

**Call: HORIZON-SESAR-2025-DES-ER-03**  
(Digital European Sky Exploratory Research 03)

**Topic: HORIZON-SESAR-2025-DES-ER-03-WA1-3**

**Type of Action: HORIZON-JU-RIA**  
(HORIZON JU Research and Innovation Actions)

**Proposal number: 101289612**

**Proposal acronym: QUANTAIR**

**Type of Model Grant Agreement: HORIZON Lump Sum Grant**

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# Administrative forms

Proposal ID **101289612**

Acronym **QUANTAIR**

## 1 - General information

Fields marked \* are mandatory to fill.

Topic	HORIZON-SESAR-2025-DES-ER-03-WA1-3	Type of Action	HORIZON-JU-RIA
Call	HORIZON-SESAR-2025-DES-ER-03	Type of Model Grant Agreement	HORIZON-AG-LS

Acronym **QUANTAIR**

Proposal title **Quantum Technologies for Airspace Innovation and Resilience**

Note that for technical reasons, the following characters are not accepted in the Proposal Title and will be removed: < > " &

Duration in months **24**

Free keywords *Quantum Federated Learning, Quantum Machine Learning, Data Security, Privacy preservation, Demand Capacity Balancing, ETOT optimisation, Improve Predictability of ATM operations*

### Abstract \*

European air traffic management is becoming increasingly complex. The system now has to handle a growing variety of airspace users — from hypersonic vehicles and high-altitude long-endurance platforms such as stratospheric balloons and HAPS, to conventional subsonic flights. These vehicles often operate in overlapping altitude bands but have vastly different speeds, climb/descent profiles, and manoeuvring capabilities.

At the same time, environmental policy drivers are stronger than ever. The EU Green Deal, ICAO's long-term aspirational goals, and national climate strategies are pushing for measurable reductions in both CO<sub>2</sub> and non-CO<sub>2</sub> impacts, such as persistent contrails. Resilience has also become a priority, with the network increasingly affected by severe weather, technical failures, and geopolitical events that can close or restrict airspace at short notice.

One of the biggest technical challenges in all of these contexts is that many stakeholders — States, ANSPs, airlines, and defence operators — cannot freely share operationally, privacy, or commercially sensitive data. Without that data, current modelling and optimisation tools have to work with partial information, limiting their effectiveness.

Previous European research has already demonstrated that Federated Learning (FL) can bridge this gap, enabling accurate predictions without requiring data to leave its origin. QUANTAIR proposes to take this further by pairing FL with quantum optimisation — allowing us to integrate richer, privacy-protected data from multiple stakeholders, and then solve the resulting large-scale, multi-variable problems at speeds suitable for operational decision-making.

Remaining characters **315**

Has this proposal (or a very similar one) been submitted in the past 2 years in response to a call for proposals under any EU programme, including the current call?

Yes  No

Please give the proposal reference or contract number.

*Previously submitted proposals should be with either 6 or 9 digits.*

# Administrative forms

Proposal ID **101289612**

Acronym **QUANTAIR**

## Declarations

Field(s) marked \* are mandatory to fill.

- 1) We declare to have the explicit consent of all applicants on their participation and on the content of this proposal. \*
- 2) We confirm that the information contained in this proposal is correct and complete and that none of the project activities have started before the proposal was submitted (unless explicitly authorised in the call conditions). \*
- 3) We declare:
- to be fully compliant with the eligibility criteria set out in the call
  - not to be subject to any exclusion grounds under the [EU Financial Regulation 2018/1046](#)
  - to have the financial and operational capacity to carry out the proposed project. \*
- 4) We acknowledge that all communication will be made through the Funding & Tenders Portal electronic exchange system and that access and use of this system is subject to the [Funding & Tenders Portal Terms and Conditions](#). \*
- 5) We have read, understood and accepted the [Funding & Tenders Portal Terms & Conditions](#) and [Privacy Statement](#) that set out the conditions of use of the Portal and the scope, purposes, retention periods, etc. for the processing of personal data of all data subjects whose data we communicate for the purpose of the application, evaluation, award and subsequent management of our grant, prizes and contracts (including financial transactions and audits). \*
- 6) We declare that the proposal complies with ethical principles (including the highest standards of research integrity as set out in the [ALLEA European Code of Conduct for Research Integrity](#), as well as applicable international and national law, including the Charter of Fundamental Rights of the European Union and the European Convention on Human Rights and its Supplementary Protocols. [Appropriate procedures, policies and structures](#) are in place to foster responsible research practices, to prevent questionable research practices and research misconduct, and to handle allegations of breaches of the principles and standards in the Code of Conduct. \*
- 7) We declare that the proposal has an exclusive focus on civil applications (activities intended to be used in military application or aiming to serve military purposes cannot be funded). If the project involves dual-use items in the sense of [Regulation 2021/821](#), or other items for which authorisation is required, we confirm that we will comply with the applicable regulatory framework (e.g. obtain export/import licences before these items are used). \*
- 8) We confirm that the activities proposed do not
- aim at human cloning for reproductive purposes;
  - intend to modify the genetic heritage of human beings which could make such changes heritable (with the exception of research relating to cancer treatment of the gonads, which may be financed), or
  - intend to create human embryos solely for the purpose of research or for the purpose of stem cell procurement, including by means of somatic cell nuclear transfer.
  - lead to the destruction of human embryos (for example, for obtaining stem cells)
- These activities are excluded from funding. \*
- 9) We confirm that for activities carried out outside the Union, the same activities would have been allowed in at least one EU Member State. \*
- 10) For Lump Sum Grants with a detailed budget table: We understand and accept that the EU lump sum grants must be reliable proxies for the actual costs of a project and confirm that the detailed budget for the proposal has been established in accordance with our usual cost accounting practices and in compliance with the basic eligibility conditions for EU actual cost grants (see [AGA - Annotated Grant Agreement, art 6](#)) and exclude costs that are ineligible under the Programme. Purchases and subcontracting costs must be done taking into account best value for money and must be free of conflict of interest. \*

The coordinator is only responsible for the information relating to their own organisation. Each applicant remains responsible for the information declared for their organisation. If the proposal is retained for EU funding, they will all be required to sign a declaration of honour.

**False statements** or incorrect information may lead to administrative sanctions under the EU Financial Regulation.

# Administrative forms

Proposal ID **101289612**

Acronym **QUANTAIR**

## 2 - Participants

### List of participating organisations

#	Participating Organisation Legal Name	Country	Role	Action
1	DEUTSCHES ZENTRUM FUR LUFT - UND RAUMFAHRT EV	Germany	Coordinator	
2	Ooro Quantum Ltd	UK	Partner	
3	SkyNav Europe	BE	Partner	

## Organisation data

<b>PIC</b>	<b>Legal name</b>
999981731	DEUTSCHES ZENTRUM FUR LUFT - UND RAUMFAHRT EV
Short name: DLR	
Address	
Street	LINDER HOHE
Town	KOLN
Postcode	51147
Country	Germany
Webpage	www.dlr.de
<b>Specific Legal Statuses</b>	
Legal person .....	yes
Public body .....	no
Non-profit .....	yes
International organisation .....	no
Secondary or Higher education establishment .....	no
Research organisation .....	yes
<b>SME Data</b>	
Based on the below details from the Participant Registry the organisation is <b>not an SME (small- and medium-sized enterprise) for the call.</b>	
SME self-declared status .....	03/01/2022 - no
SME self-assessment .....	unknown
SME validation .....	28/10/2008 - no

# Administrative forms

## Departments carrying out the proposed work

### Department 1

Department name	Space Operations and Astronaut Training	<input type="checkbox"/> not applicable
	<input type="checkbox"/> Same as proposing organisation's address	
Street	Münchener Straße 20	
Town	Oberpfaffenhofen-Weßling	
Postcode	82234	
Country	Germany	

## Links with other participants

Type of link	Participant
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# Administrative forms

## Main contact person

This will be the person the EU services will contact concerning this proposal (e.g. for additional information, invitation to hearings, sending of evaluation results, convocation to start grant preparation). The data in blue is read-only. Details (name, first name and e-mail) of Main Contact persons should be edited in the step "Participants" of the submission wizard.

Title Dr

Gender  Woman  Man  Non Binary

First name\* **Andreas**

Last name\* **Spörl**

E-Mail\* **andreas.spoerl@dlr.de**

Position in org. group lead

Department Space Operations and Astronaut Training

Same as organisation name

Same as proposing organisation's address

Street Münchener Straße 20

Town Oberpfaffenhofen-Weßling

Post code 82234

Country Germany

Website Please enter website

Phone +XXX XXXXXXXXXX

Phone 2 +XXX XXXXXXXXXX

## Other contact persons

First Name	Last Name	E-mail	Phone
Catharina	Broocks	catharina.broocks@dlr.de	+XXX XXXXXXXXXX
Sylvia	Hutzschenreuter	sylvia.hutzschenreuter@dlr.de	+XXX XXXXXXXXXX
Mirjam	Kopp	mirjam.kopp@dlr.de	+XXX XXXXXXXXXX

## Administrative forms

### Researchers involved in the proposal

Title	First Name	Last Name	Gender	Nationality	E-mail	Career Stage	Role of researcher (in the project)	Reference Identifier	Type of identifier
Dr	Andreas	Spörl	Man	Germany	andreas.spoerl@dlr.de	Category B Senior research	Leading	0009-0003-0727-440X	Orcid ID
Ms	Catharina	Broocks	Woman	Germany	catharina.broocks@dlr.de	Category D First stage research	Team member	0000-0002-4965-1934	Orcid ID

## Administrative forms

### Role of participating organisation in the project

Project management	<input checked="" type="checkbox"/>
Communication, dissemination and engagement	<input checked="" type="checkbox"/>
Provision of research and technology infrastructure	<input checked="" type="checkbox"/>
Co-definition of research and market needs	<input type="checkbox"/>
Civil society representative	<input type="checkbox"/>
Policy maker or regulator, incl. standardisation body	<input checked="" type="checkbox"/>
Research performer	<input checked="" type="checkbox"/>
Technology developer	<input type="checkbox"/>
Testing/validation of approaches and ideas	<input type="checkbox"/>
Prototyping and demonstration	<input type="checkbox"/>
IPR management incl. technology transfer	<input checked="" type="checkbox"/>
Public procurer of results	<input type="checkbox"/>
Private buyer of results	<input type="checkbox"/>
Finance provider (public or private)	<input type="checkbox"/>
Education and training	<input checked="" type="checkbox"/>
Contributions from the social sciences or/and the humanities	<input type="checkbox"/>
Other If yes, please specify: (Maximum number of characters allowed: 50)	<input type="checkbox"/>

## Administrative forms

List of up to 5 publications, widely-used datasets, software, goods, services, or any other achievements relevant to the call content.

Type of achievement	Short description (Max 500 characters)
Publication	"Evolving Spacecraft Quantum On-Call Scheduling" (Prüfer S., Sajko W. et al (DLR), SpaceOps-2023, ID 388) explores applying Grover's algorithm on quantum computers to optimize a simplified operator shift scheduling problem at the German Space Operations Center (GSOC). The study of this combinatorial optimization problem improves constraint handling and achieves reduced gate costs of up to 90%. While focused on spacecraft, these methods are also applicable to other scheduling tasks.
Publication	"QUARGS – Quantum Reinforced Ground Station Scheduling" (Leidreiter D. A., Petrak A., et al (DLR); SpaceOps-2025; ID 267) investigates the application of quantum computing to optimize ground station scheduling for satellite operations. It introduces the QUARGS library that utilizes quantum algorithms like QAOA, QA, VQE, and E-VQE. The study compares these methods to classical solvers and addresses challenges in scalability and constraint implementation.
Publication	"QEOPS – Quantum Earth Observation Planning System" (Prüfer S., Anderle M. A. (DLR); IW PSS 2025) discusses a spacecraft mission planning use-case from the Quantum Mission Planning Challenges (QMPC) project by the German Quantum Computing Initiative at DLR. It formalizes the problem as an Integer Linear Programming (ILP) task, shares insights from applying quantum computing, and compares early results between classical solvers and quantum optimization algorithms.
Software	QUEASARS - Quantum Evolving Ansatz Variational Solver (Leidreiter D. A., Prüfer S. (DLR), <a href="https://github.com/DLR-RB/QUEASARS">https://github.com/DLR-RB/QUEASARS</a> ) is an open-source, qiskit-based, python package implementing quantum variational eigensolvers which use evolutionary algorithms to find a good ansatz during the optimization process, like E-VQE, MoG-VQE or QNEAT. Currently only EVOE is implemented.

List of up to 5 most relevant previous projects or activities, connected to the subject of this proposal.

Name of Project or Activity	Short description (Max 500 characters)
QMPC	Quantum Mission Planning Challenges (QMPC) is a DLR QCI project (Nov 2022–Oct 2026) developing quantum algorithms to solve real-world mission planning optimization problems such as on call operator scheduling, ground station contact planning, and earth observation acquisition for the German Space Operations Center (GSOC). It integrates hybrid and quantum methods into GSOC workflows and extends to a Vehicle to Grid use case with the project partner E.ON.
MuQuaNet	MuQuaNet (Munich Quantum Network) is a QKD-based quantum network in Munich, enabling secure communication for research and government use. Within it, DLR's QSOC integrates QKD into space operations by linking GSOC to the network and testing quantum-encrypted data transmission. These efforts support future QKD-based space missions and extend QSOC's role from quantum computing to secure quantum communication.
QAthMOS	QAthMOS (Quantum Telemetry and Health Monitoring System) is a QSOC led project aiming to enhance satellite operations via quantum powered anomaly detection and predictive analytics on telemetry data. It applies quantum machine learning techniques to monitor satellite health, detect irregularities, and forecast issues—advancing the integration of quantum technologies into operational spaceflight systems.

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work.

Name of infrastructure of equipment	Short description (Max 300 characters)
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## Administrative forms

<i>Quantum computers and Simulators</i>	<i>Our connection to the DLR-QCI (Quantum Computing Initiative) allows access to a variety of quantum computers and simulators based on different quantum hardware platforms. Small scaled demo examples can therefore be computed and executed on actual quantum hardware.</i>
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## Gender Equality Plan

Does the organization have a Gender Equality Plan (GEP) covering the elements listed below?

Yes  No

### Minimum process-related requirements (building blocks) for a GEP

- **Publication:** formal document published on the institution's website and signed by the top management
- **Dedicated resources:** commitment of human resources and gender expertise to implement it.
- **Data collection and monitoring:** sex/gender disaggregated data on personnel (and students for establishments concerned) and annual reporting based on indicators.
- **Training:** Awareness raising/trainings on gender equality and unconscious gender biases for staff and decision-makers.
- **Content-wise, recommended areas to be covered** and addressed via concrete measures and targets are:
  - o work-life balance and organisational culture;
  - o gender balance in leadership and decision-making;
  - o gender equality in recruitment and career progression;
  - o integration of the gender dimension into research and teaching content;
  - o measures against gender-based violence including sexual harassment.

## Administrative forms

PIC	Legal name
870017348	<i>Qoro Quantum Ltd</i>

Short name: Qoro Quantum Ltd

### Address

Street	R27 Atlas Building, Fermi Avenue,
Town	Harwell
Postcode	OX11 0QX
Country	United Kingdom
Webpage	<a href="https://qoro.uk">https://qoro.uk</a>

### Specific Legal Statuses

Legal person .....	yes
Public body .....	no
Non-profit .....	no
International organisation .....	no
Secondary or Higher education establishment .....	no
Research organisation .....	no

### SME Data

Based on the below details from the Participant Registry the organisation is an SME (small- and medium-sized enterprise) for the call.

SME self-declared status .....	18/08/2025 - yes
SME self-assessment .....	unknown
SME validation .....	unknown

## Administrative forms

### Departments carrying out the proposed work

#### No department involved

Department name *Name of the department/institute carrying out the work.*  not applicable

Same as proposing organisation's address

Street *Please enter street name and number.*

Town *Please enter the name of the town.*

Postcode *Area code.*

Country *Please select a country*

### Links with other participants

Type of link	Participant
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# Administrative forms

## Main contact person

This will be the person the EU services will contact concerning this proposal (e.g. for additional information, invitation to hearings, sending of evaluation results, convocation to start grant preparation). The data in blue is read-only. Details (name, first name and e-mail) of Main Contact persons should be edited in the step "Participants" of the submission wizard.

