TÉCNICO LISBOA

PTQCI

Space Mission Design for Quantum Communications

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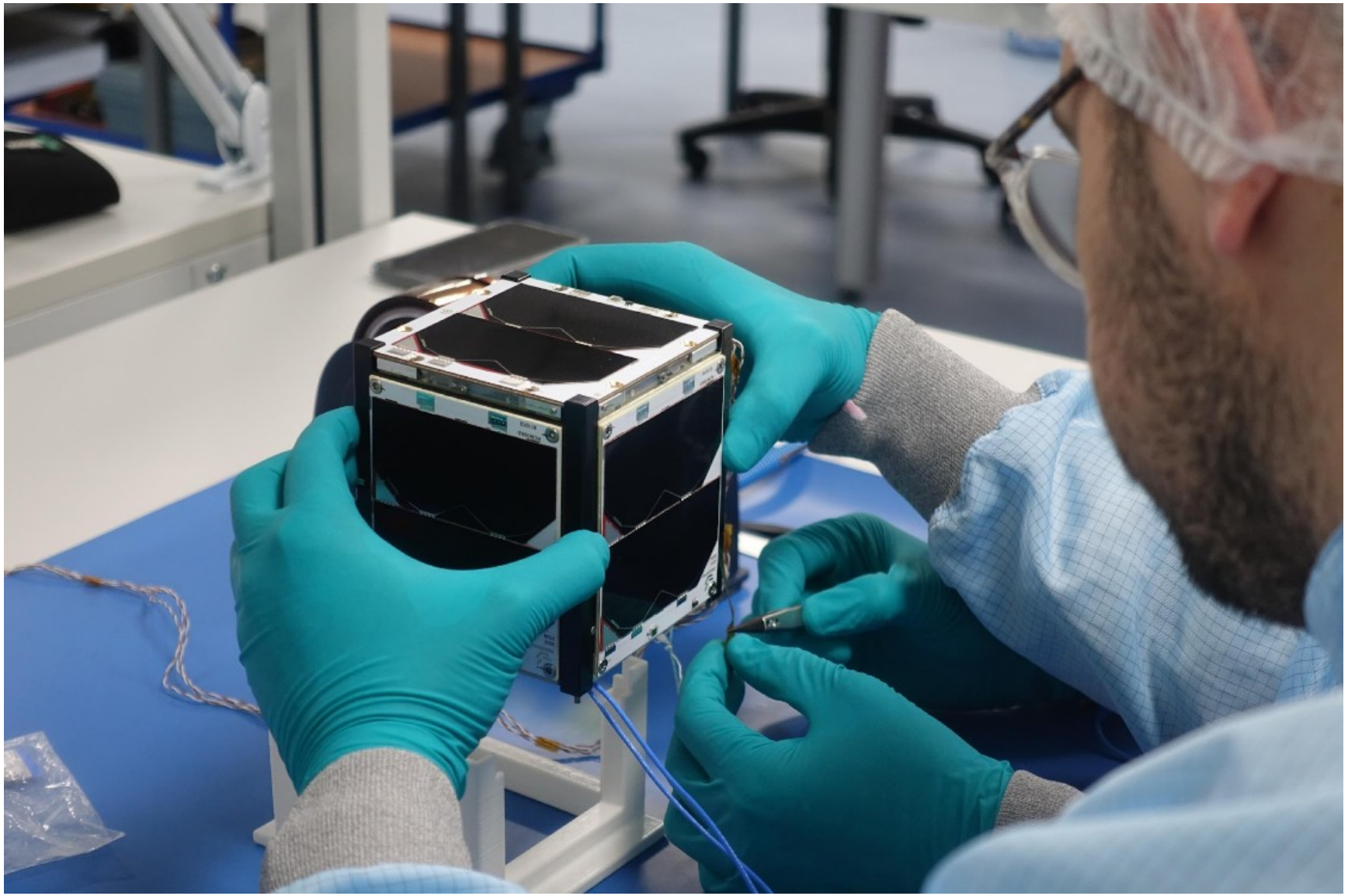
About myself

