NASA: We are SCaN - YouTube

Quantum Technology Development at NASA

Presentation for the Quantum / Optical Meeting
Canberra, Australia

July 21-22, 2022

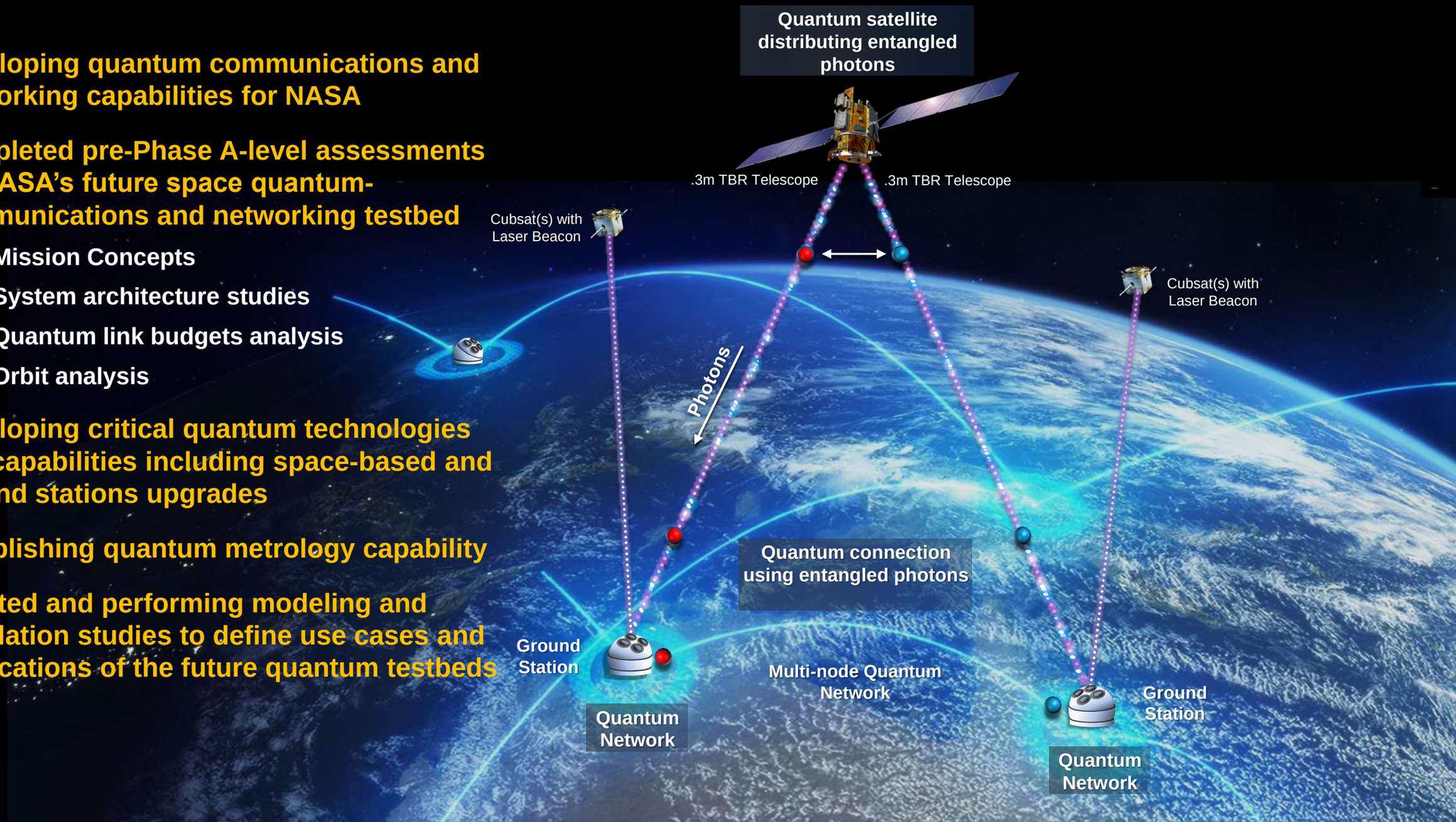
Dr. Angela Hodge, Program Executive
Quantum-communications Science & Technology (QS&T)