Title Dr

Gender  Woman  Man  Non Binary

First name\* **Stephen**

Last name\* **DiAdamo**

E-Mail\* **stephen@qoroquantum.de**

Position in org. CTO & Co-Founder

Department Qoro Quantum Ltd

Same as organisation name

Same as proposing organisation's address

Street R27 Atlas Building, Fermi Avenue,

Town Harwell

Post code OX11 0QX

Country United Kingdom

Website www.qoroquantum.net

Phone +4915254519041

Phone 2 +XXX XXXXXXXXXX

## Other contact persons

First Name	Last Name	E-mail	Phone
Dan	Holme	dan@qoro.uk	+XXX XXXXXXXXXX

## Administrative forms

### Researchers involved in the proposal

Title	First Name	Last Name	Gender	Nationality	E-mail	Career Stage	Role of researcher (in the project)	Reference Identifier	Type of identifier
Dr	Stephen	DiAdamo	Man	Italy	stephen@qoroquantum.uk	Category B Senior research	Leading	0000-0001-5758-9563	Orcid ID
Ms	Amana	Liaqat	Woman	United Kingdom	amana@qoroquantum.uk	Category C Recognised	Team member		
Mr	Dan	Holme	Man	United Kingdom	dan@qoro.uk	Category C Recognised	Leading		

## Administrative forms

### Role of participating organisation in the project

Project management	<input checked="" type="checkbox"/>
Communication, dissemination and engagement	<input checked="" type="checkbox"/>
Provision of research and technology infrastructure	<input type="checkbox"/>
Co-definition of research and market needs	<input type="checkbox"/>
Civil society representative	<input type="checkbox"/>
Policy maker or regulator, incl. standardisation body	<input type="checkbox"/>
Research performer	<input checked="" type="checkbox"/>
Technology developer	<input checked="" type="checkbox"/>
Testing/validation of approaches and ideas	<input checked="" type="checkbox"/>
Prototyping and demonstration	<input checked="" type="checkbox"/>
IPR management incl. technology transfer	<input type="checkbox"/>
Public procurer of results	<input type="checkbox"/>
Private buyer of results	<input type="checkbox"/>
Finance provider (public or private)	<input type="checkbox"/>
Education and training	<input checked="" type="checkbox"/>
Contributions from the social sciences or/and the humanities	<input type="checkbox"/>
Other If yes, please specify: (Maximum number of characters allowed: 50)	<input type="checkbox"/>

## Administrative forms

List of up to 5 publications, widely-used datasets, software, goods, services, or any other achievements relevant to the call content.

Type of achievement	Short description (Max 500 characters)
Publication	"QAOA in Quantum Datacenters: Parallelization, Simulation, and Orchestration." 2025 IEEE International Conference on Quantum Software, 2025. Introduces Qoro's architecture for automated quantum software execution across distributed computing networks. Demonstrates orchestration strategies that parallelize workloads and allocate resources dynamically, critical foundations for federated quantum computing.
Publication	"Practical quantum k-means clustering: Performance analysis and applications in energy grid classification." IEEE Transactions on Quantum Engineering 3, 2022. Demonstrates hardware-aware quantum machine learning methods, showing performance gains when hardware constraints are integrated into software design. Provides evidence for scaling machine learning and optimization workloads over heterogeneous quantum-classical infrastructures.
Publication	"Quantum algorithms and simulation for parallel and distributed quantum computing." 2021 IEEE/ACM Second International Workshop on Quantum Computing Software. IEEE, 2021. Presents a software framework for parallel execution of quantum algorithms across clusters. Lays groundwork for distributed execution models, including federated approaches used in this project.
Software	Qoro's Divi. Divi is a Python-based software development kit that builds and parallelizes quantum programs. It partitions tasks and transmits them to distributed compute resources through Composer, enabling large-scale workloads such as optimization and machine learning. It supports hybrid execution, key to federated computing.
Software	Qoro's Composer. Composer is a scheduling and orchestration engine that dynamically selects resources for distributed workloads. It evaluates real-time network and device conditions to route jobs efficiently, forming the backbone of federated learning and computation in hybrid HPC-quantum environments.

List of up to 5 most relevant previous projects or activities, connected to the subject of this proposal.

Name of Project or Activity	Short description (Max 500 characters)
ESA Business Incubation	Selected for ESA's incubation program, Qoro applied Divi and Composer to satellite communications optimization. Demonstrated distributed computing and task partitioning over satellite constellations, proving the scalability and adaptability of our approach for mission-critical environments.
Pilot projects with HPC centers	In partnership with CESGA, we deployed Composer to orchestrate quantum-classical workloads over HPC nodes, integrating security and scheduling for multi-node execution. This work validated interoperability across heterogeneous systems and demonstrated scaling strategies relevant to air traffic management.
Pilot projects with Enterprise	Collaborated with enterprise partners (e.g., E.ON, Multiverse Computing) to integrate Divi into energy and finance workflows. Showcased parallelization and partitioning of real-world optimization problems over hybrid clusters, demonstrating readiness to bring federated models to complex industries.

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work.

Name of infrastructure of equipment	Short description (Max 300 characters)
Qoro's cloud computing service	A scalable cloud platform hosting Qoro's distributed orchestration stack, enabling deployment, benchmarking, and execution of federated quantum-classical workloads across multiple sites.

## Administrative forms

<i>Qoro's GPU-based quantum simulator</i>	<i>High-performance GPU-accelerated simulator for quantum circuits, optimized for batch execution and hybrid workflows, enabling realistic modeling of large-scale federated computing scenarios.</i>
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## Gender Equality Plan

Does the organization have a Gender Equality Plan (GEP) covering the elements listed below?

Yes

No

### Minimum process-related requirements (building blocks) for a GEP

- **Publication:** formal document published on the institution's website and signed by the top management
- **Dedicated resources:** commitment of human resources and gender expertise to implement it.
- **Data collection and monitoring:** sex/gender disaggregated data on personnel (and students for establishments concerned) and annual reporting based on indicators.
- **Training:** Awareness raising/trainings on gender equality and unconscious gender biases for staff and decision-makers.
- **Content-wise, recommended areas to be covered** and addressed via concrete measures and targets are:
  - o work-life balance and organisational culture;
  - o gender balance in leadership and decision-making;
  - o gender equality in recruitment and career progression;
  - o integration of the gender dimension into research and teaching content;
  - o measures against gender-based violence including sexual harassment.

## Administrative forms

PIC	Legal name
870906450	SkyNav Europe

Short name: SkyNav Europe

### Address

Street	Rue Coppens 16
Town	Brussels
Postcode	1000
Country	Belgium
Webpage	www.skynavintl.com

### Specific Legal Statuses

Legal person .....	yes
Public body .....	no
Non-profit .....	no
International organisation .....	no
Secondary or Higher education establishment .....	no
Research organisation .....	no

### SME Data

Based on the below details from the Participant Registry the organisation is an SME (small- and medium-sized enterprise) for the call.

SME self-declared status .....	27/09/2024 - yes
SME self-assessment .....	27/09/2024 - yes
SME validation .....	unknown

## Administrative forms

### Departments carrying out the proposed work

#### No department involved

Department name *Name of the department/institute carrying out the work.*  not applicable

Same as proposing organisation's address

Street *Please enter street name and number.*

Town *Please enter the name of the town.*

Postcode *Area code.*

Country *Please select a country*

### Links with other participants

Type of link	Participant
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# Administrative forms

## Main contact person

This will be the person the EU services will contact concerning this proposal (e.g. for additional information, invitation to hearings, sending of evaluation results, convocation to start grant preparation). The data in blue is read-only. Details (name, first name and e-mail) of Main Contact persons should be edited in the step "Participants" of the submission wizard.

Title **Mr**

Gender  Woman  Man  Non Binary

First name\* **Ben**

Last name\* **Kings**

E-Mail\* **ben.kings@skynavintl.com**

Position in org. **Managing Director/Owner**

Department **SkyNav Europe**

Same as organisation name

Same as proposing organisation's address

Street **Rue Coppens 16**

Town **Brussels**

Post code **1000**

Country **Belgium**

Website **https://skynavintl.com/**

Phone **+31615625092**

Phone 2 **+XXX XXXXXXXXXX**

## Other contact persons

First Name	Last Name	E-mail	Phone
Duncan	Auld	duncan.auld@skynavintl.com	+XXX XXXXXXXXXX

## Administrative forms

### Researchers involved in the proposal

Title	First Name	Last Name	Gender	Nationality	E-mail	Career Stage	Role of researcher (in the project)	Reference Identifier	Type of identifier
Mr	Ben	Kings	Man		ben.kings@skynavintl.com	Category A Top grade re	Leading		
Mr	Duncan	Auld	Man		duncan.auld@skynavintl.com	Category A Top grade re	Leading		

## Administrative forms

### Role of participating organisation in the project

Project management	<input checked="" type="checkbox"/>
Communication, dissemination and engagement	<input checked="" type="checkbox"/>
Provision of research and technology infrastructure	<input type="checkbox"/>
Co-definition of research and market needs	<input checked="" type="checkbox"/>
Civil society representative	<input type="checkbox"/>
Policy maker or regulator, incl. standardisation body	<input checked="" type="checkbox"/>
Research performer	<input checked="" type="checkbox"/>
Technology developer	<input type="checkbox"/>
Testing/validation of approaches and ideas	<input checked="" type="checkbox"/>
Prototyping and demonstration	<input type="checkbox"/>
IPR management incl. technology transfer	<input type="checkbox"/>
Public procurer of results	<input type="checkbox"/>
Private buyer of results	<input type="checkbox"/>
Finance provider (public or private)	<input type="checkbox"/>
Education and training	<input type="checkbox"/>
Contributions from the social sciences or/and the humanities	<input type="checkbox"/>
Other If yes, please specify: (Maximum number of characters allowed: 50)	<input type="checkbox"/>

## Administrative forms

List of up to 5 publications, widely-used datasets, software, goods, services, or any other achievements relevant to the call content.

Type of achievement	Short description (Max 500 characters)
Service	<i>Operational ATM experience Decades of global, operational Air Traffic Control experience across all ATC disciplines (Tower, Approach, Area, Oceanic) and at all function levels. Operational supervision, flow management, training, training management, safety and technical committee representation, operational procedure development, international cross-border negotiations, airspace design, safety risk assessments and environmental impact studies</i>
Service	<i>Project Management &amp; Leadership Expertise Extensive track record in project and organisational leadership, including executive roles within IFATCA (International Federation of Air Traffic Controllers' Associations). Demonstrated ability to manage complex international initiatives, coordinate diverse stakeholders, and oversee multi-million-euro budgets. Proven experience in steering strategic aviation projects, ensuring delivery of innovative outcomes aligned with European policy &amp; industry need</i>
Service	<i>ECHO2 subcontractor Participation in the ECHO2 consortium as a contractor focusing on higher airspace and space transport integration. Contributions include operational concept refinement, validation planning, stakeholder mapping, and alignment with ANSP procedures and Network functions. The work informs scalable approaches for trajectory management and airspace reservations. Includes project management and deliverable lead.</i>
Service	<i>ICAO drafting and representation Contributed to drafting and review activities at ICAO in relation to Annex 11, Annex 10 and PANS-ATM material. Work includes requirements structuring, procedure text, and consistency checks across datasets and guidance, supporting globally harmonised ATM provisions relevant to STO and HAO integration. Leading working groups on ATM planning &amp; implementation, development of Global ATM Operational Concept, development of Aviation System Block Upgrades</i>
Service	<i>State regulatory drafting and representation Several years of regulatory drafting support for a Gulf State authority, updating national civil aviation regulations, AMC/GM-style guidance and implementation procedures across ANS, operations and oversight. Emphasis on practicality, traceability and alignment with ICAO and regional provisions. Leadership of ICAO regional groups and task forces related to integration of space transport activities.</i>

List of up to 5 most relevant previous projects or activities, connected to the subject of this proposal.

Name of Project or Activity	Short description (Max 500 characters)
<i>SESAR ECHO / ECHO2 – HAO Integration</i>	<i>Participation in ECHO and ECHO2 on higher airspace and space transport integration. Roles covered operational scenarios, requirements traceability, validation planning, stakeholder engagement and alignment with EUROCONTROL and ICAO practices for cross-border coordination and dynamic, minimal-impact airspace management.</i>
<i>iNEO – Project Management Plan &amp; Governance Appr.</i>	<i>Development of a rigorous PMP and governance model for multi-partner R&amp;D, covering schedule baselining, risk and compliance, quality assurance, and reporting. The approach underpins efficient WP coordination and is directly reusable for other HORIZON projects.</i>
<i>UAE National Regulations Development Programme</i>	<i>Regulatory drafting support for a Gulf State authority, updating national civil aviation regulations, AMC/GM-style guidance and implementation procedures across ANS, operations and oversight. Emphasis on practicality, traceability and alignment with ICAO and regional provisions.</i>

## Administrative forms

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work.

Name of infrastructure of equipment	Short description (Max 300 characters)

## Gender Equality Plan

Does the organization have a Gender Equality Plan (GEP) covering the elements listed below?

Yes  No

### Minimum process-related requirements (building blocks) for a GEP

- **Publication:** formal document published on the institution's website and signed by the top management
- **Dedicated resources:** commitment of human resources and gender expertise to implement it.
- **Data collection and monitoring:** sex/gender disaggregated data on personnel (and students for establishments concerned) and annual reporting based on indicators.
- **Training:** Awareness raising/trainings on gender equality and unconscious gender biases for staff and decision-makers.
- **Content-wise, recommended areas to be covered** and addressed via concrete measures and targets are:
  - o work-life balance and organisational culture;
  - o gender balance in leadership and decision-making;
  - o gender equality in recruitment and career progression;
  - o integration of the gender dimension into research and teaching content;
  - o measures against gender-based violence including sexual harassment.

