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Intelligent control and orchestration of 5G NTN through O-RAN RIC/SMO

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Satellites now native to 3GPP

From 2022, with the **Release 17** of the 3GPP standard, The 5G family of air interfaces (**5G NR, NB-IoT, eMTC**) now **natively supports non-terrestrial access**, in both FR1-NTN and FR2-NTN bands (above 10 GHz)

Major question remains:

How does one efficiently control the network?

*VSAT = Very Small Aperture Terminal

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3GPP scratched the surface of NTN orchestration

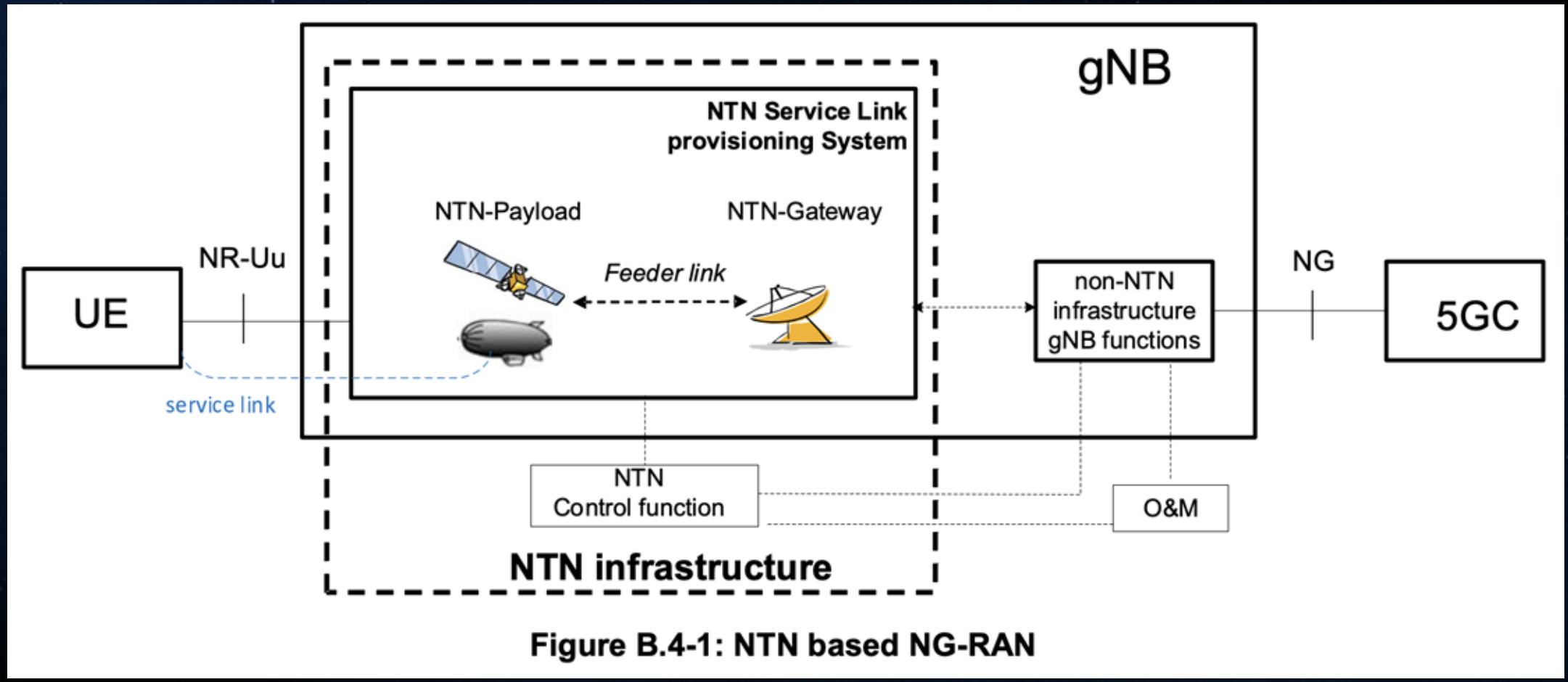

Figure B.4-1: NTN based NG-RAN

3GPP Release 17 - TS 38.300

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3GPP scratched the surface of NTN orchestration

