Satellite for 5G – Tomorrow's connected World
5G Satellite Initiative (S45G)
Presentation

ITU Forum "Towards 5G Enabled Gigabit Society", 11-12 October 2018, Athens

European Space Agency

Satellite for 5G Tomorrow's connected World: Executive Summary

1. 5G is a revolution in telecommunications, a set of technologies, a set of services, a network of networks

2. Satellite can complement 5G terrestrial systems and offer important societal and economic benefits

3. Satellite offer important attributes to 5G, like security, resilience, capacity and ubiquitous coverage

4. ESA has set up the "Satellite for 5G Initiative" to facilitate the integration of satellite in 5G

Connectivity, edge and cloud computing enable Digital Transformation

A⁴ - Access to data:

☐ Anytime
☐ Anywhere
☐ Any Volume
☐ Any Thing (M2M/IoT)

Connectivity
✓ Ubiquitous
✓ Resilient
✓ Secure

Cloud native services, big data, AI

Digital Transformation – Digital Economy

- ➤ GDP increase 1%⬆ for every 20% ⬆ in ICT investment
- ➤ Productivity: 20%⬆   by 2025
- ➤ Connected devices: 100 Billion by 2025
- ➤ Relationship between broadband speed & new skills development, increase reach, etc
- ➤ ICT innovation drives inclusive growth and sustainable development

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What will 5G bring You?

Relevance and Opportunities for Satellite

- VHTS satellites and broadband LEO constellations
- Ubiquitous coverage and network integration
- Push information & processing at edge of networks (Mobile access Edge Computing)
- Integration terrestrial/satellite and new satellite technologies for mMTC/IoT
- Satellite are energy and cost efficient in most areas
- Software defined networks, network function virtualization
- Safety security and resiliency offered by satellite

What will 5G bring you?   5G applications

Amazing volume / Amazingly fast — Hologram TV, immersive presence, augmented reality, ultra large volume transfers

Always best connected — Staying connected everywhere including high-speed trains, planes, ships, crowds

No perceived delay — Staying connected everywhere including high-speed trains, planes, ships, crowds

Massive amount of connected things and people — Internet of things, smart cities, connected cars, e-health

Energy efficiency — 80% energy saving; deployment in developing countries

Flexible integrated programmable networks — New business models for provision of network functions, emergence of super MVNOs, pan-European hybrid networks, faster innovation in network services

Secure networks — Networks for police, civil protection, public safety and security professionals

ESA Satellite for 5G Initiative (S45G)

1. Support the space industry in developing and demonstrating convergence and seamless integration with 5G terrestrial technologies and enable 5G Satellite services

2. Reach out to the 5G terrestrial community and standardisation bodies to promote awareness and integration with satellite

3. Reach out to 5G national and international bodies to ensure coordination

4. EC-ESA alignment and collaboration on 5G

5. Promote developments, validation trials and vertical pilots to support global rollout of integrated satellite and terrestrial 5G services

https://artes.esa.int/satellite-5g

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ESA Satellite for 5G Initiative - Membership

ESA S45G initiative supports along the path of integration

Important steps to reach the target

1. **Show satellite benefits & added value in different vertical markets**

2. **Ensure the 5G standards include satellite**

3. **Develop the 5G features in satellite networks**

4. **Test and demonstrate end-to-end system, network and service interoperability**

5. **Participate in large scale 5G pilots for different vertical markets**

Practically prove the 5G satellite advantages

Add satellite parameters to 5G requirements

Selected standardization activities (5G, NFV, SDN, MEC)

R&D, testing and interop

Developing new satellite based services

Satellite

Roadmap

Terrestrial

Consider satellite for interop

Convergence of standards

Consider satellite as a technology alternative
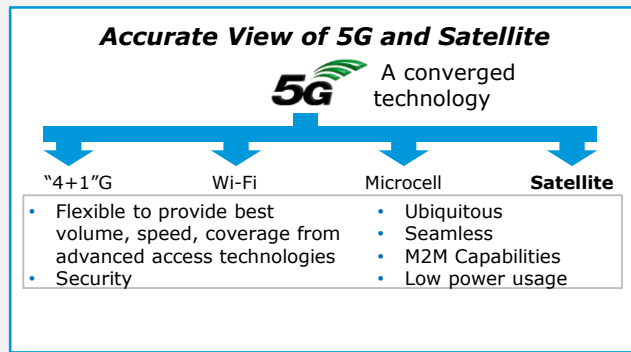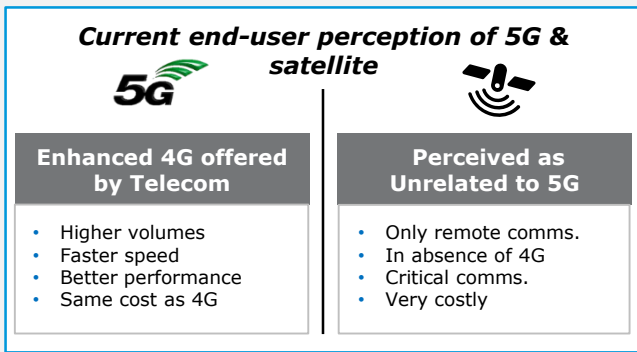
5G Integrated Terrestrial-Satellite Network