Administrative forms

Proposal ID 101289612

Acronym QUANTAIR

3 - Budget

No	Name of Beneficiary	Country	Role	Requested grant amount	Income generated by the action	Financial contributions	Own resources	Total estimated income
1	Deutsches Zentrum Fur Luft - Und Raumfahrt Ev	DE	Coordinator	167 350.00	0	0	0	167 350.00
2	Qoro Quantum Ltd	UK	Partner	435 086.16	0	0	20 000	455 086.16
3	Skynav Europe	BE	Partner	342 890.63	0	0	0	342 890.63
	Total			945 326.79			20 000	

# Administrative forms

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## 4 - Ethics & security

### Ethics Issues Table

1. Human Embryonic Stem Cells and Human Embryos		Page
Does this activity involve Human Embryonic Stem Cells (hESCs)?	<input type="radio"/> Yes <input checked="" type="radio"/> No	
Does this activity involve the use of human embryos?	<input type="radio"/> Yes <input checked="" type="radio"/> No	
2. Humans		Page
Does this activity involve human participants?	<input type="radio"/> Yes <input checked="" type="radio"/> No	
Does this activity involve interventions (physical also including imaging technology, behavioural treatments, etc.) on the study participants?	<input type="radio"/> Yes <input checked="" type="radio"/> No	
Does this activity involve conducting a clinical study as defined by the Clinical Trial <a href="#">Regulation (EU 536/2014)</a> ? (using pharmaceuticals, biologicals, radiopharmaceuticals, or advanced therapy medicinal products)	<input type="radio"/> Yes <input checked="" type="radio"/> No	
3. Human Cells / Tissues (not covered by section 1)		Page
Does this activity involve the use of human cells or tissues?	<input type="radio"/> Yes <input checked="" type="radio"/> No	
4. Personal Data		Page
Does this activity involve processing of personal data?	<input type="radio"/> Yes <input checked="" type="radio"/> No	
Does this activity involve further processing of previously collected personal data (including use of preexisting data sets or sources, merging existing data sets)?	<input type="radio"/> Yes <input checked="" type="radio"/> No	
Is it planned to export personal data from the EU to non-EU countries?	<input type="radio"/> Yes <input checked="" type="radio"/> No	
Is it planned to import personal data from non-EU countries into the EU or from a non-EU country to another non-EU country?	<input type="radio"/> Yes <input checked="" type="radio"/> No	
Does this activity involve the processing of personal data related to criminal convictions or offences?	<input type="radio"/> Yes <input checked="" type="radio"/> No	
5. Animals		Page
Does this activity involve animals?	<input type="radio"/> Yes <input checked="" type="radio"/> No	
6. Non-EU Countries		Page
Will some of the activities be carried out in non-EU countries?	<input checked="" type="radio"/> Yes <input type="radio"/> No	0
United Kingdom		
In case non-EU countries are involved, do the activities undertaken in these countries raise potential ethics issues?	<input type="radio"/> Yes <input checked="" type="radio"/> No	
It is planned to use local resources (e.g. animal and/or human tissue samples, genetic material, live animals, human remains, materials of historical value, endangered fauna or flora samples, etc.)?	<input type="radio"/> Yes <input checked="" type="radio"/> No	
Is it planned to import any material (other than data) from non-EU countries into the EU or from a non-EU country to another non-EU country? For data imports, see section 4.	<input type="radio"/> Yes <input checked="" type="radio"/> No	
Is it planned to export any material (other than data) from the EU to non-EU countries? For data exports, see section 4.	<input type="radio"/> Yes <input checked="" type="radio"/> No	

# Administrative forms

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Does this activity involve [low and/or lower middle income countries](#), (if yes, detail the benefit-sharing actions planned in the self-assessment)  Yes  No

Could the situation in the country put the individuals taking part in the activity at risk?  Yes  No

## 7. Environment, Health and Safety Page

Does this activity involve the use of substances or processes that may cause harm to the environment, to animals or plants.(during the implementation of the activity or further to the use of the results, as a possible impact) ?  Yes  No

Does this activity deal with endangered fauna and/or flora / protected areas?  Yes  No

Does this activity involve the use of substances or processes that may cause harm to humans, including those performing the activity.(during the implementation of the activity or further to the use of the results, as a possible impact) ?  Yes  No

## 8. Artificial Intelligence Page

Does this activity involve the development, deployment and/or use of Artificial Intelligence-based systems?  Yes  No 0

## 9. Other Ethics Issues Page

Are there any other ethics issues that should be taken into consideration?  Yes  No

I confirm that I have taken into account all ethics issues above and that, if any ethics issues apply, I will complete the ethics self-assessment as described in the guidelines [How to Complete your Ethics Self-Assessment](#)



# Administrative forms

Proposal ID **101289612**

Acronym **QUANTAIR**

## Ethics Self-Assessment

### Ethical dimension of the objectives, methodology and likely impact

#### 6. Non-EU Countries

Will some of the activities be carried out in non-EU countries?

Parts of the research is carried out in UK. The work is of documentary type.  
No impacts and/or misuses on environment, social or political groups are expected.

#### 8. Artificial intelligence

Does this activity involve the development, deployment and/or use of Artificial Intelligence-based systems?

Yes, first for text generation and second, because the project elaborates on concepts (quantum) machine learning approaches.

Remaining characters

4491

### Compliance with ethical principles and relevant legislations

#### 6. Non-EU Countries

Due to the involvement of UK as non-EU country, the project confirms compliance to the highest ethical standards.  
All research conducted (in either EU Memberstates or UK) will be of legal type in all mentioned countries.

#### 8. Artificial intelligence

QUANTAIR's actively integrates privacy, safety, fairness, environmental responsibility, dual-use safeguards, and transparency into its objectives. Wherever AI is used, it only contributes as a preliminary step for further verification.

Remaining characters

4492

# Administrative forms

Proposal ID **101289612**

Acronym **QUANTAIR**

## Security issues table

1. EU Classified Information (EUCI) <sup>2</sup>		Page
Does this activity involve information and/or materials requiring protection against unauthorised disclosure (EUCI)?	<input type="radio"/> Yes <input checked="" type="radio"/> No	
Does this activity involve non-EU countries which need to have access to EUCI?	<input type="radio"/> Yes <input checked="" type="radio"/> No	
2. Misuse		Page
Does this activity have the potential for misuse of results?	<input type="radio"/> Yes <input checked="" type="radio"/> No	
3. Other Security Issues		Page
Does this activity involve information and/or materials subject to national security restrictions? If yes, please specify: (Maximum number of characters allowed: 1000)	<input type="radio"/> Yes <input checked="" type="radio"/> No	
Are there any other security issues that should be taken into consideration? If yes, please specify: (Maximum number of characters allowed: 1000)	<input type="radio"/> Yes <input checked="" type="radio"/> No	

## Security self-assessment

(No Security Issue was marked with Yes)

Remaining characters **4961**

<sup>2</sup>According to the Commission Decision (EU, Euratom) 2015/444 of 13 March 2015 on the security rules for protecting EU classified information, "European Union classified information (EUCI) means any information or material designated by an EU security classification, the unauthorised disclosure of which could cause varying degrees of prejudice to the interests of the European Union or of one or more of the Member States".

<sup>3</sup>Classified background information is information that is already classified by a country and/or international organisation and/or the EU and is going to be used by the project. In this case, the project must have in advance the authorisation from the originator of the classified information, which is the entity (EU institution, EU Member State, third state or international organisation) under whose authority the classified information has been generated.

<sup>4</sup>EU classified foreground information is information (documents/deliverables/materials) planned to be generated by the project and that needs to be protected from unauthorised disclosure. The originator of the EUCI generated by the project is the European Commission.

# Proposal template Part B: technical description

## QUANTAIR

[This document is tagged. Do not delete the tags; they are needed for processing.] #@APP-FORM-HERIAIA@#

### List of participants

Participant No. *	Participant organisation name	Country
1 (Coordinator)	Deutsches Zentrum für Luft- und Raumfahrt (DLR e.V.)	Germany
2	Qoro Quantum	United Kingdom
3	SkyNav International	Belgium

### 1. Excellence #@REL-EVA-RE@#

#### 1.1 Objectives and ambition #@PRJ-OBJ-PO@#

QUANTAIR investigates the feasibility of applying Quantum Federated machine Learning (QFL) to Air Traffic Management (ATM) at TRL 1. Federated Machine Learning (FedML) is a distributed approach in which models are trained across multiple independent data sources without requiring the exchange of raw data. This is of clear relevance to ATM, where operational datasets are fragmented across various stakeholders such as airlines, ANSPs, airports, and regulators, and where data protection, confidentiality, and sovereignty considerations prevent centralisation.

Quantum computing is still at an early stage and cannot yet be used in operational systems. However, research in other fields suggests that certain quantum algorithms can eventually provide advantages when dealing with very large or complex problems, such as those involving many interdependent variables [1]. FedML, by contrast, is already a recognised approach that allows different stakeholders to train models collaboratively without sharing their raw data [2]. In QUANTAIR, the focus is on exploring the feasibility of combining FedML with the capabilities of Quantum computing for ATM at TRL 1.

The project aims to provide the first structured assessment of QFL for ATM. Its contribution is not the development of prototypes or operational tools, but rather the creation of a conceptual and methodological foundation on which future SESAR research can build. QUANTAIR clarifies whether QFL represents a promising research direction for ATM, defines the conditions under which it might deliver benefits, estimates quantum resources, and identifies the steps required to advance to TRL 2–3. The previous work by EUROCONTROL for the SESAR programme, called AICHAIN [3], proved that classical federated learning (FL) can improve ATM predictions such as ETOT and route forecasting without requiring sensitive data to be centralised. This showed clear value in applying FedML to fragmented, confidential datasets across airlines, ANSPs, and airports. However, classical FedML faces limits as ATM problems grow in size and complexity. Multi-flight trajectory optimisation, higher airspace operations, contrail modelling, and large-scale disruption management create exponential decision spaces and high-dimensional data where classical methods struggle.

QFL offers a pathway beyond these constraints. Quantum machine learning and sampling techniques could improve scalability and trainability, speed up convergence, and capture correlations that classical FedML may miss [4]. They also enable richer modelling of rare but safety-critical events, strengthening resilience. The benefit is twofold: immediate applicability through privacy-preserving FedML, and long-term potential to exploit quantum acceleration once hardware matures. This positions QFL as both a natural evolution of AICHAIN's work and a future-proofed approach aligned with SESAR's digital and green ATM priorities [5]. By targeting ATM, the project provides a

demanding testbed for QFL. ATM data is fragmented across many stakeholders, highly sensitive, and time-critical, which pushes QFL beyond simpler academic demonstrations. Developing the ATM use cases will expose how QFL copes with heterogeneous datasets, privacy constraints, and multi-objective optimisation. These lessons will be transferable to other sectors that face similar challenges, such as energy grids, healthcare networks, or logistics chains [1]. The project also clarifies where quantum methods add value beyond classical FL, for example in scaling federated models, simulating rare events, or solving complex optimisation problems. In doing so, it creates benchmarks, reference architectures, and research roadmaps that the wider QFL community can build upon. The outputs therefore go beyond ATM: they define generic methods, highlight open technical questions, and establish a foundation for advancing QFL across domains.

To achieve the project objectives, the work is organised around four Exploratory Cases, each representing a distinct ATM challenge.

- **PREDICT (Privacy-Respecting Enhanced Departure Integration with Coordinated Timing)** focuses on departure predictability and slot allocation. Today, flight departure times are subject to frequent uncertainty, creating knock-on effects for network efficiency and traffic flow management. The case investigates whether federated models trained across multiple stakeholders could improve A-CDM performance in areas such as estimate accuracy (Estimated Take-Off Time (ETOT), Target Take-Off Time (TTOT), etc.) and CTOT regulation application (supporting the SESAR goal of reduced CTOT allocation through 4D trajectory management), without requiring the sharing of commercially sensitive data.
- **HORIQON (High-altitude Operations with Real-time Integrated Quantum-Optimised Navigation)** examines trajectory planning and integration in higher airspace. As new entrants, such as high-altitude platforms and space transport operations, begin to interact with conventional aviation, new methods will be required to manage trajectories where little operational data currently exists. The case explores how QFL could enable collaborative modelling of such trajectories in a way that protects sensitive data and supports safe integration.
- **SHIELD (Strengthened Handling of Irregular Events and Landing Diversions)** addresses diversion capacity and network resilience. Disruptions such as weather, technical failures, or security incidents often require diversions, but the available diversion capacity across the network is not always visible to all actors. This case considers whether QFL could allow stakeholders to model and share diversion capacity information without exposing sensitive or commercially confidential data, improving the network's ability to respond to disruptions.
- **CONTRADE (Climate-Optimised Navigation for TRAjectory DEsign)** investigates contrail prediction to support environmentally optimised planning. Avoiding persistent contrails is recognised as a key measure for reducing the climate impact of aviation, but predicting where contrails will form requires combining data from multiple sources. The case explores whether QFL could be used to generate contrail risk maps collaboratively, improving environmental outcomes while respecting data ownership and privacy.

PREDICT focuses on operational efficiency and network capacity. HORIQON addresses the integration of new entrants such as high-altitude and space transport operations. SHIELD responds to the need for resilience in the face of disruption. CONTRADE tackles environmental sustainability by examining contrail avoidance strategies. Together, they demonstrate how QFL could be applicable to very different aspects of the ATM system rather than concentrating on a single narrow problem.

Together, these cases ensure that the research addresses operational efficiency, integration of new entrants, resilience, and sustainability. They provide representative contexts for assessing QFL concepts at TRL 1, without moving into prototyping or operational validation. They were chosen to ensure that results are relevant across the breadth of the European ATM Master Plan.

QUANTAIR sets out to achieve the following objectives:

1. Investigate whether FedML is conceptually applicable to ATM problems, while also considering where quantum methods might support its scalability.
  - The first objective is to determine the feasibility of applying QFL to representative ATM challenges. This involves examining whether distributed learning methods can be adapted to the constraints of ATM, such as heterogeneous data sources, privacy restrictions, and operational time-criticality. It also considers whether quantum techniques could, in future, play a role in scaling these methods to larger or more complex problems. The outcome will be a feasibility analysis supported by conceptual models and indicators.
2. Develop high-level frameworks for QFL in each Exploratory Case.
  - Each of the four cases is chosen to represent a distinct ATM challenge. For each case, the project will develop a conceptual framework describing how QFL could be applied, what the learning architecture might look like, what kinds of data would be needed, and how results could support operational decision-making. These frameworks will be high-level and exploratory, but they will provide a structured representation that can be taken forward in subsequent research.
3. Identify potential benefits, limitations, and open research questions.
  - The third objective is to move beyond purely speculative discussion by systematically assessing both advantages and drawbacks. Potential benefits may include improved predictability, resilience, or environmental outcomes. Limitations may relate to data quality, computational constraints, or explainability of the models. Open questions may include how federated models could be validated in a safety-critical environment or how quantum methods could be integrated when hardware becomes more mature. The identification of such gaps is itself a valuable outcome, as it directs future SESAR work towards areas of highest relevance.
4. Define the steps needed to advance this research to TRL 2–3 in future work.
  - Finally, the project aims to provide a roadmap for subsequent SESAR research. This includes identifying the data-sharing frameworks, modelling techniques, and validation approaches that would be required for TRL 2–3 studies. It also considers how and when quantum machine learning methods might become relevant. This ensures that the project’s outputs are not isolated academic results but are directly linked to the SESAR innovation pipeline.

QUANTAIR responds directly to the scope of HORIZON-SESAR-2025-DES-ER-03-WA1-3 by investigating the application of quantum computing methods to ATM. At TRL 1, the emphasis is placed on federated learning approaches and their conceptual integration into ATM, while also identifying where quantum machine learning could in future support scalability. The objectives are realistic within a TRL 1 framework and are measurable through conceptual indicators such as model fidelity, scalability analysis, and qualitative assessment of potential benefits. In doing so, the project provides a structured contribution to the SESAR Master Plan’s long-term vision of the Digital European Sky and the research priorities set out in the Work Programme.

In terms of ambition and positioning, QUANTAIR fills a critical research gap. FedML has been explored in limited ways within aviation, mostly for localised applications such as airport processes or isolated ANSP datasets. There has been no systematic investigation of whether these techniques could be scaled across the network or used in multi-stakeholder settings where privacy and sovereignty concerns prevent centralised data sharing. Similarly, while quantum computing research is advancing rapidly, applications to ATM have not yet been explored. QUANTAIR is therefore the first structured attempt to bring all of the previous research initiatives together into a tangible plan for development towards future ATM solutions beyond TRL 3.

The project targets TRL 1 and does not intend to develop prototypes, demonstrators, or operational tools. Its ambition lies instead in being the first project to provide a structured assessment of QFL in holistic ATM, grounded in representative use cases, and linked to SESAR’s strategic objectives. The outputs will be conceptual frameworks, feasibility analyses, and roadmaps that guide the next phase of research. This ensures that the project is both realistic in its scope and ambitious in its contribution, establishing a research direction that could shape European ATM innovation for the next decade.

#\$PRJ-OBJ-PO\$#

## 1.2 Methodology #@CON-MET-CM@# #@COM-PL-CP@#

FedML is a machine-learning approach in which models are trained collaboratively across distributed data sources without the need to pool raw data in a central repository. This is relevant to ATM, where operational data is fragmented between stakeholders (such as airlines, ANSPs, airports, and regulators) and where concerns over privacy, sovereignty, and commercial sensitivity prevent centralisation. By allowing stakeholders to contribute to shared models without releasing their raw data, FedML provides a potential way of overcoming these barriers.

In defining the methodology, QUANTAIR focuses on the use of quantum computing as a conceptual analysis. The project is scoped at TRL 1 not due to a lack of capability, but because current quantum hardware is not yet sufficiently mature to enable higher-TRL validation in ATM. QUANTAIR therefore focuses on conceptual feasibility while identifying the pathways that can be pursued once the technology advances. The research examines how federated learning frameworks in ATM could, in principle, benefit from quantum methods for future TRLs, particularly in handling large-scale optimisation and high-dimensional learning tasks. This ensures the project remains grounded in what is achievable at TRL 1, while establishing a forward-looking research pathway relevant to SESAR's long-term ambitions.

