

Luxembourgish activities on B5G/6G-NTN

Dr. Jorge Querol
Research Scientist at SIGCOM Research Group
Head of the 6GSPACE Lab



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Outline

□ Introduction

□ 5G NTN Demonstrators

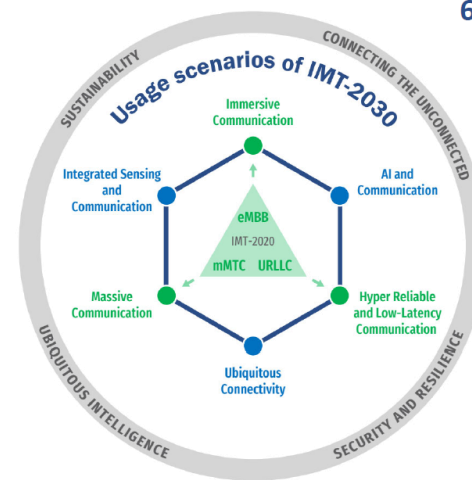
- In-lab
- Over-the-air
- In-orbit

□ NTN for 6G

- Ubiquitous Connectivity
- AI-enhanced communications
- Integrated Sensing and Communications

□ Quantum Communications

Usage scenarios



So called "Wheel diagram"

<https://www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/imt-2030/Pages/default.aspx>

6 Usage scenarios

Extension from IMT-2020 (5G)

- eMBB → Immersive Communication
- mMTC → Massive Communication
- URLLC → HURLLC (Hyper Reliable & Low-Latency Communication)

New

- Ubiquitous Connectivity
- AI and Communication
- Integrated Sensing and Communication

4 Overarching aspects:

act as design principles commonly applicable to all usage scenarios

Sustainability, Connecting the unconnected,
Ubiquitous intelligence, Security/resilience

Introduction

Coordinates: Luxembourg → University of Luxembourg → SnT → SIGCOM



450+
Workforce



65+
Nationalities



60+
Partners



70%
External project
funding

SIGCOM Research Group



Track Record (2024)

- 15 years in operation
- 90+ Researchers
- 60+ R&D projects
- 60M€+ Funding
- 6 Industrial Partnerships



Research Areas

- 6G Communication Systems
- Non-Terrestrial Networks (SatCom-UAVs)
- Massive Antenna Arrays
- Quantum Communication Infrastructure



NOKIA
Bell Labs

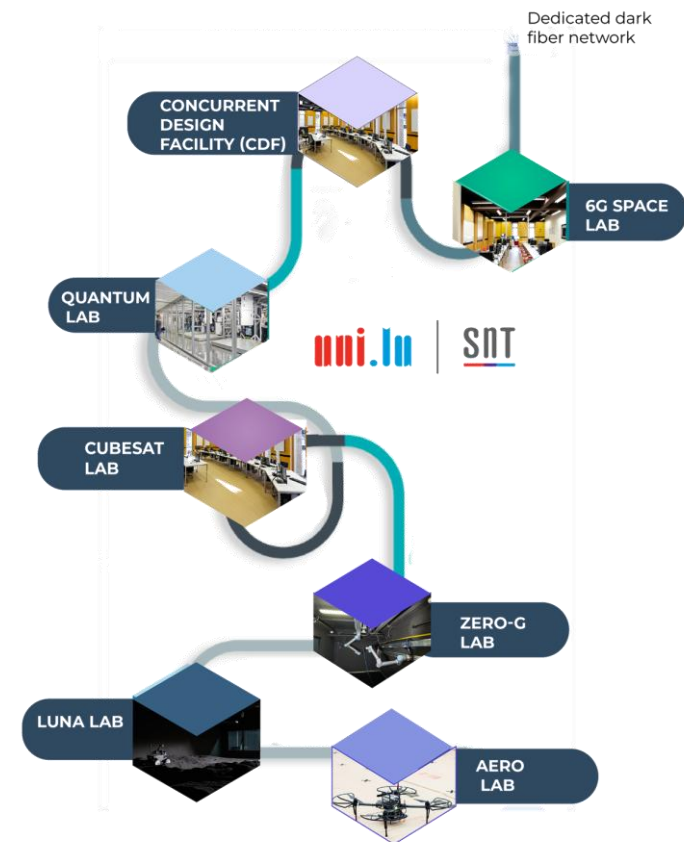


Industry Partners

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SnT Space Labs



5G NTN Demonstrators → In-lab



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6GSPACE Lab funded by Luxembourg Space Agency and Ministry of Economy (2020–2022)