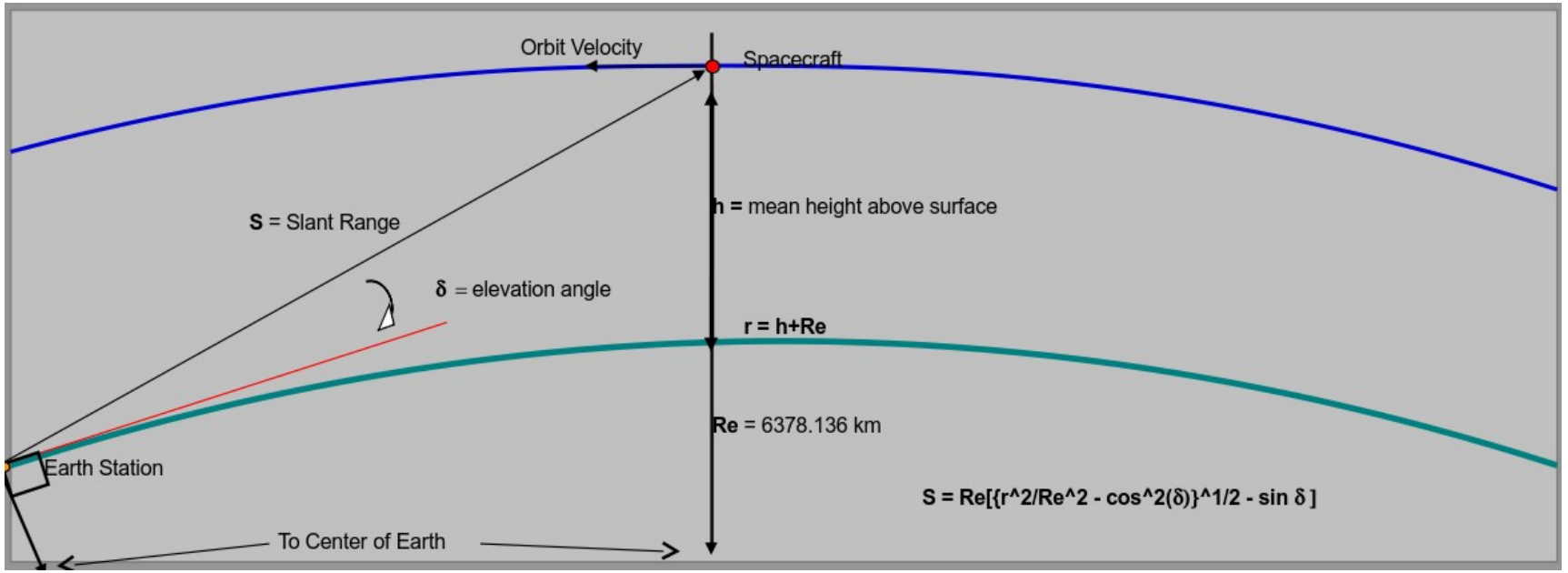
- MSc Aerospace Engineering (IST, 2017)
- PhD Engineering Design (IST, 2024)
- Researcher at IST Nanosatlab / ISR
- Lead systems engineer for ISTSat-1

ISTSat-1



Why Space-based QKD?

