Ref. Ares(2025)737092 - 30/01/2025

6GNTN

D2.4 MARKET AND BUSINESS MODEL ANALYSIS

Revision: 1

Work package	WP 2
Task	Task 2.4
Due date	31/12/2024
Submission date	29/01/2025
Deliverable lead	TASF
Version	1.1
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Abstract	This document explores the 6G Non-Terrestrial Networks (6G NTN) market, emphasizing its transformative potential to integrate satellite and terrestrial networks. With enhanced capabilities like higher data rates, reduced latency, improved reliability, and advanced sensing, 6G NTN supports applications such as autonomous systems, augmented reality, and disaster recovery. It addresses diverse markets—consumer, enterprise, and verticals like public safety, automotive, and utilities—offering global connectivity and bridging gaps in underserved areas. Economic sustainability, environmental efficiency, and interoperability are central design principles. The document highlights collaborative frameworks among stakeholders, market drivers, challenges, and the projected $30 billion annual revenue potential by 2035, positioning 6G NTN as a cornerstone of future telecommunications.
Keywords	Business model, Role model, Addressable Market, Market segmentation, Market adoption

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Grant Agreement No.: 101096479
Call: HORIZON-JU-SNS-2022

Topic: HORIZON-JU-SNS-2022-STREAM-B-01-03
Type of action: HORIZON-JU-RIA

Document Revision History

Version	Date	Description of change	List of contributor(s)
V.0.0	01/09/2023	Document creation with draft ToC for comment	Romain Bucelle (TASF)
V.0.7	22/11/2024	Final draft for contributors review	All authors
V.0.8	29/11/2024	Document submitted to internal review	All authors
V0.9	13/12/2024	Document updated following internal review	All authors
V1.0	17/12/2024	Document submitted to project coordinator	Romain Bucelle (TASF)

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Project funded by

Schweizerische Eidgenossenschaft
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Swiss Confederation

Federal Department of Economic Affairs, Education and Research EAER
State Secretariat for Education, Research and Innovation SERI

6G-NTN (*6G Non Terrestrial Network*) project has received funding from the **Smart Networks and Services Joint Undertaking (SNS JU)** under the European Union's **Horizon Europe research and innovation programme** under Grant Agreement No 101096479. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them. This work has received funding from the Swiss State Secretariat for Education, Research and Innovation (SERI).

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Project co-funded by the European Commission in the Horizon Europe Programme		
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* R: Document, report (excluding the periodic and final reports)

DEM: Demonstrator, pilot, prototype, plan designs

DEC: Websites, patents filing, press & media actions, videos, etc.

DATA: Data sets, microdata, etc.

DMP: Data management plan

ETHICS: Deliverables related to ethics issues.

SECURITY: Deliverables related to security issues

OTHER: Software, technical diagram, algorithms, models, etc.

EXECUTIVE SUMMARY

This document provides an in-depth analysis of the 6G Non-Terrestrial Networks (6G NTN) market, focusing on its potential to revolutionize telecommunications by integrating satellite and terrestrial networks. With enhanced capabilities over 5G NTN, 6G NTN aims to deliver global, resilient, and sustainable connectivity, supporting advanced applications such as Direct-to-Device (D2D) connectivity, autonomous vehicles, and disaster recovery.

6G NTN offers substantial performance improvements, including higher data rates, reduced latency, and improved location accuracy. It also introduces new metrics like sensing, AI adaptability, and environmental sustainability. The network's ability to seamlessly integrate terrestrial and satellite components through unified terminals and advanced interoperability is a key driver of its transformative potential.

The addressable market is segmented into three categories: consumer, enterprise, and verticals. The consumer market focuses on connecting underserved areas, while enterprises benefit from enhanced connectivity for remote operations. Vertical sectors, including automotive, public safety, utilities, and transport, are poised to leverage 6G NTN for critical use cases, such as emergency communications and infrastructure management.

Economic and environmental sustainability are core design principles of 6G NTN. By optimizing energy usage and reducing costs, the network aims to provide affordable and inclusive connectivity, addressing terrestrial networks coverage gaps for billions of users worldwide. Collaboration between stakeholders, including network operators, service providers, and policymakers, is essential for overcoming technological, regulatory, and economic challenges.

The 5G/6G NTN market is expected to grow significantly, with satellite D2D services projected to generate over $30 billion annually by 2035 compared to less than $1 billion in 2025. This growth underscores the economic importance of 6G NTN in driving innovation and bridging the digital divide.

In conclusion, 6G NTN represents a paradigm shift in telecommunications, enabling a fully connected world where advanced applications and global coverage become the norm. Success depends on aligning technology, policy, and market dynamics to ensure its widespread adoption and transformative impact.

