16-17 February 2023
ESA/ESTEC

# IOT4EO 2023 WORKSHOP (IOT FOR EARTH OBSERVATION)

## INTERNET OF THINGS IN SPACE NETWORKS

SPEAKER: VINCENZO SCHENA



**Date:** 16-17 February 2023
**Ref:** Internet of Things Space Networks
**Template:** 83230347-DOC-TAS-EN-010

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# INTRODUCTION: INITIAL OBSERVATION AND MOTIVATION

The Key Technical Domains of this challenge is a **Complex Systems** that allow the **integration of the terrestrial network with the space segment assets**. The type of technologies that will be integrates in this challenge are:

- Internet of Things (IoT) is a disruptive technology that ubiquitously connects all low cost and low power pseudo-intelligent devices integrated in everyday objects into a global network to allow their access at any time.
- The 5G NTN is becoming an opportunity to have a transversal standard for space and ground application.

**WHO?**

- **Surveillance**
- **Critical infrastructure** data colleting
- **Smart Cities**
- **Narrow-Band communication (Crisis or emergency)**
- **Broad-Band communication**

**WHY SATELLITE?**

- **Ensures availability of unreached coverage**
- **Decrease the digital divide**
- **Improve QoS**
- **Emergency and crisis management**
- **Broadcasting service**
- **The development and opportunity of Low-Earth Orbit (LEO) communication satellites are being highlighted as an attractive system compared to GEO satellites as they have greater advantages in terms of:**
  - communication link performance;
  - propagation delay;
  - cost.



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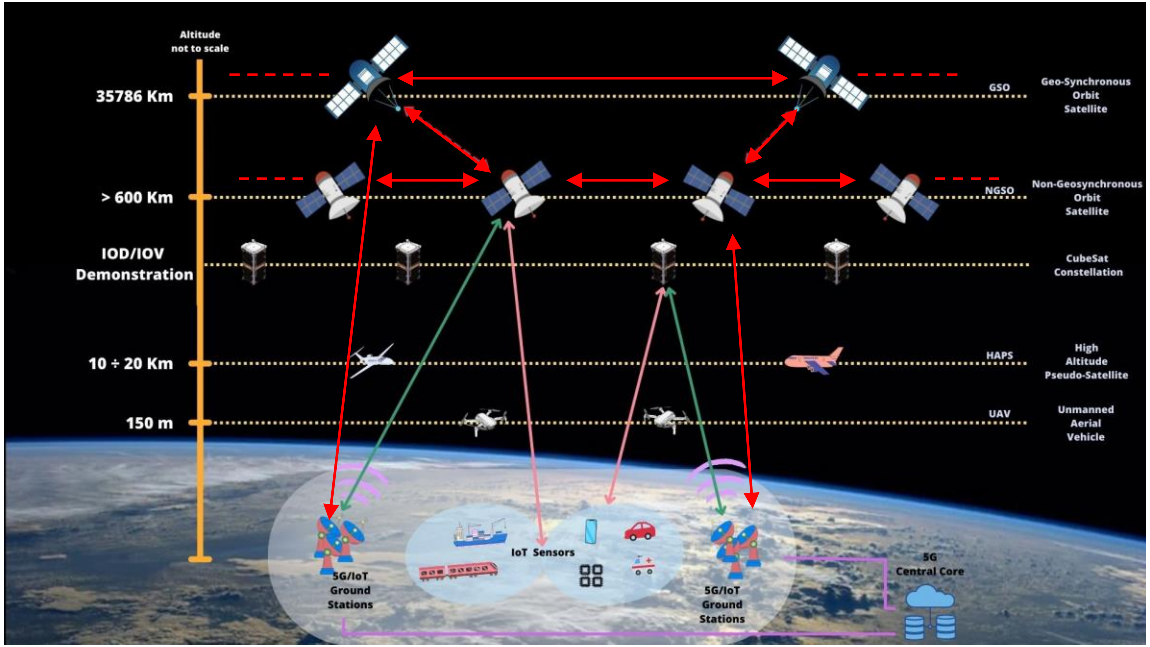
# INTRODUCTION: INITIAL OBSERVATION AND MOTIVATION (CONT'D)

## Mission Concept Overview

The **Mission of 5G/IoT activity** and initiative is integrate terrestrial and non terrestrial network in order to achieve the **multi-dimensional** and multi-layer Broad Band and Narrow Band **hybrid connectivity**