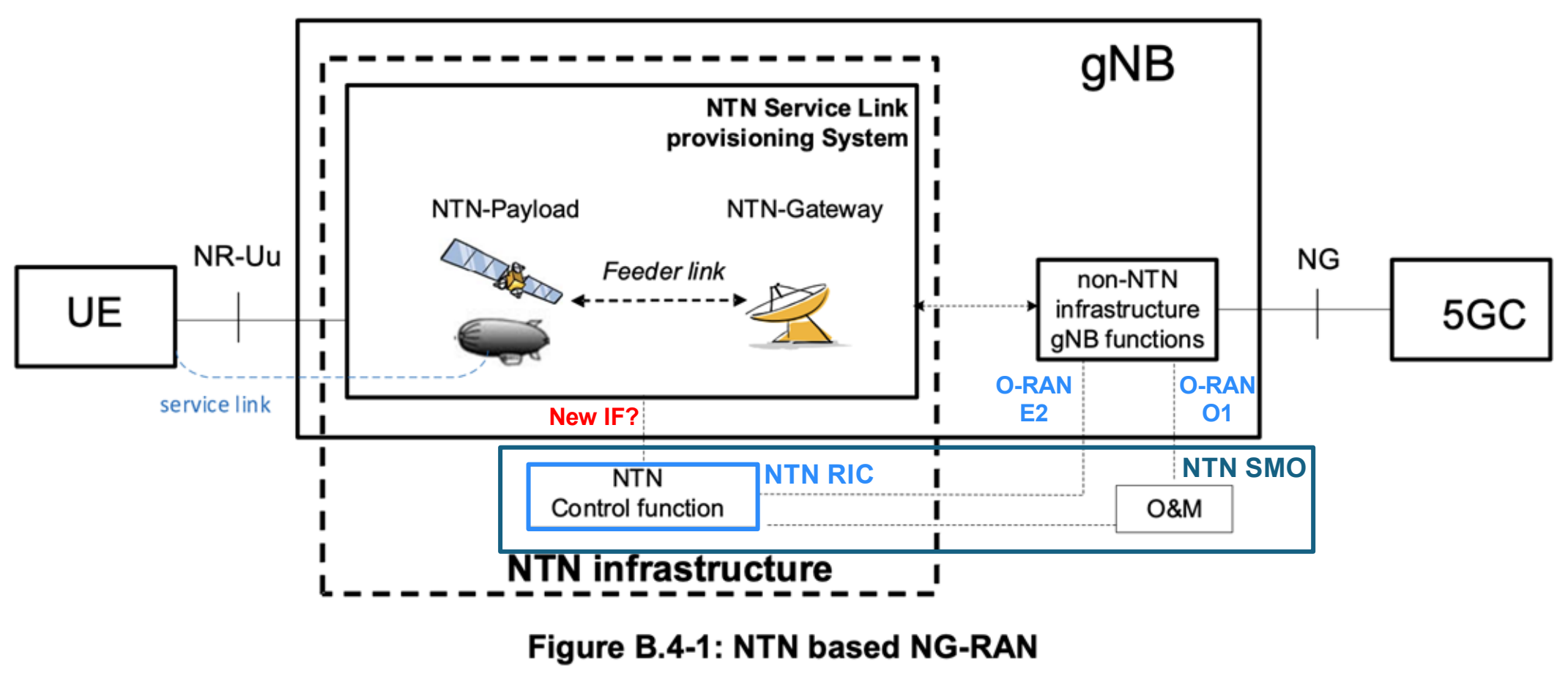
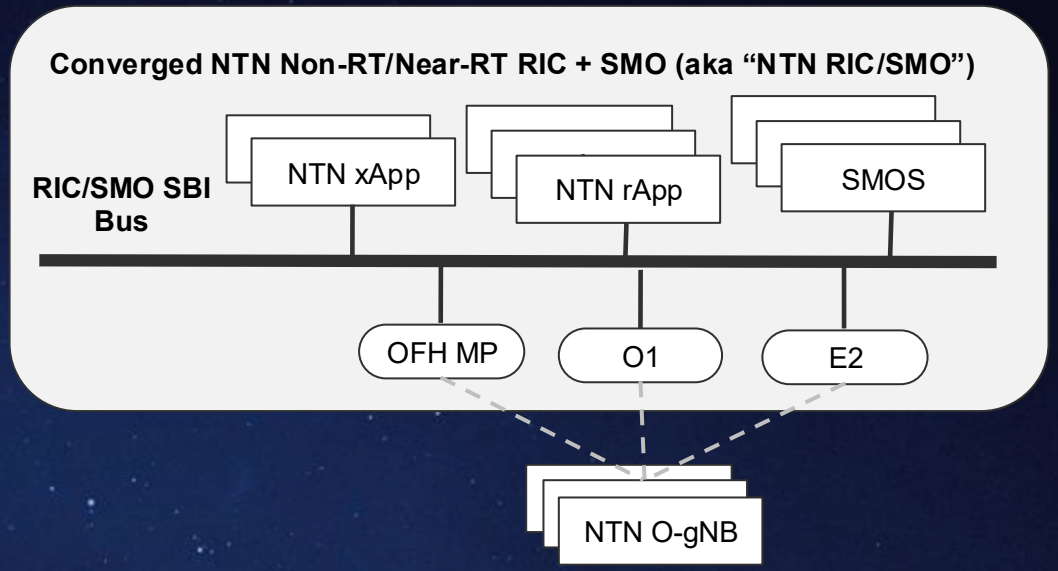


Figure B.4-1: NTN based NG-RAN

3GPP Release 17 - TS 38.300

Near-RT/Non-RT RIC Convergence for NTN

- **O-RAN RIC/SMO framework** a natural **implementation** choice for the 3GPP **NTN Control Function (NCF)** (from TS 38.300 Rel-17)
- **Non-Terrestrial Networks (NTN)** bear many differences from TN
- Boundaries between **Near-RT and Non-RT domains in NTN blur-out**, and they can even be correlated/co-dependent.
- An **NTN Converged RIC** will need to manage both Near- and Non-RT operations in a coordinated manner - potentially from the same "brain" (i.e., xApps/rApps)
- O1 interface matures for NTN through evolution of 3GPP SA5 NRM – the story can't end here though
- E2 interface and its Service Models need to evolve to support NTN-specific control plane signaling



