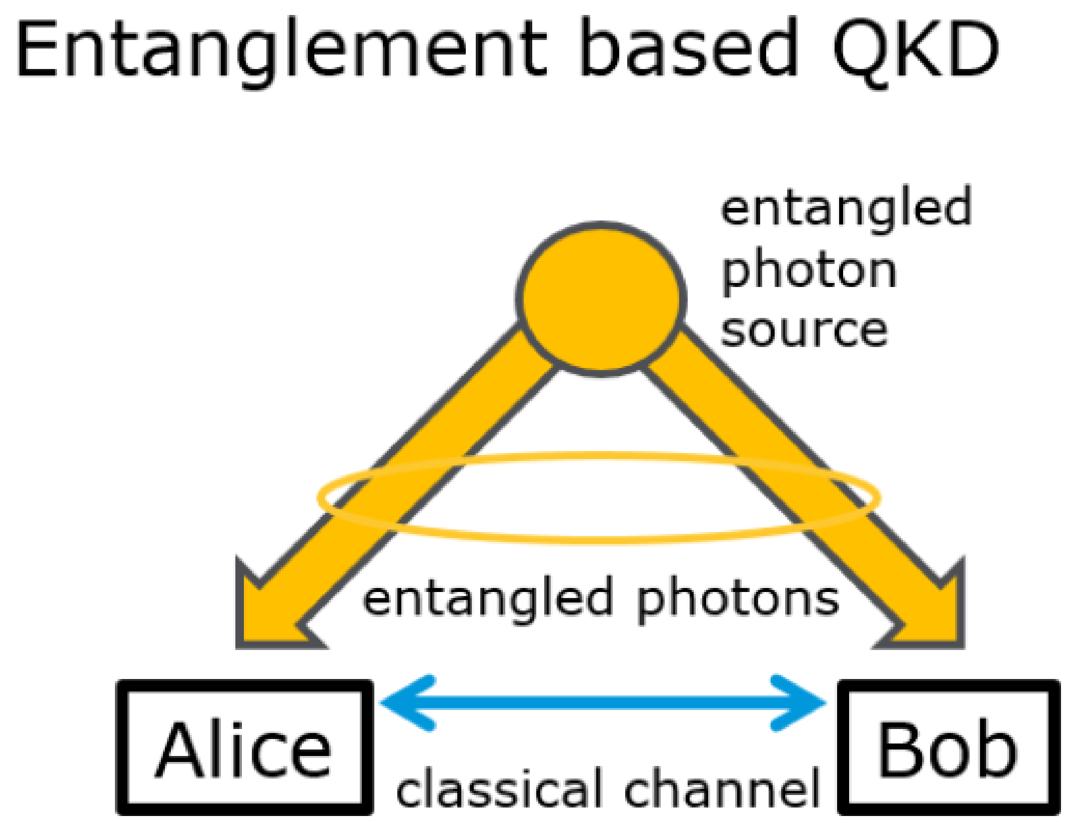
User requirements

Specific user requirements will have to be elaborated for each use case and will have to follow the security requirements of the system to be protected. The following list provides the main points to be considered for the design trade off:

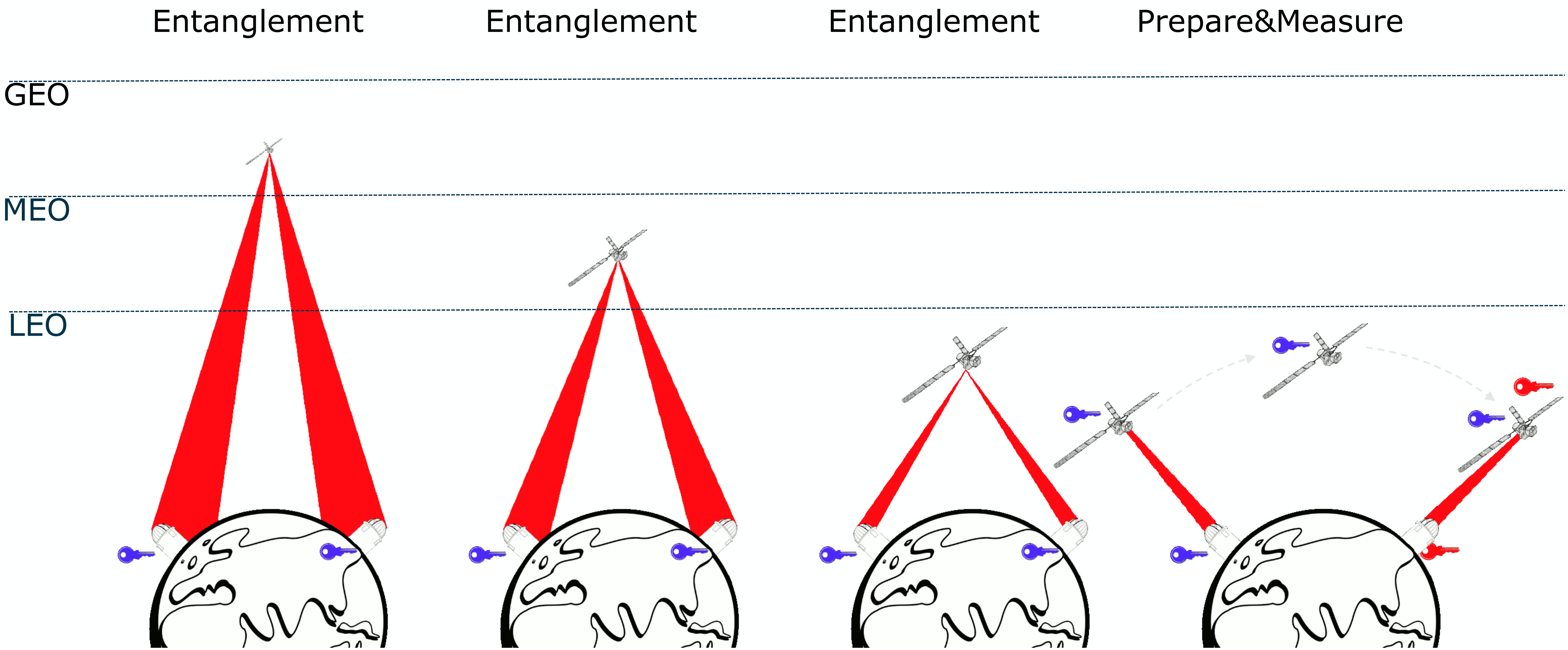
- High key rate (both: bits/s and average bits/year)
- Geographic coverage (Europe, overseas regions, worldwide)
- Security requirements (eg. trusted nodes; certification complexity for space/ground segment)
- Ground terminal number, size and complexity (must be installed close to user locations)
- Suitability for non-QKD services (quantum sensors, timing, quantum computers)
- Overall system cost (space segment, ground segment, operations)