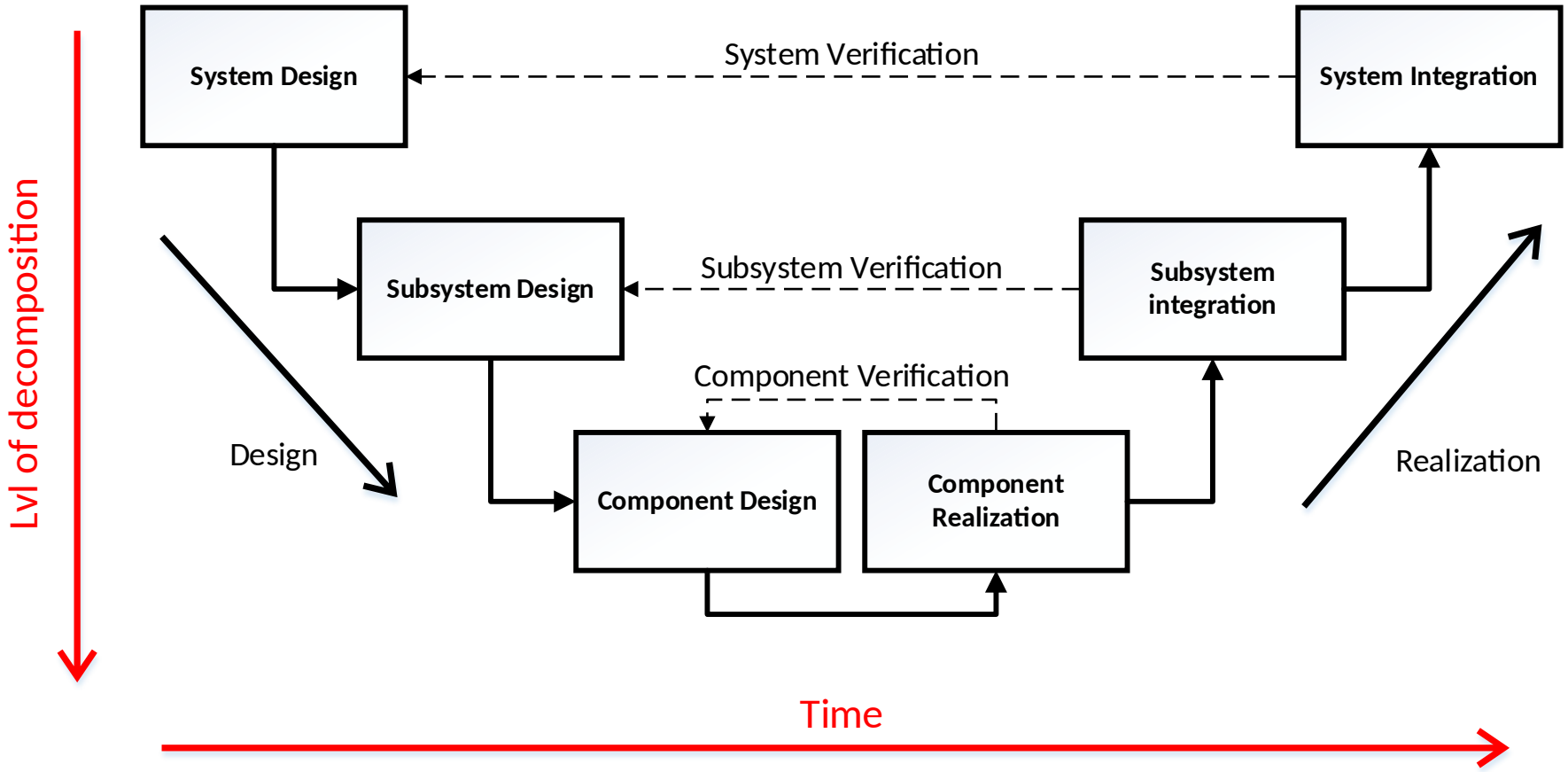
- Physical transmission limit of around 400 km through Op. Fiber
- Limited or no possibility of using repeaters/amplifiers on ground
- Satellite in a 400 km circular orbit has a > 2000 km radius footprint



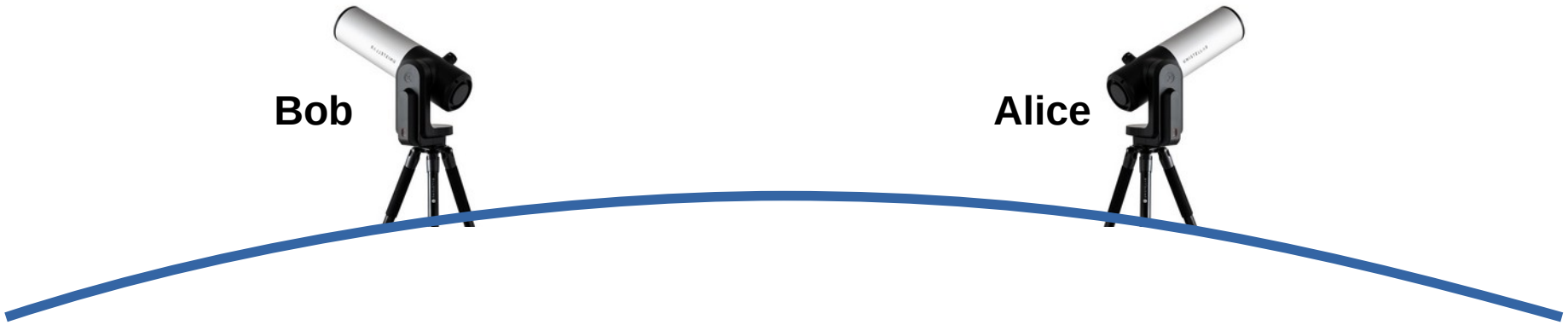
Mission Design - Phases

1) Define Concept of Operations
2) Define Spacecraft / Ground Station Requirements
3) Define Platform / Payload Architecture
4) Design and development
5) Subsystem testing
6) System testing
7) Launch and Early Operations
8) Nominal Operations