In QUANTAIR, QFL[DS1] is defined as the use of federated learning to enable distributed model training across ATM stakeholders, combined with an explicit recognition of the potential role of quantum methods in future TRLs. The research is not intended to deliver operational tools but to establish whether this approach is feasible and useful in an ATM context.

The methodology is based on several assumptions. It assumes that relevant data is distributed across multiple stakeholders, that this data varies in quality and format, and that privacy and sovereignty concerns will prevent full centralisation. It assumes that local training and global aggregation can be adapted to ATM use cases, and that scalability may require quantum-enabled methods in future TRLs. These assumptions frame the scope of the work and define the limits of the feasibility analysis.

This conceptual basis is well suited to the project's objectives. The aim is not to deliver prototypes but to investigate feasibility, develop high-level frameworks, identify potential benefits and limitations, and define pathways towards higher-TRL research. FedML provides the structure for exploring distributed collaboration in ATM, and quantum computing offers a forward-looking perspective that connects the work to the long-term vision of SESAR.

FedML is a machine-learning approach in which models are trained collaboratively across distributed data sources without the need to pool raw data in a central repository. This is relevant to ATM, where operational data is fragmented between stakeholders (such as airlines, ANSPs, airports, and regulators) and where concerns over privacy, sovereignty, and commercial sensitivity prevent centralisation. By allowing stakeholders to contribute to shared models without releasing their raw data, FedML provides a potential way of overcoming these barriers.

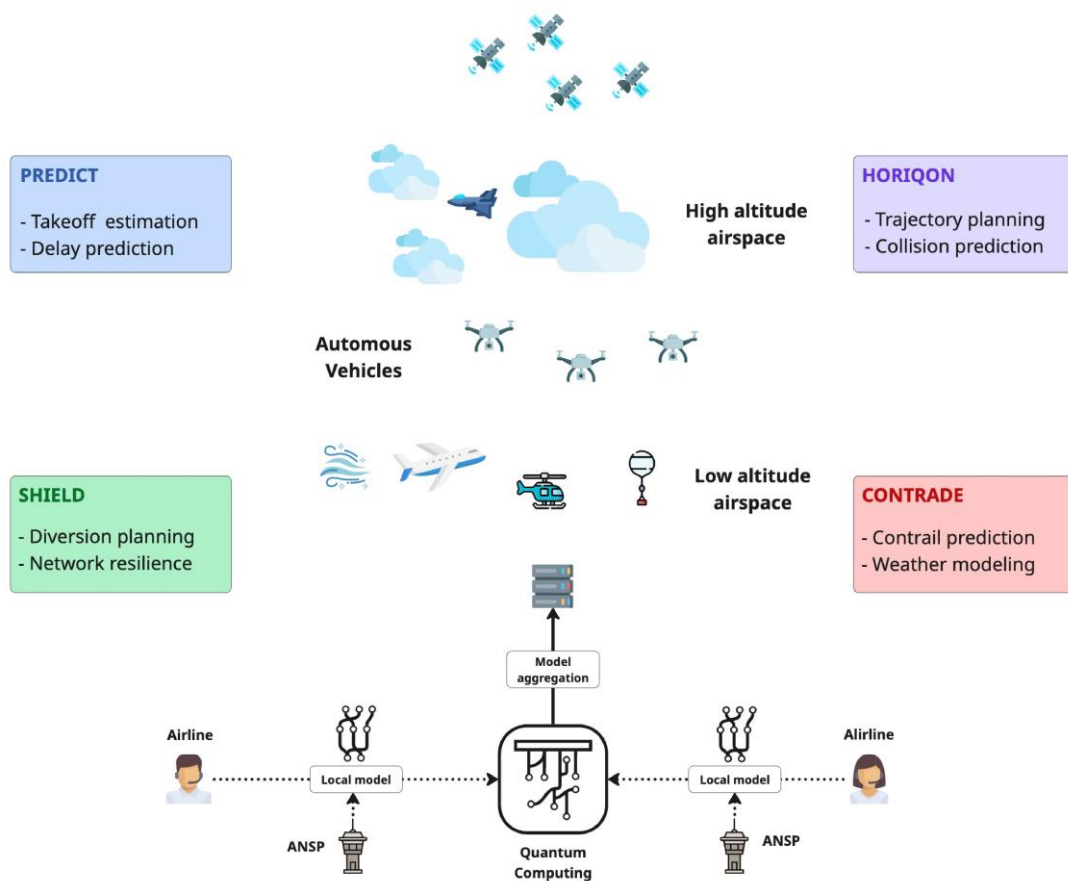
In defining the methodology, QUANTAIR focuses on the use of quantum computing as a conceptual analysis. The project is scoped at TRL 1 not due to a lack of capability, but because current quantum hardware is not yet sufficiently mature to enable higher-TRL validation in ATM. QUANTAIR therefore focuses on conceptual feasibility, while identifying the pathways that can be pursued once the technology advances. The research examines how federated learning frameworks in ATM could, in principle, benefit from quantum methods once they become more capable, particularly in handling large-scale optimisation and high-dimensional learning tasks. This ensures that the project remains grounded in what is achievable at TRL 1, while still establishing a forward-looking research pathway that is relevant to SESAR's long-term ambitions.

In QUANTAIR, QFL is defined as the use of federated learning to enable distributed model training across ATM stakeholders, combined with an explicit recognition of the potential role of quantum methods in overcoming computational bottlenecks in the future. The research is not intended to deliver operational tools but to establish

whether this approach is feasible and useful in an ATM context.

The methodology is based on several assumptions. It assumes that relevant data is distributed across multiple stakeholders, that this data varies in quality and format, and that privacy and sovereignty concerns will prevent full centralisation. It assumes that local training and global aggregation can be adapted to ATM use cases, and that scalability may eventually require quantum-enabled methods. These assumptions frame the scope of the work and define the limits of the feasibility analysis.

This conceptual basis is well suited to the project’s objectives. The aim is not to deliver prototypes but to investigate feasibility, develop high-level frameworks, identify potential benefits and limitations, and define pathways towards higher-TRL research. FedML provides the structure for exploring distributed collaboration in ATM, and quantum computing offers a forward-looking perspective that connects the work to the long-term vision of SESAR.



**Exploratory Case 1: PREDICT (Privacy-Respecting Enhanced Departure Integration with Coordinated Timing)**

One of the four exploratory cases is PREDICT, which examines the problem of departure predictability and slot allocation. In the current ATM system, uncertainty in the timing of departures is a persistent source of inefficiency. Airlines, airports, and the Network Manager rely on estimates for the various trigger points within the flight, which are used to consider airspace loading and whether regulation needs to be applied to protect the airspace. This includes estimates used within A-CDM, such as Target Off-Blocks Time (TOBT), Target Start Approval Time (TSAT), Estimated Take-Off Time (ETOT) etc., which are used to plan the allocation of slots via Calculated Take-Off Time (CTOT) and to coordinate traffic flows, but these estimates are often unreliable and have a tolerance window applied. Delays caused by late boarding, pushback, or ground handling propagate through the system, leading to inefficient use of airport capacity and sub-optimal flow management decisions. Improving departure predictability has been a

long-standing goal in SESAR, but progress has been constrained by the limitations of centralised modelling approaches.

The challenge is that the information required to predict departures accurately is distributed across multiple actors. Airlines hold data on crew, passengers, and turnaround processes. Airports manage gate availability, ground handling, and sequencing. Air navigation service providers track surface movements and manage departure clearances. The network manager needs a system-wide picture in order to coordinate slots at a regional level. At present, much of this information is kept within individual organisations, either because it is operationally sensitive or because there are no mechanisms to share it in real time. As a result, centralised models rely on incomplete data, and their predictions lack the accuracy needed to deliver significant improvements.

The PREDICT case investigates whether FedML could provide a more effective framework. In a federated approach, each stakeholder would train a local model on its own data, and only model parameters would be shared. A global model could then be constructed that reflects the behaviour of the entire system without requiring the exchange of raw data. For example, an airline's local model could capture patterns in boarding times, while another airport's model could capture ground handling delays. The aggregated model could then produce more reliable A-CDM estimates, which in turn could improve slot allocation and flow management decisions.

At TRL 1, the project does not attempt to build such models but rather to examine their conceptual feasibility. The methodology involves defining a high-level framework for how federated models might be constructed in this context, identifying what types of data would be needed at each node, and analysing the assumptions required for the models to function. Indicators such as potential improvements in model fidelity, the robustness of aggregation across heterogeneous datasets, and the scalability of the approach will be considered. The analysis will also examine the limitations of FedML in this application, such as the risk of bias if data quality differs significantly between stakeholders or the difficulty of validating models in a safety-critical environment.

The role of quantum computing is considered solely as a conceptual pathway for future TRLs. With more accurate ETOT predictions produced by federated models, the subsequent task of sequencing departure slots becomes a high-dimensional, NP-hard scheduling problem in which classical methods are known to struggle.

Here, the federated setup is essential: only by combining distributed insights from airlines, airports, and network managers can a sufficiently rich optimisation space be created for downstream quantum-machine-learning algorithms to act upon. The project will evaluate how quantum techniques, particularly hybrid quantum-classical approaches such as the Quantum Approximate Optimization Algorithm (QAOA), variational quantum circuits, and quantum-annealing-based methods, could be applied at this global level. For example, quantum-machine-learning models, seeded with federated-learning-derived estimates, could generate high-quality slot sequences that minimise delay propagation.

Furthermore, we will investigate whether quantum computers can effectively evaluate the probability of rare but critical events, such as sector congestion, enabling unsafe or inefficient allocations to be rejected without exhaustive simulation. Hybrid workflows will be designed so that classical pre-processing (e.g., feature extraction, constraint filtering) feeds into the quantum optimiser, while classical post-processing (e.g., solution refinement, robustness checks) cleans and validates the quantum output.

These techniques illustrate how federated learning provides the conceptual foundation for future quantum integration, while hybrid quantum-classical methods offer a practical bridge between current capabilities and the eventual deployment of fully quantum-enhanced scheduling solutions.

The expected output of the PREDICT case is therefore twofold: first, a conceptual framework showing how federated learning can provide a privacy-preserving yet system-wide approach to departure predictability and slot allocation; and second, a roadmap outlining how quantum machine learning could build on this federated foundation in future TRL 2–3 work. By emphasising that accurate, system-wide models can only emerge in a federated setting, the case highlights that quantum methods are not an alternative to data sharing but a complement that relies on federated

inputs to be effective. This dual perspective will clarify both the feasibility and the limitations of QFL, and determine whether distributed learning combined with quantum acceleration offers a credible path toward improved A-CDM accuracy, operational efficiency, and capacity management.

## **Exploratory Case 2: HORIQON (High-altitude Operations with Real-time Integrated Quantum-Optimised Navigation)**

HORIQON addresses trajectory planning and integration in higher airspace. New entrants such as high-altitude platforms, sub-orbital vehicles, supersonic and hypersonic aircraft, space transport systems, and certain military operations create demands that differ significantly from conventional traffic. These vehicles operate with unique performance profiles, often cross through controlled airspace at high speed, and interact with en-route flows at non-standard altitudes. Current trajectory planning methods are not well adapted to these conditions, and the lack of operational data makes it difficult to develop predictive models. HORIQON investigates whether QFL could provide a framework for sharing knowledge across stakeholders, enabling collaborative modelling of higher-airspace and high-speed trajectories while protecting sensitive operational and security-related data.

The main difficulty is that responsibility for higher airspace operations is spread across multiple organisations. All stakeholders hold sensitive operational data, individual states maintain oversight of safety and sovereignty, and ANSPs must manage interactions with conventional traffic within current controlled airspace. Sharing of information is complex due to national security considerations, the commercial confidentiality of operational profiles, and financial sensitivities. As a result, efforts to model higher airspace trajectories are often fragmented, and the lack of integrated predictive capability makes it difficult to anticipate how such operations will affect the wider network.

The HORIQON case examines whether QFL could provide a way of combining insights from distributed datasets without requiring disclosure of sensitive information. A federated model could allow the various stakeholders to train local models on their own data while contributing to a global model that captures trajectory behaviours in higher airspace. For example, space operators could train models on ascent and descent profiles, while ANSPs could contribute models on interactions with controlled airspace. Aggregating these models could improve the ability to predict trajectories and their impact on the network, without requiring operators to reveal sensitive operational details.

At TRL 1, the focus is on developing a conceptual framework for how such federated models might be constructed and on identifying the assumptions needed for them to function. The feasibility analysis will consider factors such as the extreme heterogeneity of data sources, the sparsity of available datasets, and the sensitivity of mission information. Indicators of feasibility will include the ability of federated models to generalise from limited local data, the robustness of aggregation when nodes have very different information, and the potential scalability of the approach.

The role of quantum computing is considered solely as a conceptual pathway for future TRLs. High-altitude 4D trajectory deconfliction requires balancing safety, mission objectives, restricted zones, and sovereignty constraints across multiple flight information regions. This rapidly becomes a computationally hard problem, where classical methods are unlikely to scale. A federated setup is indispensable since no single operator or authority can or will provide the data diversity required to model high-altitude trajectories; only by linking their local models can a realistic system-wide view emerge. On this federated foundation, quantum methods could potentially be applied in future TRLs.

We will analyse if quantum machine learning algorithms and hybrid approaches are able to provide scalable ansatzes to explore the large space of possible solutions, thus converging more rapidly to high-quality, conflict-free routes than classical only approaches may allow. Quantum enhanced algorithms could evaluate rare-event probabilities such as high-altitude conflict likelihood or space-weather-induced route degradation, leveraging distributed risk models trained by operators. Quantum kernel methods are able to classify trajectory feasibility under multiple constraints, refining the features provided.

While quantum computing offers significant benefits for high-altitude 4D trajectory deconfliction, it is essential to consider the potential obstacles that may arise during implementation, such as hardware limitations, regulatory obstacles, and difficulties in integrating quantum algorithms with existing classical systems. Addressing these concerns will help ensure that the proposed solution is feasible and effective in practice.

The project will analyse the basic application principles of appropriate hybrid quantum algorithms in ATM according to TRL 1.

Higher airspace, generally above flight level 550, is at present largely unused by commercial aviation. This relative vacancy offers a rare opportunity to introduce new technologies and working methods without the immediate constraints of dense traffic. By treating this environment as a testing ground, ATM can explore innovative approaches to integration, coordination, and trajectory management more rapidly than in lower airspace, where changes are slowed by operational complexity and legacy systems.

The expected output of the HORIZON case is therefore twofold: first, a conceptual framework for using federated learning to support collaborative trajectory modelling in higher airspace; and second, a roadmap identifying where quantum machine learning, and classification techniques could naturally extend this framework in later TRLs. By making the federated approach explicit as the necessary foundation, the case highlights that quantum computing is not a substitute for collaboration, but a complement that depends on federated inputs to be effective.

### **Exploratory Case 3: SHIELD (Strengthened Handling of Irregular Events and Landing Diversions)**

SHIELD addresses the challenge of diversion capacity and network resilience. Air traffic management must be able to cope with unexpected events such as severe weather, technical failures, medical emergencies, or security incidents. When diversions occur, the availability of suitable airports and the capacity of surrounding airspace become critical factors. At present, diversion planning is often managed locally, with each airline or ANSP focusing on its own area of responsibility. The wider network view is limited, and information on diversion capacity is not always shared across stakeholders. This leads to situations where capacity is underused in some areas while others face excessive pressure, reducing the resilience of the system as a whole.

A key difficulty is that the data required to build a comprehensive picture of diversion capacity is distributed and often sensitive. Airlines hold data on operational priorities and alternate airport preferences. Airports manage runway and parking availability, ground handling resources, and emergency procedures. ANSPs control the surrounding airspace and determine how many diversions can be safely accommodated. The Network Manager is responsible for regional coordination but does not always have access to timely or detailed information from all stakeholders. At a broader level, the European Aviation Crisis Coordination Cell (EACCC) is tasked with coordinating responses to major disruptions, but its effectiveness depends on the availability of accurate and up-to-date information from across the network. This fragmentation makes it difficult to anticipate the network-wide impact of diversions or to allocate resources effectively during disruptions.