The key-technologies of this mission concept are:

- Small Satellite at low orbit (VLEO)
- Small Active Multi-Beam Antennas
- On-Board Digital Processing
- Inter Satellite Links (ISL) with large interest on Optical-ISL (see picture)



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# INTRODUCTION: COVERED TECHNICAL AREAS BY TAS-I/TAS

## System architecture definition, standardization, protocols studies and adaptation

- **Roadmap 5G** (Contract n. 4000123652/18/TASI) (role: SUBCO) ……..Successfully Concluded
- **EAGER** (Contract n. 4000133232/21/UK/A) (role: SUBCO)
- **R3** (Contract) ARTES 4.0 4S SPL 3A.167 / 4S.024 **Civil Security from Space (CSS) opportunities** (role: SUBCO)
- **GADGET** Phase 1 (Contract n. 4000133232/21/UK/AL) (role: PRIME)
- **3GPP NB-IoT 4Space Preliminary Phase** (contract n. 4000129810/20/NL/CLP) (role: SUBCO)
- **TRACK Preliminary Phase** ARTES 4.0 4S SPL 3A.136 / 4S.006 (role: PRIME)
- **CoRAL** IoT terminal ON-BOARD (Contract n. 4000135323/21/UK/AL) (role: PRIME)

## E2E System TestBed

- **GADGET** Phase 2 (Contract n. 4000133232/21/UK/AL) (role: PRIME)
- **3GPP NB-IoT 4 Space Implementation Phase** (contract n. 4000129810/20/NL/CLP) (role: SUBCO)
- **TRACK Implementation phase** ARTES 4.0 4S SPL 3A.136 / 4S.006

## Space segment technologies (all the activity are at proposal submitted phase)

- **CORAL** IoT terminal ON-BOARD (Contract n. 4000135323/21/UK/AL)
- **ON BOARD PROCESSOR** (Iris Phase 3 start in Q2 2022, other initiatives)
- **Demonstration of a 5G g-NodeB IN SPACE** (Initiative)


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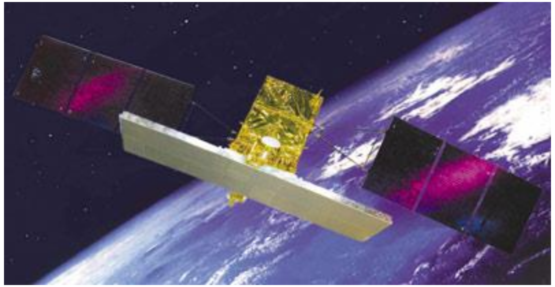
# IOT SPACE NETWORK UTILISATION IN THE EO (OPPORTUNITY)

In the Earth Observation (EO) context, the IoT space networks give the opportunity to target continuous access space infrastructure for the application needing of a low bitrate as the “Tasking”. Some possible applications can be:

1. continuous access allowing to immediately program an image acquisition on the observation satellite, based on user urgent requests and not having to wait for the scheduled steps with the ground stations used for telemetry and satellite remote control management. This can save a lot of time (several hours)



2. Possibility of exploiting very low latency of information content with high added value but whose volume could be very small such as to be managed with low data rates. This possibility could be expressed even with the predictable advent of "on-board“ image processing, currently being studied, which would make it possible to extract information from what is acquired by the sensor (SAR or/and Optical) thanks to an appropriate processing which requires resources and architectures appropriate on the EO satellite.

The above scenarios can be framed in the CoRAL Study objective as possible application on top of the simple telemetry forward in space-to-space as in following detailed.



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# SATELLITE TELEMETRY AND CONTROL USING SPACE IOT NETWORKS FOR SMALL SATELLITES (CORAL)

/// **The Objective of CoRAL** project **is to develop telemetry and control communication system utilising existing space-based IoT networks independent from the existing terrestrial infrastructure**. The activity is developping prototype satellite IoT terminals reusing and adapting terrestrial terminals compatible with existing space IoT networks.