Motivation

- Convergence of terrestrial and satellite communications in 5G-NTN requires evolved testing capabilities
- Study of new standards and applications for Lunar communications



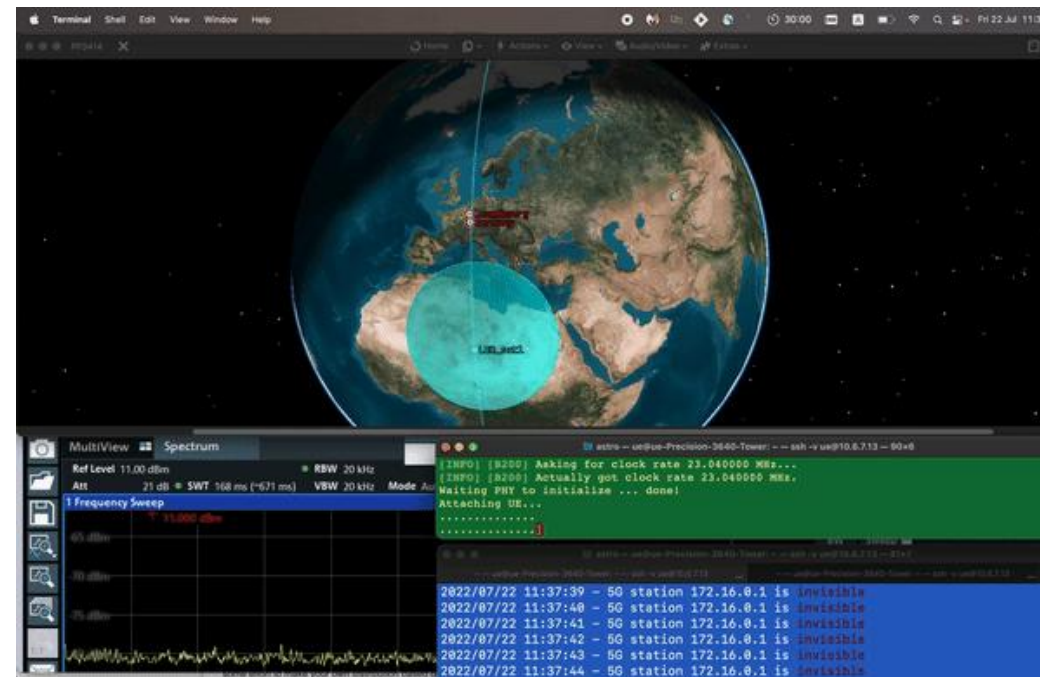
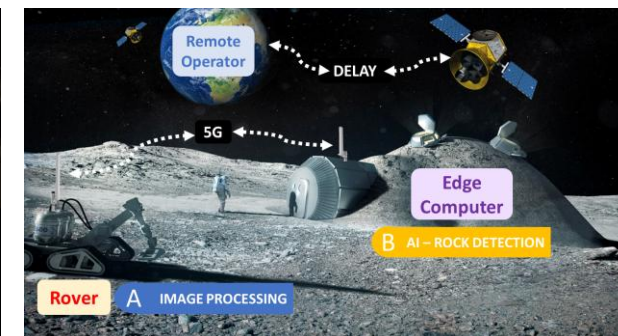
Expertise and Labs

- Long-standing satellite communications expertise and previous communications laboratory
- Develop a worldwide unique facility to teach and research on next-generation of Space applications



Outcomes

- Earth-orbiting 5G Non-Terrestrial Networks Communications Test-Bed
- Lunar 5G Edge Computing Test-Bed for Rover Teleoperation



5G NTN Demonstrators → In-lab

Pre5G NR: Precoding for 5G-NTN funded by FNR (National Funding Agency) Bridges program (2024–2026)



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Motivation

- 3GPP precoding not available in NGSO
- Necessary to joint design of NR precoding and dynamic spectrum in NGSO contexts