Courtesy: EURESCOM
ARTES FP INSTINCT

The relationship between 5G & Satellite is misinformed across different sectors; well defined commercial offerings are needed

The satellite industry needs to change perception about 5G enabled satellite
5G is a cooperative ecosystem

Current end-user perception of 5G & satellite

Enhanced 4G offered by Telecom
- Higher volumes
- Faster speed
- Better performance
- Same cost as 4G

Perceived as Unrelated to 5G
- Only remote comms.
- In absence of 4G
- Critical comms.
- Very costly

Accurate View of 5G and Satellite

A converged technology

"4+1"G | Wi-Fi | Microcell | **Satellite**

- Flexible to provide best volume, speed, coverage from advanced access technologies
- Security

- Ubiquitous
- Seamless
- M2M Capabilities
- Low power usage

To deliver on the promises of 5G, service providers need to deliver an access technology agnostic service, and focus on QoS

|	Actions Needed	Status
1	**Definition of Standards –** *Satellite is included as a chapter in the 3GPP 5G standardization activities*	◕
2	**Technology solution availability –** *Plug & play solutions are not available yet in the market*	◔
3	**Regulations maturation –** *Rules around defined service parameters still evolving*	◕
4	**Commercial Packaging –** *Service providers do not package all 5G capabilities commercially*	○