Agenda

- **Quantum Communications NASA/SCaN**
- **Technology Development: Detectors, Ground Stations, & Testbeds**
- **Metrology**
- **Modeling, Simulations, & Use Cases**
- **Laser Communications Relay Demonstration (LCRD)**

Quantum Communications at NASA SCaN

- **Developing quantum communications and networking capabilities for NASA**
- **Completed pre-Phase A-level assessments for NASA's future space quantum-communications and networking testbed**
  - Mission Concepts
  - System architecture studies
  - Quantum link budgets analysis
  - Orbit analysis
- **Developing critical quantum technologies and capabilities including space-based and ground stations upgrades**
- **Establishing quantum metrology capability**
- **Initiated and performing modeling and simulation studies to define use cases and applications of the future quantum testbeds**



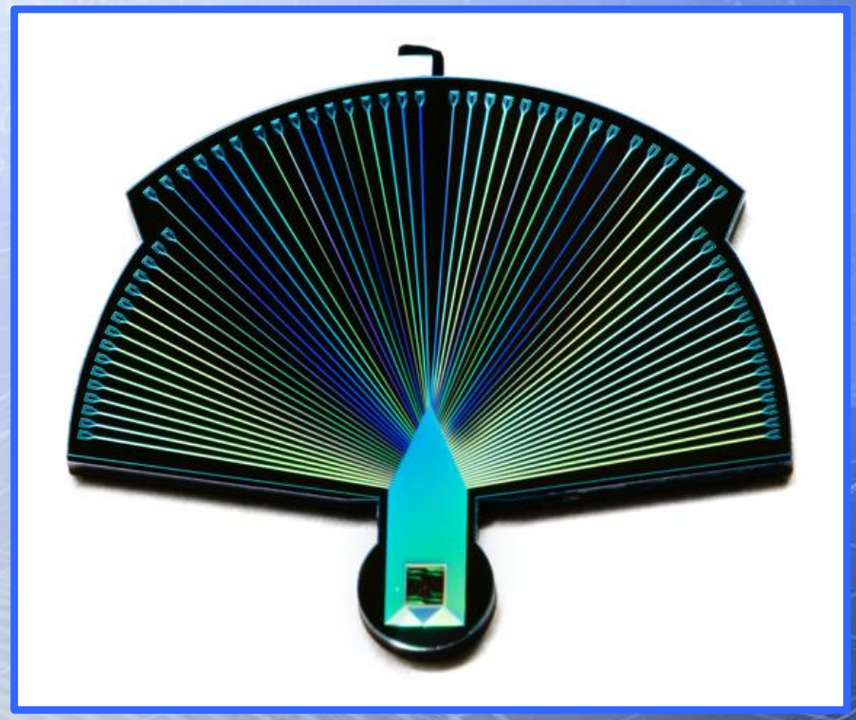
SCaN Funded Quantum Testbeds

- Developed and lab tested a high-rate, spectrally pure entanglement source. Prototype is on a future path to flight
- Validated entanglement swap and pump-forward precision synchronization
- Successfully demonstrated high-efficiency, high-count rate single photon detector array
- Developing entangled photon source flight-grade packaging design concept