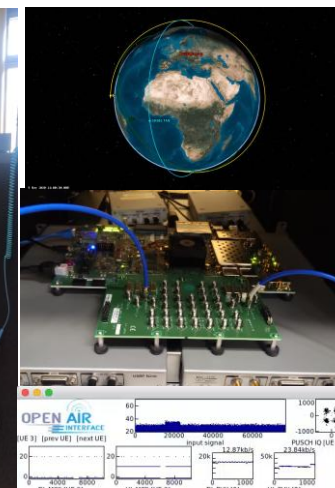
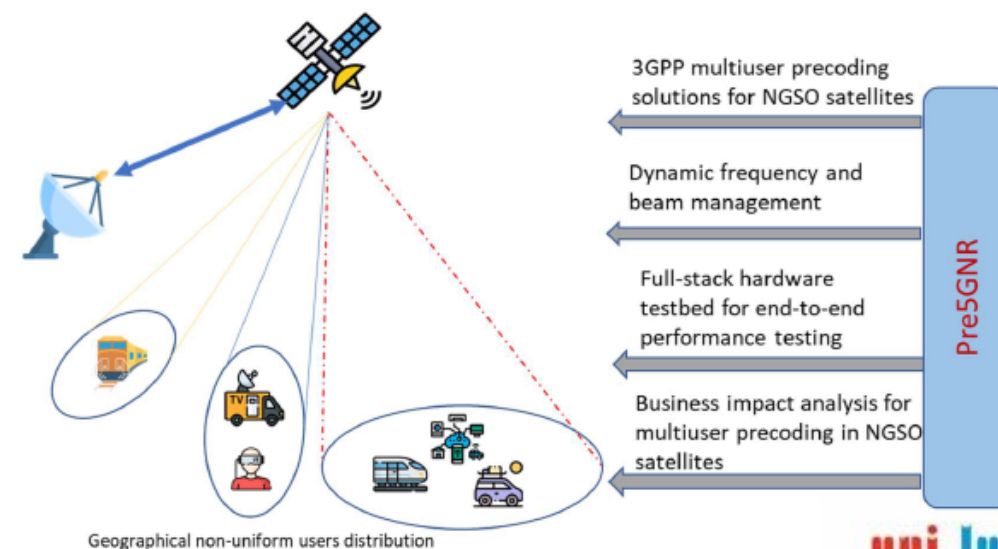
Expertise and Labs

- 3GPP NR precoding design demonstration for TN
- Codebook and non-codebook precoding
- Dynamic spectrum and beam management



Outcomes

- 3GPP NR precoding and beam management algorithms for 5G NTN
- Complete hardware testbed for experimentally evaluate the performance of 3GPP NR multiuser



5G NTN Demonstrators → Over-the-air



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MICRO5G: Mobile Edge Computing for 5G DROne Systems funded by SMC (Ministry of Presidency) (2020–2022)



Motivation

- Enhance 5G-UAV autonomy in TN and NTN
- Develop Disaster-Resilient Networks with 5G-UAVs and NTN backhauling



Expertise and Labs

- Flying UAV in-campus experimentation from AeroLab
- C-band campus license with OpenAirInterface5G and commercial 5G gNBs from 6GSPACE Lab



Outcomes

- Satellite backhauling for flying 5G-UAV gNBs
- Autonomous UAVs flight path calculation and network recovery in case of disaster event on the network via Edge computing



5G NTN Demonstrators → Over-the-air

ENGAGE (5G over-the-satellite experimentation) industrial project (2022–2023)



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Motivation

- To conduct a live over-the-satellite demonstration of an end-to-end 5G NTN link over a geostationary orbit (GEO) satellite.
- Study the implementation overhead of OpenAirInterface for prospective 5G-NTN applications