The SHIELD case explores whether federated learning could support more effective modelling of diversion capacity. In this approach, each stakeholder would train a local model on its own data, capturing patterns such as airport throughput under different weather conditions or airline diversion preferences. These models could then be aggregated to create a broader picture of diversion capacity at the network level, without requiring any actor to release its raw operational data. Such a framework could improve situational awareness and decision-making during disruptive events, helping the system to absorb shocks more effectively.

At TRL 1, the work does not involve implementing such models but rather examining their feasibility. The analysis will define a conceptual framework showing how QFL might be applied to diversion capacity modelling. It will consider assumptions such as the availability of local data, the variability of conditions across airports, and the need for near-real-time aggregation during an unfolding disruption. Feasibility will be assessed using indicators such as whether federated approaches can capture the diversity of conditions across the network, how robust aggregated models would be to incomplete or delayed inputs, and what kinds of benefits might arise in terms of resilience.

The role of quantum computing is considered solely as a conceptual pathway for future TRLs. Diversion planning requires balancing multiple constraints (such as fuel states, alternate readiness, sector loads, and weather) while ensuring safety and minimising delay. This quickly becomes a largescale combinatorial optimisation problem, especially during cascading disruptions where time pressure is critical. For diversion capacity, federation is crucial: airlines, airports, ANSPs, and the Network Manager each control different pieces of the puzzle, and only their combined local models can reveal the network's true resilience during disruptions.

On this federated foundation, quantum techniques could potentially be applied in future TRLs. Kernelbased quantum anomaly detection could identify unusual diversion patterns from historical disruptions, enabling early recognition of bottlenecks in evolving crises. Quantum random walks could explore the connectivity graph of airports and sectors, rapidly highlighting underused alternates and feasible redirection chains. Quantum algorithms for probability estimation could assess the likelihood of alternate overload or excessive airborne holding for candidate diversion plans, improving safety assessments without the need for extensive classical Monte Carlo runs.

Hybrid quantumclassical methods (such as variational quantum circuits), the Quantum Approximate Optimization Algorithm (QAOA), and quantumannealing based solvers will be evaluated for the diversion allocation problem itself. These algorithms can encode the allocation task, producing high-quality allocations that minimise overload and delay even with lastminute changes, while classical pre and postprocessing handles data preparation and result validation.

The project will analyse the basic application principles of appropriate hybrid quantum algorithms in ATM according to TRL 1.

The expected output of the SHIELD case is a feasibility assessment of federated learning for diversion capacity modelling, coupled with a forward-looking roadmap showing how quantum optimisation, anomaly detection, and probability estimation could reinforce network resilience under disruption. By making the federated approach explicit as the foundation, the case highlights that quantum computing is not an alternative to collaboration but a complement that depends on federated inputs. In doing so, SHIELD will clarify whether distributed approaches can improve visibility and coordination during crises, supporting the long-term goal of a more resilient and robust European ATM system.

#### **Exploratory Case 4: CONTRADE (Climate-Optimised Navigation for TRAjectory DEsign)**

CONTRADE investigates contrail prediction to support environmentally optimised planning. Persistent contrails and the cirrus clouds they can form are recognised as a significant contributor to the climate impact of aviation. Avoiding contrail-forming regions can therefore reduce the environmental footprint of flights, but predicting where contrails will occur is technically challenging. Accurate prediction maps require the integration of meteorological data, complex atmospheric conditions, aircraft performance characteristics, and traffic patterns. At present, this integration is limited, and decision-making relies on simplified models that cannot capture the full variability of the prevailing atmospheric conditions.

The challenge lies in the distributed nature of the relevant data. Meteorological agencies produce forecasts of temperature, humidity, and wind fields at multiple altitudes. Airlines hold data on aircraft performance and operational routing preferences, including cost-index settings that determine whether the airline prioritises speed, fuel efficiency, or other operational factors. This information is highly sensitive, as it reflects commercial strategies and fuel-burn targets. ANSPs manage the airspace structure and flow constraints that determine whether avoidance trajectories are feasible. In addition, contrail mitigation itself involves a complex trade-off: avoiding contrail-forming regions may require flying at less efficient altitudes, leading to higher fuel burn and associated harmful emissions. Each actor therefore possesses part of the information needed, but there is no mechanism for combining it into shared contrail-risk maps without significant data exchange. Concerns over intellectual property, operational sensitivity, and the lack of common standards further hinder centralised approaches.

The CONTRADE case investigates whether federated learning could provide a framework for collaborative contrail-risk modelling. In this approach, each stakeholder would train local models that capture how their data contributes to contrail formation. Meteorological agencies could model atmospheric conditions, while aircraft manufacturers could contribute data on performance characteristics and contrail sensitivity of specific airframes and engines. Airlines would provide models based on their operational use of these aircraft, including cost-index preferences that determine whether flights are optimised for speed, fuel efficiency, or specific fuel-burn targets. ANSPs could contribute models that reflect operational feasibility in terms of sector capacity and airspace restrictions. Aggregating these models could produce risk maps that are richer and more accurate than those generated by any single actor, without requiring raw data to be shared.

At TRL 1, the work is limited to conceptual analysis. The methodology involves defining the types of local models that might be trained, the assumptions needed for aggregation, and the indicators that could be used to judge feasibility. These indicators include the potential improvement in the resolution and reliability of risk maps, the robustness of results when datasets are incomplete or inconsistent, and the scalability of the approach to larger geographic regions. The analysis will also consider limitations, such as the challenge of validating contrail predictions against observed outcomes and the computational demands of processing large volumes of atmospheric data.

The role of quantum computing is considered a potential future enabler. Contrail avoidance routing is inherently a multi-objective optimisation problem: flights must minimise climate forcing, fuel burn, and congestion simultaneously. Classical methods struggle as the number of route/altitude combinations grows.

Here, the federated setup is essential: only by combining local models from meteorological agencies, aircraft manufacturers, airlines, and ANSPs can the diverse data needed for contrail prediction be assembled without compromising sensitive inputs.

On this federated foundation, quantum methods could extend capability. Hybrid quantumclassical optimisation (such as variational quantum circuits or the Quantum Approximate Optimization Algorithm (QAOA)) could evaluate many potential route–altitude combinations more efficiently, enabling targeted contrail avoidance without degrading overall network performance. Quantum algorithms for probability estimation could assess the chance of contrail persistence along candidate routes using aggregated weather performance models, reducing the need for largescale classical sampling. Finally, quantum kernels could project aggregated weather performance data into high-dimensional feature spaces where persistent contrail conditions become linearly separable, improving the precision of contrail riskmaps.

The expected outcome of the CONTRADE case is to demonstrate whether federated learning can provide a practical basis for collaborative contrail-risk mapping, and to highlight where quantum methods could eventually enhance such models. Rather than positioning quantum as a separate solution, the analysis will explore how machine learning, estimation, and classification techniques can be layered on top of federated inputs to deliver more accurate and actionable risk maps. By extending QFL into the environmental domain, CONTRADE broadens the project's relevance: alongside efficiency, integration, and resilience, it directly supports SESAR's strategic objective of reducing aviation's climate impact and making Europe the most environmentally sustainable region to fly.

## **A Coordinated approach**

Taken together, the four exploratory cases ensure that the methodology is comprehensive and representative of the challenges facing European ATM. PREDICT addresses operational efficiency in day-to-day traffic management, HORIQON looks ahead to the integration of new entrants in higher airspace, SHIELD focuses on network resilience under disruption, and CONTRADE examines environmental sustainability. By covering efficiency, integration, resilience, and environment, the project avoids concentrating on a single niche problem and instead demonstrates how Quantum Federated Learning could, in principle, be applied across the full scope of the European ATM Master Plan. This breadth ensures that the feasibility analysis is robust, highlights both common and domain-specific challenges, and maximises the value of the results for guiding future SESAR research.

## **Transversal cross-cutting**

The four exploratory cases provide the primary structure for the research, but several cross-cutting considerations influence the methodology as a whole. These reflect the interdisciplinary nature of the work, the constraints under which the research must operate, and the principles that ensure it is consistent with European policy goals.

The project requires expertise from multiple domains. Air traffic management provides the operational context, defining the problems that need to be addressed and the performance criteria against which solutions must be judged. Machine learning contributes the methods for distributed model training, while quantum research provides the longer-term perspective on scalability and algorithmic possibilities. Regulatory and policy insight ensures that the proposed frameworks remain realistic in the institutional environment of European aviation. The combination of these perspectives is essential; no single discipline is capable of addressing the research questions in isolation. The methodology is therefore deliberately interdisciplinary, ensuring that technical feasibility is always considered in relation to operational relevance and policy constraints.

The assumptions underpinning the methodology are also common across the exploratory cases. These include the expectation that operational data will remain fragmented across multiple stakeholders, that privacy and sovereignty concerns will prevent full centralisation, and that datasets will be heterogeneous in both quality and structure. The feasibility analyses therefore focus on whether federated learning can function under these conditions rather than assuming idealised data availability. A further assumption is that validation of distributed models in a safety-critical domain will pose challenges that cannot be fully resolved at TRL 1. Instead, the project aims to identify those challenges explicitly, providing a roadmap for how they could be addressed in higher-TRL work.

The research is conducted in accordance with the “do no significant harm” principle of the EU Taxonomy Regulation. The work involves only conceptual frameworks and analyses, and does not generate environmental impacts directly. Its contribution is instead positive, particularly in the CONTRADE case, where the methodology is explicitly directed towards reducing the climate impact of aviation by enabling contrail avoidance strategies. The project also contributes indirectly to sustainability by exploring methods that may improve efficiency and resilience, thereby reducing unnecessary fuel burn.

Because the project involves the application of machine learning concepts, attention is given to the robustness and explainability of such methods. Federated learning introduces specific risks, including the potential for bias if local datasets are unbalanced and the difficulty of validating aggregated models when raw data is not accessible. These issues will be examined systematically in the feasibility analyses, and potential safeguards will be identified. The project anticipates that any future integration of quantum methods will require similar attention to transparency and verification, particularly in a safety-critical environment. The project therefore aligns with European principles on trustworthy AI by ensuring that robustness, reproducibility, and explainability are considered from the outset, even at TRL 1.

In summary, the methodology integrates expertise from multiple disciplines, is grounded in explicit assumptions about the ATM environment, complies with European sustainability principles, and recognises the importance of robustness and explainability in AI methods. These cross-cutting considerations ensure that the exploratory analyses are not only technically sound but also aligned with the broader requirements of the aviation system and the European research framework.

## **Open Scientific Principles and Responsible Research**

The methodology also incorporates principles of open science and responsible research management. Although the project is exploratory and limited to TRL 1, the outputs include conceptual frameworks, feasibility assessments, and analytical results that can be openly shared. Publications will be made available in open-access journals or repositories in line with Horizon Europe requirements. Preprints and working papers will be released where appropriate to support early dissemination and peer feedback. Models and analytical frameworks developed during

the project will be documented and, where possible, shared in a way that enables scrutiny and reuse by the wider research community.

Research data management follows the FAIR principles (Findable, Accessible, Interoperable, Reusable). The project will not generate new operational datasets from its activities. Instead, it will make use of modest datasets that may include synthetic data created for illustrative purposes, publicly available sources such as EUROCONTROL performance statistics or open meteorological data, and structured documentation of modelling assumptions. These materials will be curated with clear documentation of provenance, scope, and format. A data management plan will be produced by month six of the project and updated as required. Persistent identifiers will be used to ensure findability, and trusted repositories will be selected for long-term preservation. Access will be granted in line with open-access requirements, while any data subject to restrictions for confidentiality or security will be documented with clear justification. Reusability will be supported by applying open licences where appropriate and by providing explanatory documentation of models and algorithms.

The project recognises that the integration of a gender dimension in research content is mandatory under Horizon Europe unless clearly irrelevant. In the case of QUANTAIR, the subject matter involves the conceptual exploration of federated learning and quantum computing in ATM. The scientific and operational questions addressed are not influenced by biological sex or social gender factors, and the research outputs do not have a differentiated impact along those lines. For this reason, the gender dimension is not directly relevant to the research content. However, the project will ensure that dissemination and communication activities are inclusive, using language and imagery that reflect diversity, and ensuring that engagement with stakeholders and end users is representative of the community.

These measures ensure that QUANTAIR is aligned with the principles of open and responsible science. The outputs will be accessible to the wider research community, the data will be managed transparently, and inclusivity will be ensured in dissemination and communication. Even at TRL 1, these practices increase the value of the research by making it reproducible, transparent, and usable as a foundation for future SESAR work.

### **Leveraging National and International R&I Activities**

The proposed research builds directly upon major European R&I activities and SESAR strategic priorities, ensuring continuity and maximising return on investment from prior programmes. One important foundation is *AI-CHAIN (EUROCONTROL, 2022–2024)*, which validated the use of collaborative machine learning on distributed, privacy-sensitive ATM datasets, including Estimated Take-Off Times (ETOT) and trajectory prediction. *AI-CHAIN* showed that federated models could deliver improved accuracy without requiring raw data sharing. QUANTAIR will extend these results by exploring Quantum Federated Learning (QFL) as a means to address the scalability and machine learning challenges identified in *AI-CHAIN*. This will be achieved by reusing *AI-CHAIN* benchmarks, adapting its federated architectures, and maintaining close contact with EUROCONTROL stakeholders to guarantee methodological alignment.

The *SESAR Master Plan 2025* provides further direction. It explicitly recognises that “machine learning is used in combination with conventional deterministic algorithms for trajectory prediction, ATFM and ATC conflict detection” and calls for the development of AI capabilities enabling the next generation of ATM platforms. It also underlines the importance of “virtualisation and cyber-secure data sharing” and identifies “AI for aviation” as an industrial research priority. Furthermore, the Master Plan stresses the need for ATM modernisation to shift towards “a modern, data-driven and cloud-based service-oriented architecture,” facilitating privacy-preserving and interoperable collaboration across stakeholders. QUANTAIR responds to these calls by investigating QFL as a privacy-preserving AI mechanism to overcome sovereignty and sensitivity barriers that prevent centralised data sharing, aligning its exploratory cases (departure predictability, higher airspace integration, diversion capacity, and contrail avoidance) with SESAR Strategic Deployment Objectives, notably SDO 3 on Dynamic Airspace Configuration, SDO 5 on the Transformation to Trajectory-Based Operations (TBO), and SDO 8 on Service-Oriented Delivery Models. In doing so, the project contributes to SESAR’s long-term roll-out objectives, directly addressing the shift towards SDO 5 for precise 4D trajectory optimisation, enabling resilience and scalability in line with SDO 3, and supporting the transition to SDO 8. It also adds value to SESAR’s automation and AI research

stream, particularly in the areas of high-dimensional optimisation, safety-critical validation, and cross-stakeholder model aggregation.

Beyond SESAR, QUANTAIR will connect to the broader European and international R&I ecosystem. It will ensure consistency with *Digital Sky Demonstrators*, align its environmental work on contrail avoidance and climate-optimised trajectories with the *Clean Aviation and Zero-Emission Aircraft programmes*, and take into account international initiatives such as ICAO, FAA NextGen, and NASA ATM-X to ensure interoperability and standardisation.

To embed its results in the SESAR ecosystem, QUANTAIR will feed its conceptual frameworks and feasibility analyses into SESAR repositories and knowledge-sharing channels, organise technical workshops with AI-CHAIN and SESAR 3 JU expert groups to align assumptions and validation methods, and publish results in open-access venues while maintaining strong links with SESAR Innovation Days and technical consultation fora. In this way, the project will not duplicate previous work but rather extend and complement SESAR's federated learning strategy, anchoring its results in the Master Plan 2025 vision of a Digital European Sky enabled by AI, privacy-preserving data sharing, and service-oriented architectures.

### **Interdisciplinary Integration of Expertise**

The consortium combines three complementary disciplines essential to the project: quantum algorithms, distributed orchestration, and operational ATM. DLR QSOC contributes expertise in quantum computing, quantum machine learning and optimisation, leading the scientific feasibility assessment of applying quantum methods to federated learning. Qoro Quantum brings knowledge of distributed systems and orchestration, ensuring that the frameworks are technically realistic, privacy-preserving, and aligned with SESAR's transition to service-oriented architectures. SkyNav International adds operational ATM and navigation expertise, embedding safety, regulatory, and interoperability requirements into the exploratory cases so that the results reflect real-world constraints and stakeholder needs.