## Already Performed Activities

1. The first outcome of the activity has been the system architecture definition following the scenario choice and identification of issues and challenges

2. Selection of the most suitable IoT protocol and orbit based on the proposed scenario to guarantee windows for the transmission taking into account the terrestrial protocol restriction

3. Based on the simulations, definition of the appropriate In Orbit Demonstrator Architecture (payload and space segment)

## Ongoing and next activities

5. Execution of the Test Plan on ground in order to prove the efficiency of the proposed in orbit demonstrator architecture (verification phase)

6. In orbit mission implementation (launch and In orbit test or IOT)

7. Completion of IOT in order to validate the design and execute the experiment in orbit (demonstration) for TC/TM IoT applications




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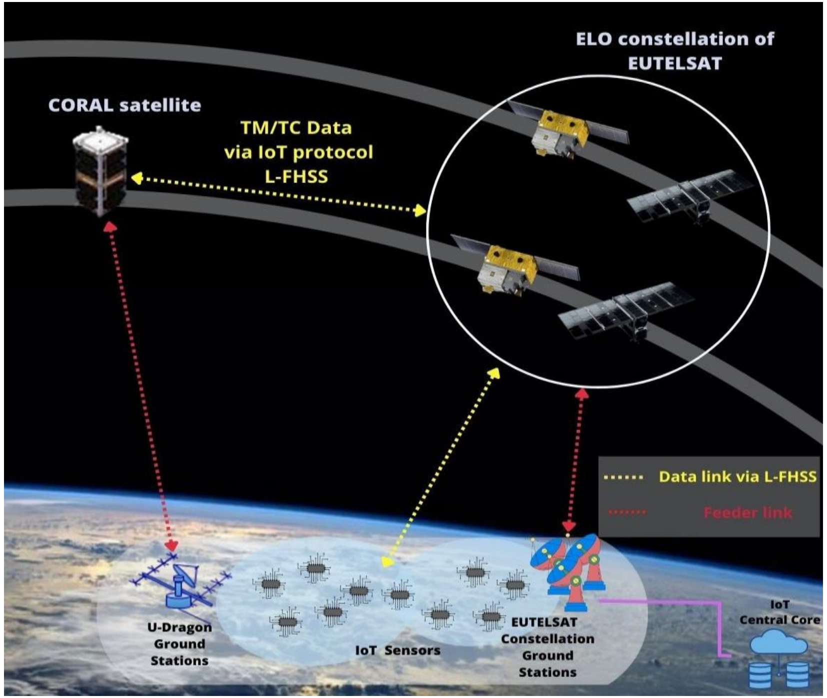
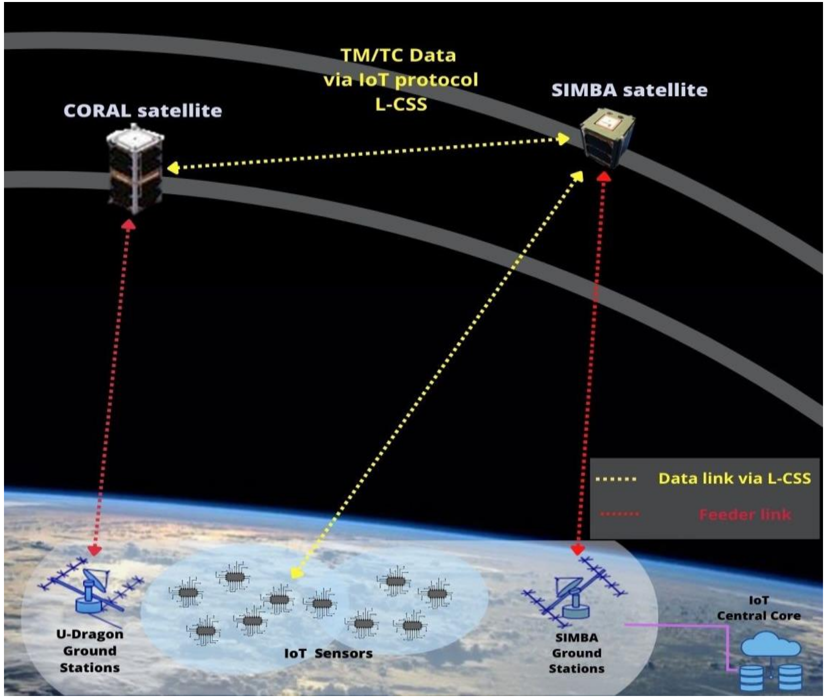
# CORAL:  SYSTEM ARCHITECTURE IOD




## Implementation

Two scenarios for the IOD have been identified accessing to ELO IoT Constellation of EUTELSAT and using the Università La Sapienza (UNIROMA1) SIMBA satellite system adding in it the CoRAL CUBESAT implemented still by UNIROMA1.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# CORAL IOT: TERRESTRIAL PROTOCOL AND ORBIT TRADE-OFF