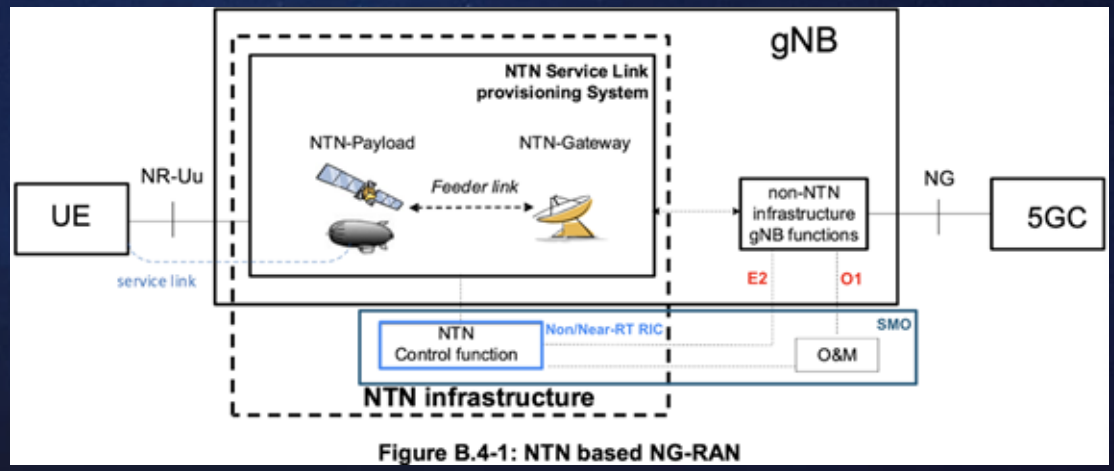


Figure B.4-1: NTN based NG-RAN

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NTN RAN & Transport network

- With **Non-Terrestrial Networks (NTN)**, the **RAN and its transport layers** become a **dynamic element of the network**
- At least one of the RAN interfaces now **traverses an orbiting network asset**, introducing **a time-space variant wireless link**, such as:
- Feeders and ISLs form the **Satellite Transport Network (STN)**
- **Viability** and **capabilities** of the wireless links depend on **numerous constraints**, such as available **on-board power**, regionally available **spectrum**, **weather**, etc.
- **Several interdependencies** between the 5G/LTE NTN RAN and the underlying STN, e.g. **latency, reliability, throughput,** etc.

The NTN Control Plane must be aware of both the RAN and the STN and address those inter-dependencies between them

The NTN Control Plane must leverage a multi-domain, multi-orbit Digital Twin of the 5G NTN space and ground segments.

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Control of Non-3GPP Network Elements in NTN

- An NTN network comprises network elements which are not standardised by 3GPP (e.g. GW, Feeder/SRI, Satellite payload, ISL, OBP, etc.).
- **Coordinated control/management of 3GPP + non-3GPP** infrastructure is required to run the network (optimally and reliably)
- The NTN Control Function (NCF) architecture in TS 38.300 implies that the NCF also controls these non-3GPP network elements, but does not specify its interface (indicated in diagram with the **New IF?**).
- This poses a requirement for a new interface (or an extension of the existing O-RAN E2/O1) to be defined which will evolve over time to represent the unique control functions.