NASA/SCaN – Development of SNSPDs @ NASA/JPL

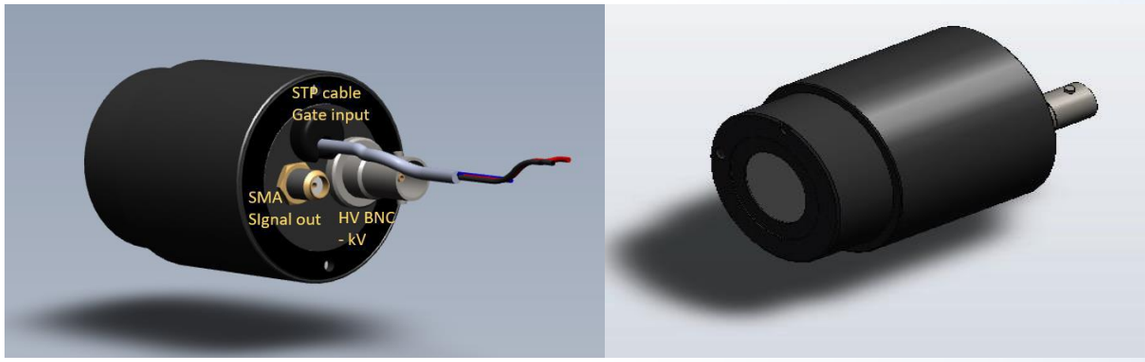
Task Objectives:

- Develop high-rate, low jitter SNSPDs appropriate for M2.0 Ground System
- Perform exploratory research on applicability of SNSPDs for flight applications
- Implement an instrument with 4x 32-channel detectors capable of performing Bell State Measurements on 10 GHz clock at 4 Gcps count rate, for use at OCTL in future quantum communication demonstrations



Warm Detectors for Quantum Apparatus in Space

NASA/GSFC evaluating Microchannel Plate Photomultiplier Tube (MCP-PMT), a photon counting detector:



1. **No Cryo-cooling needed**
2. **Low dark count rate (1.5cps at -60C)**
3. **Radiation harden (200KRad)**
4. **Low time jitter (30ps)**
5. **High linear count rate (>100MHz)**
6. **Short pulse resolution time)1ns)**

Proposed Photon Counting Detector Specification

Parameter	Value	condition
Count rate (photoelectron)	100MCPS	20%*500MCPS (75% drop from linear count, detector count at 75MCPS?)
Quantum Efficiency	20%	800nm
Jitter (TTS)	30ps 200ps	FWHM (log scale plot to show 1% width is needed) 99% width
Pulse Pair resolution	<1ns	Burst rate (bunched photon resolution)
Lifetime	>5 years	20C/cm2 total dynode charge, actual life is calculated with the detector loading, gain, and total charges
Dark count (CPS_	1600 (1.5)	Cooled to -10C (-60C, projected)
Radiation	200kRad	Total dose

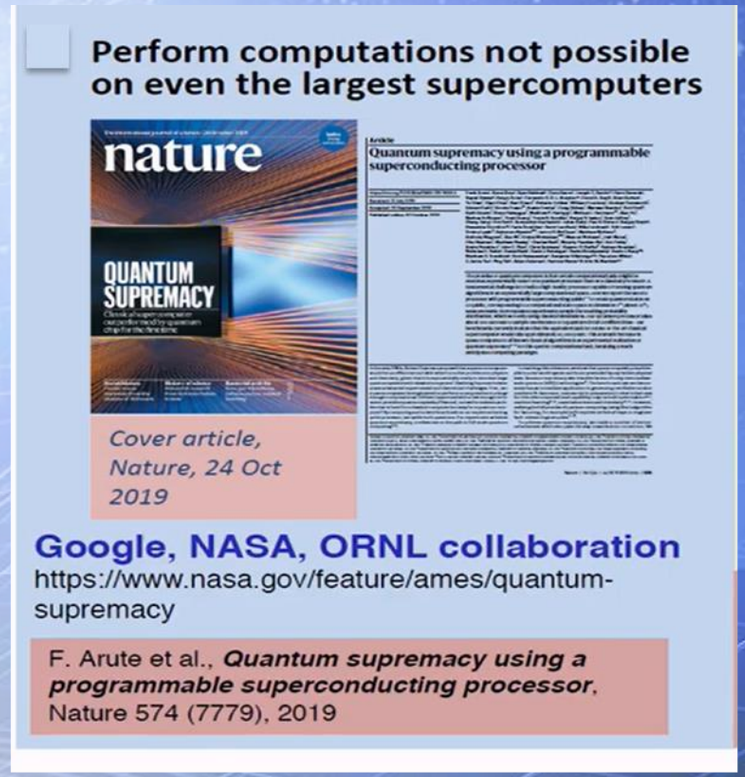
* multipixel devices are available for higher burst rate and higher average rate configuration

