# ETHER: Energy- and cost-efficient framework for seamless connectivity over the integrated terrestrial and non-terrestrial 6G networks

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www.ether-project.eu

# General information

- **Project Number**: 101096526
- **Project Name**: Self-Evolving Terrestrial/Non-Terrestrial Hybrid Networks
- **Project Acronym**: ETHER
- **Call**: HORIZON-JU-SNS-2022-STREAM-B-01-03
- **Topic**: HORIZON-JU-SNS-2022-STREAM-B-01-03 – Communication Infrastructure Technologies and Devices
- **Targeted Areas**: *NTN infrastructures* and *Integrated NTN service provision*
- **Type of Action**: Horizon Research and Innovation Action
- **Project start**: 01/01/2023
- **Project Duration**: 36 months
- **Keywords**: Hybrid Terrestrial/Non-Terrestrial Networks, Coverage, Service Continuity, Reliability, Energy Efficiency, Direct Handheld Device Access, Edge Computing, Caching, Semantics, NFV, Automated MANO, AI/ML, Network Optimization, Technoeconomic Analysis
- **Budget**: Total Eligible Costs: 4 901 867.50 Max grant amount: 4 660 693.25

# Consortium

| Number | Role | Short name | Legal name | Country |
|---|---|---|---|---|
| 1 | COO | uni.lu | UNIVERSITE DU LUXEMBOURG | LU |
| 2 | BEN | AUTH | ARISTOTELIO PANEPISTIMIO THESSALONIKIS | GR |
| 3 | BEN | CA | COLLINS AEROSPACE IRELAND, LIMITED | IE |
| 4 | BEN | AVA | AVANTI HYLAS 2 CYPRUS LIMITED | CY |
| 5 | BEN | SIOT | SATELIO IOT SERVICES, SL | ES |
| 6 | BEN | Ubiwhere | UBIWHERE LDA | PT |
| 7 | BEN | I2CAT | FUNDACIO PRIVADA I2CAT, INTERNET I INNOVACIO DIGITAL A CATALUNYA | ES |
| 8 | BEN | NBC | NEARBY COMPUTING SL | ES |
| 9 | BEN | NCSR "D" | NATIONAL CENTER FOR SCIENTIFIC RESEARCH "DEMOKRITOS" | GR |
| 10 | BEN | LIU | LINKOPINGS UNIVERSITET | SE |
| 11 | BEN | OPL | ORANGE POLSKA SPOLKA AKCYJNA | PL |
| 12 | AP | MARTEL GMBH | MARTEL GMBH | CH |
| 13 | AP | Net AI | NET AI TECH LTD | UK |

# Motivation

- Ongoing deployment of 5G networks, initial visions on 6G use cases and capabilities
- Rural applications of growing social and economic importance (forestry, mining, agriculture, logistics, asset tracking, telemedicine, etc.) not facilitated by 5G
- Non-urban areas generally under-covered (service availability, supported QoS)
- Extending coverage via Terrestrial Network (TN) densifying not profitable for Mobile Network Operators (cost, energy, low density of users) – integration with Non-Terrestrial Networks (NTN) is necessary
- Lack of architectural framework providing efficient & smart resources management of the heterogeneous dynamic 3D network in zero-touch manner
- ETHER (*sElf-evolving terrestrial/non-Terrestrial Hybrid nEtwoRks*) a holistic approach for energy- and cost-efficient integrated Terrestrial-Non-Terrestrial Networks

# ETHER goal and pillars

ETHER goal: provide a framework for the terrestrial/non-terrestrial network ecosystem that involves an efficient and zero-touch resource management, provides solution for key RAN challenges, and identifies the business opportunities for potential stakeholders

ETHER pillars:

I. Unified RAN advancements that enable broadband connectivity from every corner of the world, even with handheld devices and in challenging frequency bands, such as the Ka band (26–40 GHz)