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ABBREVIATIONS

3GPP	Third Generation Partnership Project
AI	Artificial Intelligence
AR	Augmented Reality
CAGR	Compound Annual Growth Rate
B2C	Business to Consumer
B2B	Business to Business
CPE	Customer Premises Equipment
CSP	Communication Service Provider
D2D	Direct-to-Device
DCSP	Data Center Service Provider
eMBB	Enhanced Mobile Broadband
ESN	Esquema Nacional de Seguridad
EUSPA	European Union Agency for the Space Programme
FR1	Frequency Range 1 (below 6 GHz)
FR2	Frequency Range 2 (above 24 GHz)
GNSS	Global Navigation Satellite System
GovMil	Governmental and Military
HAPS	High-Altitude Platform Stations
HD Maps	High-Definition Maps
IoT	Internet of Things
IIoT	Industrial IoT
ISO	International Organization for Standardization
ITS	Intelligent Transportation Systems
LEO, MEO, GEO	Low Earth Orbit, Medium Earth Orbit, Geostationary Earth Orbit
LTE	Long-Term Evolution
MC	Mission Critical
mMTC	Massive Machine-Type Communications

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MNO	Mobile Network Operator
MVNO	Mobile Virtual Network Operator
NB-IoT	Narrowband Internet of Things
NE	Network Element
NEF	Network Element Function
NFVI	Network Function Virtualization Infrastructure
NGN	Next Generation Networks
NGSO	Non-GeoStationary Orbit
NOP	Network Operator
NSP	Network Slice Provider
NTN	Non-Terrestrial Networks
OEM	Original Equipment Manufacturer
PPDR	Public Protection and Disaster Relief
Q-Type	Reference to a value instance
RAN	Radio Access Network
RRF	Réseau Radio du Futur
SAMU	Service d'Aide Médicale Urgente (Emergency Medical Assistance Service)
SEF	Service Element Functions
SMUR	Service Mobile d'Urgence et de Réanimation (Mobile Emergency and Resuscitation Service)
SNO	Satellite Network Operator
TEF	Transport Element Functions
TETRA	Terrestrial Trunked Radio
TETRAPOL	TETRA for Police and Public Safety
TN	Terrestrial Networks
TS	Technical Specification
UAV	Unmanned Aerial Vehicle
UE	User Equipment
UHF	Ultra High Frequency

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URLLC	Ultra-Reliable Low-Latency Communications
VHF	Very High Frequency
VISP	Virtualized Infrastructure Service Provider
VNF	Virtualized Network Function
VR	Virtual Reality

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1 INTRODUCTION

1.1 SCOPE AND OBJECTIVES

This document provides the output of the work performed within “Task 2.4 Market and Business model analysis” of the “WP2 Requirements analysis”. This deliverable objective is to analyse the 6G NTN opportunity from a business perspective by providing a description and segmentation of the addressable market and the business role models, i.e. description of the actors and their business relationships, including the identification of possible key conditions to foster a viable adoption of 6G NTN by the ecosystem.

Task 2.4 was performed in line with the outputs and deliverables of Task 2.1, 2.2, 2.3 and 2.5. Especially uses cases [1], user requirements [2], system requirements [3], regulatory landscape [4] are directly inherited from previously completed tasks within WP2.

1.2 STRUCTURE OF THE DOCUMENT

This deliverable is structured as follows.

Section 2 provides an overall 6G NTN ecosystem and market description. It highlights the 6G NTN added value compared to 5G NTN in order to show the possible evolution path of the associated market and actors. Section 2 also brings some considerations on the complex market segmentation.

Sections 3 to 7 provide a deep dive into several market segments that were identified in section 2 as the most promising subjects by the contributors to the task. In each of these sections the analysis tries to follow the same path with market description and segmentation, role model and value chain and finally an addressable market sub section. Depending on the market segment maturity and information availability the addressable market subsection can be merged into the market description and segmentation.

Section 8 provides an overall synthesis by attempting to factorize the different market segment analysis output and identify overall trends and key conditions to 6G NTN adoption.

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2 6G NTN MARKET DESCRIPTION, ADDED VALUE IDENTIFICATION AND ROLE MODEL FRAMEWORK

2.1 MARKET DESCRIPTION

We assume in this deliverable that “6G NTN Market” is the market of services delivered to end users using a 6G NTN System. These services are communication services and location services such as the one described in section 5 of [2].

- Communication services : Voice, Message, Data, Video
- Location services : Standard, 3D location

Section 2.1 gives some insight on what the added value of 6G NTN services is compared to 5G NTN services. In other words, what 6G NTN may bring the end user that 5G NTN may not bring. This added value is the basis to understand how 6G NTN may enlarge the 5G NTN market by for instance being able to fulfil needs that are not fulfilled by 5G NTN and consequently enlarging the addressable market.

2.1.1 6G NTN in a nutshell

Prior to the advent of the 5G NTN standard, satellite and mobile networks were designed independently from one another and were addressing separate user markets. With the 3GPP defined Non-Terrestrial Networks (NTN) standard, a non-terrestrial network component can be added in the 5G system to extend the service coverage in unserved or underserved areas. In the context of the IMT-2030 system (also referred to as 6G system), it will be advantageous to **natively support the operational integration of a non-terrestrial network component together with the «terrestrial» mobile network component for an improved connectivity experience**. Moreover, the **performances and capabilities of NTN in 6G can be further extended** compared to 5G Non-Terrestrial Networks. This will allow to improve the user experience especially with handheld terminals as well as drone/vehicle mounted terminals and to **offer improved network operation allowing greater efficiency of human actions while ensuring lower impact on its environment**. This would result in global, resilient, reliable or sustainable connectivity capabilities thanks to a fast reconfigurable 3D network topology to address the traffic demand across space and time.