QKD basic methods

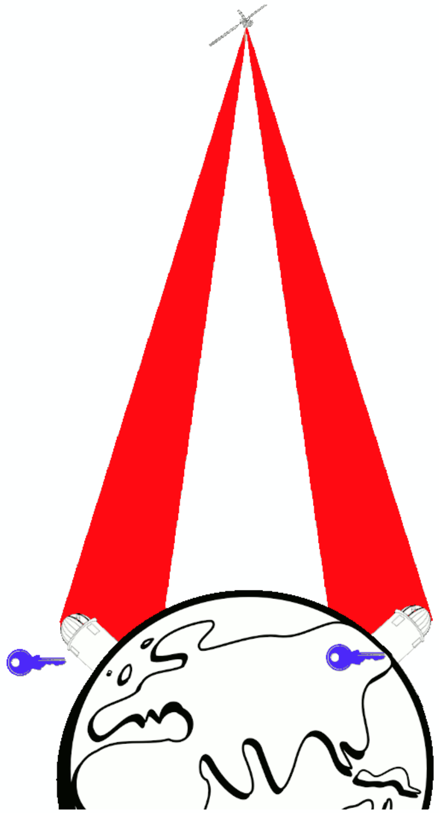




Different QKD space systems



GEO Entanglement QKD



GEO based Entangled QKD Satellites

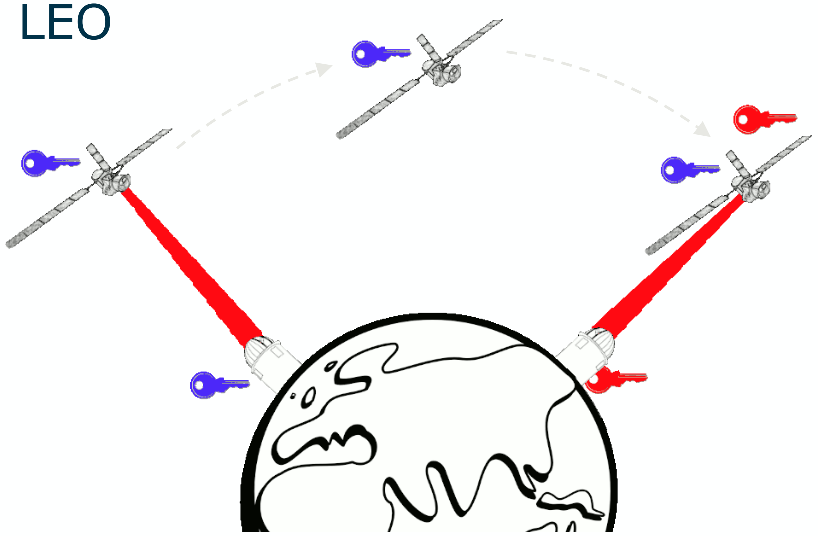
- entanglement based protocol
+ trusted node free concept
+ full EC coverage with single Sat
+ long link times & flexible key delivery service
- double downlinks
- demanding technical implementation
- no global coverage
- large telescopes (>1m / no tracking)
- large ground telescopes (>3m / no tracking)

LEO Prepare&Measure QKD

LEO based Prepare and Measure Satellites

- prepare and measure QKD protocol
- \- trusted node
- \+ global reach
- \+ small telescopes w. tracking (5-10cm)
- \+ small ground telescopes w. tracking (<80cm)
- \- short time overhead

LEO



ESA: QUARTZ (Lux led) and QKDSat (UK led)

ESA and SES-led Consortium to Develop Satellite-based Cybersecurity

Written on 02 May 2018

Consortium will develop a system for generation of encryption keys in space and their secure transmission via laser

Luxembourg, 3 May 2018 – The European Space Agency (ESA) and an SES-led consortium are developing a system that will allow the generation of encryption keys from space, as well as their secure transmission to users on Earth via laser.

QUARTZ signing (Magali Vaissiere, ESA Director of Telecommunications and Integrated Applications; Nicole Robinson, SVP Global Government at SES Networks), picture credit: ESA/Grimault

D/TIA partners with UK-based ArQit to develop first Quantum Encryption Satellite

On 31st August 2018, the European Space Agency via its Directorate of Telecommunication and Integrated Applications signed a contract with UK based start-up Arqit Ltd, to develop the first European Quantum Key Distribution Satellite (QKDSat).

QKDSat is a highly innovative project, the first of its kind, which will validate Quantum Key Distribution via satellite technologies. The contract also covers the development of service delivery through a pre-operational deployment, prior to an envisaged full global commercial service via multiple satellites in the near future. The installation of further Ground Optical Communications Terminals to support the projected market needs is also foreseen in the agreement, which was signed at ESA's European Space Research and Technology Center, Noordwijk, the Netherlands.

D Bestwick, ArQit CEO and A Cotellessa, Senior Satellite Programmes Manager exchange contracts at ESTEC on 31/8/2018 /Photo Credit: Genevieve Porter ESA

The industrial consortium led by ArQit is composed of European leaders in their field, such as QinetiQ of Belgium, BT of United Kingdom and Fraunhoffer and Mynaric of Germany.

EC/ESA: EuroQCI

2019: European Quantum Communication Infrastructure initiative

Declaration of Cooperation signed by 20 Member States (by end of 2019)

Purpose

The participating Member States:

1. Plan to work together to establish a cooperation framework – EuroQCI – for exploring within the next 12 months, the possibility of developing and deploying in the Union, within the next 10 years, a certified secure end-to-end quantum communication infrastructure (QCI) composed of space-based and terrestrial-based solutions, enabling information and data to be transmitted and stored ultra-securely and capable of linking critical public communication assets all over the Union.

ESA ScyLight and SAGA

Two programmes include QKD:

ScyLight started 2016

As dedicated programme for optical communication, including:

- Quantum cryptography technologies
- Initial services demonstration

SAGA started 2019

(Security And cryptoGrAphic mission)

- Developing the space segment of the EuroQCI
- Satellites, ground stations, operations and technology

Thank you for your attention!