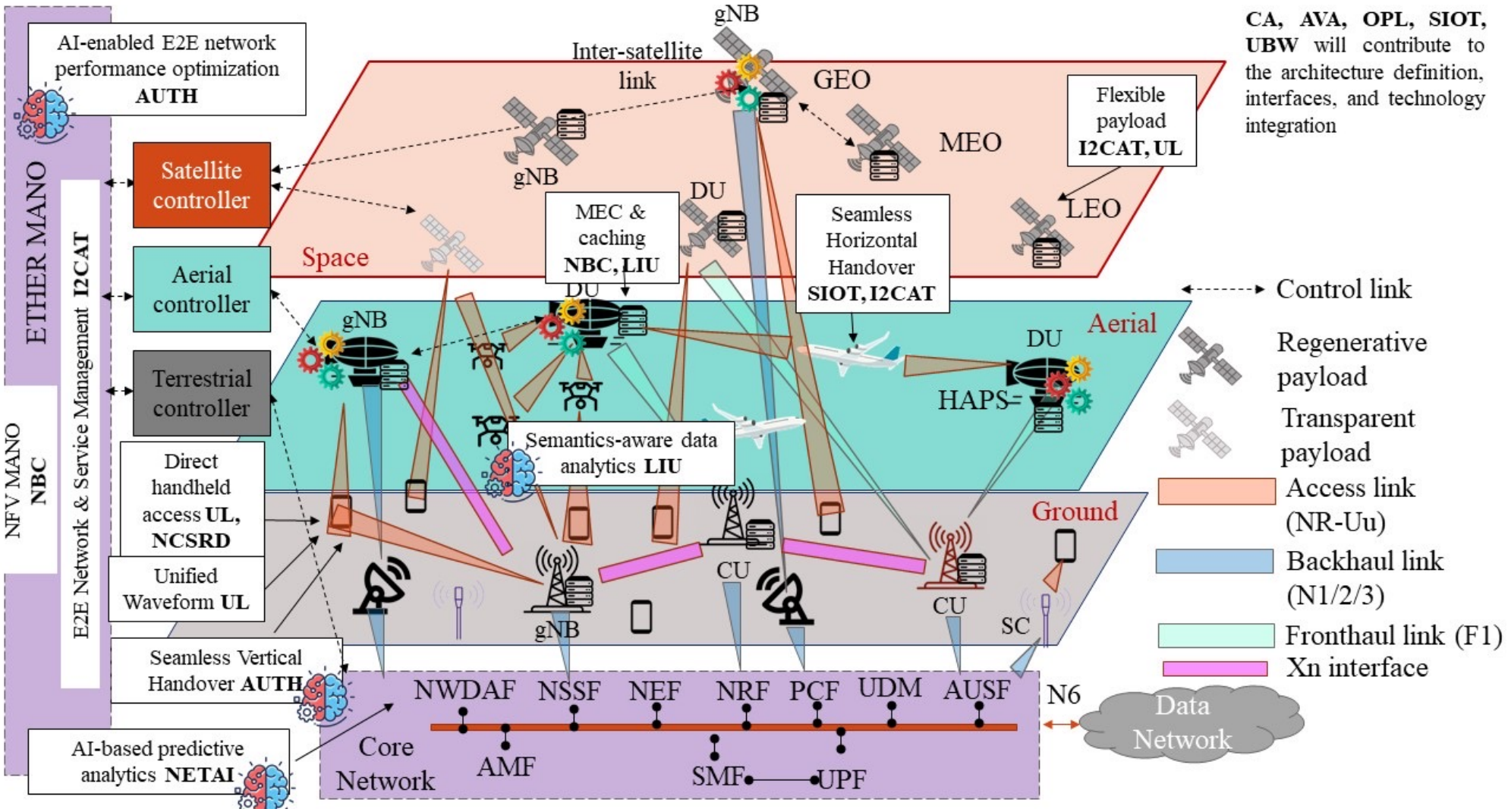
II. Intelligent management of the 3D network resources for meeting predefined KPIs, allowing the network to self-adapt to rapidly evolving traffic conditions and situations on the ground without human intervention

III. A distributed 3D computing and caching continuum enabling the reduction of response delays by alleviating congestions towards cloud data centre

# Envisioned technical innovations

1. Integrated architecture → terrestrial, aerial (HAPSs, drones), and satellite (LEO, MEO, and GEO) layers integrated with a common CN, with distributed SDN-based transport and storage/compute capabilities in each layer
2. Direct handheld terminal access in the Ka band → compact phase array antennas (integrated with UE for LEO satellites access), distributed beamforming (link budget enhancements by LEO swarms)
3. Uniform waveform design for high channel impairment robustness → context-aware waveform adaptation, i.e., ML-based selection of Orthogonal Frequency-Division Multiplexing (OFDM) or Orthogonal Time Frequency Space (OTFS) multiplexing scheme (using SNR, Doppler shift sensitivity, or channel estimation complexity)
4. Flexible payloads of satellite nodes → the ability to orchestrate the satellite hosts resources + interfaces between orchestration systems and satellite payloads (SDR-based)
5. Data analytics, edge computing, and caching for low-latency energy-efficient aerial and space layers → communication and networking functionalities on aerial/satellite nodes, elimination of unnecessary round-trip control signals delays, utilising the information semantics, caching schemes, and cooperative computing techniques
6. Horizontal/vertical handovers (inter-, intralayer) → seamless connection continuity, variety of handover criteria in hybrid TNs/NTNs, AI-based decisions (based on E2E context and network evolution, handovers-related energy consumption)
7. Automated MANO for the integrated network → unified management and orchestrator framework for satellite systems and aerial platforms, and AI-based adaptive resource orchestration optimisation mechanism for service provisioning
8. E2E integrated TN and NTN performance optimisation → low-complexity algorithms for energy-efficient user association, traffic routing, VNF placement and caching, efficient predictive analytics for E2E service-level network optimisation

# Vision




**CA, AVA, OPL, SIOT, UBW** will contribute to the architecture definition, interfaces, and technology integration

"By adopting a hybrid network, NTNs can offer significant CAPEX and OPEX reductions compared to deploying only terrestrial base stations to achieve the same amount of coverage. According to the same case study, providing full 5G coverage across the UK would require tens of thousands of additional terrestrial sites, while the same coverage could be achieved with a fleet of around 60 HAPs[1]."