/// The chosen IoT protocol is LORA. The choice was leaden by the commercial state of the art. The most of already existing IoT constellations space-based use the LORA (CSS or FHSS) protocols;

/// Orbit trade-off

- From the orbital trade-off analysis the orbit injection from ISS at an altitude of around 430-450 Km and an inclination of 51.7°resulted the preferred one.
- The main reasons are the lower altitude and inclination which ensure the correct pointing of the IoT antennas (mounted on CORAL on Zenith and on IoT Sat's on Nadir orientations) and several Zone of Convergences with all IoT Sat targets at moderate inclination.
- The disadvantages of this solution is represented by the relatively high relative velocity wich reducing the convergence time and is increasing the Doppler effects on the transmission (both the frequency shift and frequency shift rate). However this is an opportunity to validate in a representative environment the protocols for space based solution
- The Launch Provider selected is the Italian branch of Nanoracks which already has defined a suitable launch windows for CoRAL.

| Parameter | ISS Orbit | SSO Orbits |
|---|---|---|
| **Launch Parameters** | | |
| Access to Launch Services | ✔ | ✔✔ |
| Launch Opportunities | ✔ | ✔ |
| Launch Cost | ✔✔ | ✔ |
| **Satellites Dynamics** | | |
| Average Target Satellite Elevation inside Zone of Convergences (ZoC) | ✔ | ✖ |
| Passage Duration | ✔ | ✔✔ |
| ZoC Time Distribution | ✔✔ | ✖ |
| Orbits Altitude gap between Target and Chaser Satellites | ✔✔ | ✖✖ |
| **ISL Communication** | | |
| Electromagnetic Disturbance in ZoC | ✔✔ | ✖ |
| Doppler Shift Effects | ✖ | ✔ |



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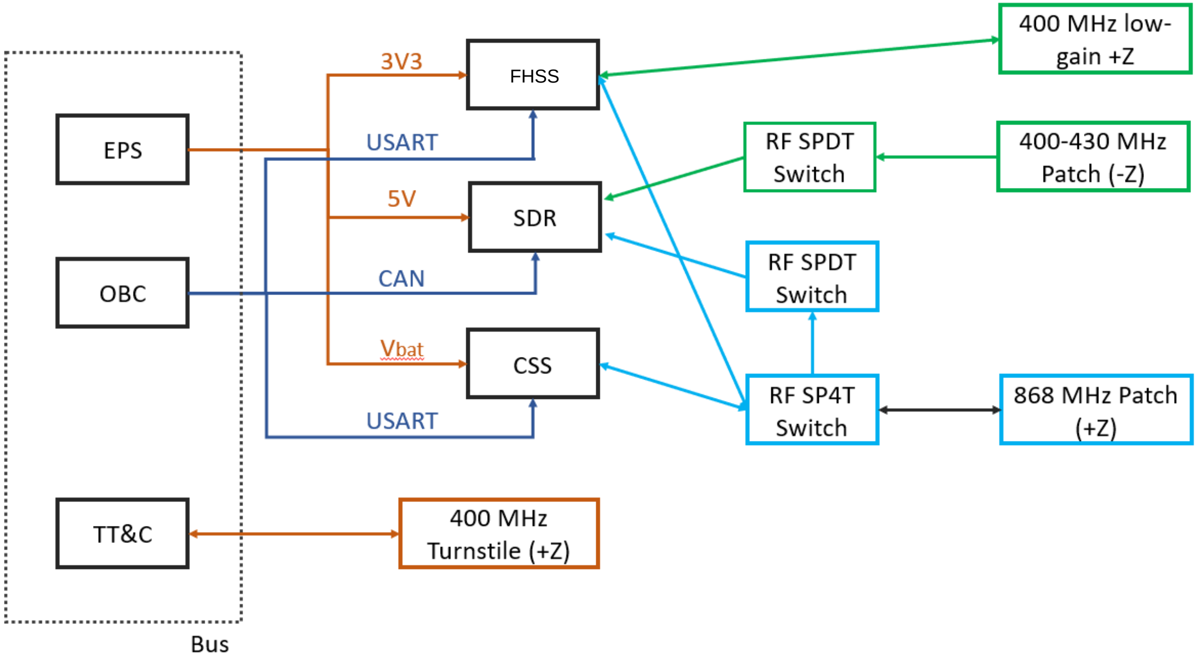
# CORAL IOT: PAYLOAD ARCHITECTURE




EPS: Electric Power Subsystem
OBC: On board Computer
TT&C: Telemetry and Telecommand sub-system

**The payload of CORAL is composed of:**

- A LoRa CSS* transceiver in the 868 MHz ISM Band;
- A LorA FHSS* terminal in the 868 MHz ISM Band;
- A Software Defined Radio connected both to the 400MHz and the 868 MHz antenna.