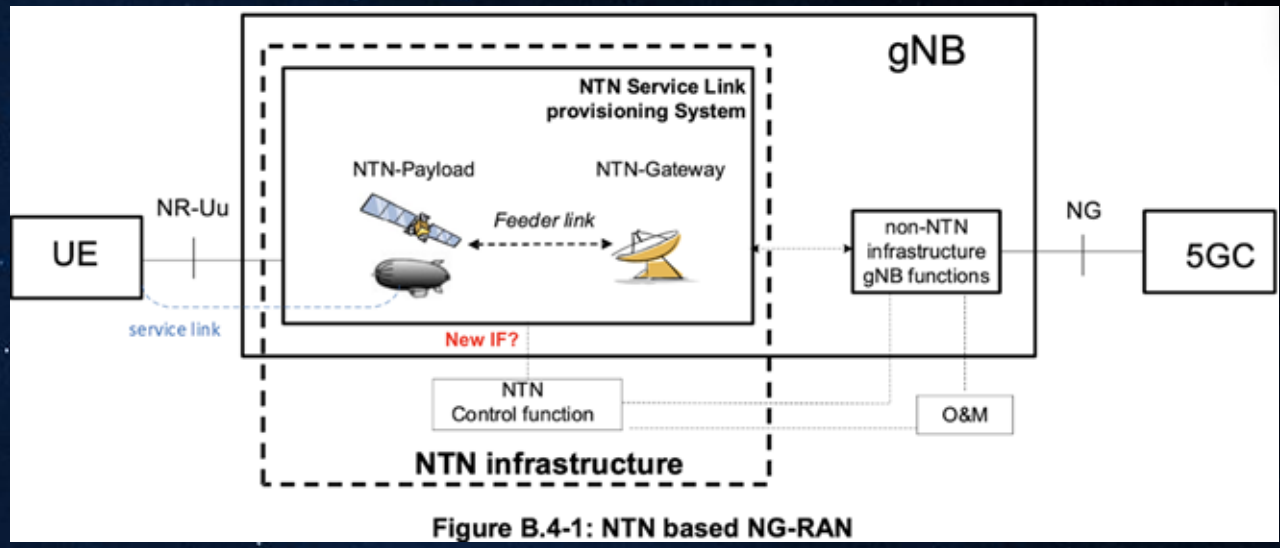

Figure B.4-1: NTN based NG-RAN

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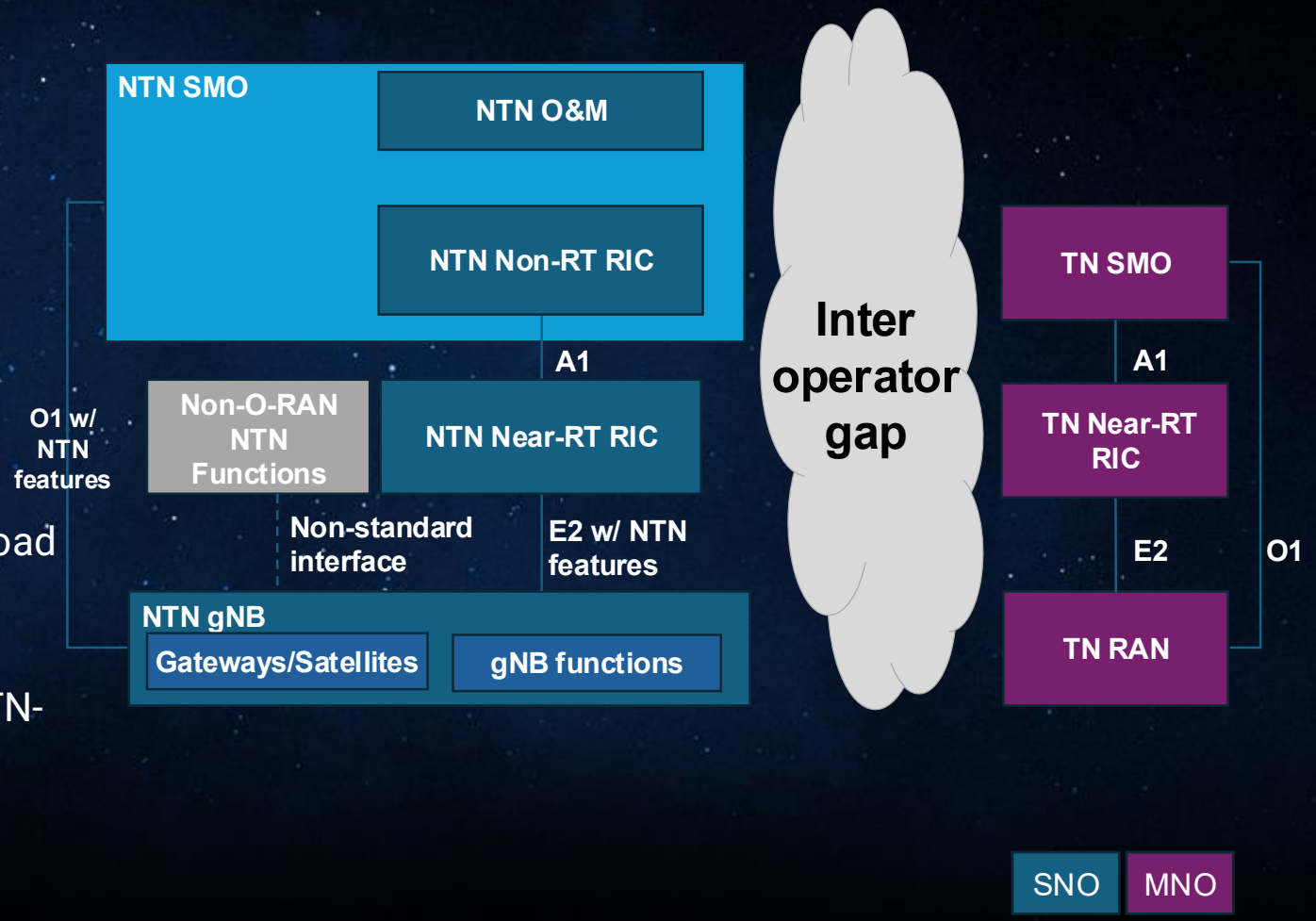
Coordination between TN & NTN

- Several gaps in **inter-Operator** interworking at **Radio Network Layer**
  - NTN is highly dynamic
  - No means to exchange information (no Xn)

- **Key TN-NTN Use Cases Include, e.g.:**
  - TN-NTN Coverage Information Sharing
  - TN-NTN Mobility (Idle, Connected)
  - On-Demand NTN Coverage Activation (e.g. **Disaster Coverage**)
  - Slice Policy, Incoming Demand and Current Load information Sharing
  - Dynamic Spectrum Lease/Management
- Further potential beyond TN-NTN (e.g. NTN-NTN, TN-TN)



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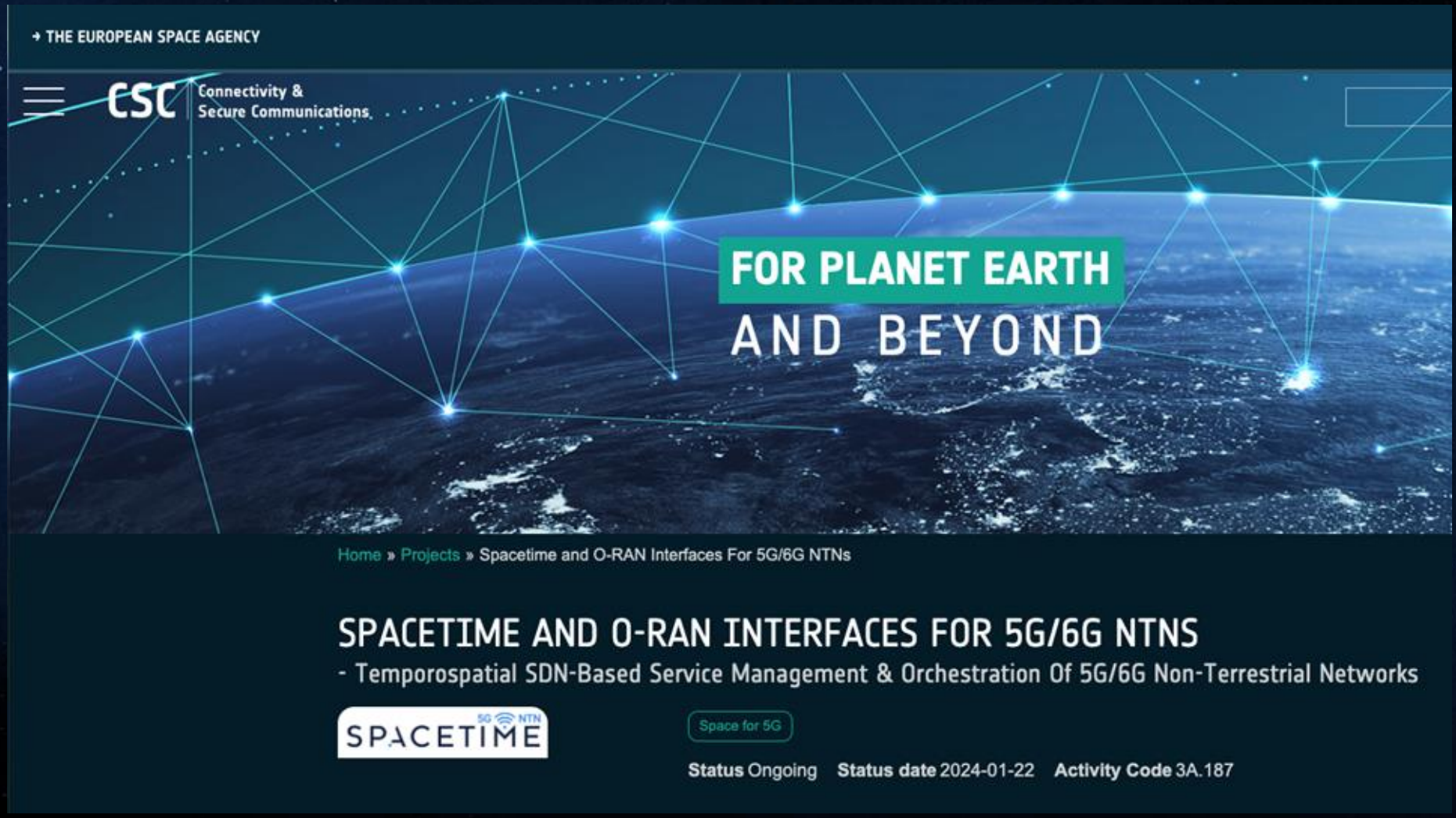
Evolution of O-RAN NTN RIC developed under ESA banner