[1]5G's future is hybrid – the non-terrestrial opportunity," Mobile World Live, Tech. Rep.

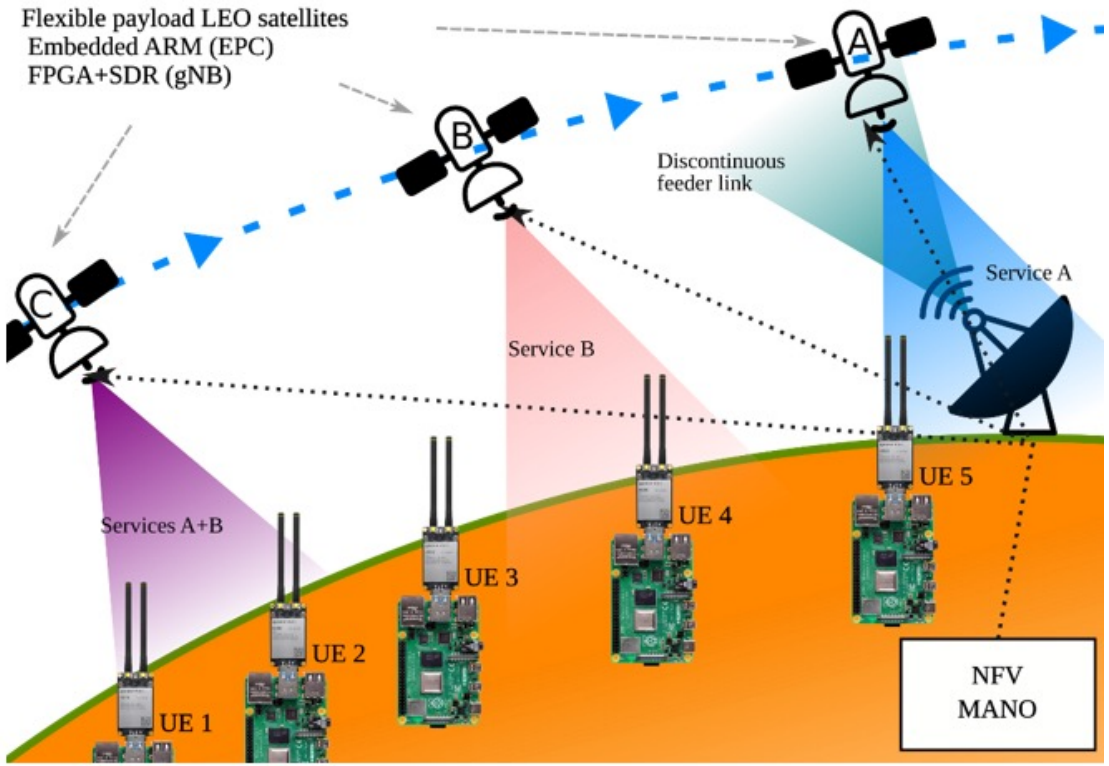
# UC1: Horizontal handovers for delay-tolerant IoT applications

## Motivation:

- Significant part of UEs in rural areas dedicated to mMTC applications using NB-IoT
- Delay-tolerant – can be served by LEO satellites
- Issues: service link discontinuity (low density of LEO constellations), limited number of feeder links

## Scope:

- Regenerative payload architecture and a store-and-forward mechanism for both UP and CP
- Efficient horizontal handovers to handle satellite constellation changes
- Service continuity maintained by the ground NFV MANO coordinating the ETHER flexible payload