Integration will be achieved through co-design workshops, joint development of conceptual frameworks, and systematic cross-review of results. DLR will validate the scientific soundness of the approaches, Qoro will ensure architectural robustness and scalability, and SkyNav will test operational relevance against SESAR's Strategic Deployment Objectives. This structure ensures that the project outputs are not isolated academic exercises but practical and credible contributions to SESAR's research pipeline, providing actionable pathways for future work on Quantum Federated Learning in ATM.

The combined skill set is both unique and directly relevant to the project's aims. Quantum algorithm research alone cannot address operational feasibility; distributed orchestration expertise alone cannot resolve ATM privacy and sovereignty barriers; and operational ATM expertise alone cannot scale to emerging computational methods. By uniting these three perspectives, the consortium can evaluate Quantum Federated Learning in a way no single partner could achieve in isolation. This integration ensures that the project bridges the gap between theoretical research, technical system design, and operational ATM practice, delivering results that are both innovative and usable within the SESAR framework.

### **Role of Social Sciences and Humanities (SSH)**

The proposed work does not directly require integration of Social Sciences and Humanities (SSH) disciplines, as the focus is on the conceptual feasibility of Quantum Federated Learning for Air Traffic Management at TRL 1. The research is primarily technical, combining quantum algorithmics, distributed computing architectures, and operational ATM knowledge. Its outputs will be high-level frameworks, feasibility analyses, and pathways for future research rather than social or behavioural studies.

That said, the consortium recognises that ATM modernisation is a socio-technical transformation. The SESAR Master Plan 2025 explicitly highlights the evolving *role of human operators in human-machine teaming* and the

need for *trustworthy AI-based systems* to ensure adoption in safety-critical contexts. These aspects fall outside the TRL 1 scope of QUANTAIR but are highly relevant to subsequent SESAR research. The project will therefore remain attentive to SSH findings from related SESAR activities on data governance, human–machine trust, and stakeholder acceptance, and ensure that its conceptual frameworks are compatible with future interdisciplinary studies. In this way, while SSH integration is not required for the current exploratory work, the project establishes a technical foundation that can be enriched by SSH contributions in later phases.

## Research Data Management and Research Outputs

QUANTAIR is scoped at TRL 1 and will not generate large operational datasets. The main outputs will be *conceptual frameworks, feasibility analyses, modelling artefacts, and small synthetic datasets* used to test federated learning and quantum machine learning concepts. Outputs will be textual (reports, frameworks), numerical (synthetic trajectory/weather data), and software-based (lightweight code templates), with total volume <10 GB. Where public datasets (e.g. Eurocontrol performance reports, meteorological data) are combined with synthetic data, provenance will be documented.

*Findability.* All outputs will be assigned persistent identifiers (DOIs) via trusted repositories. Metadata will follow Horizon Europe requirements to ensure indexing and searchability.

*Accessibility.* Deliverables and publications will be open access. Software and modelling artefacts will be hosted on GitHub. Sensitive information, if any, will be restricted but metadata will remain visible for verification. Importantly, in line with the federated learning approach, *only trained model weights and parameters will be shared*, never raw stakeholder data.

*Interoperability.* Data and code will be provided in non-proprietary formats (CSV, JSON, Python notebooks). Metadata will use recognised standards (e.g. Dublin Core) and SESAR taxonomies to ensure compatibility with other ATM projects.

*Reusability.* Outputs will carry open licenses (CC-BY for documents, Apache 2.0 or MIT for code) to enable reuse and integration into future SESAR projects. Documentation and environment files will accompany software to support reproducibility.

*Curation and Storage.* DLR will curate scientific data and models, Qoro will maintain software repositories, and SkyNav will validate operational relevance. Outputs will be preserved in institutional repositories for at least ten years. A Data Management Plan will be delivered by Month 6 and updated before project close.

This approach ensures compliance with FAIR principles and makes results directly reusable by the SESAR community in follow-on TRL 2–3 activities.

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## 2. Impact #@IMP-ACT-IA@#

### 2.1 Project's pathways towards impact

The results of QUANTAIR are expected to make a meaningful contribution to the SESAR programme's medium-term outcomes and to the wider long-term impacts described in the Work Programme. The project is positioned at TRL 1, and its immediate outputs are conceptual frameworks and feasibility assessments. The impact therefore lies not in the delivery of deployable systems, but in shaping the research agenda by establishing whether Quantum Federated Learning (QFL) provides a credible new approach for ATM. By clarifying the potential scope, identifying

enabling conditions, and defining pathways to higher-TRL research, the project provides the knowledge base required for Europe to maintain leadership in this field, both in federated approaches to ATM and in the application of emerging quantum methods for large-scale optimisation and risk assessment.

The pathways to impact extend across four domains that correspond to the project's exploratory cases. Each case addresses a distinct challenge within the ATM Master Plan, ensuring that the project's contribution is broad and relevant.

The PREDICT case supports efficiency and capacity by addressing the challenge of departure predictability and slot allocation. Delays at departure propagate through the network, and current models are limited because the relevant information is fragmented across stakeholders. By investigating whether QFL could enable collaborative prediction without compromising data privacy, the project contributes to the SESAR objective of improving predictability as a foundation for advanced demand–capacity balancing. Even at TRL 1, the project identifies how federated approaches might reduce uncertainty in departure planning and sets out pathways for higher-TRL research that could ultimately improve the efficiency of European airspace.

The HORIZON case supports the safe integration of new entrants in higher airspace. The growing presence of high-altitude platforms, sub-orbital flights, super- and hyper-sonic vehicles, and space transport operations introduces uncertainty into ATM, and the lack of shared data across stakeholders makes it difficult to model these trajectories. QUANTAIR explores whether QFL could provide a framework for collaborative trajectory modelling under strict confidentiality constraints. This aligns with SESAR's objective of ensuring the seamless integration of all airspace users and supports the EASA Higher Airspace Operations roadmap. It also complements ICAO's ongoing work in the ATMOPS Panel, ATMRPP, and ICAO Paris, where the need for new coordination mechanisms for high-altitude operations has been identified. The project's outputs provide a research basis that can inform both European and global efforts in this domain.

The SHIELD case contributes to resilience and contingency management by addressing diversion handling and rapid network reorganisation. Current approaches are fragmented, with limited visibility of network-wide capacity during disruptions. By examining whether QFL could enable distributed modelling of diversion capacity, the project explores how resilience could be enhanced without requiring stakeholders to share sensitive operational data. This directly supports SESAR's long-term ambition of building a more resilient Digital European Sky. It also aligns with ICAO's GATMOC, which emphasises the need for globally harmonised contingency procedures and collaborative decision-making. By identifying how distributed modelling could underpin these objectives, QUANTAIR contributes to the policy and research foundations required to manage disruptions more effectively at both regional and global levels.

The CONTRADE case contributes to environmental sustainability by considering contrail prediction mapping. Persistent contrails represent one of aviation's most significant climate impacts, but predicting them requires combining data from meteorological agencies, airlines, and ANSPs. QUANTAIR explores whether QFL could be used to generate richer and more reliable contrail prediction maps without requiring raw data exchange. This supports SESAR's environmental pillar, directly addresses the Horizon Europe priority of making Europe the most environmentally friendly region to fly, and complements wider European climate objectives. It also aligns with ICAO's sustainability agenda by exploring methods to reduce the non-CO<sub>2</sub> impacts of aviation. By identifying pathways for integrating distributed contrail modelling into ATM processes, the project sets the stage for future research that could enable environmentally optimised trajectory planning.

Across these domains, the project contributes to the realisation of the Digital European Sky vision. QFL represents a novel way of enabling scalable services supported by a digital ecosystem, where distributed data sources can contribute to shared models without compromising sovereignty or security. This directly addresses one of the structural challenges of the Digital European Sky: how to build a networked architecture that is both data-rich and privacy-preserving. While QUANTAIR does not deliver technical systems, it identifies how distributed and potentially quantum-enabled approaches could contribute to this architecture in the longer term, by combining federated models with quantum machine learning, estimation, and classification methods capable of handling the

scale and complexity of future ATM services.

The expected impacts also extend beyond SESAR. By addressing data-sharing challenges in ATM through QFL, the project informs EASA's regulatory strategies for higher airspace, ICAO's work on contingency and environmental management, and the global framework established by the GATMOC. It provides European stakeholders with early insight into how quantum methods might eventually support large-scale, secure, and collaborative ATM services, strengthening Europe's position as a leader in both ATM modernisation and quantum research.

The scale and significance of these impacts must be interpreted in the context of TRL 1. The project does not produce immediate operational benefits, but it does set the agenda for higher-TRL work that could. Its contribution lies in providing the first structured assessment of QFL in ATM, across efficiency, new entrants, resilience, and sustainability. By demonstrating that the concept is feasible in principle, QUANTAIR enables future SESAR projects to pursue targeted TRL 2–3 developments with confidence. If successful, this pathway could, over the medium to long term, support Europe's ambition to deliver the most environmentally friendly, efficient, resilient, and digitally integrated ATM system in the world.

The achievement of these impacts depends on several factors beyond the scope of the project. Progress in quantum hardware and algorithms may be slower than anticipated, delaying the availability of scalable quantum methods. Conversely, rapid advances could create opportunities earlier than expected, underlining the importance of SESAR being prepared with conceptual frameworks and use cases that can be taken up as soon as technology allows. Stakeholders may also be cautious about adopting federated approaches if they perceive the governance, validation, or liability arrangements as unclear. Regulatory frameworks for higher airspace and environmental modelling may evolve at different speeds across regions, creating asymmetries in adoption. These are not risks to the project itself, but barriers that may influence whether the pathways identified can be realised in practice. By identifying them early, QUANTAIR ensures that future SESAR and policy work can anticipate these challenges and address them systematically.

## 2.2 Measures to maximise impact - Dissemination, exploitation and communication #COM-DIS-VIS-CDV@#

The project adopts a proportionate but structured approach to dissemination, exploitation, and communication to ensure that its results are visible, usable, and positioned to generate impact beyond the immediate project lifetime. At TRL 1, the outputs are primarily conceptual frameworks, feasibility analyses, and structured assessments of Quantum Federated Learning (QFL) in ATM. The plan therefore emphasises knowledge sharing, policy relevance, and preparing pathways for follow-on research, rather than commercialisation.

Communication activities will be modest but continuous, designed to ensure visibility of the project and to inform a wider audience about its purpose and benefits. The consortium will establish a project website as a primary information point, complemented by short news items and updates on professional social media platforms. These activities will highlight the relevance of quantum computing and federated learning to aviation in terms understandable to non-specialists, showing how such research contributes to efficiency, resilience, sustainability, and the safe integration of new entrants. Outreach will be proportionate to the scale of the project, relying on existing channels within the consortium, which collectively offers a global and cross-disciplinary network of contacts across research, industry, and regulatory communities.

Dissemination will focus on the scientific and technical community, particularly those engaged in ATM modernisation and quantum computing research. Results will be published in open-access journals and presented at conferences such as SESAR Innovation Days and relevant academic venues. Where appropriate, preprints will be released to encourage early engagement and peer feedback. The project will also contribute to SESAR knowledge-sharing channels and technical workshops to ensure that results feed directly into the wider programme. Dissemination will be coordinated so that outputs are available in formats that are accessible and reusable, consistent with open science practices.

Exploitation will take place primarily through institutional and programme channels. The conceptual frameworks and feasibility assessments generated by QUANTAIR are intended for direct uptake by future SESAR research at TRL 2–3. They also provide material of interest to ATM stakeholders, who can use the findings to inform early thinking on data-sharing models and the potential of federated approaches. Regulators such as EASA, and international bodies such as ICAO, will also benefit from the insights generated, particularly in areas of higher airspace operations, contingency management, and environmental sustainability. Although no commercial exploitation is expected at TRL 1, the intellectual outputs represent a foundation that can be carried forward in subsequent projects or policy initiatives. Intellectual property will be managed in line with Horizon Europe rules, with ownership of results defined in the consortium agreement. Given the conceptual nature of the work, results will primarily be disseminated openly, with protection measures applied only if necessary to safeguard future exploitation potential.

Feedback to policy measures is an integral part of the plan. The project's outputs are directly relevant to ongoing European and international discussions, including EASA's Higher Airspace Operations roadmap, ICAO's ATMOPS and ATMRPP panels, and the global framework provided by the GATMOC. By sharing findings through technical workshops, regulatory consultations, and programme-level interactions, QUANTAIR will provide evidence to support policy development and help shape future research agendas.

This first version of the dissemination and exploitation plan provides a framework that is appropriate to the scope and maturity of the project. A detailed plan will be produced as a mandatory deliverable within three months of project start and updated as necessary during the project. Together, these measures will ensure that the outputs of QUANTAIR are widely disseminated, appropriately exploited, and communicated effectively to the scientific community, policymakers, stakeholders, and the public.

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## 2.3 Summary

### KEY ELEMENT OF THE IMPACT SECTION

#### SPECIFIC NEEDS

*What are the specific needs that triggered this project?*

Air Traffic Management (ATM) faces structural barriers to data sharing, scalability, and resilience. Operational datasets are fragmented across airlines, ANSPs, airports, and regulators, making centralised modelling infeasible due to sovereignty, confidentiality, and security constraints. At the same time, growing system complexity (multi-flight optimisation, integration of higher-airspace entrants, resilience to disruption, and contrail avoidance pushes classical methods to their limits. Europe requires a structured assessment of whether Quantum Federated Learning (QFL) can provide a privacy-preserving, scalable framework for collaborative modelling that is aligned with SESAR's Digital European Sky ambitions.

#### EXPECTED RESULTS

What do you expect to generate by the end of the project?

By the end of the project, QUANTAIR will deliver:

- Conceptual frameworks for applying QFL to four representative ATM challenges (departure predictability, higher-airspace integration, diversion capacity, contrail avoidance).
- Feasibility analyses identifying assumptions, indicators, potential benefits, and limitations.
- Roadmaps defining steps towards TRL 2–3, including conditions under which quantum methods may provide added value.
- Open, reproducible outputs (reports, models, synthetic datasets) supporting future SESAR research.

#### D & E & C MEASURES

What dissemination, exploitation and communication measures will you apply to the results?

Results will be communicated through a dedicated website, social media updates, and targeted news items for non-specialist audiences. Dissemination to the scientific community will use open-access journals, preprints, and conferences (SESAR Innovation Days, quantum/AI venues). Exploitation will occur through SESAR follow-on projects, input to regulatory roadmaps (EASA, ICAO), and alignment with international R&I activities. All outputs will be openly shared under FAIR principles, with repositories ensuring transparency and reuse. A mid-project and final dissemination event will engage stakeholders directly.

**TARGET GROUPS**

*Who will use or further up-take the results of the project? Who will benefit from the results of the project?*

- SESAR research community and Joint Undertaking programme teams.
- ATM operational stakeholders (airlines, ANSPs, airports, Network Manager).
- Regulatory and policy bodies (EASA, ICAO panels, European Commission).
- Academic and industrial researchers in federated learning, quantum computing, and AI for aviation.
- Wider environmental and climate policy stakeholders interested in contrail mitigation and sustainable aviation.

**OUTCOMES**

*What change do you expect to see after successful dissemination and exploitation of project results to the target group(s)?*

The project will provide the first structured evidence base for QFL in ATM, enabling SESAR to judge whether and how to pursue higher-TRL development. Stakeholders will gain conceptual frameworks that inform data-sharing models, integration of new entrants, resilience strategies, and climate-optimised navigation. Dissemination ensures that results are embedded in SESAR roadmaps, regulatory debates, and international standardisation efforts.

**IMPACTS**

*What are the expected wider scientific, economic and societal effects of the project contributing to the expected impacts outlined in the respective destination in the work programme?*

Wider impacts include:

- **Scientific:** establishment of benchmarks and methodologies for QFL across distributed, safety-critical domains.
- **Economic:** foundations for more efficient, resilient, and sustainable European ATM, reducing costs from delay, disruption, and inefficient fuel burn.
- **Societal:** enhanced resilience of the air transport system, reduced climate impact via contrail avoidance, and strengthened European leadership in privacy-preserving AI and quantum research. In the longer term, QUANTAIR contributes directly to the Work Programme objective of delivering the most environmentally friendly, efficient, resilient, and digitally integrated ATM system worldwide.