https://connectivity.esa.int/projects/spacetime-and-oran-interfaces-5g6g-ntns

SPACETIME

A temporospatial SDN platform for all-domain mesh orchestration

MARTIAN ORBIT

LUNAR ORBIT

GEOSTATIONARY ORBIT (GEO)

MID EARTH ORBIT (MEO)

LOW EARTH ORBIT (LEO)

LAND, SEA & AIR

- Antenna tasking, routing, and RRM
- Ground segment SDN and SD-WAN
- Planet scale digital twin
- ITU Article 22 and weather-aware ITU-R Propagation loss modeling (1 MHz to 100 GHz)
- Delay / disruption tolerance
- Atmospheric free space optics ready
- Hosted on K8s with pod autoscaling

In a nutshell:

A software control plane and orchestrator for planet-scale dynamic multi-layer, multi-domain aerospace networks and multi-orbit constellations.

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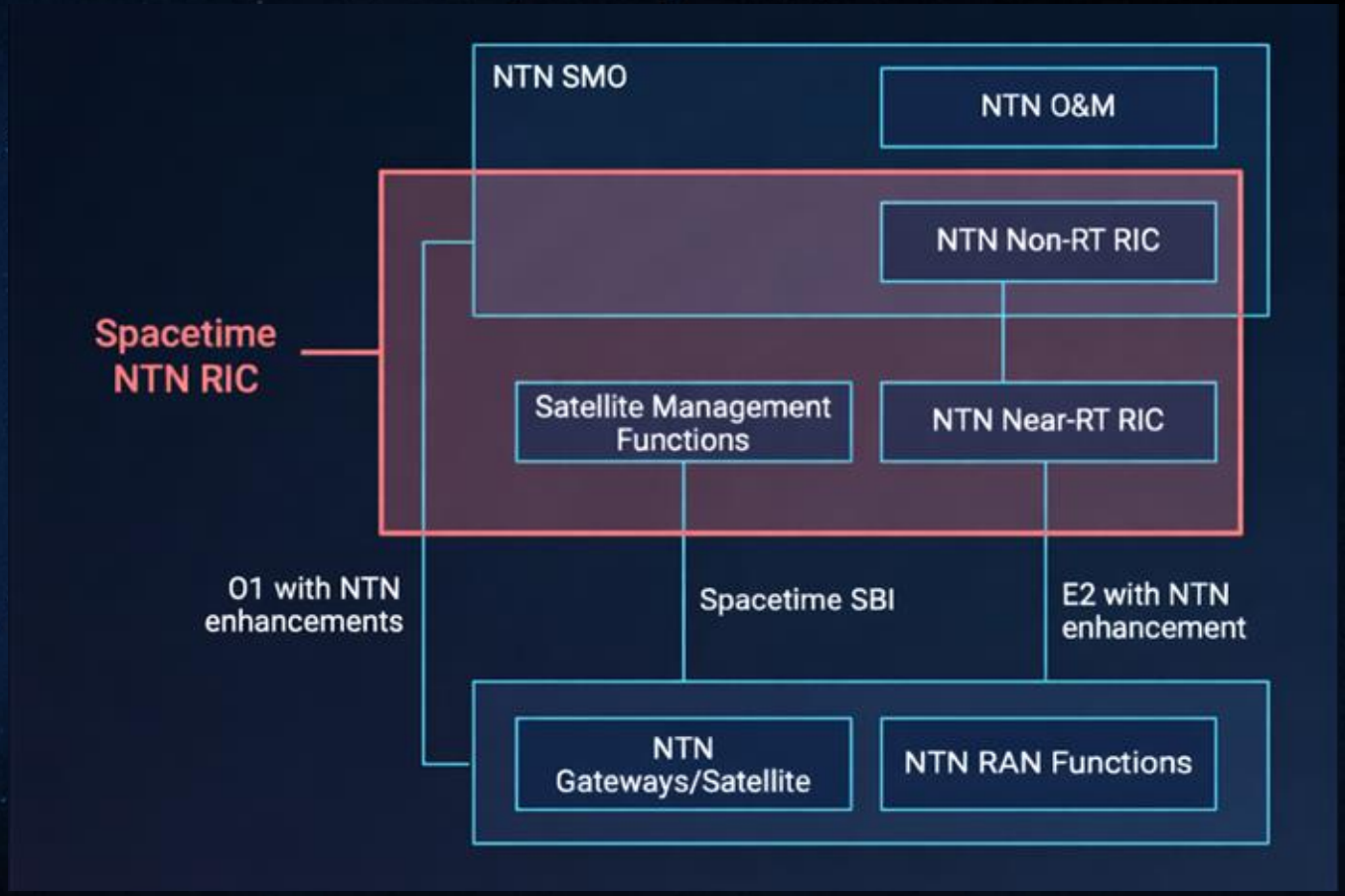
Spacetime as an NTN RAN Intelligent Controller (RIC)