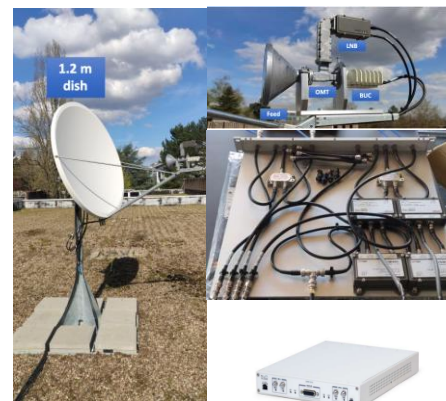
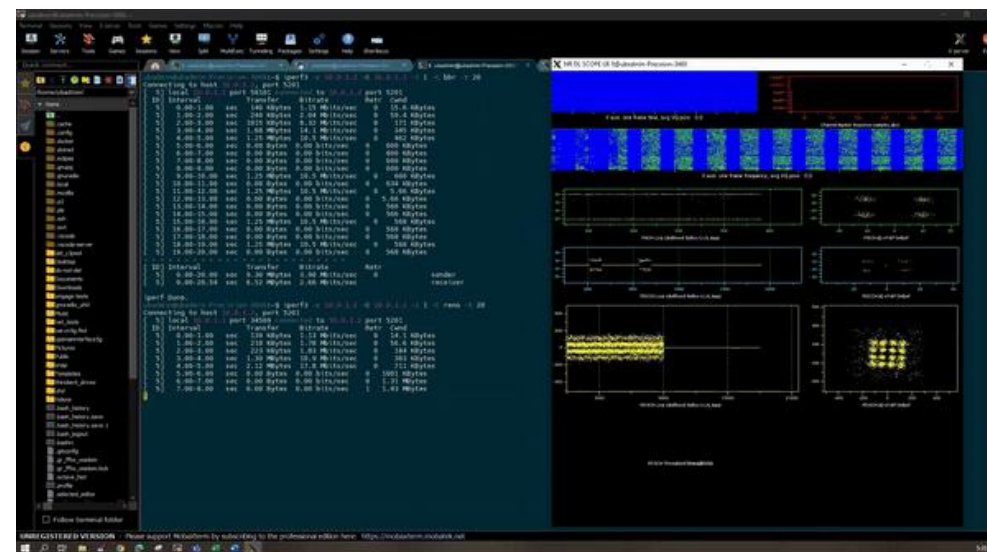
Expertise and Labs

- Dedicated infrastructure for over-the-satellite testing
- SDR Based testbed for 5G (gNB & UE)
- In-house developed satellite channel emulator



Outcomes

- Extensive hands-on expertise on over-the-satellite testing with 5G NR waveforms via GEO satellites
- Comparison of 5G NR waveform and DVB-S2X



5G NTN Demonstrators → In-orbit

5G-Nanosatellite industrial project (2024–2027)



Motivation

- Earth-observation missions generate huge amounts of data that needs to be downloaded from the satellites
- A network of dedicated 5G ground stations can provide high-bandwidth connectivity to thousands of satellites



Expertise and Labs

- SIGCOM has been working towards providing new solutions for the use of 5G signals from/to satellites
- The 6GSPACE Lab has performed several demonstration of 5G connectivity from GEO and emulated-LEO satellites