** detector bias can be gated for extended operational life with low duty cycle operations

Modeling, Simulation & Use Cases

NASA Ames Research Center (ARC) – Quantum Computing

- Developing use cases based on NASA SCaN's testbed architecture, particularly photonic based approaches to quantum computing
- Supports distributed quantum computing over a quantum network
- Leverage and improve upon ARC's state-of-the-art simulation software HybridQ (A Hybrid Quantum Simulator for Large Scale Simulations)
  - ✓ Measurement-based quantum computing models
  - ✓ Photonic noise models

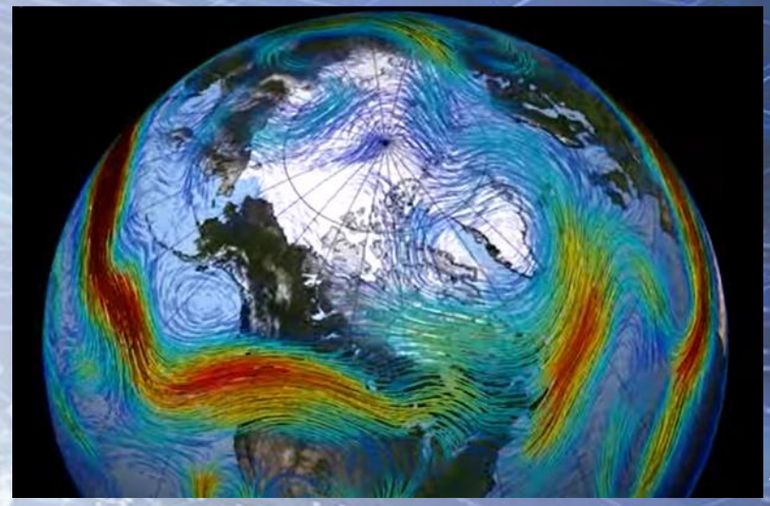


NASA Glenn Research Center (GRC)

Computer simulation tool to aide in planning quantum missions

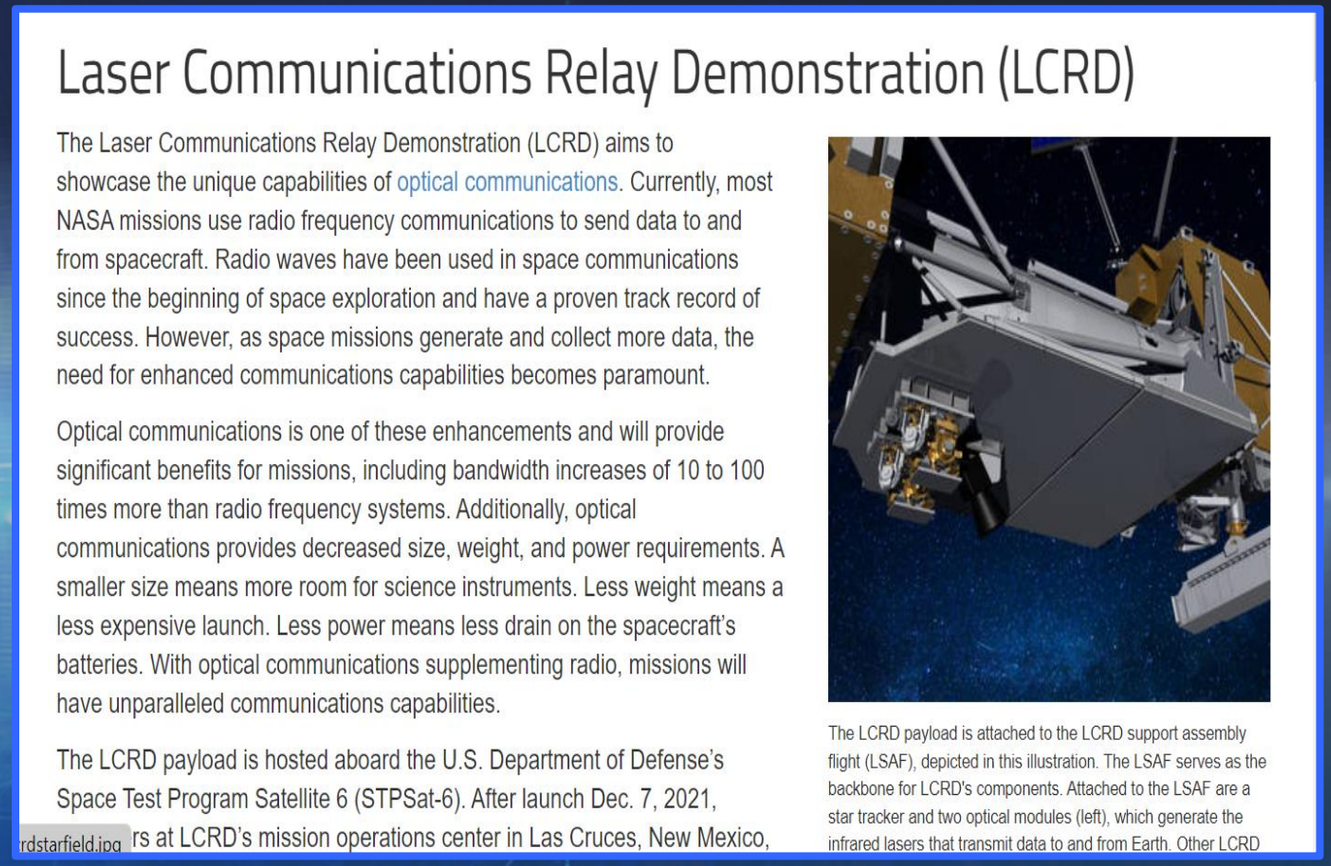
Weather model used for performance prediction can support link budget calculations as well as mission planning