Mature ● Very Nascent ○

Courtesy: Strategy& analysis ARTES FP

5G opportunity for Satellite : New Connectivity models

Integration of satellite as technology providing **direct access in 5G**, the self-backhauling capabilities of **proxy** edge nodes and by integration of **backhaul as part of the end-to-end communication**
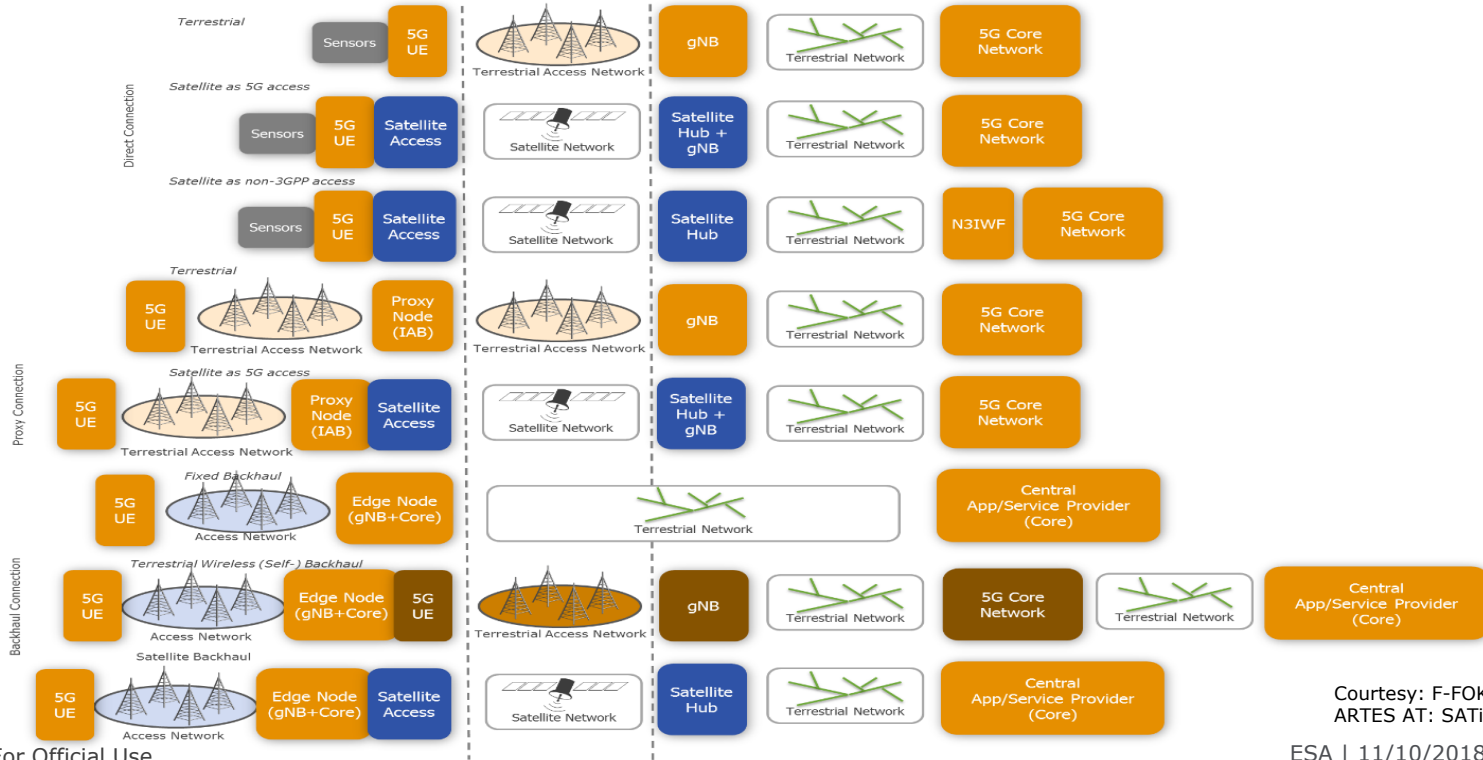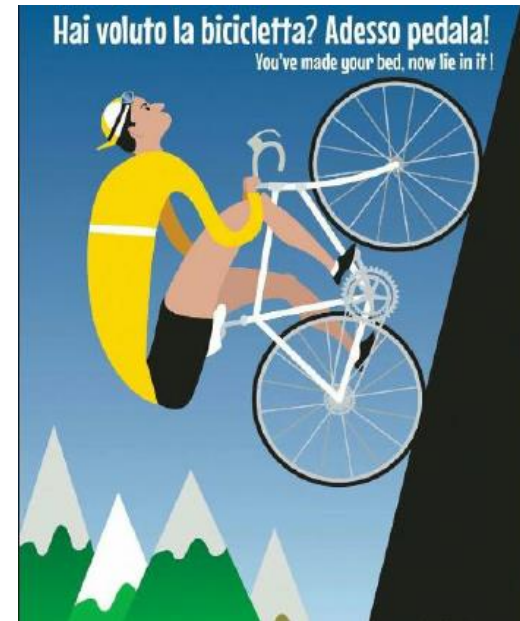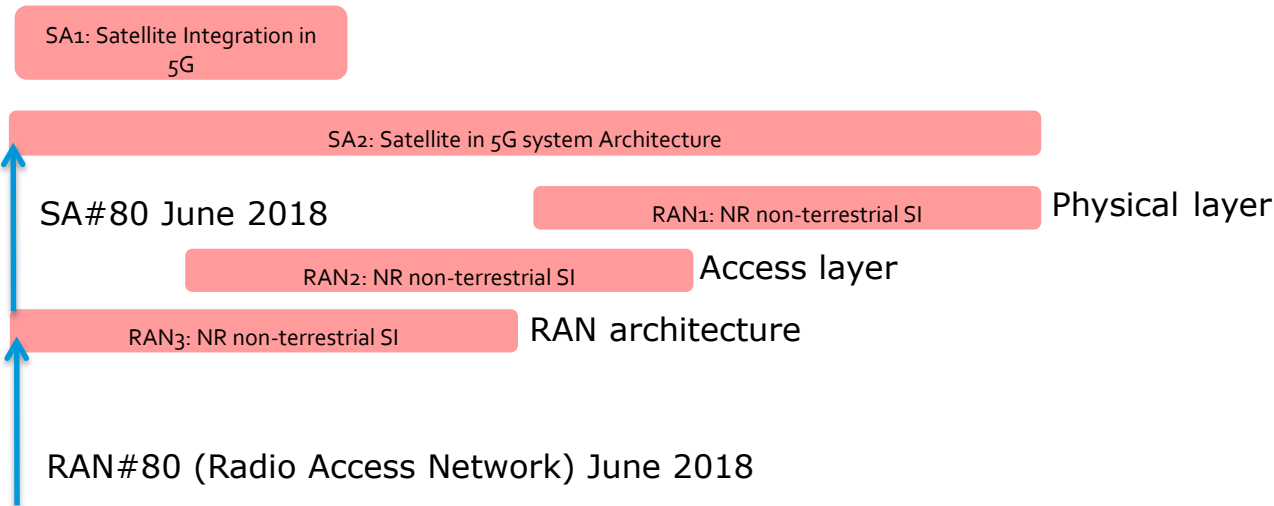

Courtesy: F-FOKUS
ARTES AT: SATis5

Expected costs reductions

Connectivity Models	Impact (CAPEX /OPEX)	Rational
Direct Access	+++	Access to global economy of scale of cellular market thanks to technology commonalities including UE chipset and hardware platforms.
Proxy (Satellite enabled edge)	+++	Same as above Leveraging edge connectivity, integrated access and backhaul features to allow tenants to control radio resources of the integrated NTN-Terrestrial – Reduce development costs through reuse of 5G core network functions.
Integrated e2e backhaul	++	Only service/network management system common between cellular and SatCom

From convergence to integration

Unified Service/Network Control & Management: more flexibility, creation of new services,...
SDN, VNF technology adoption necessary for all connectivity models: common technology drive costs down