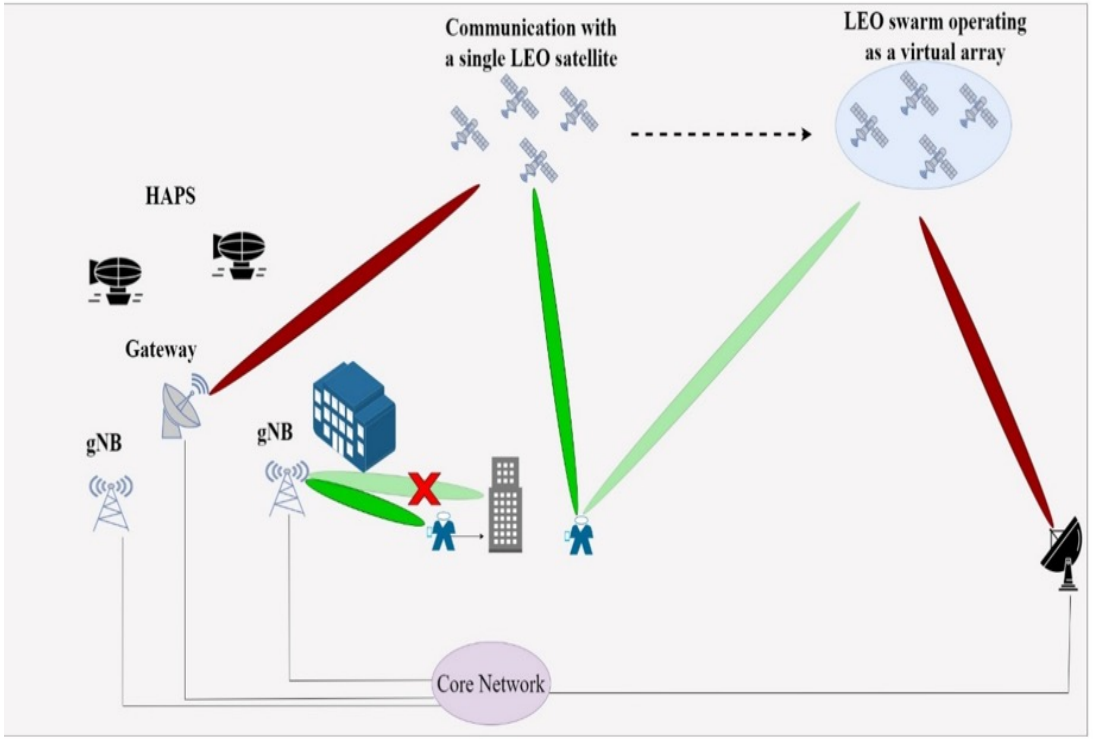
# UC2: ETHER unified RAN for direct handheld device access in the Ka band

## Motivation:

- Sub-6 GHz bands envisioned to be supplemented by mmWaves → much larger bandwidths but more susceptible to blockages
- Deployment of 100% mmWave broadband coverage with TN not economically feasible

## Scope:

- TN to NTN vertical handover triggered by algorithms maximising energy efficiency
- Modulation selection (OFDM/OTFS) using the ETHER AI-driven algorithms
- UE operation in Ka band with integrated antenna



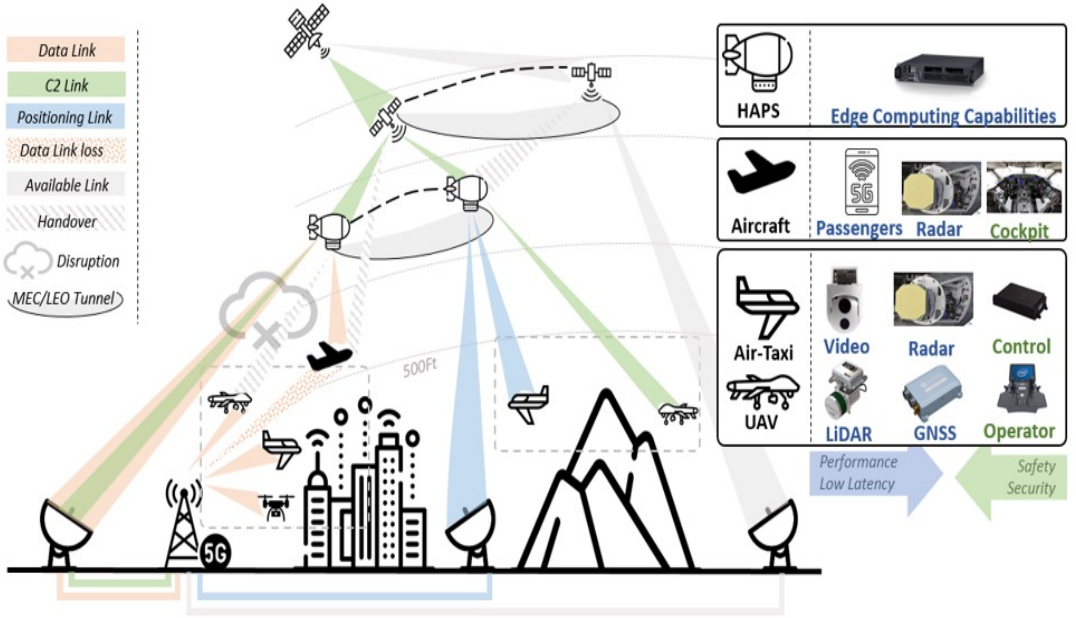
# UC3: ETHER architecture demonstration for air-space safety-critical operation