As initially exposed in “5G Non-Terrestrial Networks” book [5], the 6G system aims at supporting a fully connected world, where the physical world is digitalized with high detail so as to be analysed and acted upon. As such, it will support Augmented and Virtual Reality (AR/VR), digital twinning, immersive communications and multi-sensory interactions (e.g., tactile/haptic Internet), integration of sensing and communication, collaborative robots, autonomous driving of vehicles and drones. Designed as cloud-based network infrastructure thanks to distributed computing and intelligence, we believe that 6G will leverage and integrate a complementary set of access technologies (mobile, satellite, HAPS, wireless, wireline, etc.) as well as previous generation access technologies through smooth interworking enablers.

The next generation mobile system will have to consider a general trend calling for improved **spectrum usage efficiency, drastic environmental impact reduction and sustainability, and high resiliency,** given that telecommunications are key for the economy. In this context NTN will be a native network component for ubiquitous service experience, resilient network operation as well as addressing new use cases especially for handheld terminals as well as drone/vehicle mounted terminals. Hence **NTN will no longer be just an add-on component providing “connectivity to the unconnected” users as in 5G**.

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This will require to ensure that the specific characteristics (altitude, speed, spectrum, etc.), of the different NTN components are taken into account since the inception of the development of the specifications of the 6G systems**. It will also require to ensure an economic sustainability of such a multi component system under the constraint to provide affordable services to the end users**.

For the consumers, the provision of emergency communications to smartphones such as paging, messaging and even voice calls shall be enabled **in outdoor as well as in indoor environments directly from space**. Moreover, the **spectral efficiency should be further improved to support a wider range of applications based on broadband services such as video streaming, VR/AR, telemedicine**. In order to support regulated services, the **time to locate reliably the terminals shall be reduced to below one second**.

For the vertical stakeholders such as automotive, transport (aeronautic, maritime and railway), utilities, public safety, media and entertainment, agriculture and defence, **the installation and operational constraints of user equipment on vehicles, drones as well as aeronautic, maritime and railway platforms** shall be carefully considered. This will set the **size, weight and power constraints on the devices**. Fast service setup should be enabled by an agile network infrastructure, potentially leveraging space-based network nodes until terrestrial nodes can be deployed. Increased service availability shall be ensured, especially in case of temporary or geographically localized GNSS service failure.

Non-terrestrial networks will become an important additional connectivity layer to terrestrial connectivity services, e.g. to provide coverage in underserved areas, provide global connectivity to logistics and transport, support disaster relief and serve as a fallback layer or backhaul for terrestrial networks. Thereby, thanks to this smart combination of its non-terrestrial and terrestrial network components, the 6G system will be able to:

- Provide broadband connectivity to (semi) autonomous cars and drones (including urban air mobility) in high mobility with a true seamless global service continuity (zero packet loss/zero interruption/no service rate degradation);
- Ensure high resiliency with respect to a temporary failure of a given node (e.g. NGSO, GSO, HAPS and/or drone mounted) of the 3D network infrastructure;
- Minimize the energy consumption and delivery cost across with smart traffic routing techniques between bidirectional and unidirectional access links;
- Optimize the overall usage of partially shared spectrum;
- Maintain an economic affordability from the end user perspective.

2.1.2 Added value of 6G NTN vs 5G NTN

Focusing on the NTN components of 6G, here are the main directions where one may expect added value compared to 5G NTN.

- Improved user experience
    - Increasing data rate with regards to 5G
    - Increased reliability
    - Coverage extension to light indoor/in-car areas
    - Increased location accuracy/reliability
    - Reduced latency
- Improved network capabilities
    - Resiliency
    - Spectrum sharing NTN/TN and across orbits
    - Reduced environmental footprint (improved energy saving)

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    - Reinforced security
    - Capacity/connection density
    - GNSS free operation
    - Fast network deployment
    - Sensing capability
- Improved support of several usage scenarios
    - Terminal design adapted to installation/operational constraints (vehicles/drones)
    - Automotive, public safety, transport (aeronautic, railway, road and maritime), utilities, media & entertainment, defence
- Interoperability with 5G
    - Multi connectivity and mobility across orbits and with 5G-NTN

2.1.3 Focus on key 6G NTN design principles

Beyond classical objectives of ensuring resilience and connecting the unconnected, the design principles of the future 6G system target the following [1].

- **Unified terminals:** The nascent interoperability promises the design of unified terminals, supporting both terrestrial and non-terrestrial accesses, transparently managed thanks to a single network service subscription. This constitutes a major driver for most vertical industries and for the consumer market. Compared to existing devices and beyond currently available satellite voice and messaging, enhanced data services will be offered with a handheld terminal, satisfying size, cost and energy consumption constraints.