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refine and consolidate. By the end of month 18, the core research outputs are complete and ready for review.

The final work package (WP4) is dedicated to ensuring that the results are not only written down but also communicated, preserved, and made available for exploitation. This includes the production of the final exploitation and impact strategy, compliance with open science and repository requirements, and the organisation of a final event to share the findings with both the research community and operational stakeholders. Dedicating a separate work package to this task provides clarity and ensures that dissemination and exploitation are not left to the margins of project management, but treated as substantive outputs in their own right.

The sequencing of activities is straightforward. WP2 provides the initial research outputs and ensures that the consortium can demonstrate progress at the interim review. WP3 takes these results forward, deepening the analysis and completing the research effort. WP4 then consolidates the outputs and ensures their visibility. WP1 runs throughout, providing governance, coordination, and quality assurance. The interdependencies are limited but clear: WP2 feeds WP3, WP3 feeds WP4, and WP1 underpins the whole process. This simplicity is deliberate, allowing the consortium to concentrate on the substance of the research rather than the mechanics of coordination.

Overall, the work plan balances clarity with proportionality. The structure makes it possible to demonstrate progress at the interim and final stages, while keeping the number of work packages aligned to the scale of a TRL 1 activity. Most of the effort is concentrated in the two research phases, where the exploratory cases are scoped, analysed, and refined. Management, communication, and exploitation activities run in parallel but remain light and focused, ensuring that resources are directed primarily to the research. In this way, the plan ensures that the project's objectives can be met within the available timeframe and that the results are prepared for further development in future SESAR research.

### 3.2 Capacity of participants and consortium as a whole #@CON-SOR-CS@# #@PRJ-MGT-PM@#

The consortium for QUANTAIR is deliberately small and highly focused. It brings together three partners with complementary expertise that together cover the full range of knowledge needed for exploratory research on Quantum Federated Learning in Air Traffic Management. This structure avoids fragmentation while ensuring that the project objectives are addressed from scientific, operational, and regulatory perspectives.

The disciplinary scope is broad. The project combines expertise in advanced computing and federated learning, in ATM modelling and SESAR research methods, and in the operational and regulatory environment of European aviation. This inter-disciplinary mix is central to the project's feasibility. Quantum computing and federated learning alone cannot be meaningfully assessed without ATM expertise to define realistic use cases and indicators, and ATM modelling by itself cannot explore the potential of novel computational paradigms. By combining the three, the project ensures that technical exploration remains grounded in operational reality, while operational questions are informed by the latest research in computing and data science.

Each partner contributes distinct capabilities. One partner provides established experience in ATM research and modelling, including the frameworks and methods that underpin SESAR exploratory research. A second partner contributes deep expertise in quantum computing and federated learning, with access to state-of-the-art algorithmic research and computational frameworks. The third partner contributes operational and regulatory insight, drawing on direct experience with ATM stakeholders, industry bodies, and international regulators. This combination ensures that the project not only develops and analyses conceptual frameworks, but also tests their plausibility in the context of the real ATM system.

The consortium also has access to the infrastructures required for this work. The ATM research partner maintains modelling platforms and reference datasets that support exploratory analysis in a SESAR context. The quantum computing partner has access to quantum simulators and federated learning frameworks suitable for conceptual testing. The operational partner brings established stakeholder networks and access to policy and regulatory processes that allow the project results to be evaluated in relation to real-world governance and adoption constraints. Together, these infrastructures provide the project with all the tools needed for TRL 1 exploration.

The partners complement one another across the research chain. The computing expertise ensures that new methods are explored rigorously, the ATM research expertise ensures that methods are tested against relevant operational questions, and the operational expertise ensures that outputs are credible for stakeholders and aligned with regulatory processes. None of these alone would be sufficient; together they provide a coherent and proportionate team for the project.

Cross-cutting considerations are also addressed. The consortium applies open science practices in line with Horizon Europe requirements, including publication in open-access journals, sharing of analytical frameworks, and compliance with FAIR data management principles. The project also acknowledges that the integration of the gender dimension in R&I is not directly relevant to the scientific content, since the research addresses computational and operational questions without differentiated gender impacts. However, dissemination and communication activities will be inclusive, with attention to diversity in language, imagery, and stakeholder engagement.

Overall, the consortium is proportionate to the scale and ambition of QUANTAIR. It combines complementary expertise in computing, ATM research, and operational regulation, has access to the required infrastructures, and is well positioned to deliver the project's objectives while preparing the ground for future SESAR research at higher maturity levels.

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### Tables for section 3.1

**Table 3.1a: List of work packages**

Work package No	Work Package Title	Lead Participant No	Lead Participant Short Name	Person-Months	Start Month	End month
1	Project Management & CDE	1	DLR	10	01	24
2	QUANTAIR Research Activity, Part A	2	Qoro	18	01	09
3	QUANTAIR Research Activity, Part B	2	Qoro	18	09	18
4	CDE Wrap-up	3	SkyNav	4	18	24

**Table 3.1b: Work package description**

For each work package:

<b>Work package number</b>	1
<b>Work package title</b>	Project Management & CDE

## Objectives

This work package ensures that the project is managed efficiently and in full alignment with Horizon Europe and SESAR 3 JU requirements. It provides governance, financial and administrative management, reporting, and quality assurance across the project. It also covers the planning and execution of communication, dissemination, exploitation, and data management activities, ensuring that results are properly documented and shared. In doing so, it establishes the framework for the project's visibility and impact, and leads directly into the final CDE phase (WP4) where these activities are consolidated and completed.

The specific objectives are to:

1. Ensure effective project governance and coordination, including quality assurance and compliance with SESAR 3 JU requirements.
2. Establish and maintain the project's management framework through delivery and updating of the Project Management Plan (PMP), Data Management Plan (DMP), and related documentation.
3. Provide timely and accurate reporting, including periodic reports and preparation for SESAR reviews.
4. Plan and implement communication, dissemination, and exploitation activities, including the Communication and Dissemination Plan (CDE), project website, online presence, and events.
5. Support long-term uptake and impact by drafting and finalising the exploitation and impact strategy, ensuring compliance with open science and FAIR data requirements, and preparing the transition into the final CDE wrap-up phase.

## Description of work

Governance will be provided by a Project Management Board (PMB), chaired by the Coordinator and composed of one representative from each partner. The PMB will meet quarterly to review progress, monitor risks, and take decisions on both technical and administrative issues. The Project Coordinator will manage day-to-day operations and act as the primary interface with SESAR 3 JU. A Kick-off Meeting (KoM) in Month 1 will formally establish working procedures, confirm roles and responsibilities, and launch project activities.

A Project Management Plan (PMP) will be delivered in Month 3 to formalise procedures for governance, reporting, quality assurance, and risk management. This will include internal review mechanisms to ensure that all deliverables are technically sound, consistent, and aligned with SESAR standards before submission. The PMP will be updated at mid-point (M12) to reflect lessons learned and adjustments. Progress will be monitored continuously, with corrective measures applied promptly in case of deviations.

Research data will be managed under a Data Management Plan (DMP), produced in Month 3 and updated as needed. The DMP will describe the types of data generated, their provenance, and how FAIR principles (Findable, Accessible, Interoperable, Reusable) will be applied. Where confidentiality or security constraints apply, these will be documented with clear justification. Datasets and analytical outputs will be preserved in trusted repositories with persistent identifiers to ensure long-term access.

The Communication, Dissemination and Exploitation (CDE) Plan will also be delivered in Month 3 and updated at least once during the project (M12). It will define the channels and activities to ensure visibility and uptake of results, including the project website, open-access publications, contributions to SESAR dissemination events, and targeted outreach to scientific, operational, and policy audiences. A mid-project dissemination event will be held at M12 to share initial results and prepare the ground for the final wrap-up phase. WP1 therefore establishes the framework for CDE activities, while the final consolidation and impact reporting are delivered in WP4.

Exploitation measures will focus on enabling results to be taken forward in future SESAR research and by stakeholders such as ANSPs, regulators, and ICAO working groups. Intellectual property will be managed in

line with Horizon Europe rules and the consortium agreement, with a principle of openness unless specific protection is required to preserve exploitation potential. A draft post-research exploitation and impact strategy will be delivered in M24, which then feeds into WP4 for finalisation and promulgation.

Reporting will cover all mandatory submissions to SESAR 3 JU, including periodic reports at the end of each reporting period and the final project report at closure. SESAR review meetings will be treated as milestones in project governance. The consortium will prepare collectively for these reviews, ensuring that deliverables, presentations, and supporting evidence are complete and coherent. Internal review meetings will be scheduled in advance to prepare for each review and ensure alignment with SESAR expectations.

<b>Work package number</b>	2
<b>Work package title</b>	QUANTAIR Research Activity, Part A

**Objectives**

This work package establishes the conceptual and analytical foundations for applying Quantum Federated Learning (QFL) in Air Traffic Management. It provides the first structured exploration of how QFL could be framed within ATM constraints, how it might operate across distributed stakeholders, and what benefits or limitations may arise in different operational contexts. The emphasis is on scoping and structuring the research, and on producing verifiable outputs that are consistent with the TRL 1 nature of the project and suitable for review at the end of the first reporting period.

The specific objectives are to:

1. Define the conceptual framework for QFL in ATM, including assumptions on data distribution, privacy constraints, stakeholder behaviour, and computational resources.
2. Scope and characterise the four exploratory cases (PREDICT, HORIZON, SHIELD, CONTRADE), identifying the ATM challenges they represent and their relevance to SESAR priorities.
3. Develop baseline analytical models for each case, using synthetic data and structured representations of ATM processes to test conceptual feasibility.
4. Identify potential benefits, limitations, and open research questions arising from each case, recording these in interim deliverables.
5. Produce a consolidated interim report that synthesises findings across all cases and highlights cross-cutting requirements for advancing to TRL 2–3 research.

**Description of work**

The purpose of WP2 is to establish the conceptual and analytical basis of the project. The first nine months are dedicated to scoping the research in a structured way, producing tangible outputs that allow progress to be verified at the interim review. This reflects both the TRL 1 nature of QUANTAIR and the SESAR requirement for clear evidence of achievement within the first reporting period. The work ensures that Quantum Federated Learning is not treated as an abstract concept, but is defined in relation to the constraints and opportunities of Air Traffic Management.

The work begins with the development of the conceptual framework for QFL in ATM. This framework sets out the core assumptions on which the research is based, including the distribution and heterogeneity of data sources, the privacy constraints that prevent raw data exchange, the behavioural preferences of stakeholders

such as airlines’ cost-index settings, and the computational resources that can realistically be assumed at different maturity levels. It also addresses governance considerations, such as how trust and participation are established between stakeholders, and what indicators of feasibility can be applied at TRL 1. This step creates the common reference point against which each exploratory case can be analysed.

Each of the four exploratory cases is then scoped in detail. For PREDICT, HORIZON, SHIELD, and CONTRADE, the partners will describe the operational challenge, its connection to SESAR Master Plan objectives, and the specific way in which QFL could apply. This scoping ensures that the project covers a broad spectrum of ATM challenges (predictability, high-altitude integration, resilience, and environmental optimisation) rather than variations on a single theme. It also defines for each case the boundaries of what can be assessed at TRL 1, the types of data or models that would be relevant, and the expected indicators of benefit or limitation.

Once the scoping is complete, baseline analytical models will be developed for each case. These models will use synthetic data and structured representations of ATM processes, rather than operational datasets, to ensure that the work remains feasible within a TRL 1 scope. The models are intended to test conceptual feasibility: whether QFL can in principle represent the ATM dynamics involved, whether stakeholder constraints can be incorporated in a distributed way, and whether potential benefits can be expressed in measurable terms. This activity requires close collaboration between the partners: the quantum computing expertise to design federated and distributed model structures, the ATM research expertise to represent operational processes, and the operational expertise to validate the plausibility of assumptions.

Findings from the framework and case models will be captured continuously and compared across cases. This cross-case analysis is a critical part of WP2: it ensures that common themes are identified, that lessons from one case inform the others, and that gaps and limitations are recorded in a way that can guide WP3. Interim deliverables, including the Exploratory Research Plan (ERP), Exploratory Research Report (ERR), and Concept Outlines, provide formal records of this work. These deliverables will undergo internal review and PMB approval before submission to SESAR 3 JU, ensuring technical soundness and alignment with SESAR standards.

Resource allocation in WP2 reflects the intensity of this phase. All three partners are engaged in parallel across the four cases, with effort distributed according to expertise: ATM research leads the case scoping and conceptual assumptions, the quantum partner leads federated modelling structures, and the operational partner ensures realism, regulatory alignment, and traceability to stakeholder concerns. The effort in WP2 is proportionately the largest, as it defines the trajectory for the remainder of the project and provides the evidence required at the first review milestone.

By the end of WP2, the project will have established a conceptual framework for QFL in ATM, scoped and modelled its application across four distinct operational contexts, and produced the first structured assessment of feasibility. These outputs provide the foundation for refinement and integration in WP3, and allow SESAR to judge progress at the interim stage with confidence that the project is on track.

<b>Work package number</b>	3
<b>Work package title</b>	QUANTAIR Research Activity, Part B

**Objectives**

This work package builds directly on the foundations established in WP2. Whereas WP2 defined the

conceptual framework and developed initial models for the exploratory cases, WP3 is focused on refinement, cross-case synthesis, and the production of final research outputs. The emphasis is on consolidating results into a coherent assessment of Quantum Federated Learning (QFL) in ATM, and on defining realistic pathways for future research at higher maturity levels. WP3 therefore completes the scientific work of the project before the CDE wrap-up phase begins.

The specific objectives are to:

1. Refine and extend the exploratory case models developed in WP2, incorporating lessons learned and addressing the open questions identified in the first reporting period.
2. Conduct systematic cross-case analysis to identify common challenges, benefits, and limitations of QFL across diverse ATM domains.
3. Develop structured recommendations for advancing QFL research towards TRL 2–3, including the conditions under which quantum machine learning and other quantum methods could provide additional value.
4. Produce a consolidated final research report that synthesises the project’s findings, documents conceptual advances, and defines priorities for future SESAR research.
5. Frame the results to support dissemination and exploitation, ensuring that outputs are relevant for SESAR follow-on projects, ATM stakeholders, and international bodies such as ICAO and EASA.

### **Description of work**

WP3 represents the second phase of the research activity and builds directly on the foundations established in WP2. While the first nine months of the project are focused on scoping and baseline modelling, the following nine months are dedicated to refinement, integration, and the delivery of the final research outputs. The aim is to consolidate the work of the exploratory cases into a coherent assessment of Quantum Federated Learning in ATM, and to provide recommendations and pathways for how this early-stage research can be taken forward at higher maturity levels.

The work begins with refinement of the exploratory case models. Each case - PREDICT, HORIZON, SHIELD, and CONTRADE - will be revisited using the frameworks and assumptions established in WP2. The baseline models developed earlier will be extended to incorporate lessons learned, address gaps identified in the interim review, and respond to stakeholder feedback where appropriate. Refinement may include adjusting assumptions on data distribution or stakeholder behaviour, testing alternative formulations of the federated learning approach, or clarifying the conditions under which conceptual feasibility is most evident. This ensures that the case outputs are not static one-off analyses but part of an iterative process of validation and improvement.

Once the case models have been refined individually, the consortium will conduct systematic cross-case analysis. The purpose of this activity is to extract common themes and divergences across the four contexts. For example, it may be that QFL appears most promising in situations where privacy constraints dominate (as in SHIELD or CONTRADE), but less so where operational predictability is already supported by centralised models (as in PREDICT). Cross-case analysis allows the consortium to identify these patterns, quantify similarities and differences where possible, and derive generalisable insights. It also ensures that the project delivers more than four separate case studies: the results are integrated into a broader understanding of where QFL can contribute to ATM and where its limitations are most apparent.