Spacetime: a unique NTN-native RIC/SMO:

- NTN Native → full time-space and physics Digital Twin
- “Converged” Near-RT+Non-RT
- Combines focused capabilities of:
  - Near-RT RIC
  - Non-RT RIC
  - SMO functions
  - non-3GPP function support *(required to manage NTN transport infrastructure)*
- Converged architecture allows for holistic and fine grained control of 3GPP and non-3GPP segments, for instance for Beam Hopping



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Spacetime UI - Example LEO Ka band (w/ Beam Hopping)

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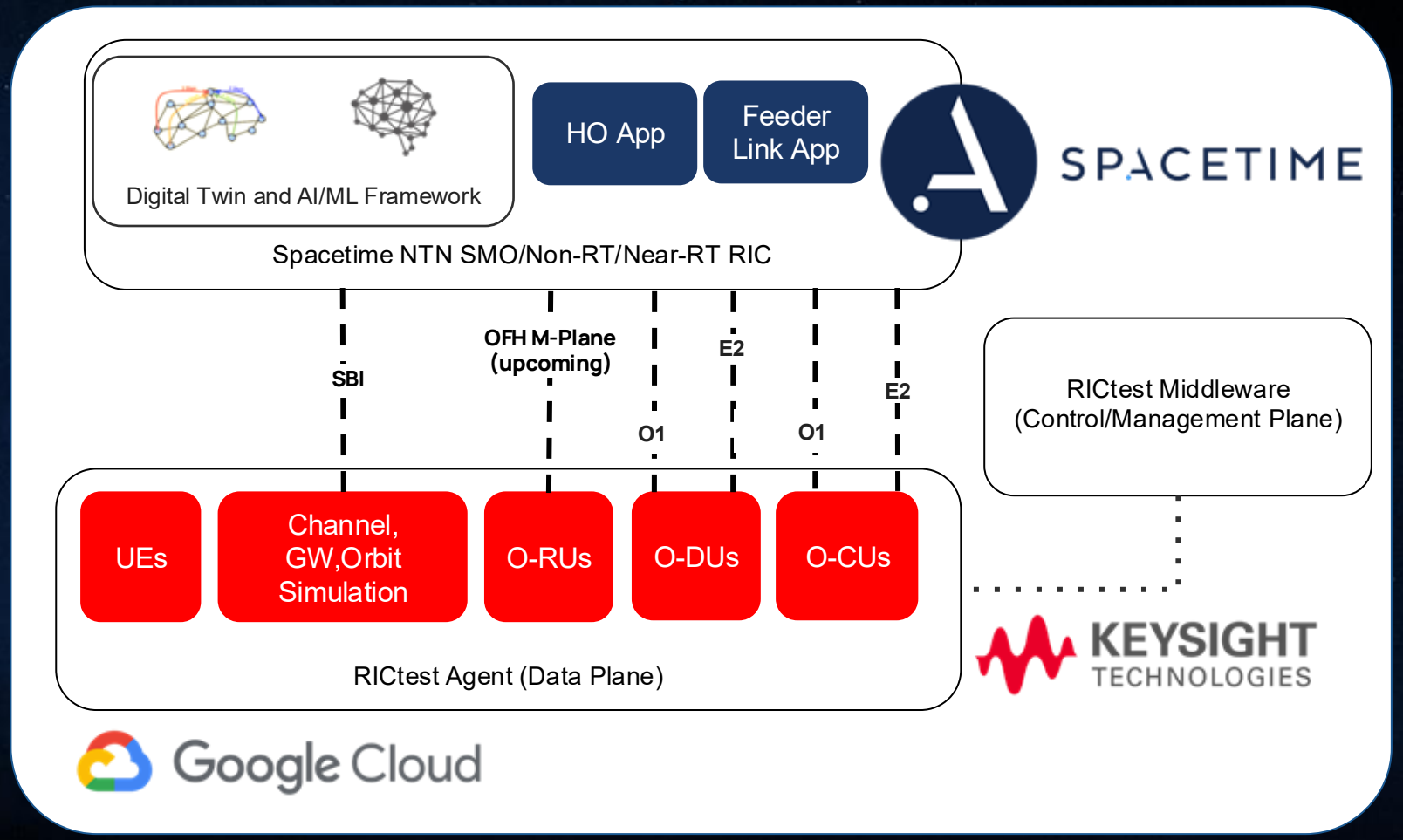
Keysight and Aalyria - First NTN-centric RIC integration

- Partnered with Keysight for the 1st O-RAN NTN RIC integration, fully in GCP Cloud Lab
- Demonstrated at MWC 2025 (at ESA, UKSA and Keysight booths)
- Demonstrated full RIC-controlled NR-NTN inter-satellite L3 mobility procedures
- More evolved demonstrations to come in MWC 2026



More information:
https://www.keysight.com/gb/en/assets/7125-1011/article-reprints/Advancing-NTN-Deployments-with-O-RAN-RIC.pdf