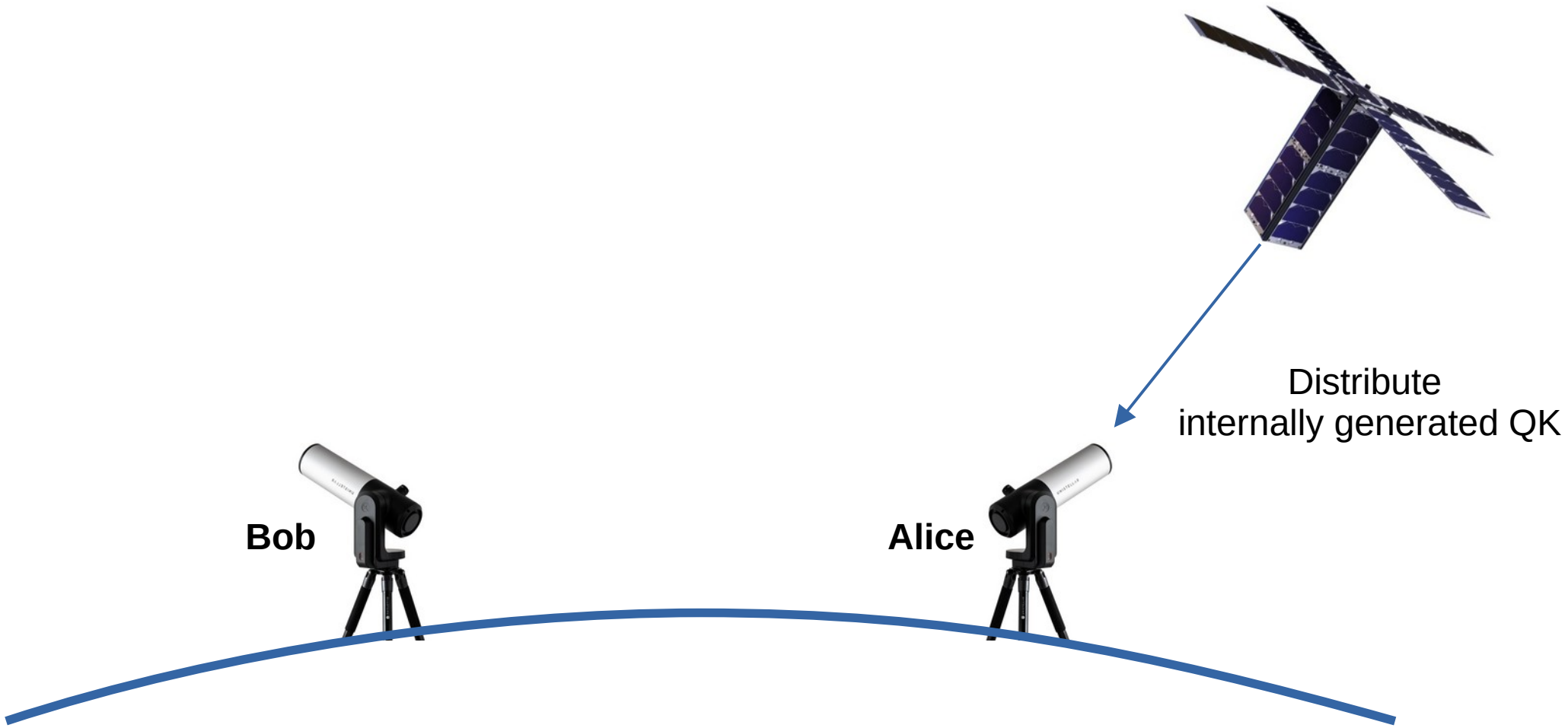
Mission Design - Phases



Concept of Operations for QKD



Concept of Operations for QKD



Concept of Operations for QKD

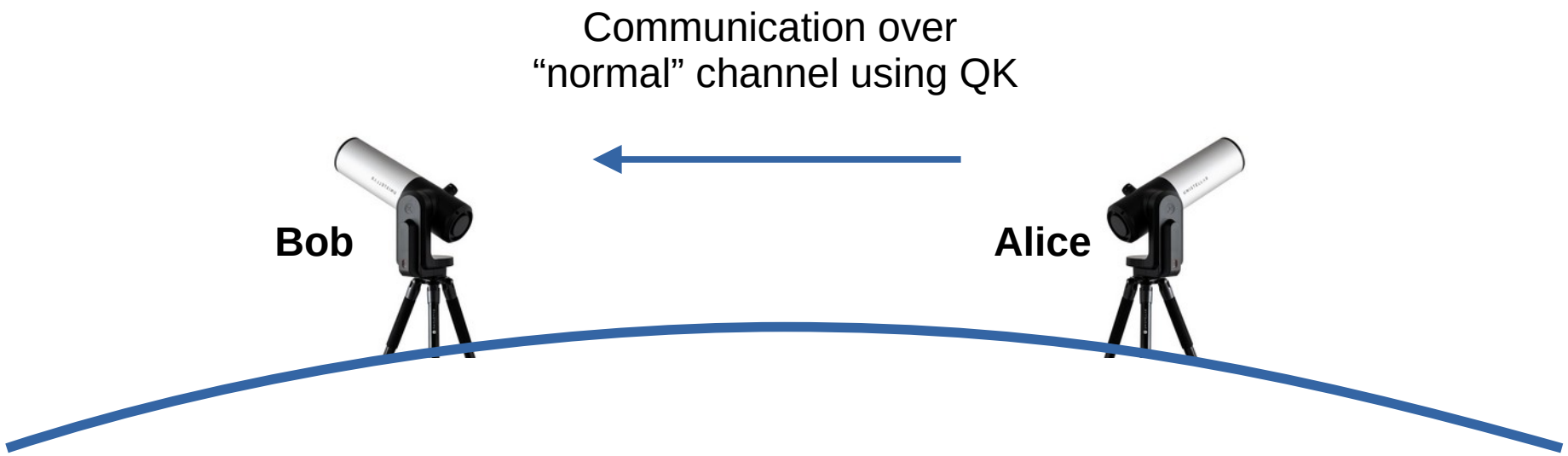
Time (a few minutes)

Distribute