In parallel, WP3 develops structured recommendations for the future. These recommendations will set out the steps required to advance QFL research to TRL 2–3, including what kinds of datasets, computational tools, and stakeholder collaborations will be needed. They will also identify where quantum optimisation and other quantum computing methods could in future provide additional value, recognising that current hardware is not

yet sufficient for operational validation but that pathways towards higher maturity can be mapped. The recommendations will be positioned within the SESAR programme context, linking to Master Plan objectives and ensuring coherence with European and international research agendas.

The culmination of WP3 is the production of the final consolidated research report. This document will synthesise the project’s findings, document the conceptual advances achieved, and set out the open questions that remain. It will provide the first structured TRL 1 assessment of QFL in ATM, written in a way that supports both technical follow-on research and policy-level consideration. The report will be accompanied by consolidated concept outlines for each case, ensuring that results are clearly traceable and can be compared across contexts.

The work in WP3 also contributes directly to dissemination and exploitation. By framing results in a way that is relevant for SESAR follow-on projects, ATM stakeholders, and international bodies such as ICAO and EASA, the outputs of WP3 are designed to be immediately useful beyond the project itself. This includes highlighting potential contributions to international guidance documents (such as ICAO’s GATMOC) and to regulatory roadmaps such as the EASA AI and Higher Airspace Operations strategies.

The resources allocated to WP3 reflect the need for intensive collaborative work. All partners are fully engaged: quantum computing expertise is used to refine federated modelling structures and assess long-term scalability; ATM research expertise leads the cross-case synthesis and ensures coherence with SESAR frameworks; and operational and regulatory expertise ensures that recommendations are framed in a way that is credible to stakeholders and aligned with the wider aviation ecosystem. WP3 therefore represents the point where the strands of the project are brought together, refined, and translated into outputs that are not only scientifically sound but also operationally meaningful.

By the end of WP3, the project will have moved from initial feasibility exploration to a consolidated set of findings. The results will provide a clear picture of how QFL could contribute to ATM, what limitations must be addressed, and what steps are required to move forward. This provides a natural transition into WP4, where dissemination, exploitation, and open science compliance are finalised and the project’s impact is secured.

<b>Work package number</b>	4
<b>Work package title</b>	Post Research CDE Activity

**Objectives**

This work package consolidates and amplifies the results of the project, ensuring that the outputs of QUANTAIR are visible, accessible, and usable for future research, regulatory processes, and operational stakeholders. While CDE activities are initiated in WP1, the final phase provides dedicated focus on exploitation, open science compliance, and high-impact dissemination. WP4 demonstrates the consortium’s commitment to maximising the value of Horizon Europe and SESAR investment, by delivering results that are technically credible, operationally relevant, and aligned with European and international aviation strategies.

The specific objectives are to:

1. **Finalise the exploitation and impact strategy**, translating project results into clear recommendations for SESAR follow-on activities, national and European research agendas, and international bodies such as ICAO and EASA.
2. **Ensure compliance with open science and FAIR principles**, producing a repository of project outputs (reports, models, datasets, metadata) in trusted long-term archives with persistent identifiers.
3. **Maximise dissemination to the research community**, through open-access publications, contributions to SESAR dissemination events, and active presence in scientific fora.

4. **Promote visibility towards operational and policy stakeholders**, including ANSPs, airlines, regulators, and industry, by framing project results in terms of operational feasibility, policy relevance, and long-term research pathways.
5. **Deliver a final public event and supporting materials**, showcasing the project's achievements and providing a platform for dialogue with the wider ATM community, demonstrating the value of SESAR exploratory research and its contribution to the Digital European Sky vision.

### Description of work

WP4 consolidates the results of the project and ensures that they are visible, accessible, and exploitable beyond the lifetime of QUANTAIR. While communication, dissemination, and exploitation activities are initiated under WP1 to give early visibility, this final phase provides dedicated focus on maximising impact. The emphasis is on producing a final exploitation and impact strategy, ensuring compliance with open science principles, and delivering a high-quality public event that promotes the project's results to both technical and policy audiences.

The first strand of work concerns the exploitation and impact strategy. A draft version is developed under WP1, but in WP4 this is finalised based on the complete research results. The strategy translates conceptual findings into concrete recommendations for SESAR follow-on activities, as well as guidance for national and European research agendas. It also identifies how the results can support international bodies such as ICAO, for example through inputs to the Global Air Traffic Management Operational Concept (GATMOC), and EASA, through alignment with the AI Roadmap and Higher Airspace Operations strategy. By framing the results in terms of both research and policy pathways, the strategy ensures that QUANTAIR provides maximum value to SESAR and the wider aviation community.

The second strand addresses open science and data preservation. A final repository of project outputs will be prepared, ensuring that reports, conceptual models, metadata, and other analytical products are made available in trusted long-term archives. All materials will carry persistent identifiers to guarantee findability and access, and licensing conditions will be clearly stated to encourage reuse where possible. This ensures that the research remains transparent and accessible, in line with the FAIR principles (Findable, Accessible, Interoperable, Reusable) and Horizon Europe's open science obligations. Sensitive or restricted material will be clearly documented, with justifications for any limitations on access.

The third strand is dissemination to the research community. Results will be submitted for publication in open-access journals and conference proceedings, ensuring peer-reviewed visibility and providing a foundation for subsequent academic and industrial research. The consortium will also contribute to SESAR dissemination events, workshops, and thematic fora, presenting QUANTAIR as a case study of how Horizon Europe exploratory research can be used to investigate emerging concepts at TRL 1. This creates continuity with other SESAR activities and supports the integration of results into the wider Digital European Sky programme.

A fourth strand focuses on visibility towards operational and policy stakeholders. While the research is conceptual, its framing will be tailored to the concerns of ANSPs, airlines, regulators, and manufacturers. Materials will highlight the operational implications of the findings, such as the handling of sensitive airline preferences (e.g. cost index), or the potential for privacy-preserving collaboration on contrail avoidance. The project will also prepare concise policy briefs, targeted at European institutions, to make the research outputs accessible to decision-makers without requiring them to engage with technical detail.

Finally, WP4 delivers a high-impact final dissemination event. This event, organised at the end of the project, will bring together the SESAR research community, operational stakeholders, and policy representatives. It will showcase the project's achievements, present the consolidated results, and provide a forum for discussion

on how QFL research should be taken forward. Supporting materials, including an event report, presentations, and a digital archive of outputs, will ensure that the visibility of the project extends beyond the event itself.

The work in WP4 requires contributions from all partners. The ATM research partner ensures that the exploitation strategy is aligned with SESAR frameworks. The quantum computing partner provides visibility on how the conceptual work can evolve as technology matures. The operational partner ensures that dissemination is framed in terms that resonate with industry and regulators. Together, the consortium ensures that the final outputs are technically credible, operationally meaningful, and presented in a way that maximises their uptake.

By the end of WP4, QUANTAIR will have delivered not only a comprehensive set of scientific results, but also the supporting materials, strategies, and outreach activities needed to ensure that those results have impact. The project will leave behind a transparent and accessible record of its findings, contribute to SESAR's long-term research programme, and demonstrate the role of Horizon Europe exploratory research in shaping the future of ATM.

**Table 3.1c: List of Deliverables**

<b>Nr.</b>	<b>Deliverable name</b>	<b>Short description</b>	<b>Work package number</b>	<b>Short name of lead participant</b>	<b>Type</b>	<b>Dissemination level</b>	<b>Delivery date (in months)</b>
1.1	KOM Report	Report from the Kick-off Meeting	1	DLR	R	PU	1
1.2	Initial PMP	Initial Project Management Plan	1	DLR	R	PU	3
1.3	Initial CDE Plan	Initial Communication, Dissemination & Exploitation plan	1	SkyNav	R	PU	3
1.4	Online presence	Project Website and Online presence	1	SkyNav	DEC	PU	3
1.5	Initial DMP	Initial Data Management Plan	1	DLR	R	PU	6
1.6	HE Report	Periodic HE technical and Financial report	1	Qoro	R	CO	9
1.7	Updated PMP	Updated Project Management Plan	1	DLR	R	PU	12
1.8	Updated CDE Plan	Updated Communication, Dissemination & Exploitation plan	1	SkyNav	R	PU	12
1.9	Mid-project Event	Information event about research progress	1	SkyNav	OTH	PU	12
1.10	Updates DMP	Updated Data Management Plan	1	DLR	R	PU	15
1.11	Final project report	Final project report	1	DLR	R	CO	24

2.1	Initial ERP	Initial Exploratory Research Plan	2	Qoro	R	PU	4
2.2	Initial ERR	Initial Exploratory Research Report	2	Qoro	R	PU	6
2.3	Initial CO	Initial Concept Outline	2	Qoro	R	PU	6
3.1	Final ERP	Final Exploratory Research Plan	3	Qoro	R	PU	16
3.2	Final ERR	Final Exploratory Research Report	3	Qoro	R	PU	18
3.3	Final CO	Final Concept Outline	3	Qoro	R	PU	18
4.1	Initial EI Strategy	Initial Post-Research Exploitation & Impact Strategy	4	SkyNav	R	PU	20
4.2	Final EI Strategy	Final Exploitation & Impact Strategy	4	SkyNav	R	PU	24
4.3	Compliance Report	Repository & Open Science Compliance Report	4	SkyNav	R	PU	24
4.4	Final Event Report	Final Promulgation Event Report	4	SkyNav	R	PU	24

Table 3.1d: List of milestones

Milestone number	Milestone name	Related work package(s)	Due date (in month)	Means of verification
MS1.1	Project Governance Established	1	1	PMB in place; KoM held; PMP development launched. KoM report (D1.1).
MS1.2	Management and CDE Frameworks Approved	1	3	PMP, DMP, and initial CDE Plan delivered and accepted. Submission of D1.2/1.3/D1.5.
MS1.3	Mid-Project Review Prepared	1	12	Updated PMP and CDE delivered; Mid-project event held. Submission of D1.5–D1.8.
MS1.4	Draft Exploitation & Impact Strategy Produced	1	18	Exploitation and impact strategy delivered in draft, ready for hand-over to WP4. Submission of D1.10.
MS1.5	Final Review & Project Closure	1, 4	24	Final project report delivered; SESAR final review completed. Acceptance of D1.9–D1.10.

**Table 3.1e: Critical risks for implementation #@RSK-MGT-RM@#**

<b>Description of risk (indicate level of (i) likelihood, and (ii) severity: Low/Medium/High)</b>	<b>Work package(s) involved</b>	<b>Proposed risk-mitigation measures</b>
<b>R1. QFL concept does not yield meaningful insights at TRL 1</b> (Likelihood: Medium; Severity: High). Interim models show no plausible feasibility signals across exploratory cases.	WP2 WP3	Treat inconclusive or negative results as valid TRL 1 outcomes; ensure each case has at least two formulations so alternatives can be tested; document limits clearly and extract learning for future TRL 2–3 work.
<b>R2. Assumptions and frameworks diverge between cases</b> leading to inconsistent or incomparable results (Likelihood: Medium; Severity: Medium).	WP2 WP3	Maintain a common framework agreed in D2.1; record all assumptions in an “assumptions register” reviewed by PMB; hold cross-partner review sessions before submitting deliverables.
<b>R3. Baseline models cannot capture distributed ATM constraints realistically</b> (privacy, governance, airline cost-index preferences) (Likelihood: Medium; Severity: Medium).	WP2	Start with simplified synthetic scenarios; expand gradually; involve operational experts early; record limitations explicitly in interim reports.
<b>R4. Exploratory cases overlap too much, reducing distinct insights</b> (Likelihood: Medium; Severity: Medium).	WP2 WP3	Enforce differentiation when scoping cases; PMB validates distinct objectives for each; adjust case emphasis if overlap is detected.
<b>R5. Over-reliance on synthetic data reduces credibility of results</b> (Likelihood: Medium; Severity: Medium).	WP2 WP3	Anchor synthetic datasets to published SESAR references; use sensitivity analyses to show robustness; invite stakeholder feedback at mid-project event.
<b>R6. Role of quantum computing is overstated or too vague</b> (Likelihood: Medium; Severity: High).	WP2 WP3	Link all quantum-related statements to clear conditions of validity; maintain a “claims register”; ensure internal peer review of evidence before submission.
<b>R7. Limited stakeholder engagement reduces visibility and uptake</b> (Likelihood: Low; Severity: Medium).	WP1 WP4	Use consortium networks across ATM, regulatory, and research communities; organise mid-project and final events; publish open-access outputs and policy briefs.
<b>R8. Unavailability of key staff due to illness, turnover, or conflicting commitments</b> (Likelihood: Medium; Severity: Medium).	WP1 WP2 WP3 WP4	Redistribute effort across the consortium where possible, using flexibility in the Horizon Europe rules; adjust timelines for lower-priority tasks to protect critical deliverables; replace staff within the same partner if necessary, ensuring continuity of expertise.

#\$RSK-MGT-RM\$#

**Table 3.1f: Summary of staff effort**

	WP1	WP2	WP3	WP4	Total Person-Months per Participant
<b>1/DLR</b>	5	5	5	1	16
<b>2/Qoro</b>	6	14	12	3	35
<b>3/SkyNav</b>	11.8	6	6	4	27.8
<b>Total Person Months</b>	22.8	25	23	8	78.8

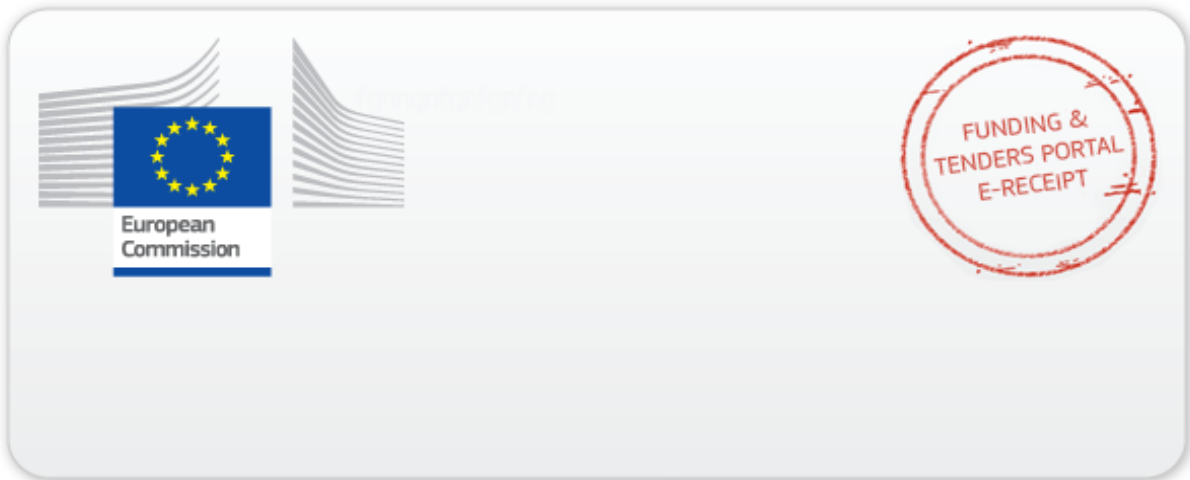
**Table 3.1h: 'Purchase costs' items (travel and subsistence, equipment and other goods, works and services)**

<b>1/DLR</b>		
	Cost (€)	Justification
<b>Travel and subsistence</b>	5000	Travel for conferences, workshops, and team meetings
<b>Equipment</b>	-	
<b>Other goods, works and services</b>	-	
<b>Remaining purchase costs (&lt;15% of pers. Costs)</b>	-	
<b>Total</b>	5000	

<b>2/Qoro</b>		
	Cost (€)	Justification
<b>Travel and subsistence</b>	12500	Travel for conferences, workshops, and team meetings
<b>Equipment</b>	-	
<b>Other goods, works and services</b>	2000	Consortia events, venue and facilities
<b>Remaining purchase costs (&lt;15% of pers. Costs)</b>	-	
<b>Total</b>	12500	

<b>3/SkyNav</b>		
	Cost (€)	Justification
<b>Travel and subsistence</b>	17500	Travel for conferences, workshops, and team meetings
<b>Equipment</b>	-	
<b>Other goods, works and services</b>	-	
<b>Remaining purchase costs (&lt;15% of pers. Costs)</b>	-	
<b>Total</b>	17500	

#\$QUA-LIT-QL\$# # \$WRK-PLA-WP\$#



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