## Motivation:

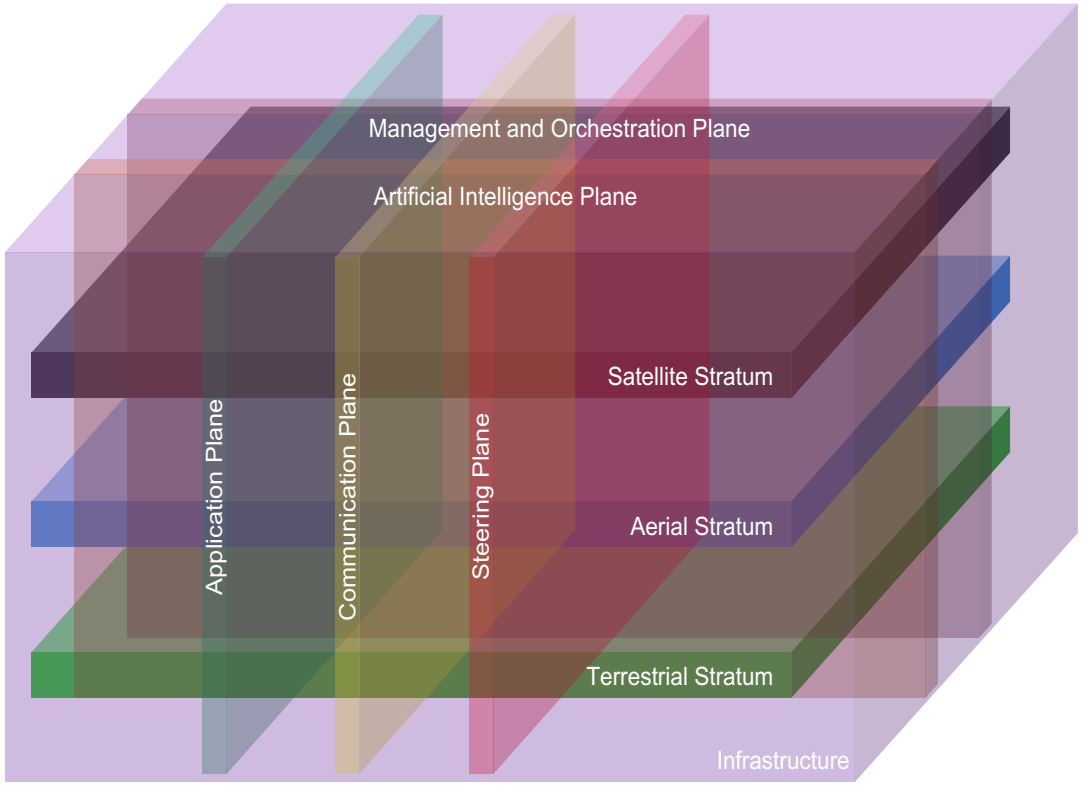
- Conformance of integrated TN-NTN with the emerging aviation and space standardisation (e.g., EUROCONTROL, EASA)
- Specific domain requirements (service continuity, mobility management, QoS enforcement, etc.) related to Air Traffic Services data communications, drones remote operation, single pilot operations, etc.

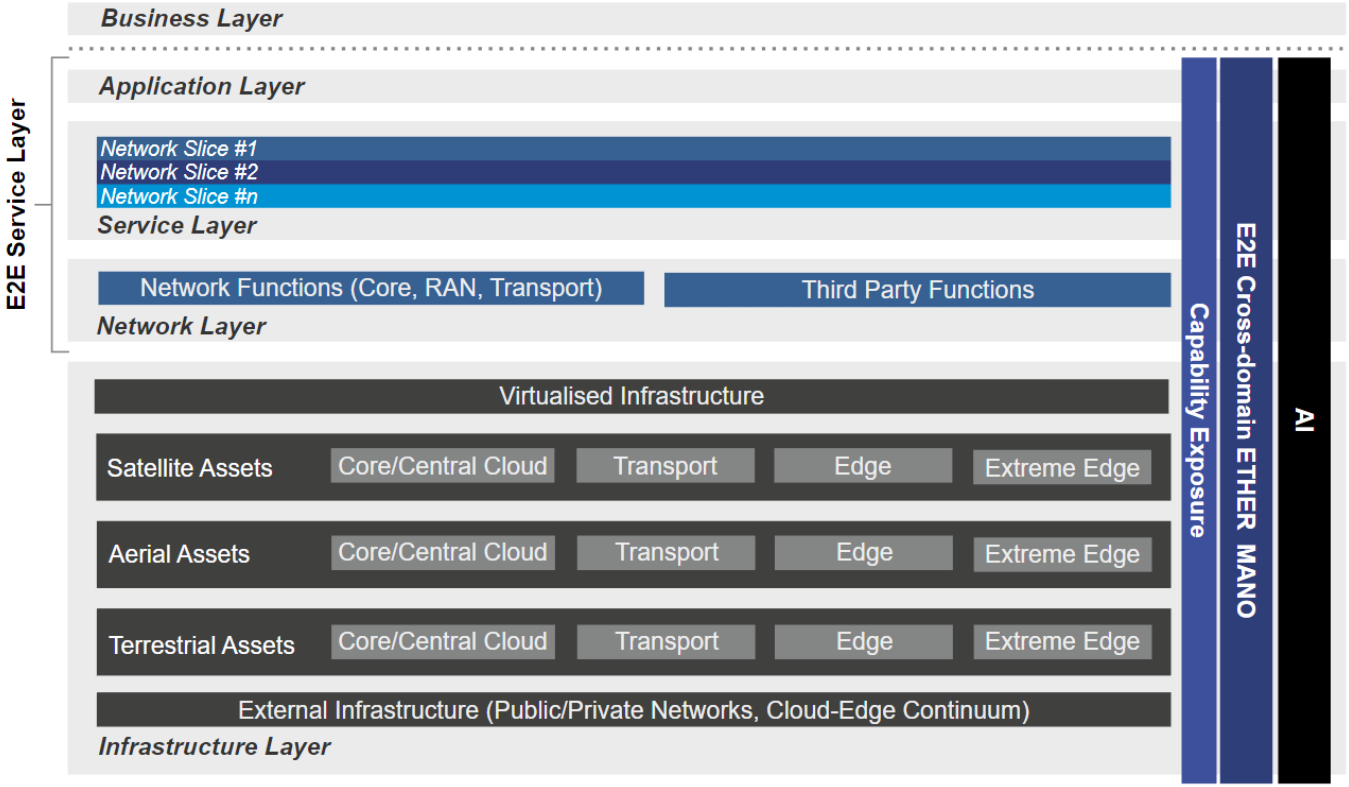
## Scope:

- Safety-critical aircraft operations → movement of one or several aircraft across the area with coverage of TN/NTN (LEO satellites)
- Multilink features and handover procedures (both horizontal and vertical) to ensure comms KPIs
- Contribution to safety of aircraft operations

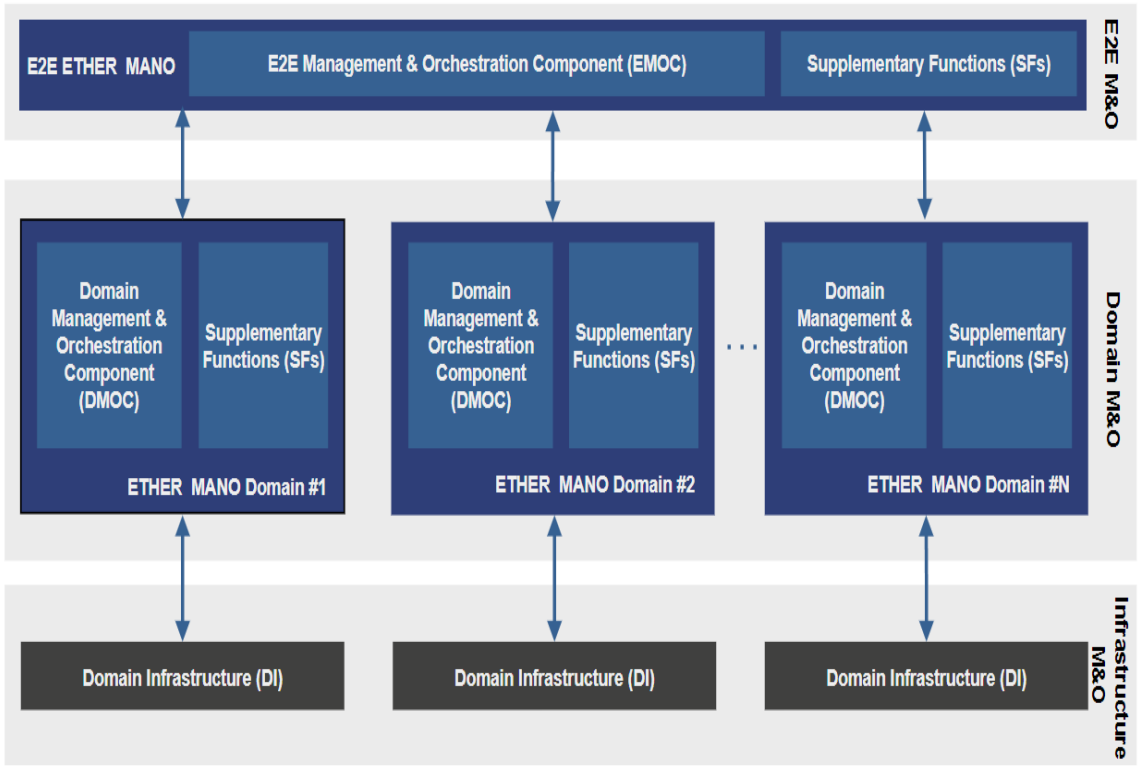