- **Ubiquitous intelligence:** For the network operator, this means the network can accommodate high dynamicity in traffic variations, at both large and small scales, and that network functions can be reconfigured on-the-fly to adapt customers' needs, towards network- or infrastructure-as-a-service, spanning over both terrestrial and satellite components. For the end-user, ubiquitous intelligence promises storage and computational capabilities located closer to data sources, especially in remote and hard-to-reach locations. It prevents from having to send data traffic over multiple untrusted networks and leverages satellite backhaul, inter-satellite links and the so-called Space Edge Computing, to build on a comprehensive "VPN"-like system, for higher quality of service, network isolation, privacy and security. This will largely benefit connectivity services with users distributed all over the world, for example governments or administrations (including embassies), logistics, mining, etc.

- **Enhanced multi-connectivity:** 3GPP has laid the foundation for multi-connectivity, for switching to satellite back-up or routing of delay-tolerant traffic. Future 6G is expected to enable true service versatility in a multi-dimensional network infrastructure, where it is possible to adjust the service requirements (e.g., in terms of latency reliability, bandwidth, and connectivity density) to the targeted capabilities of available links, whether it is drone-mounted base stations (BS), high-altitude platform stations (HAPS), LEO, MEO or GEO.

- **Seamless mobility:** Although 3GPP has tackled the mobility topic in NTN context since the first studies, there is still space for improvement. In particular, it does not offer yet the service continuity necessary for real-time or mission-critical applications in mobility, for example remote control of drones or videoconferencing of car passengers.

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- In addition, the **challenge of sustainability** has been considered as a major design principle.

2.1.4 Performances target recall

Compared to early NTN stages, going further with performance should enable 1) broadband Direct-to-Device (D2D) services – thus outperforming today's offers limited to messaging or emergency services –, 2) indoor connectivity – which so far remains unreachable, and 3) scalability – to keep up with the expected growth for both the consumer and the massive IoT markets. Similarly to the evolution from 4G to 5G networks, 6G systems are also expected to introduce significantly enhanced Key Performance Indicators (KPIs) and capabilities. The identification of the KPIs and the related target values has not yet started for 6G NTN; within ITU-R WP4B, it is expected that the definition of the 6G NTN requirements will be addressed mid-2025 onwards, while for the terrestrial network this process is already on-going.

In addition to these well-known KPIs, new performance indicators are likely to arise in order to assess the network behaviour in the complex 6G network of networks. These shall provide quantifiable means to define the network performance in the following areas: i) sensing, e.g., integrating data on speed, angle, direction, range, and location; ii) Artificial Intelligence (AI) capabilities, to measure the ability of the network elements to support AI-related operations (e.g., data collection, analysis, pre-processing); iii) sustainability iv) security and resilience, to measure the ability of the network elements to guarantee information integrity and confidentiality, as well as its robustness to cyber-attacks; and v) interface interoperability, to indicate the flexibility and openness of the various network interfaces aiming at a full seamless plug-and-play approach.

With respect to NTN, a tentative set of performance requirements compared to 5G NTN is provided in Table 1 below. It shall be noticed that the target performance is also driven by the type of receiving platform, which is directly related to the type of service to be provided. The requirements for 5G NTN are based on 3GPP and ITU-R IMT-2020 requirements for satellite access. The 6G NTN targets and KPI are based on the 6G NTN project internal assumptions which may differ from the one that 3GPP or ITU-R will eventually define.

TABLE 1 – NTN KPI EVOLUTION FROM 5G TO 6G [6]

KPI		5G NTN	6G NTN
Peak data rate (DL/UL)	Handheld	1.0 / 0.1 Mbps outdoor, up to 3 km/h	Tens of Mbps up to 250 km/h outdoor
	Vehicle/drone mounted	50 / 25 Mbps 60 cm aperture up to 250 km/h	Hundreds of Mbps up to 250 km/h outdoor
	Large aeronautic or maritime platforms	360 / 180 Mbps up to 1000 km/h	Thousands of Mbps up to 1200 km/h outdoor
Outdoor location service (accuracy and acquisition time)		1 meter <100 s	1 meter <1 s
Coverage		outdoor only	outdoor

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		light indoor (at least SMS)
Reliability	99.9%	99.999%
Over-the-air latency	CP: 40 ms UP: 10 ms	CP/UP: as TN IMT-2030
Connection density	<500 UE/km^2	>1000 UE/km^2

2.2 6G NTN MARKET SEGMENTATION

2.2.1 Overall segmentation

Different classes of connectivity scenarios are identified, each addressing different market segments and use cases. The non-terrestrial network component is expected to address consumer, enterprise and vertical market segments.

Consumer market

This market segment is associated with general public users, equipped with smartphones or wearable devices. These users are looking for either a guaranteed reach of their corresponding MNOs' coverage, or for an extension of the reach of this coverage when the terrestrial radio network cannot be extended due to economic or physical reasons (mountains, oceans, etc.) or in case of terrestrial network failure or disaster.

Users are equipped with a single User Equipment (UE). They expect voice and data services. Access to satellite or terrestrial network shall be seamless, with no modification to hardware or software. When considering automotive, possible use of dedicated user equipment and associated automotive constraints will have to be assessed when defining the corresponding system requirements.