Joint Spacetime NTN RIC Demo with Keysight RICtest @MWC2025

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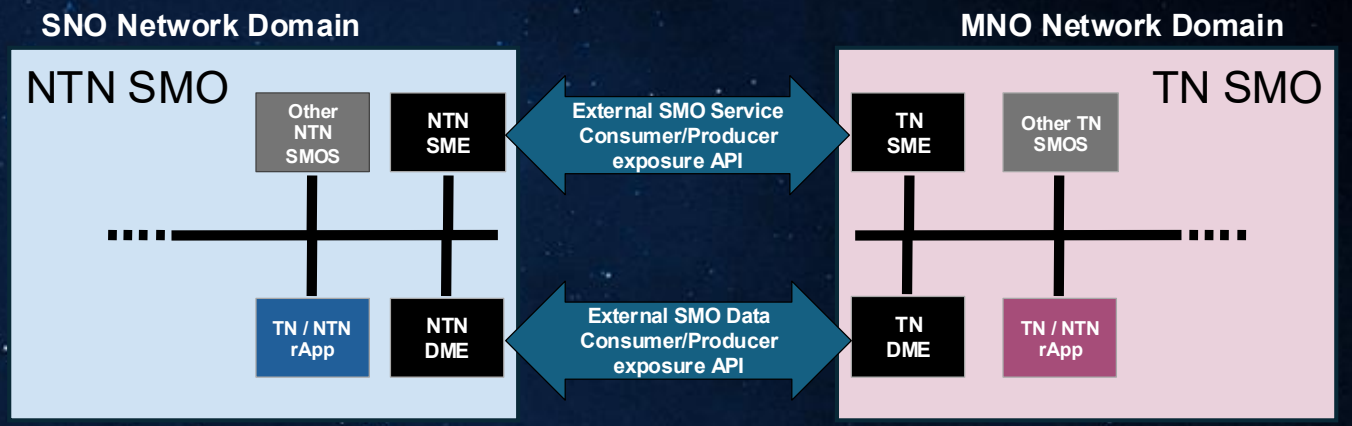
TN-NTN Interworking and Cooperation: Proposed Approach in O-RAN Alliance

- Interaction leverages Decoupled SMO architecture in O-RAN Alliance

- **New East-West external exposure of SMO Services (and/or Data)**
  - Intra-operator (e.g. different domains)
  - **Inter-operator → new security/trust boundary definition (or NF)?**

- **Flexible support for External API types/adapters (e.g. gRPC, HTTPS/REST, etc), e.g.**
  - Federation API, GSMA Network API (CAMARA), etc.



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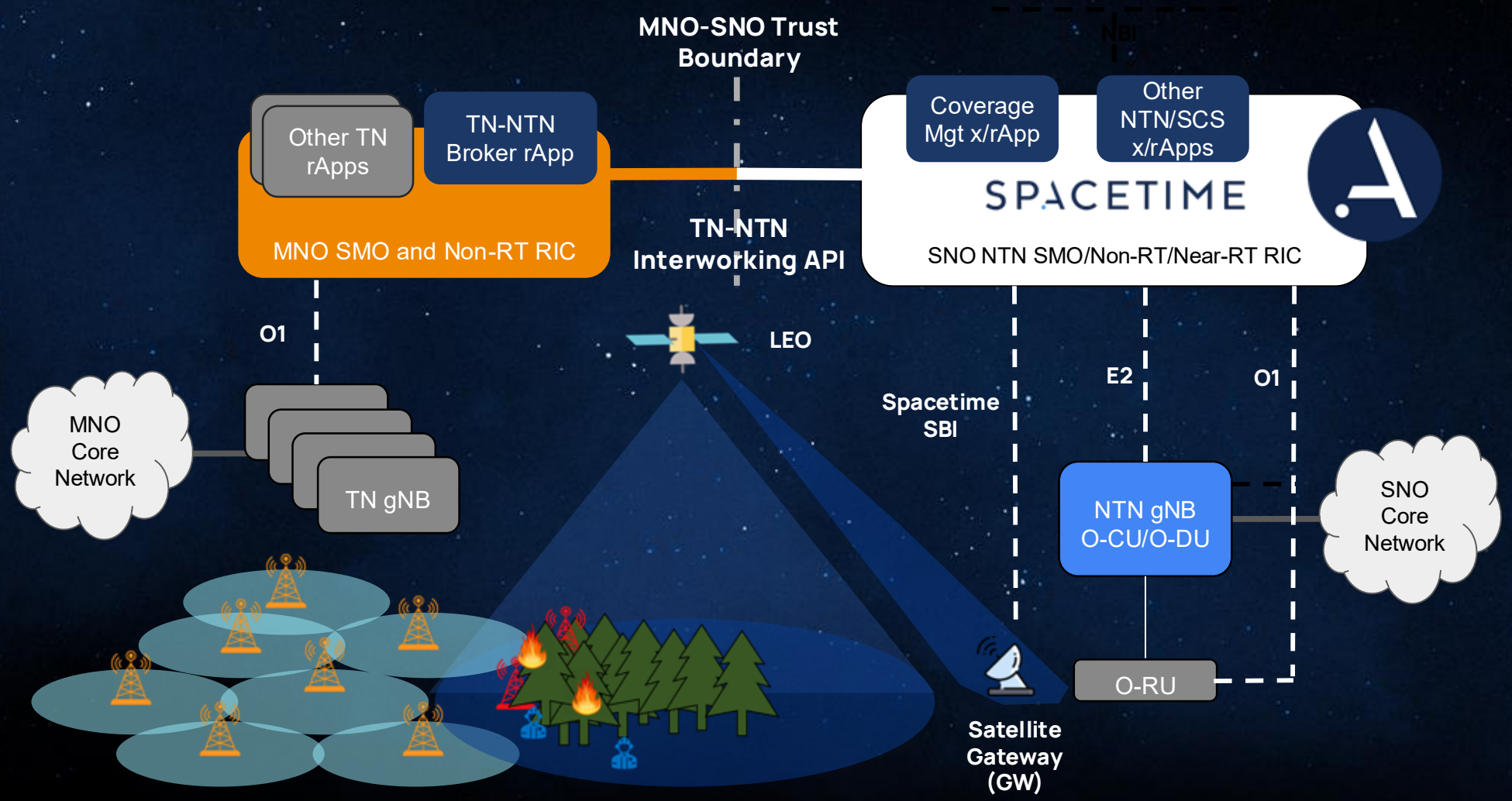
TN-NTN Interworking for Disaster Coverage