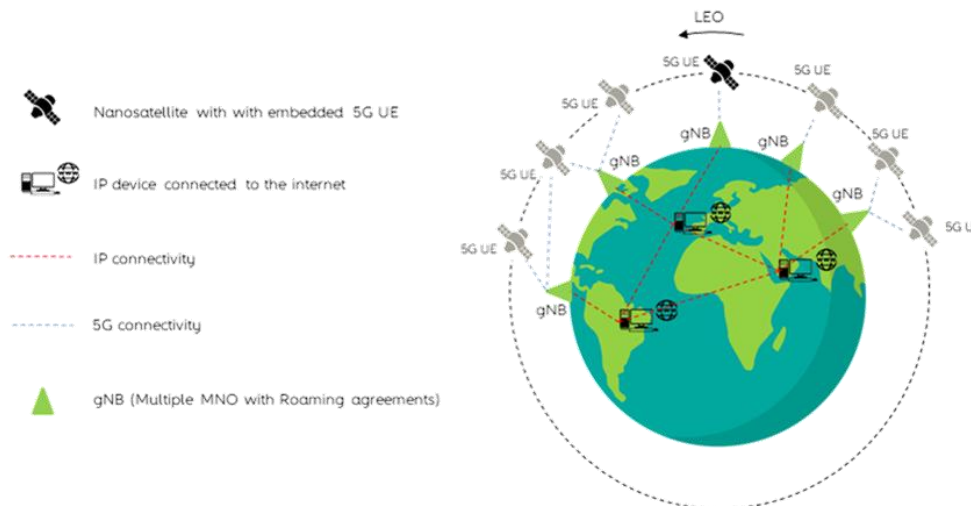
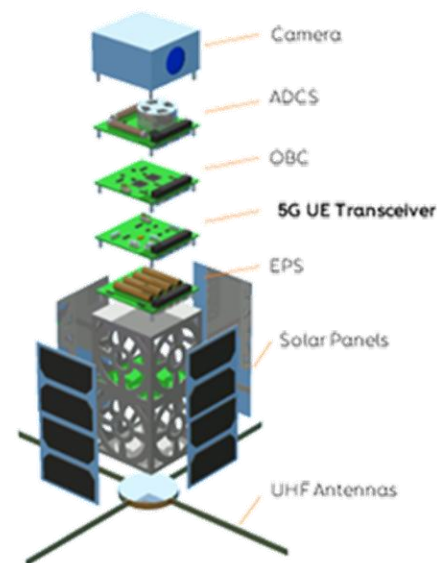
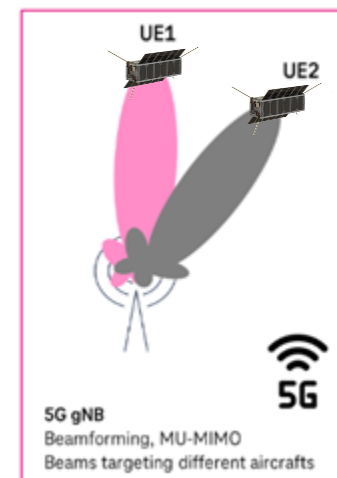
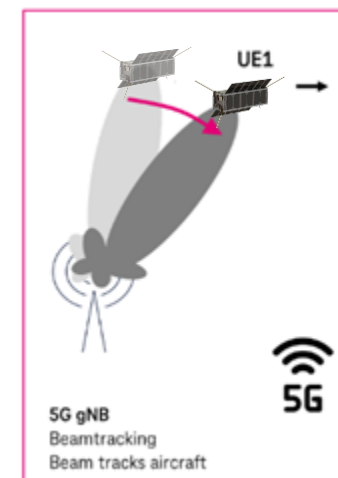


Outcomes

- 5G terminal to be embarked in a 3U Cubesat Proof-of-Concept
- The launch, operation and in-orbit validation are planned for 2026



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NTN for 6G → Ubiquitous Connectivity



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INSTRUCT: INtegrated Satellite–TeRrestrial Systems for Ubiquitous Beyond 5G CommunicaTions funded by FNR IPBG (2020–2025)



Motivation

- New Space Era require novel research methodologies and techniques, including resource management, control and security
- Promote tight collaboration between Luxembourg Space industry and research entities