Out of the total number of mobile subscribers (5.2Bn), some GSMA market research [7] estimates that at least 7.5% would acquire NTN capable user equipment by 2030. This percentage is recognized to be very conservative and could be much higher in the subsequent years.

This market segment also includes connectivity to cars with at least emergency calls, distress messages, but also an increasing demand for data services. Worldwide car sales are around 75 million per year. As assumed in [8], one can expect that at least 5% of the new cars will be equipped with satellite connectivity by 2030. This percentage will most likely continuously increase together with a continuous demand.

Enterprise market

Enterprise users are also concerned by the need for connectivity in rural areas or less developed areas where terrestrial networks are not available. As for the consumer market, significant opportunities are also identified, under the same assumption that a unique user equipment will be used for both terrestrial and satellite components. Use cases such as classic broadband connectivity for voice, video and data or access to enterprise private networks, will be similar to today's enterprise market, but as the technology becomes cheaper and more compact and easier to access, the adoption is expected to rise.

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Verticals

Verticals, such as aeronautical platforms, railways, land users, governmental users, are market segments which have very specific requirements associated with autonomy, security and possibly sovereignty. Few hundreds of thousands of subscribers, as stated in [8] are anticipated to call for satellite connectivity.

It is therefore considered that such niche verticals and the associated specific requirements should be addressed in a second stage when the core mass market and associated key requirements have been addressed in a first instance.

2.2.2 Complementary Segmentation criteria

In addition to the overall market segmentation, we identify in this section several other segmentation criteria that are usually found in various documents or publications to identify specific market segments. We generally encounter some overlap among these segmentation axis.

We identified the following segmentation criteria:

- Business sector: this segmentation axis is based on the business sector of the end user. This is a classic segmentation axis that is usually referred to as “verticals”.
    - Agriculture
    - Utilities
    - Transportation : maritime, road, rail, air
    - Aeronautic
    - Automotive
- User type: this segmentation axis is based on the type of user being the “entity” that uses a user terminal.
    - A person
    - A vehicle/platform
    - An industrial device
    - A whole subnetwork segment (home network, business premises network, ...)
- User terminal / devices type.
    - Home CPE, smartphone, laptop, tablet, wearable device such as smart watch, IoT device, VSAT, USAT, ...)
- The platform on which the user terminal is installed
    - aerial platforms : drones, planes
    - terrestrial vehicles : trains, cars, trucks, buses
    - maritime platforms
- Services
    - Home/business internet connectivity
    - Cellular backhaul
    - Trunking
    - Secured communication
    - Emergency communication
- Service performances
    - narrowband connectivity / wideband connectivity / broadband connectivity

The multiplicity of these segmentation criteria may somehow contribute to the complex task of overall 6G NTN market segmentation.

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In the following section we try to perform a segmentation exercise for the need of WP2 for which the “business sector” segmentation criteria will be used.

2.2.3 Segmentation in 6G NTN WP2

Deliverable D2.1 [1] defined an initial set of seven use cases, to illustrate the novel 6G-NTN concepts and technologies leading to the full integration between NTN and the next generation of terrestrial 6G cellular networks. D2.1’s main objective is to propose a first non-exhaustive set of use cases able to illustrate the usage of the 6G NTN technology, in particular for ten different market segments (referred to as Verticals) including:

- Consumer,
- Automotive,
- Public Safety & Defence,
- Utilities / Energy / IoT
- Media and Entertainment,
- Railways transportation,
- Maritime transportation,
- Aeronautic / drone sector,
- And Road transportation / Smart cities.

On this basis, the list of seven use cases identified in D2.1 [1] is summarized as followed:

- UC1 Maritime Coverage for search and rescue coast guard intervention
- UC2 Autonomous power line inspection using drones
- UC3 Urban air mobility
- UC4 Adaptation to PPDR or temporary events
- UC5 Consumer handheld connectivity and positioning in remote areas
- UC6 Continuous bi-directional data streams in high mobility
- UC7 Direct communication over satellites

Furthermore, a synthetic cross-mapping between the seven considered use-cases and the ten Verticals was performed and summarized in D2.1 [1], shown in the Table below that also comes with an additional column to identify which of these verticals were analysed in detail in the current deliverable.

Agriculture and Healthcare, verticals #11 and #12 in the table below come as additional identified verticals that were not in [1].

The selection of 5 market segments to be explored in detail in the following sections of this deliverable was made taking into account severable factors such as: contributors‘ perception of opportunity for NTN, interest in exploring in detail and proficiency in such task.

TABLE 2 - TARGETED MARKET SEGMENTS FOR THE PROPOSED USES CASES

	Targeted verticals	UC1	UC2	UC3	UC4	UC5	UC6	UC7	6G NTN T2.4 focus
1	Consumer					x			Yes

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2	Automotive			o		o	x	x	**Yes**
3	Public Safety & Defence	x		o	x	o		x	**Yes**
4	Utilities / Energy / IoT		x			o		x	**Yes**
5	Media and Entertainment				x				No
6	Railways transportation		o	o				o	No
7	Maritime transportation	x				o		x	No
8	Aeronautic / drone sector		x	x				o	**Yes**
10	Road transportation / Smart cities			x		o	o	o	No
11	Agriculture								No
12	Healthcare								No

Use cases are mapped to the verticals or market segments they explicitly illustrate (x) or could illustrate with minor adaptations (o)

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2.3 6G NTN ROLE MODEL FRAMEWORK

Non-terrestrial networks have become part of the 3GPP standard in Release 17, establishing a strong foundation for direct communication between satellites, smartphones and other types of mass-market user equipment.