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3GPP Rel 16/ITU 2020

2018 Q3	2018 Q4	2019 Q1	2019 Q2	2019 Q3	2019 Q4

SA1: Satellite Integration in 5G

SA2: Satellite in 5G system Architecture

SA#80 June 2018

RAN1: NR non-terrestrial SI — **Physical layer**

RAN2: NR non-terrestrial SI — **Access layer**

RAN3: NR non-terrestrial SI — **RAN architecture**

RAN#80 (Radio Access Network) June 2018

Hai voluto la bicicletta? Adesso pedala!
You've made your bed, now lie in it !
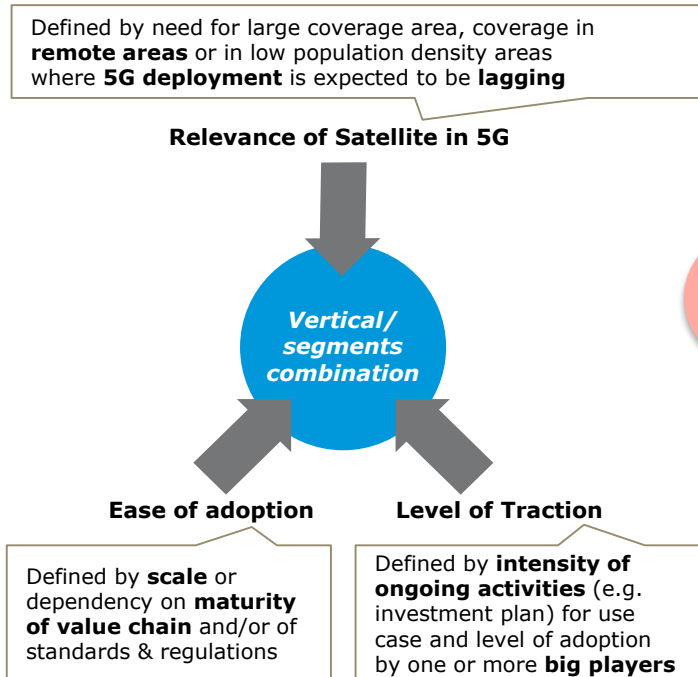
Courtesy TAS-F
ARTESFP: ALIX

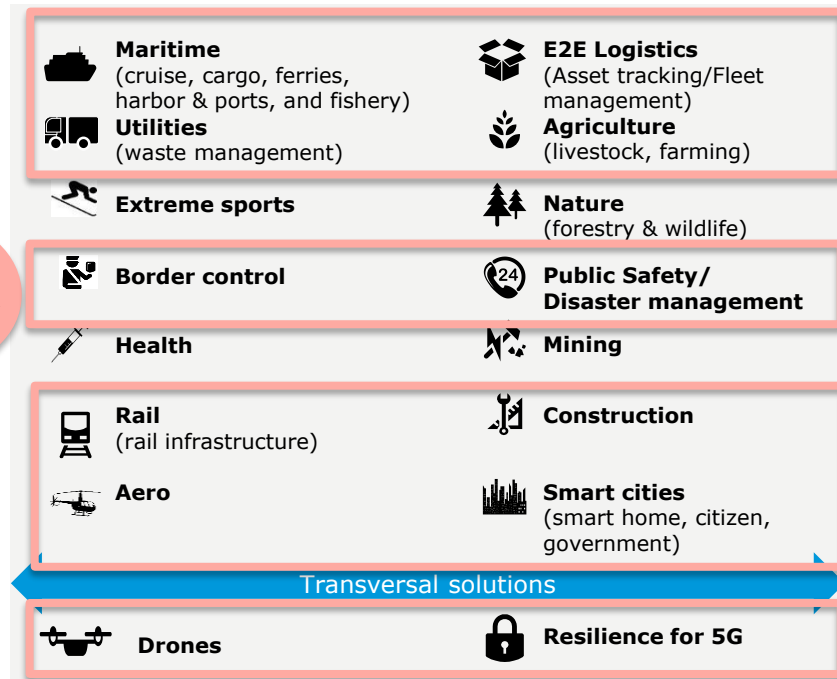# 5G Satellite Opportunity Identification study
Use a 3-lense approach to identify key verticals for satellite use cases in 5G context

3-lense approach

Defined by need for large coverage area, coverage in **remote areas** or in low population density areas where **5G deployment** is expected to be **lagging**

Relevance of Satellite in 5G

Vertical/ segments combination

Ease of adoption

Defined by **scale** or dependency on **maturity of value chain** and/or of standards & regulations

Level of Traction

Defined by **intensity of ongoing activities** (e.g. investment plan) for use case and level of adoption by one or more **big players**

MEDIA

Long list of vertical/ segments

Maritime
(cruise, cargo, ferries, harbor & ports, and fishery)

E2E Logistics
(Asset tracking/Fleet management)

Utilities
(waste management)