internally generated QK

Bob

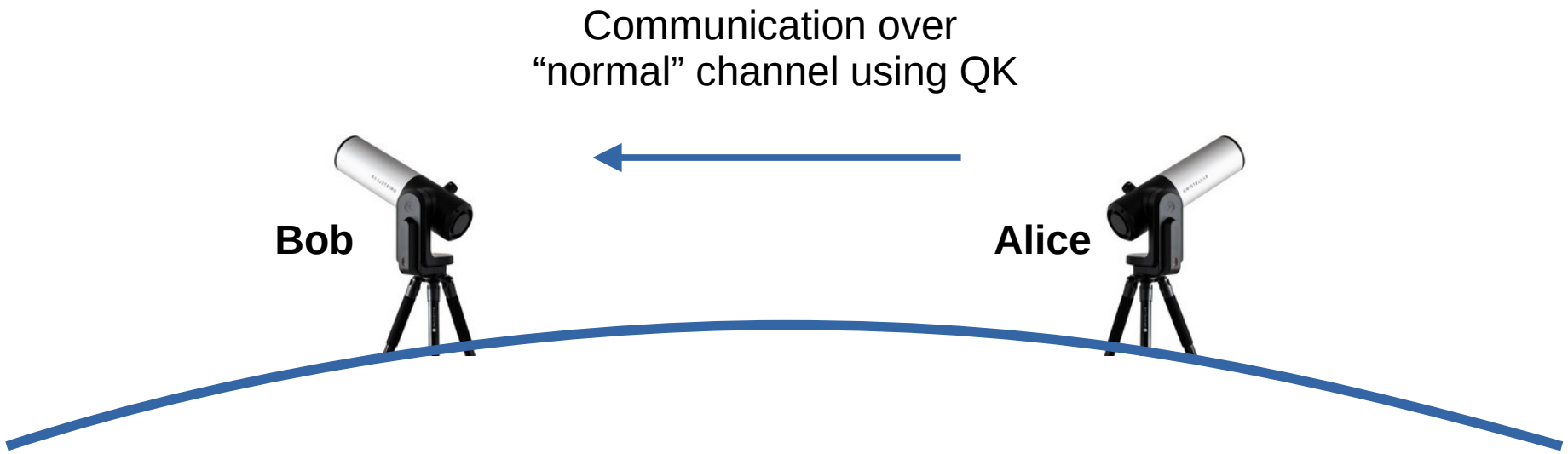
Alice

Concept of Operations for QKD



Concept of Operations for QKD

Note: current concepts usually employ spacecraft as Qbit transmitters, not receivers!