The 3GPP standard has already defined a set of roles related to network management in [9].

Here is below the extract describing the main roles:

"*In the context of next generation networks, responsibilities regarding operations have to be clearly defined and assigned to roles. The roles related to 5G networks and network slicing management include:*

- *Communication Service Customer (CSC): Uses communication services.*

- *Communication Service Provider (CSP): Provides communication services. Designs, builds and operates its communication services. The CSP provided communication service can be built with or without network slice.*

- *Network Operator (NOP): Designs, builds and operates networks and provides related services, including network services and network slices.*

- *Network Equipment Provider (NEP): Supplies network equipment to network. For sake of simplicity, VNF Supplier is considered here as a type of Network Equipment Provider. This can be provided also in the form of one or more appropriate VNF(s).*

- *Virtualization Infrastructure Service Provider (VISP): Provides virtualized infrastructure services. Designs, builds and operates its virtualization infrastructure(s). Virtualization Infrastructure Service Providers may also offer their virtualized infrastructure services to other types of customers including to Communication Service Providers directly, i.e. without going through the Network Operator.*

- *Data Centre Service Provider (DCSP): Provides data centre services. Designs, builds and operates its data centres.*

- *NFVI Supplier: Supplies network function virtualization infrastructure to its customers.*

- *Hardware Supplier: Supplies hardware.*

Depending on actual scenarios:

- *Each role can be played by one or more organizations simultaneously;*

- *an organization can play one or several roles simultaneously (for example, a company can play CSP and NOP roles simultaneously).*"

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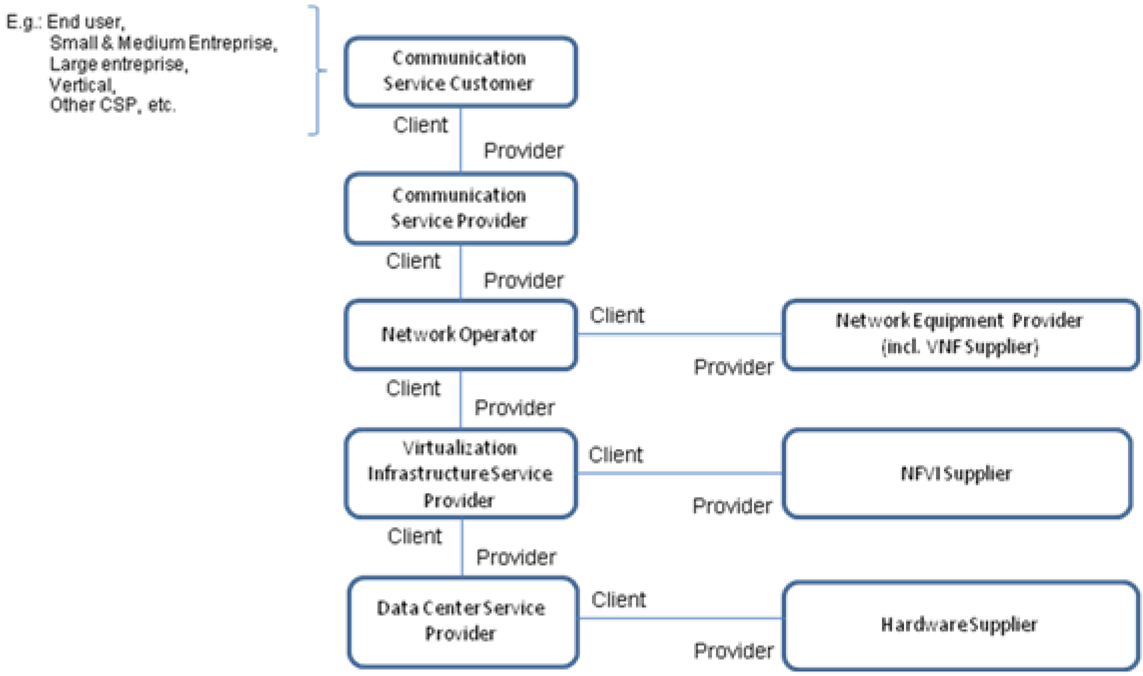

FIGURE 1 - 3GPP HIGH-LEVEL MODEL OF ROLES

In order to map the proposed 3GPP roles to 6G NTN needs, relevant services, resources management domains, and network element types have been considered with the following breakdown:

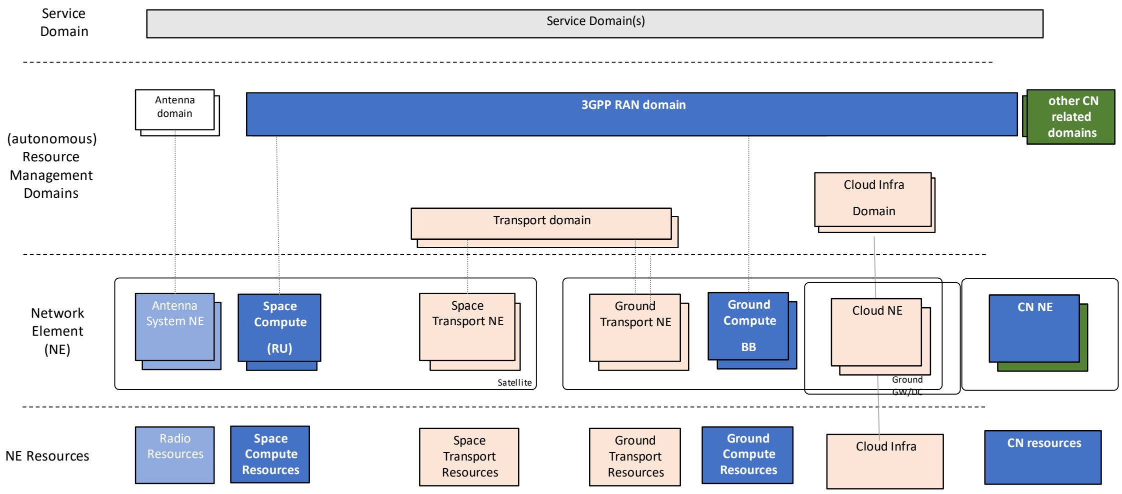

FIGURE 2 - SERVICES, RESOURCES MANAGEMENT DOMAINS, NETWORK ELEMENT TYPES BREAKDOWN

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The Network Element (NE) terminology is coming from 3GPP and is described in detail in [9], [10] and [11].

“The NE is comprised of telecommunication equipment (or groups/parts of telecommunication equipment) and support equipment or any item or groups of items considered belonging to the telecommunications environment that performs NEFs. The NE may optionally contain any of the other management function blocks according to its implementation requirements. The NE has one or more standard Q-type interfaces and may optionally have B2B/C2B interfaces. An NE performs at least one of transport element functions (TEFs) or service element functions (SEFs), and so can be deployed in an NGN transport stratum or in an NGN service stratum or in both.

Existing NE-like equipment that does not possess a standard management interface will gain access to the management infrastructure via a Q adapter (see A.1.9.1.1), which will provide the necessary functionality to convert between a non-standard and standard management interface.

A Transport Network Element is an NE that performs only TEFs. A Service Network Element is an NE that performs only SEFs. “

The Transport Domain is associated to any underlying network domain between Network Elements enabling the transport L2/L3 as defined in the ISO Model [12]. As defined in [11] Management standard interfaces are realizations of specific reference points. More details are provided in [12] for the Transport Domain reference points.

The Antenna Domain is detailed in [13] with the reference points.

Here is below an example of an NTN roles model mapping based on the above 3GPP framework.

Host Operators are in this case the ones in charge of operating different domains with infrastructures located whether in space or on ground and grouped according to pre-defined responsibility matrix and network domains breakdown. As illustrated in the diagram below, there could be one Operator in charge of Terrestrial Networks Infrastructure and one Operator in charge of Non-Terrestrial Infrastructure related to Satellite Radio Accesses.

Several Communication Service Providers (Private or Public) could be delivering different kind of services requiring specific dedicated operations from the TN and NTN operators.

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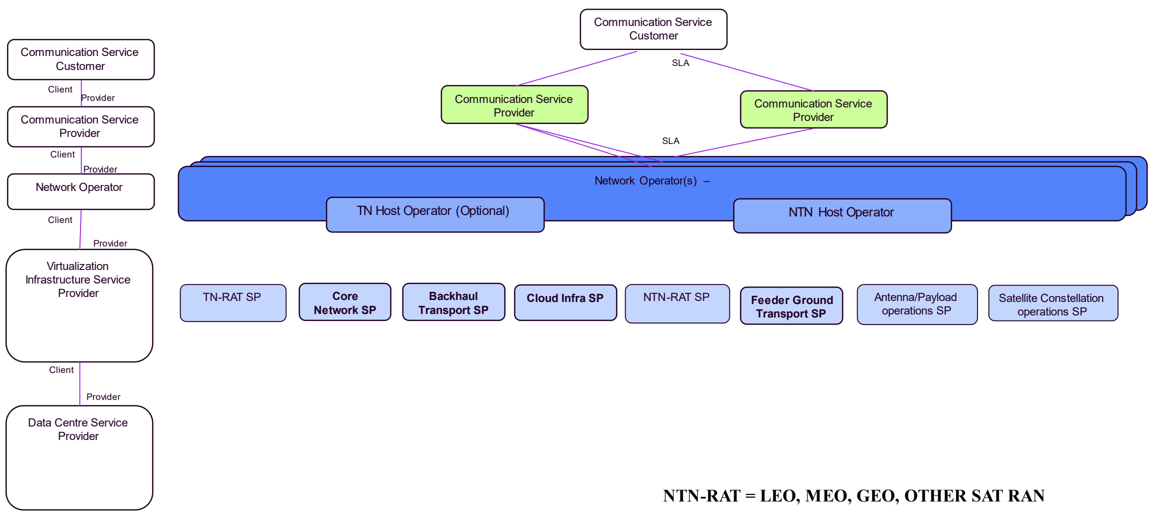

FIGURE 3 - EXAMPLE OF AN NTN ROLES MODEL MAPPING

In each market segment section in the following chapters, value chains and roles models will be proposed according to foreseen market trends and inspired by this framework.