The antennas are located on the +Z and –Z sides of the spacecraft and will actively pointing the target.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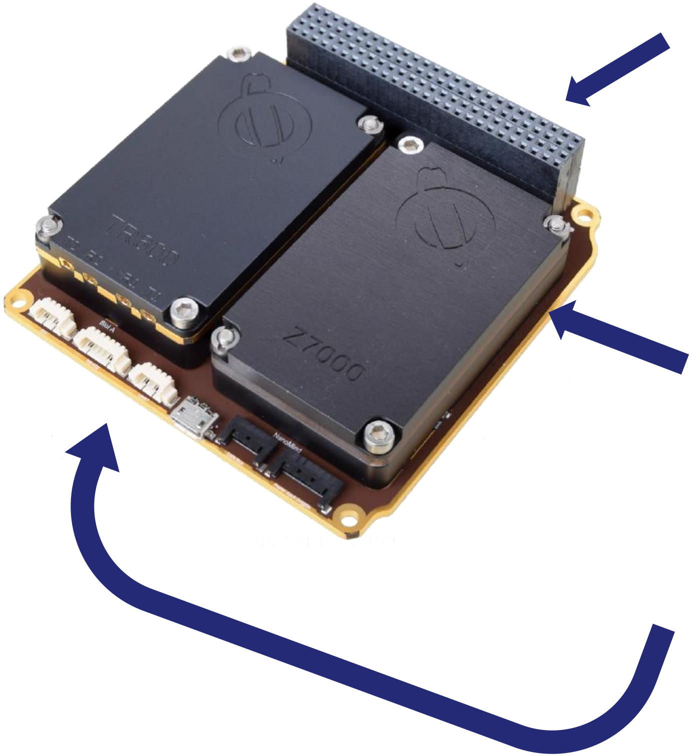
# ON-BOARDED SDR CARD OF GOMSPACE

## NanoCom SDR: SDR Dock, Z7000 and TR-600




- GomSpace Mother/Daughter board concept
- Supports the NanoMind Z7000 and 3 NanoCom TR-600s
- Flight proven
- Centralized 40 MHz clock
- Fits standard PC104
- MicroSD card connector
- USB to UART console interface for easy use in lab setup (GOSH)
- Collective mass (NanoDock, Z7000, 1 TR-600 and 2 slot shields): ~ 271 g
- Operational temperature: -40°C to +85°C
- Storage temperature: -40°C to +85°C
- IPC-A-610 Class 3A assembly

NanoDock SDR motherboard

- PCB material: Glass/Polyimide IPC 6012C cl. 3/A

NanoMind Z7000

- Xilinx Zync 7030 Programmable SoC
- ARMv7 Architecture
- Dual ARM Cortex A9 MPCore up to 800 MHz (standard clocked at 666 MHz)
- 1 GB DDR3 RAM and 32GB storage (GB: Giga Byte)
- Powerful FPGA module – 125K logic cells
- Precision milled anodized aluminium heat sink to control thermal load and provide EMI shielding
- Linux distribution/operating system
- PCB material: 22-layer glass/polyimide

NanoCom TR-600

- AD9361 IC
- 2 × 2 transceiver with integrated DACs and ADCs
- Band: 70 MHz to 6 GHz
- Channel bandwidth is tuneable from 200 kHz to 56 MHz
- Supports TDD and FDD operation.
- Multichip synchronization
- LVDS/single-ended digital BB interface
- Flight proven
- Precision milled anodized aluminium heat sink to control thermal load and provide EMI shielding
- Temperature and current sensors
- EEprom for persistent configuration storage
- PCB material: glass/polyimide ESA ECSS-Q-ST-70-11-C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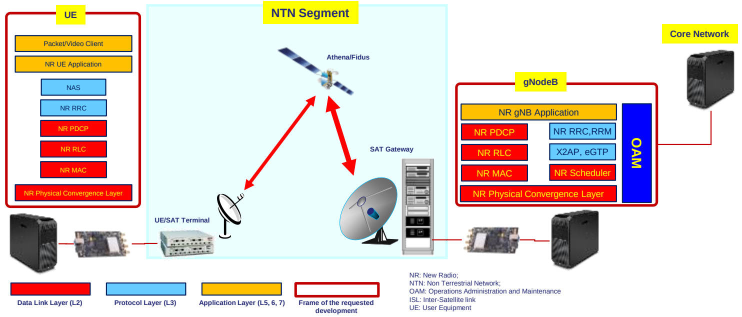
# TOWARDS SPACE NETWORKS: 5G NTN IN GADGET STUDY