Key Requirement: Quantum Data Rate

Depends on:

- **Qbit generation rate**
  - processing power
  - available memory
- **Qbit transmission efficiency**
  - Beam divergence
  - Pointing accuracy
  - Signal power

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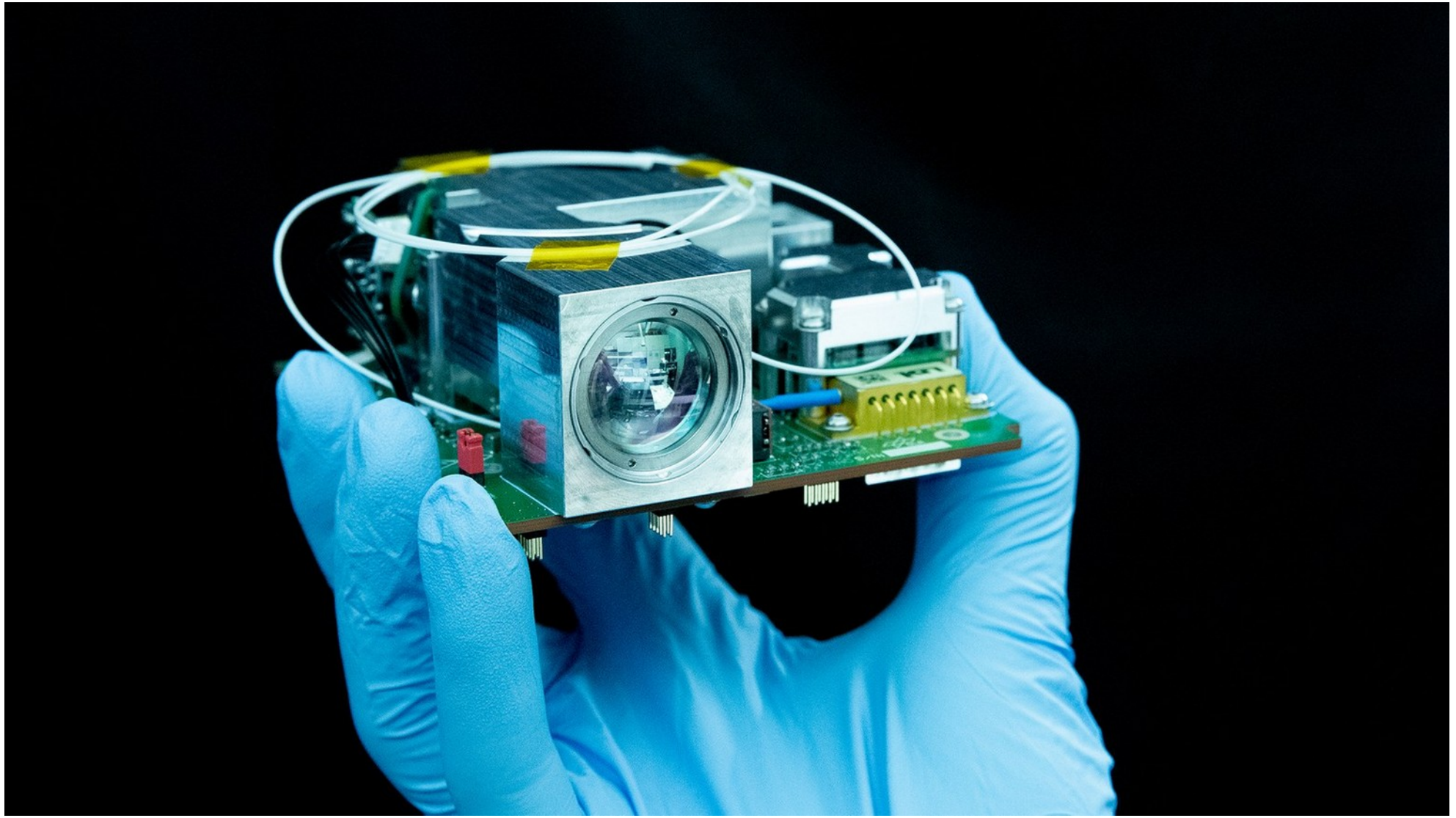
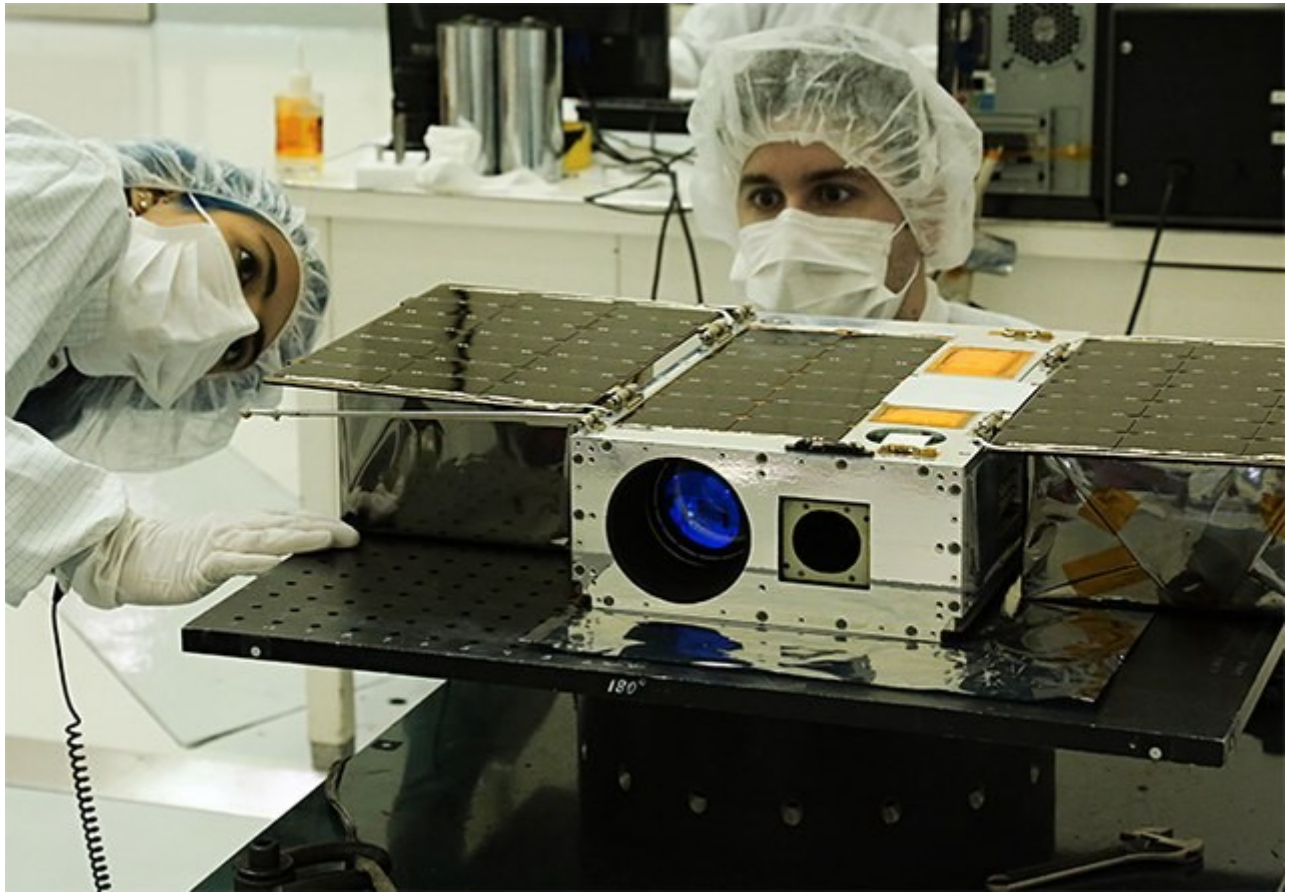
Not easy to perform these trade-offs in a small CubeSat!