Estimates the efficiency of entanglement swaps for different weather conditions.



Laser Communications Relay Demonstration (LCRD)

- LCRD showcases the unique capabilities of optical communications
- Provides benefits for missions, including bandwidth increases of 10 to 100 times more than radio frequency systems.
- Compared to RF, Optical Comms offer decreased size, weight, and power requirements.
- Optical communications will supplement radio frequency (RF), giving missions unparalleled communications capabilities.



Laser Communications Relay Demonstration (LCRD)

The Laser Communications Relay Demonstration (LCRD) aims to showcase the unique capabilities of optical communications. Currently, most NASA missions use radio frequency communications to send data to and from spacecraft. Radio waves have been used in space communications since the beginning of space exploration and have a proven track record of success. However, as space missions generate and collect more data, the need for enhanced communications capabilities becomes paramount.

Optical communications is one of these enhancements and will provide significant benefits for missions, including bandwidth increases of 10 to 100 times more than radio frequency systems. Additionally, optical communications provides decreased size, weight, and power requirements. A smaller size means more room for science instruments. Less weight means a less expensive launch. Less power means less drain on the spacecraft's batteries. With optical communications supplementing radio, missions will have unparalleled communications capabilities.

The LCRD payload is hosted aboard the U.S. Department of Defense's Space Test Program Satellite 6 (STPSat-6). After launch Dec. 7, 2021,

rdstarfield.jpg rs at LCRD's mission operations center in Las Cruces, New Mexico,

The LCRD payload is attached to the LCRD support assembly flight (LSAF), depicted in this illustration. The LSAF serves as the backbone for LCRD's components. Attached to the LSAF are a star tracker and two optical modules (left), which generate the infrared lasers that transmit data to and from Earth. Other LCRD

Laser Communications Relay Demonstration (LCRD) Overview - YouTube

Conclusions

NASA has more than a decade of experience in technology development for both optical and quantum communications

- **Experiments and performance assessments are implemented via:**
  - **Modeling & Simulation**
  - **Testbeds and laboratories on the ground and in space**
- **Projects include**
  - **Quantum Physics in Microgravity**
  - **Communications and Networks**
  - **Computing and Algorithms**
  - **Development of Use Cases**
  - **Metrology**