Agriculture
(livestock, farming)

Extreme sports

Nature
(forestry & wildlife)

Border control

Public Safety/ Disaster management

Health

Mining

Rail
(rail infrastructure)

Construction

Aero

Smart cities
(smart home, citizen, government)

Transversal solutions

Drones

Resilience for 5G

Courtesy: Strategy& analysis ARTES FP

Ship operators are driving the need for asset and operational efficiency while regulators impose safety standards

Key areas requiring 5G enabled satellite connectivity

Key segments		Four key areas requiring 5G Satellite Connectivity	
Cargo	• Used for long haul transportation of chemicals, oil, bulk and cargo • Varies from handy size carriers (10k-20k DWT[1]) to super tankers (>200k DWT)	**High Navigational safety**	• The maritime industry focuses on reducing losses due to accidents - **1186 ship losses** in the last 10 years (each single large accident costing ~ USD 2 billion) • ~80% of accidents can be attributed to **human error** • Safety-enhancing technologies require **real-time high quality data analyses**
Cruise	• Used for multi-day and multi-destination cruises • Fleet varies in size: passenger capacity ranges between 225 and 5,400	**Low maintenance costs**	• Predicting future failures before incurring major losses can reduce maintenance cost and increase asset efficiency • Maintenance constitute **10-15% of operating costs** • Predictive technologies requires rich data collection via IoT devices & sensors and continuous data analyses
Fishery	• Only includes bigger fishing vessels 30+ meters) that stay out on sea for longer periods of time	**High routing optimization**	• Ship operators seek to minimize OPEX via **route planning**, **gas consumption optimization** etc. • **Continuous data analyses** to track performance of the ship is required for routing optimization • **High connectivity** is required for **rich data** collection and continuous analyses for optimization
Ferry	• Used for short distance passenger and vehicle transport	**High connectivity**	• Passengers demand **seamless & high-speed connectivity** for social media apps and live streaming at low costs • Cruise industry **grew at 7% CAGR** with **27.2 million** passengers are expected to cruise in 2018 • Crew also seeks for high connectivity for image and video data and **high-tech applications** (e.g. AR based systems)

1) DWT: Dead Weight Tonnage
Source: Digitalship, Cruise Lines International Association, Statista, iDirect, Allianz Safety and Shipping Review 2017, UNCTAD, Strategy& analysis

Based on our prioritization criteria, we selected the assisted navigation use case for deep dive

Most promising use cases

Maritime

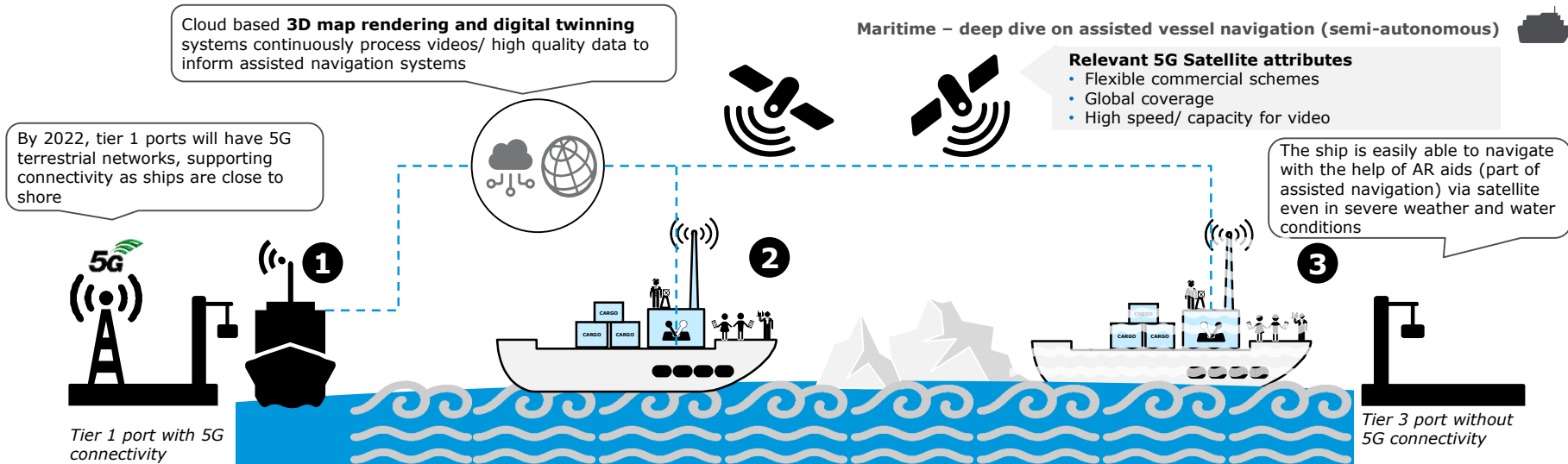|	**Predictive maintenance**	**Assisted navigation (semi-autonomous) solutions**	**Route planning and gas optimization**	**Connectivity for entertainment**
Use Cases				
Description	• **Real-time anomaly detection** with machine learning and artificial intelligence • Usage of **sensors** to collect data (e.g. **real-time** technical condition) on ship assets	• Augmented reality, digital twinning and Artificial Intelligence based systems are used in conjunction to improve **situational awareness & navigation**	• Continuous data analyses to **track performance of ship** to increase transparency and minimize OPEX via route planning, gas optimization etc. via diverse IoT devices	• **Ubiquitous and high-speed connectivity** for entertainment (e.g. live streaming) using hybrid connectivity for cost effective seamless transitions