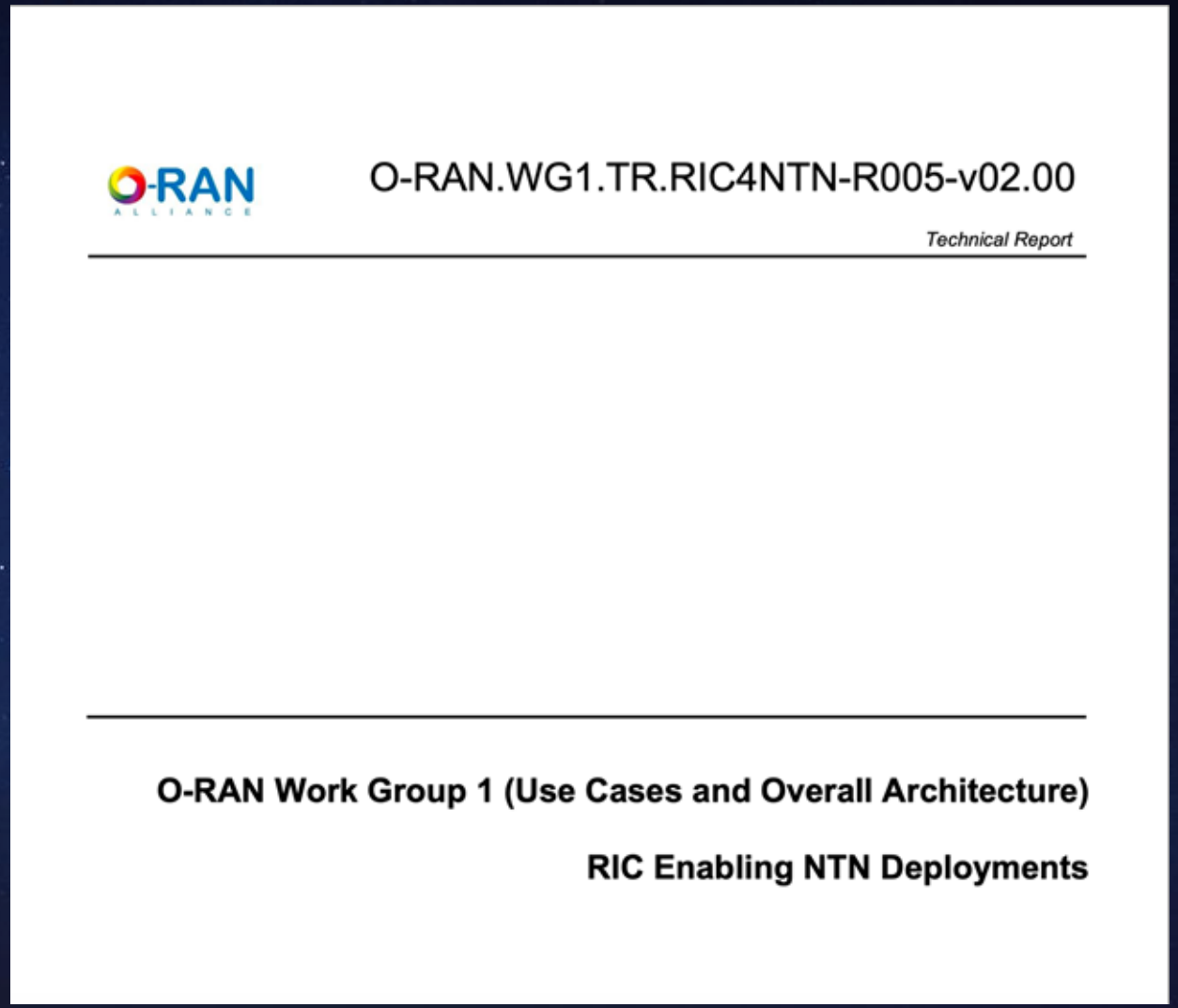


Ongoing O-RAN Activities for NTN (R006)

- **TR "O-RAN.WG1.TR.RIC4NTN - RIC Enabling NTN Deployments"**

- Two Use Case Groups (UCG) have been identified (so far):
  - UCG#1: TN and NTN interworking and cooperation based on O-RAN SMO/RIC
    - UC#1-1: TN-NTN Coverage Information Sharing
    - UC#1-2: TN-NTN Mobility
  - UCG#2: NTN Mobility and Optimizations (TBC)
    - UC#2-1: NTN Handover Management
    - UC#2-2: NTN QoS-based traffic steering and optimization
    - UC#2-3: NTN Time-based and Distance-based Conditional Handover(CHO)

- Normative work ongoing in WG1 and WG3 to enhance O-RAN interfaces with T1/D1/D2 CHO, SIB19 provisioning, SMTC4, Beam Hopping, etc.


O-RAN.WG1.TR.RIC4NTN-R005-v02.00

Technical Report

O-RAN Work Group 1 (Use Cases and Overall Architecture)

RIC Enabling NTN Deployments

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