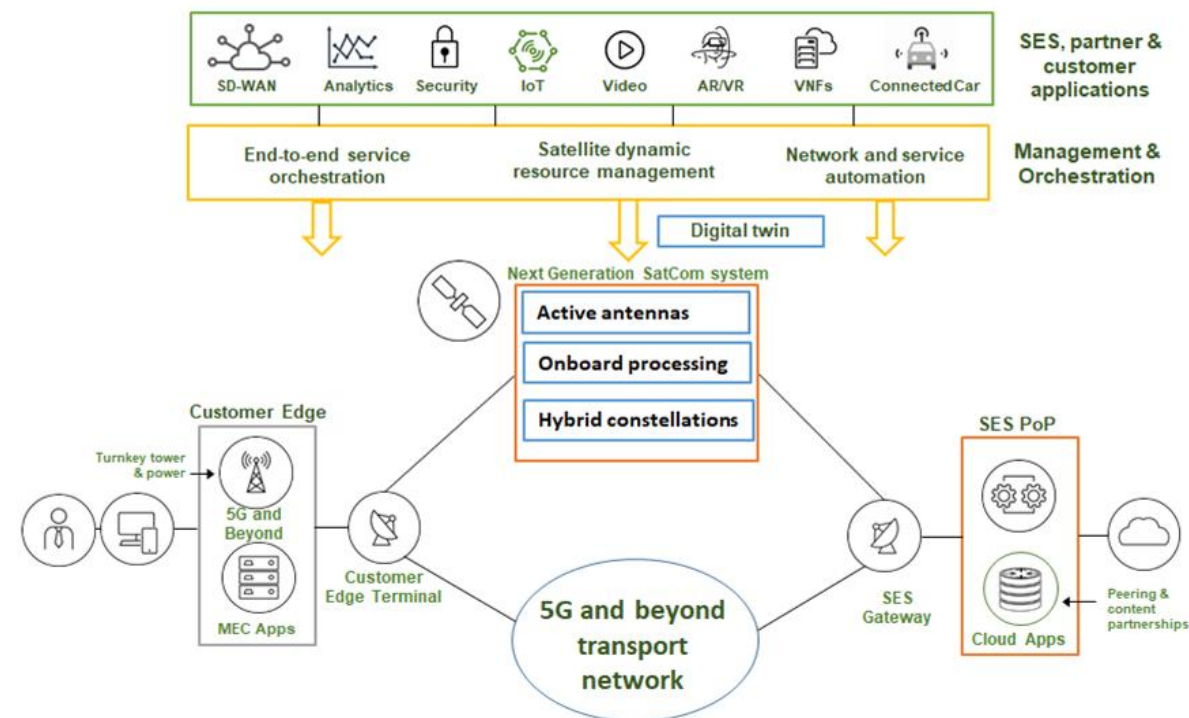
Expertise and Labs

- Over the air demonstration facilities, 6GSPACE Lab
- SDN/NFV testbed, SW simulator and testing



Outcomes

- To train the next generation of SatCom researchers/ professionals: 12 PhD students, 7 postdocs
- To create innovation opportunities within the Lux SatCom Ecosystem
- To provide significant innovations in the area of High Performance Networks and promote Luxembourg's vision of being a global hub of space and satellite services



NTN for 6G → AI-enhanced communications



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SmartSpace: Leveraging AI to Empower the Next Generation of Satellite Communication funded by FNR CORE (2023–2026)



Motivation

- Allows **algorithm acceleration**, i.e. addressing the complex resource optimization problems typically encountered in dynamic NTN environments.
- Dealing with **unknown or inaccurate system model**, complement / improve procedures that rely on sometimes inaccurate channel models
- **Network status prediction**, including traffic load prediction and channel prediction.



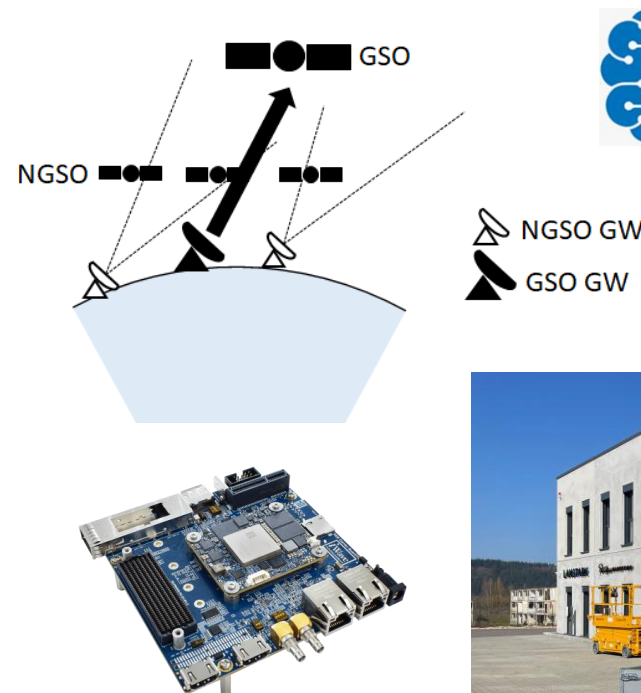
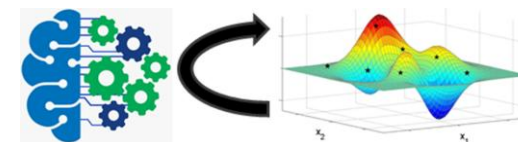
Expertise and Labs

- Strong scientific publication track record.
- AI-validation facilities based on iWave's Versal technology.
- Neuromorphic Processing validation via Intel Neuromorphic Research Community (INRC) and Loihi chipset.