Selected use case

Assisted navigation through 5G integrated terrestrial & satellite is a prominent use case that will improve safety and efficiency

Maritime – deep dive on assisted vessel navigation (semi-autonomous)

Cloud based **3D map rendering and digital twinning** systems continuously process videos/ high quality data to inform assisted navigation systems

Relevant 5G Satellite attributes
- Flexible commercial schemes
- Global coverage
- High speed/ capacity for video

By 2022, tier 1 ports will have 5G terrestrial networks, supporting connectivity as ships are close to shore

The ship is easily able to navigate with the help of AR aids (part of assisted navigation) via satellite even in severe weather and water conditions

Tier 1 port with 5G connectivity

Tier 3 port without 5G connectivity

1 A ship departing from a Tier 1 port which is connected to 5G terrestrial network (provided by telco operators) within the harbor, navigating near the shoreline using an AR based system, connected to a digital twin of the ship (managed securely on a cloud server) and other intelligent systems that constantly analyze and inform the ship's localized environment

2 Away from the coast, the ship switches to 5G satellite and navigates in dynamic environments, leveraging high throughput/ speed connectivity provided by satellite for its assisted navigational systems (sending and receiving information along the route in real-time)

3 In Tier 2 or Tier 3 harbors with no terrestrial 5G coverage, the ships can still use their assisted navigation system at the desired level of quality of services (QoS), which improves safety and efficiency (low idle time) in case of low coverage or severe weather conditions

Source: Interviews, Marinemec, Designbloom, Strategy& analysis

Addressing hurdles in technology, finance and ecosystem is key for realizing 5G enabled integrated satellite terrestrial systems
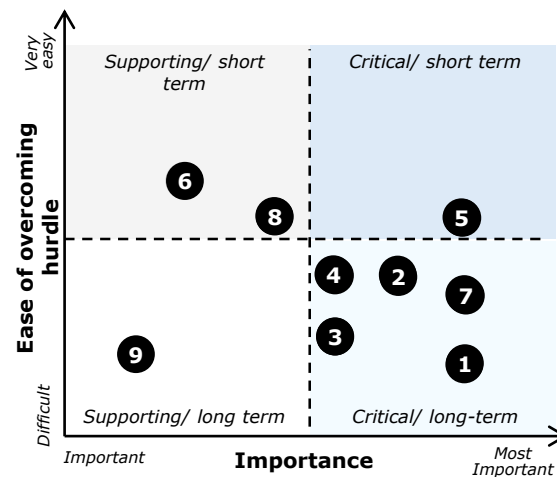
And many more use cases!

Key hurdles and initial assessment of hurdles for maritime

Maritime – deep dive on assisted vessel navigation (semi-autonomous)

Technology
1 5G enabled satellite may be unable to provide the same levels of speed, bandwidth and latency as in terrestrial 5G
2 Antennas supporting 5G & seamless connectivity between terrestrial and satellite are not yet mature or commercially available
3 Although there is traction in assisted navigation solutions, the maturity is low and needs significant push from solution providers

Finance
4 Required support systems to facilitate the solution might be expensive (CAPEX)
5 The running cost of 5G enabled satellite infrastructure may be too high for the permanent use (OPEX)
6 Demand and proof of return on investment for assisted navigation solutions is not certain, thus limiting financing options

Ecosystem
7 Solution integrators need to work with a varied, complex eco-system and very diverse information systems/ platforms
8 There is low industry maturity for the assisted navigation base standards (e.g. Digital twins, 3D map modelling, terminal modem switching)

Regulation
9 Regulatory standards still need to be defined and gain maturity across different geographies

Supporting/ short term — Critical/ short term
Supporting/ long term — Critical/ long-term

Ease of overcoming hurdle (Very easy → Difficult) vs Importance (Important → Most Important)

- **Ease of overcoming the hurdle** is defined by the time, # of players to be activated and effort required
- **Importance** is defined by the necessity to overcome the hurdle for enabling the solution

Courtesy: Interviews, Strategy& analysis –ARTES FP

ESA ARTES Business Applications

Aviation & RPAS

Transport & Logistics

Education & Development

Maritime & Offshore

Energy

**ARTES
And Verticals
> 300 activities
473 entities
26 countries**

Safety & Security

Environmental Resource Management

Media & Broadcasting

Finance, Investment & Insurance

Tourism

Food & Agriculture

Infrastructures & Smart Cities

Health

Use of SPACE ASSETS (examples)for 5G services

Earth Observation

- Optical: Geoeye, Landsat, Spot, Sentinel, PlanetLabs
- Radar: Radarsat, Terrasar-X, Cosmo Skymed, Sentinel
- Meteo: MSG, METOP, ...

