

scylight

COMMUNICA

Optical and Quantum SatCom

ESA's plan for today and vision for tomorrow

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FUTTY AND

SECURE

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We Are ESA



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EUROPE'S GATEWAY TO SPACE

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WHAT	23 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	€6.49 billion = €12 per European per year	
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Optional Programme Overview – Main Elements



In addition to ESA Science Programme, Optional Programmes cover all fields of the Space Sector



Space Trans- portation	Human & Robotic Exploration	Earth Observation	Connectivity & Secure Communi- cations	Navigation	Space Safety	Technology Support	Commerciali - sation

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ARTES Core Competitive - Objective



To improve the capability and competitiveness of the ESA Member States industry in the world satellite communications market



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Innovation Drivers





BASS Maritime Portfolio





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ROADMAP & MARITIME INITIATIVES





Data Exchange in VHF Band (VDES)



VHF Maritime Mobile is a dedicated frequency band for maritime communications under the International Telecommunication Union (ITU).

Automatic Identification System (AIS) technology has had a great positive impact in maritime safety and security

- Occupying < 1.7% of the entire VHF marine bands
- Relatively affordable equipment and service cost

Increasing AIS Technical Challenges and Constraints

- Extremely populated AIS network cells close to high traffic zones (busy harbours, popular passages, etc.)
- Vulnerable to spoofing
- AIS overload due to exchanging messages
- Unidirectional SAT-AIS (RX-only)

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VHF Data Exchange System (VDES):

- Enhanced use of spectrum for data exchange
- Enables two-way communications
- Protection of AIS from overloading (due to the message exchange)
- An integrated use of terrestrial (VDE-TER) and satellite (VDE-SAT) components

Could be used

Maritime Authorities

- Vessel Traffic Services (VTS)
- Weather ICE Charts
- Port Call Procedures
- Search and Rescue services
- Contingency Positioning,
 Navigation and Timing (PNT)
 system for maritime shipping

Service Providers & Ship owners

- Vessel Infrastructure Monitoring/predictive maintenance
- Route Optimisation
- Support to Autonomous vessels operations.
- Long-Term Performance monitoring

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Enhancing maritime domain awareness



Growing concerns from maritime authorities regarding AIS vulnerability to spoofing and 'dark vessels' activities

 VDES & IoT could support an authenticated AIS as a first response

Detecting dark vessels' RF emissions from space for identification & localization could complement information provided by Earth Observation SAR images and local observations

European industrial landscape aimed at providing vessels RF emissions detection and processing is emerging



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Non-terrestrial networks (NTNs)





NTN Hight Throughput Optical

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Why Free Space Optical Communication?





Bandwidth

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RF spectrum is becoming scarce \rightarrow optical spectrum is abundant & without ITU licensing

Kingdom Denmark l ithuania azakhsta Belgium German Radio, France Slovakia Moldova Hundary Romania Croatia Serbi Turkmenist Georgia Azerbaijan Bulgaria Svria Morocc Iraq Western Sahara Algeria United Ara Emirates Riyadl Libya Saudi Arabia Mauritania

Latvia

Москва

United

Security

Footprint \emptyset comparison: Ka-band radio frequency beam to optical beam (GEO satellite \rightarrow OGS in GR)

Assuming 135 mm antenna diameter, both for radio frequency and for optical transmitters.

Availability Clouds \rightarrow prevent optical links through the atmosphere

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NTN High Throughput Optical (HTO)





• Intrinsic security – difficult to jam, LPD, LPI

High throughput comms – > Gbps range
Beyond-Line-Of-Sight comms – constellations

with optical inter-satellite links (ISLs)

- Bidirectional optical links ISL and satellite- ground
- No RF spectrum license needed
- EMI Resistant immunity to RF interference

ScyLight – Optical and Quantum Communication



OPTICAL COMMUNICATION & NETWORKING

• Optical Inter-satellite links

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- Cross-atmospheric connectivity
- High thRoughput Optical Network (HydRON)

INTRA-SATELLITE PHOTONICS

- Data distribution and processing on-board
- Microwave Photonics

QUANTUM COMMUNICATION



- QKD
- Quantum Information Networks
- SAGA & EuroQCI

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Free space optical links – evolution



SILEX



2001 – 2009 Tx 2 Mbps Rx 50 Mbps 819 nm 847 nm

NORSAT-TD (SmallCAT)



2023-2025 1.0 Gbps C-band

European Data Relay System (EDRS)



≥2016 1.8 Gbps 1064 nm HydRON



≥2026 100 Gbps C-band

Free Space Optical Communication Technology



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- **Space Space** Inter-Satellite Links (ISLs)
- 1. LEO constellations intra-constellation satellite links
- 2. Data relay systems to third parties



Space – Earth

Space Ground Links (SGL) or cross-atmospheric

- Space to Earth for high-volume data applications, e.g. Earth Observation communication
- 2. Earth to Space feeder links for telecoms >1Tbps



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Free Space Optical Communication Technology



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Space – Earth

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Ground / Space – Deep Space

ESA's HydRON – High thRoughput Optical Network

Implementing terrestrial capabilities in space:

- Scalable data rates (Gbps -Tbps)
- flexible capacity allocation linking, routing & scheduling
- Global reach + Extendable
- Multi-Orbit Connectivity GEO, LEO, MEO & HAPS/Airborne / Sea / Land-mobile

Optical comms Interoperability ensured by: ESTOL

ESA SPECIFICATION FOR TERABIT/SEC OPTICAL

LINKS

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Why Space Networks?