Outcomes

- Open Dataset: <https://fnr-smartspace-project.uni.lu/datasets/>
- [Energy-Efficient On-Board Radio Resource Management for Satellite Communications via Neuromorphic Computing](#)



NTN for 6G → Integrated Sensing and Comms

JCAS for 6G NTN industrial project (2023–2024)

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Motivation

- Integrated Sensing and Communications (ISAC) for NTNs has the potential to combine multiple technologies in a single system
- This results in high-spectral efficiency and optimal usage of the resources
- We aim to combine the JCAS with PNT as well



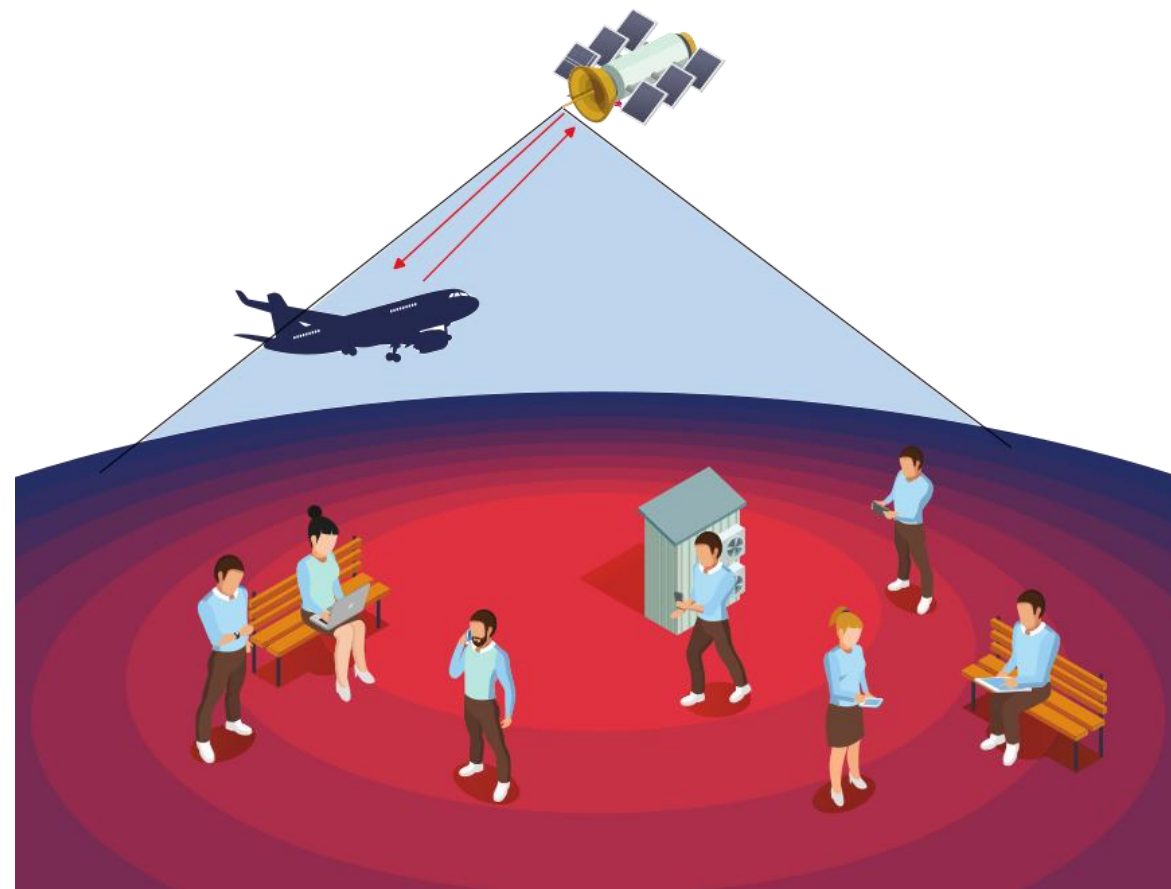
Expertise and Labs

- Strong publications track record on NTNs and currently actively contributing to the topic of JCAS
- Growing research field and subteam within the group



Outcomes

- Survey of key challenges and opportunities of multi-functional satellite systems
- Trade-off of near time-to-market multi-objective JCAS use cases and applications



Quantum Communications



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LUQCIA Lab funded by of SMC (Ministry of Presidency) via NextGenerationEU (2022–2027)



Motivation

- Design a state-of-the-art experimentation facility for Quantum Communications and Quantum Key Distribution
- Establish a framework to engage in collaborative research with local/international industrial/institutional stakeholders



Expertise and Labs

- Build upon SIGCOM's consolidated expertise in communications, electronics, and networking, enhanced with a growing group of experts in quantum theory
- Quantum Lab facilities include state-of-the-art QKD devices and dark/lit fiber links connecting several sites