SatCom

- Narrowband: Inmarsat, Iridium, Globalstar
- Broadband: SES Astra, Inmarsat, Avanti, Eutelsat, Intelsat, etc.
- Megaconstellations

Navigation

GPS, GLONASS Galileo, Beidou, Zenith, etc

→ **Developing 5G native services for 5G Verticals**

- Biological/medical science
- Physical science
- Experimental Platform

ExactEarth, Orbcomm, Kongsberg, SpaceQuest, etc.

Use of AI for use ofBig Data from Space

Manned Space Flight

Sat-AIS

Other technologies

Position   : 484550.47
            : -360.13
X coordinate : -114412.18
Z coordinate :
Longitude (deg)

Position
  X coordinate   : 383590.44
  Y coordinate   : -9059567.53
  Z coordinate   : 579956.06
  Latitude (deg) : 5.2522 N
  Longitude(deg) : 52.8060 E
                  : -25.57

Stakeholders Outreach

- 5G LoIs (Letter of Intent) signed with:
  - 5Groningen EBG (NL)
  - SatApps Catapult (UK)
  - 5G Berlin-F-FOKUS (DE)
  - 5G Barcelona –i2CAT (E)
  - 5G IA (5GPPP Industry Association)
  - Others in the process of being signed
- 5G Panel at Farnborough Air show, 07/2018
- EC 5GPPP Phase 3 Information Day 14/9/2018
- IBC, Amsterdam 15/9/2018
- SATItalia 5G, Rome 8/10/2018
- ITU Forum "Towards 5G Enabled Gigabit Society", Athens 11/10/2018
- FUSECO, FOKUS, Berlin 15-16/11/2018
- 5G SatCom Seminar, TNO, The Hague 24-25/11/2018
- 5G and Space for Society Workshop 21/11/2018, ESTEC
- ESA to chair 5G Colloquium 5GIA 15/10/2018, Toronto

The 5G Infrastructure Public Private Partnership

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Preparing for ICT-19: Advanced 5G validation trials across multiple vertical industries

ESA collaboration opportunities in support of ICT-19

Conclusions

➤ 5G is important for SatCom and SatCom are important for 5G

➤ Invest in 3GPP standardization by active participation from all satcom actors is necessary

➤ Work close with verticals for large scale 5G validation trials and pilots: Invest in innovative technologies addressing the hurdles per vertical

➤ Address ecosystem aspects: Satellite and Terrestrial sector collaborate/cooperate for quick, efficient and cost effective deployment of 5G

➤ Introduce quickly SatCom software networks: adopt agile development, use of open source tools to reduce services creation and maximize convergence and interoperability

➤ ESA supports Member States SatCom sector through the S45G initiative

➤ S45G are aligned with EU 5G Action Plan & 5G-IA roadmap

➤ S45G collaborate & coordinate with DG CNCT

To know more and benefit from S45G

1. Send an email to **5G@esa.int** with your project ideas

2. ESA will engage to explore options

https://artes.esa.int/satellite-5g

5G@esa.int

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Discussion

ESA Live Testbed for satellite-terrestrial integration in 5G context

> ➤ SATis5 provides a comprehensive testbed demonstrating the benefits of satellite for the main 5G use cases (eMBB/mMTC).

> ➤ The testbed includes live, over the air GEO and MEO satellite connectivity in addition to laboratory emulations and simulations

Partners

- Eurescom (DE) prime
- F-FOKUS (DE)
- F-IIS (DE)
- Newtec GmbH (DE)
- Univ of Berlin (TUB) (DE)
- Univ der Bundeswehr (DE)
- SES (Lux)
- Other partners joining
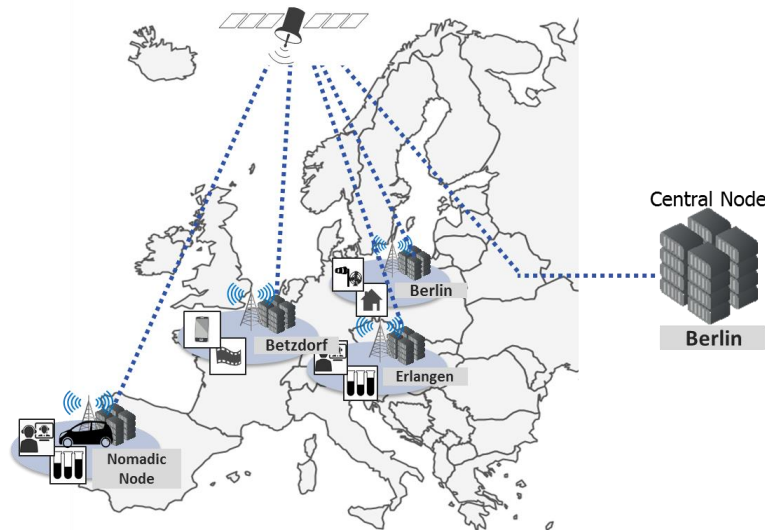
Demonstrations at FUSECO 2018, Berlin 15/11/2018