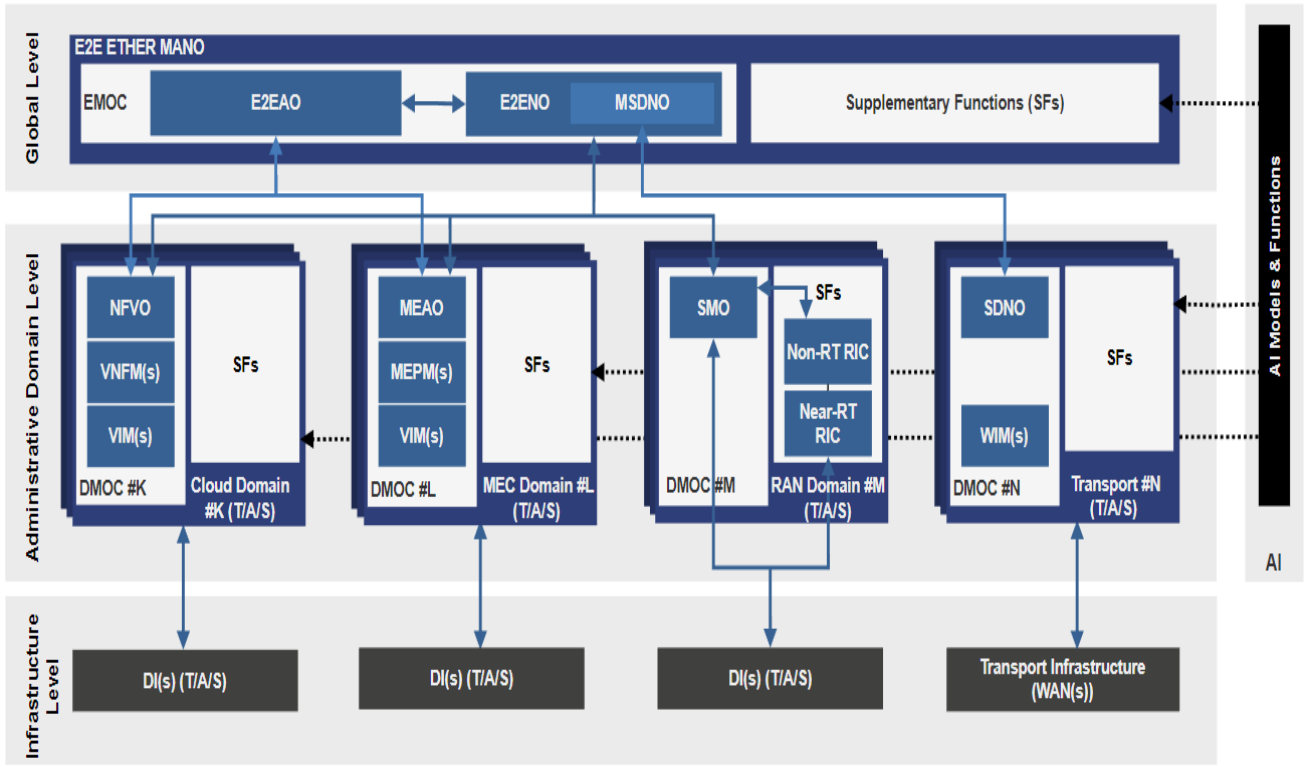
# Initial ETHER overall architecture



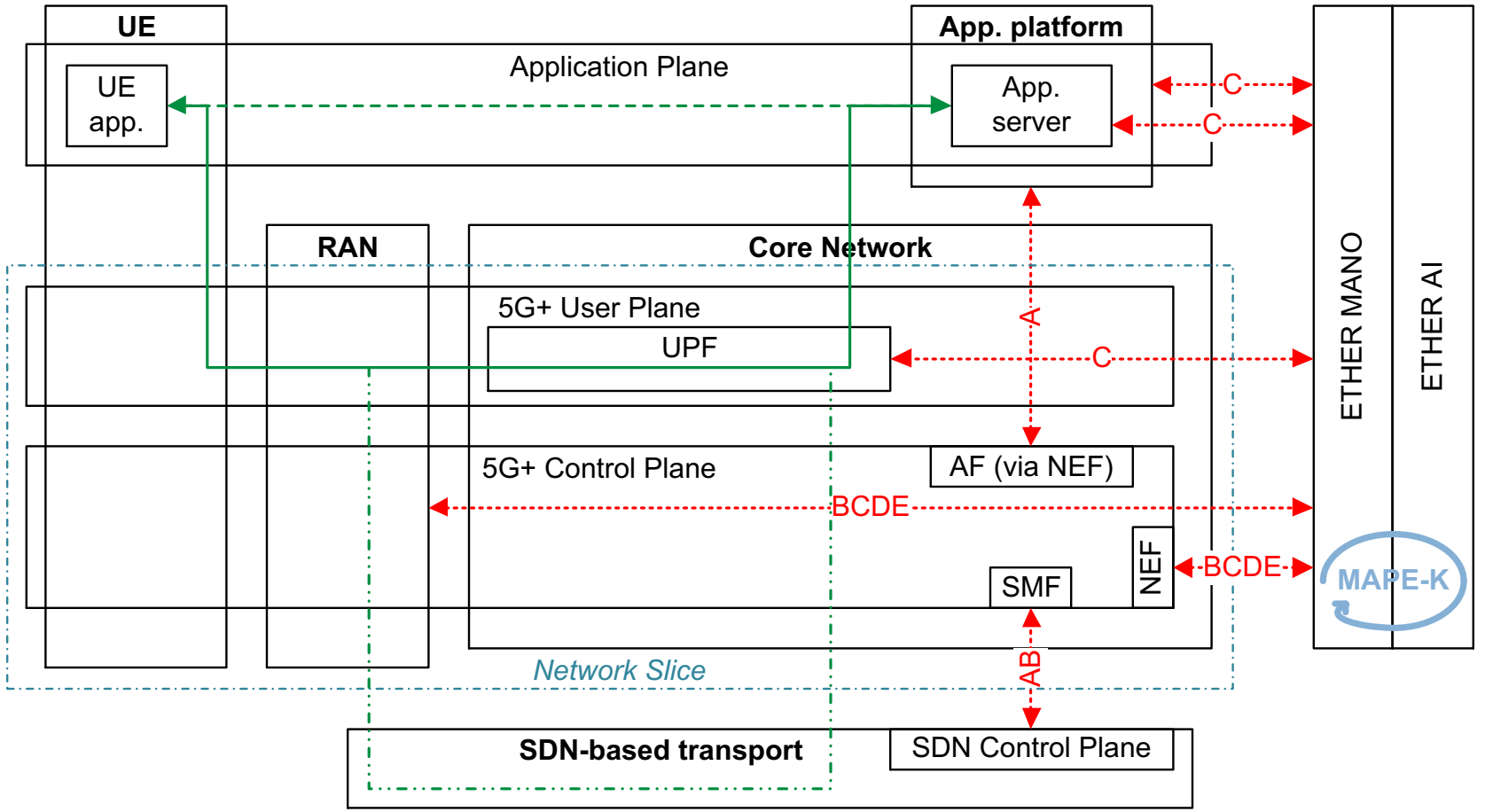



# Initial ETHER MANO layer architecture



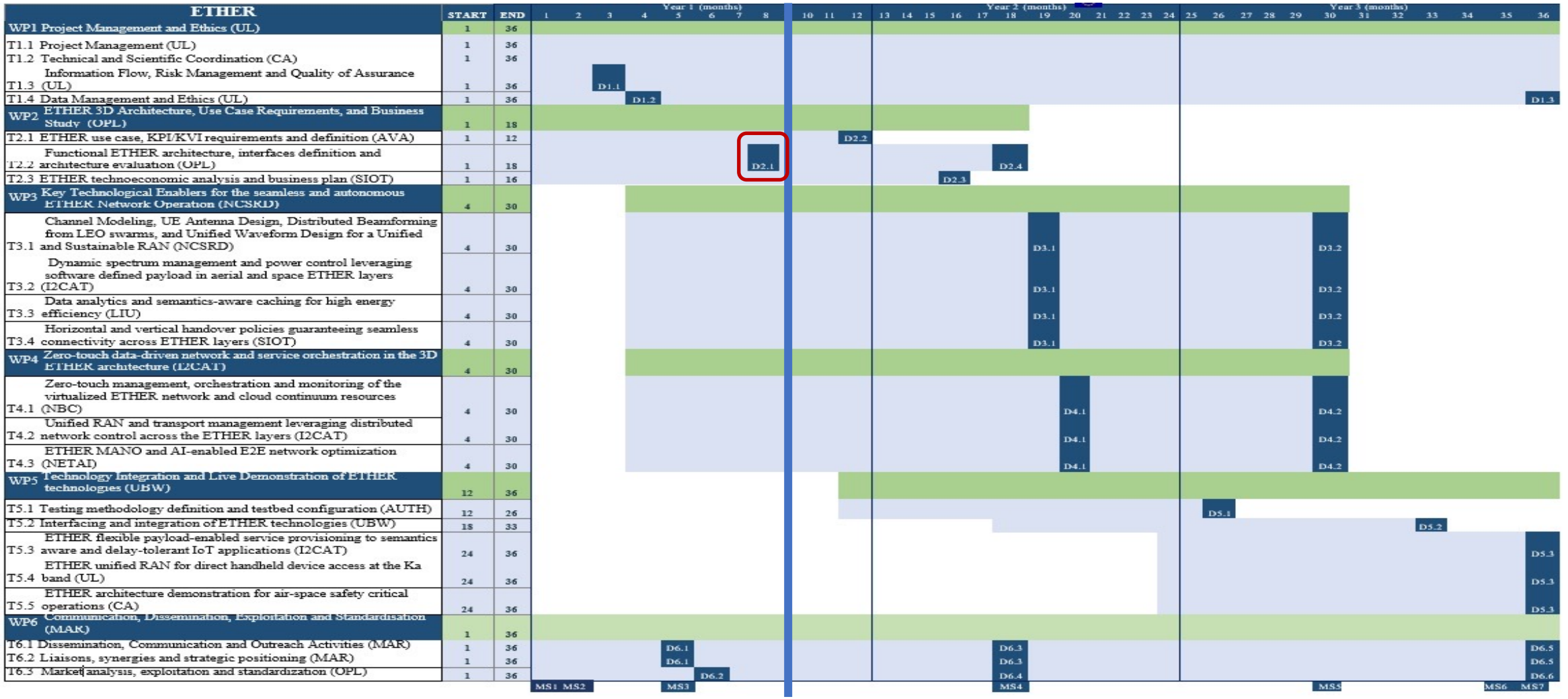



# Initial ETHER E2E service layer architecture




A. MEC & caching
B. Seamless vertical/horizontal handover
C. Semantic-aware data analytics
D. AI-based predictive analysis
E. AI-enabled E2E network performance optimisation

# Where we are, what has to be done



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# Thanks

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