Outcomes

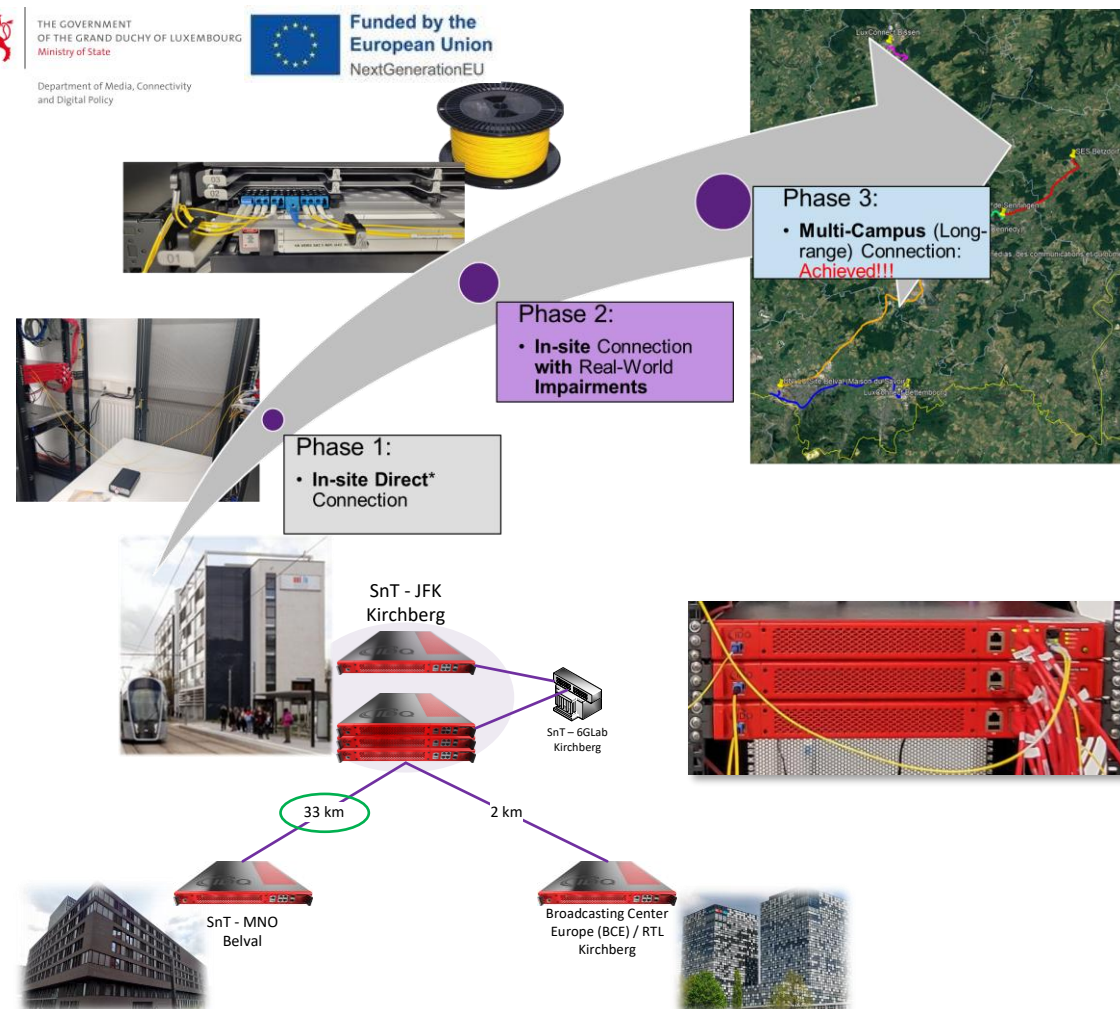
- First long-distance QKD demonstration in Luxembourg
- QKD over an operative fiber will be demonstrated
- Aiming to demonstrate a terrestrial cross-border QKD connection before the end of 2024



THE GOVERNMENT
OF THE GRAND DUCHY OF LUXEMBOURG
Ministry of State
Department of Media, Connectivity
and Digital Policy



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Interdisciplinary Centre for Security, Reliability and Trust

Contact:



Jorge.Querol@uni.lu



Symeon.Chatzinotas@uni.lu

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