5G SatCom and beyond

AI/ML & Big Data

Optical Mission

Hierarchical Networks & Mega-constellations

Satellite enabled distributed edge nodes (Edge Cloud)

Cybersecurity

Smart Integrated Satellite Terrestrial Connectivity
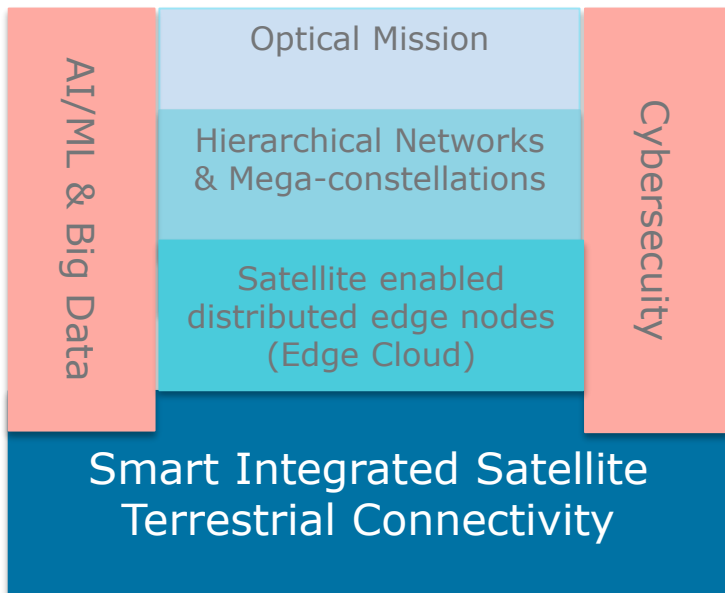
Smart connectivity based on integrated satellite terrestrial software defined networks, providing features beyond simple connectivity:

- **Multi-service/multi-vertical and Mobile access Edge Computing:** Store and process locally to reduce latency and use of network resources efficiently
- **Programmable aggregation, virtualization and built-in security & trust functions:** Internet of Smart Things and Human Centric Internet
- **Frequency Sharing & Interference Management**
- **Cost effectiveness:** based on AI/ML and network softwarization
- **New services:** based on exploration of Big Data of space networks

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S45G Expected Roadmap

Convergence / Integration Steps

Year	2018	2019	CMIN 2020	2021	2022	2023	2024	2025
Use Cases	BA LTE+ vertical pilots	Media, Transportation, public safety	Enhanced Media (VR, 360°…, Enhanced Transportation (Global land mobile, air, UAVs, marine 4.0,) disaster prevention/mitigation, public safety, cyber security, big data					
Validation trials/ Pilots	Existing space segment **Pan-European testbeds**	OneWeb F10	**Global testbeds** Pioneer	VHTS, Mega-constellations, Small Sats, HAPs, Hosted Payloads		Commercial QKD		All optical mission
R&D – Products (1) {examples}	SDN/NVF adoption in Terminals/GWs Federated Manager & MANO Orchestrator & Services Orchestrators/verticals SatCom enabled Edge nodes & flexible backhaul techniques NR Satellite Direct Access Interface Spectrum Frequency Sharing and Interference Mitigation Data Driven Real-time Managers/Cognitive Networks / AI/ML							
R&D – Products (2) {examples}	SDR onboard		SDN/NFV/Caching functions onboard					

Skylight programme {Commercial QKD, Onboard Optical Terminal, Optical Feeder links, Optical Tbps ISL/GEO/MEO/LEO/HAPS/Aircrafts/UAVs}

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Status in 3GPP

◆ At SA#80 June 2018 (Service and Architecture) Technical Specification Group in La Jolla, approval of

➢ Technical report 22.822v1.0.0 resulting from the study item Feasibility of 5G Satellite access in release 15: SP-180335

➢ Release 16 Normative Work item which will develop service requirements on 5G satellite access: SP-180326

➢ Release 16 Study item on system architecture to support satellite access: SP-180508

◆ At RAN#80 (Radio Access Network) June 2018 Technical Specification Group, approval of

➢ Technical report 38.811 resulting from the study item New radio (5G radio interface) support Non-Terrestrial Networks: RP-181393

➢ Release 16 Study item on solutions for NR to support Non-Terrestrial Network: RP-181370

Ref:

European Space Agency