The QKD Payload



The QKD Payload



The QKD Payload

- Telescope for minimizing beam divergence
- Fast steering mirrors for μrad accuracy
- 4 LED for quantum source (depending on protocol)
- Optical assembly for quantum/beacon beam separation and guidance

Key platform budgets

Data & Memory Budget

- How long are the randomly generated keys?
- How much GNSS timing data do we need to keep?
- How much telemetry data do we generate and store?

Key platform budgets

Link Budget

- What is the required bit rate to ensure usefulness?
- How much free-path loss?
- How much atmospheric loss?
- How much antenna/optical gain?
- How much transmission power?
- (compute same for “regular” communications channel)

Key platform budgets

Power & Energy Budget

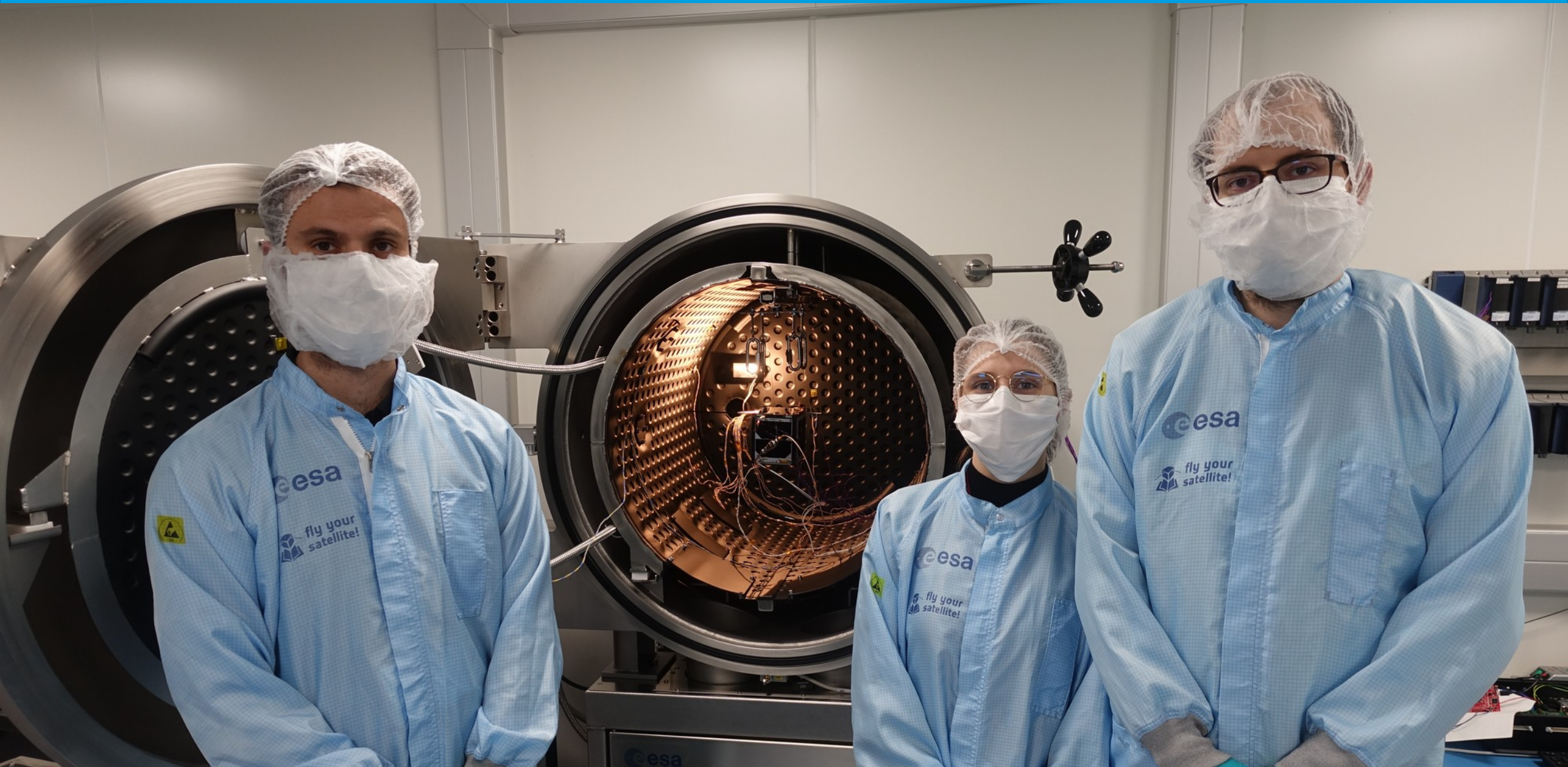
- What is the required power for the platform and payload?
- How much power can the solar panels generate?
- How much energy can be stored in the spacecraft battery?
- What is the system duty cycle for mission operation?
- What is the performance degradation of solar panels and battery?

Other concerns

- **Space Debris Mitigation**
  - Mission duration
  - Probability of collision
  - Probability of complete system disintegration on reentry

Other concerns: Vibration Testing

Other concerns: Thermal Vacuum Cycling



Other concerns: Electromagnetic Compatibility

Thank you!

Join us @ IST NanosatLab for
Hands-on space mission design!

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www.istsat.one