**Opportunity for satellite and terrestrial network operators to combine in a seamless and transparent way the space and terrestrial networks using LEO/MEO 5G NTN constellations that will provide low latency access for an affordable connectivity directly to mobile terminals (rail, maritime, road transport, avionic). GEO systems also in constellation configuration (ISL in optical technology) will provide aggregated traffic connectivity and/or non-time sensitive services.**




**"5G Enabled Ground Segment Technologies Over The Air Demonstrator" (GADGET) ESA Study**

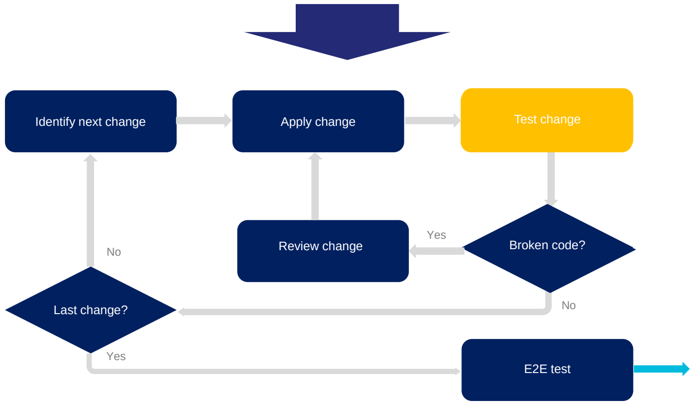
Development of a gNodeB (gNB) based gateway and the User Equipment (UE), compliant with the 5G standard Release 16 or above, for demonstrating the direct radio access connectivity in Non-Terrestrial Networks (NTN) i.e. satellite access network.

A demonstration accessing to Athena/FIDUS geo-satellite in Ka band will be carried-out.

The GADGET protocol stack has been originated by the open source code written fro terrestrial 5G standalone srsRAN.

GADGET is implementing a "fork" of the srsRAN updated and improved for satellite application (just NTN).

The logic flow to update the code and write new libraries is as in following



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# TOWARDS SPACE NETWOKS: TRACK STUDY

**Integration of Satellite and Terrestrial Railway Control Networks (TRACK)**
to develop and test the control and management protocol stacks of railway control communication via satellite, necessary also for the integration of satellite and terrestrial railway control networks. Testing will be carried out through realistic packet level simulations via a developed software-defined radio testbed.

FRMCS: Future Rail Mobile Communication System

## /// Convergence

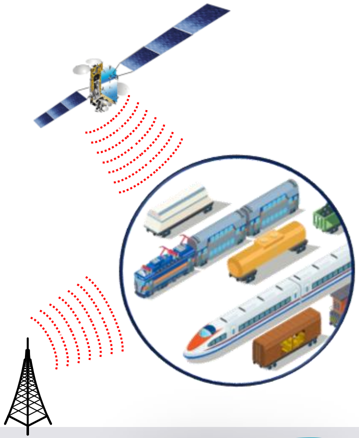
**Satellite as non-3GPP based but still compatible with the 5G core**
(seen as a short term but also long term option)

- Satellite is using another air interface, standardized (e.g. DVB, S-UMTS) or proprietary (e.g. BGAN, Iridium)
- Satellite is compatible with the 5G core at the higher layers, via for example N3IWF, to allow integration in control and management functions, such as billing, authentication, resource management etc.

## /// Integrated

**Satellite as 3GPP solution, fully integrated and compatible with 5Gcore**
(Long Term Option)

- Satellite as a network access element of 5G NR release 17 and above (see 3GPP 5G NR NTN working group)
- 5G NR air Interface over satellite for FRMCS
- Satellite and terrestrial access fully integrated under the same 5G NR umbrella

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# End of Presentation

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