Terrestrial Infrastructure is not always reliable nor accessible everywhere. Global Networking requires resilient and trusted multiple nodes.

Optical Space Networks provide: Resilient data networks Global Interconnectivity Multi-orbit to ground

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HydRON Demo System (H-DS) Elements

H-DS E#2 Multi-Orbit Extension Layer

H-DS E#1 LEO-Ring Layer

Phase-B2/C/D/E Signed in 2024 with consortium lead by Kepler Communications, Canada ESA UNCLASSIFIED - For ESA Official Use Only Phase-B2/C/D/E Signed in 2024 with consortium lead by Thales Alenia Space – Italy

Call opens is Q3 2025 Join HydRON network !

H-DS-E#3

User Segment

Space to underwater optical communications

Feasibility of high data rate space to underwater vehicle laser communications*:

- Combining the underwater and the atmospheric channel behaviours
- To improve data rate in comparison to acoustic waves
- To improve data rate offered by underwater RF wireless comms

* Contract in negotiation

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Intra-satellite Photonics Technology

Fiber Digital Interconnections

Satellites with Digital Transparent Processors require optical interconnects to handle several Tbps of data with minimum power consumption.

- First payload launched in 2021 @12.5Gbps/lane
- 12 Gbps and 25 Gbps transceivers available

Satellite communication payload can include microwave photonics equipment for:

- Fiber Analog Interconnections (RFoF)
- Photonic LO generation
- Photonic Frequency Conversion
- Photonic Filtering of Microwave signals
- Photonic Beam-forming

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Intra-satellite Photonics Technology

Fiber Digital Interconnections

Satellites with Digital Processors require optical interconnects to handle several Tbps of data with minimum power consumption.

 [p]/bit]
 O development

 15 [p]/bit]
 12 Gbps/channel

 12 [p]/bit]
 28 Gbps/channel

 5 [p]/bit]
 56 Gbps/channel (ongoing)

 5 [p]/bit]
 112 Gbps/channel (wP2023)

 <1 [p]/bit]</td>
 Electrical interconnects < 10 Gbps/channel</td>

- Energy per link target < 5 pJ/bit
- 56 Gbps and 112 Gbps in development and preparation

Intra-satellite Photonics Technology

Photonics Equipment

Satellite communication payload can include microwave photonics equipment for:

- Fiber Analog Interconnections (<400mW / link)
- Photonic LO generation (Q- V- W- D-bands)
- Photonic Frequency Conversion
- Photonic Routing / Switching
- Photonic Filtering of Microwave signals
- Photonic Beam-forming

Leveraging Photonic Integrated Circuit (PIC) technology & heterogeneous integration for System In Package (SIP) multi-die assembly and compact packaging

Courtesy of

ESA Strategy on Quantum Communication

ESA Quantum Strategy & Coordinated developments

Aligned with National Quantum Strategies, Quantum in-orbit demos, technology developments and synergies with optical comms

Supporting satellite QKD for commercial and institutional use

Answer to security challenges (QKD protocol standards, security proofs and evaluation criteria)

Preparing for the future Quantum Information Networks (QIN)

for interconnecting Quantum Computers &

Duantum Sensors

Industry-led QKD Missions

EAGLE-1

QKDSat – Quantum Key Distribution Satellite

INT-uQKD – International Use Cases for QKD

OPS-SAT VOLT – Versatile Optical Laboratory for Telecommunications

SecurityAnd cryptoGrAphic mission (ESA SAGA) & Quantumeesa Communication Infrastructure (EC EuroQCI)

- SAGA project, space element of EuroQCI, part of the EU Secure Connectivity Programme.
- Targets design, development & validation of EuroQCI space segment & shall provide global QKD classified services for European Users (governmental).
- 1st Generation System (LEO) providing P&M QKD demo & preliminary service validation.
- Future generation system implementation of a full operational service (mixture of quantum protocols & orbits, security accredited).

DECLARATION ON A QUANTUM COMMUNICATION INFRASTRUCTURE FOR THE EU

All 27 EU Member States

have signed a declaration agreeing to work together to explore how to build a quantum communication infrastructure (QCI) across Europe, boosting European capabilities in quantum technologies, cyber security and industrial competitiveness.

@FutureTechEU #EuroQCI

Quantum Communication enabled by space

Emerging quantum entanglement distribution networks and QKD networks for securely connecting:

- Banks, data centres
- International institutions
- Critical infrastructures

ESA supports development of satellite-based quantum connectivity for long distance and increased resilience

Test-nodes for QIN will benefit from

in-orbit entanglement distribution mission deployments (QUASAR) and Optical Ground Stations

Quantum Communication Applications

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