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3 CONSUMER D2D MARKET ANALYSIS

3.1 MARKET DESCRIPTION AND SEGMENTATION

The **Direct-to-Device (D2D)** consumer market is addressing the handheld devices as well as vehicles and consumer devices (tablets, etc.). This market is mainly a satellite complement of the terrestrial mobile network operator markets for regions where the terrestrial coverage is not working as expected.

The opportunity consists of providing ubiquitous and affordable connectivity directly to an installed basis of billions of mobile handhelds through satellite direct connectivity in cooperation with terrestrial wireless network connectivity.

Note that we specifically exclude here for the D2D market assessment the estimate of the Direct to Vehicle and connectivity to other platforms (Airplanes, Ships), since this is addressed as a separate use case.

3.2 ROLE MODEL & VALUE CHAINS:

3.2.1 Current or near term analysis (y2020-2025):

We follow the role model definition of chapter 2.3 based on the 3GPP reference. The following actors (roles) are considered:

1. Customer Service Customer (CSC)
   User with UE end equipment: End user, End user consumer with User Equipment (typically handheld or also vehicles)
2. Communication Service Provider (CSP) of your home network
   a. Home Network Operator, which can be a Mobile Network Operator (MNO) or Satellite Network Operator (SNO)
   b. Roaming Network Operator, which can be a Satellite Network Operator (SNO) or a Mobile Network Operator (MNO), depending on the UE location
3. Network Infrastructure Service Provider (Virtualized Infrastructure Service Provider, VISP)
   a. This VISP network infrastructure can be provided by SNO and MNO home network
4. Data Centre Service Provider (DCSP) or target network of the customer, which is connected to the core network provided by the network infrastructure

3.2.2 Evolution trends and drivers towards 6G (y2030-2035):

The identified evolution towards 6G or drivers in these role model changes consist in an integration of satellite and terrestrial network operation through a variety of cooperation and coexistence models of MNO and SNO operations.

It is expected that these cooperation will be very diverse in characteristics of commercial and market approach, depending on the country.

The 3GPP based roles in the value chain then are complemented with the Satellite Network Operator. The SNO can cooperate with MNO to provide a joint service to the end user or act as a separate network operator to which the MNO roams services, like other MNO operators.

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Both business models shall be possible in a heterogeneous cooperation and joint service provision landscape of multiple MNO and SNO operators.

As defined in the previous section, we consider that the end user can be subscribed to an MNO or SNO operator and roam to other MNO or SNO networks. We expect different service cooperation agreements options to be possible and necessary in practice to respond to the needs of local MNOs and SNOs to cooperate.

3.2.3 6G role models by y2030-2040

In the near-term future, we can recognize that this is complemented with Satellite Network Operator (SNO). The SNO can provide services in different manners in a new environment with these three main actors:

- End user consumer with User Equipment (UE)
- Mobile Network Operator (MNO)
- Satellite Network Operator (SNO)

The SNO can provide services directly to the end user consumer. In this option the UE device could have a SIM card from an MNO and an SNO and a switch between MNO to SNO could be like roaming to an adjacent network.

Another option to integrate the networks could be the joint operation between MNO and SNO network, with the SNO and MNO integrating their network capabilities and managing the UE devices in a truly seamlessly integrated network environment.

We consider that there is a need for a heterogeneous and flexible approach to consider the integration of the MNO and SNO networks because of the local country-based MNO operation combined with the need of an SNO to address a global market, since the satellite service is global and requires a global approach to reach business objectives (very likely).

Furthermore, the country-based regulation will impose operational constraints on both the MNO and SNO operation.

Therefore, a variety of cooperation agreements can emerge between SNO and MNO operators, depending on the country of operation.

3.3 ADDRESSABLE MARKET:

3.3.1 Current description, segmentation and sizing

The handheld market for 6G joint terrestrial satellite operations addresses the same handheld devices as terrestrial MNO operators.

This means that the addressable market is the handheld market for 6G devices.

This includes the usage of handheld devices in remote environments with SNO connectivity and MNO terrestrial connectivity.

This includes the pedestrian mobile access by satellite for mass-market users in under-/un-served areas (voice and data), incl. digital inclusion in unserved areas and service continuity for existing mobile users.

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It also includes the pedestrian mobile access by satellite for business users in under-/un-served areas, incl. sport events (e.g., boat races, trail/biking/ski long-distance competitions in mountains, tracking competitors, live video transmission), maritime & aero and adventure travellers (e.g., extreme trekking, safari, expeditions, etc.).

Also the network back-up for resilience in case of terrestrial network failure or disaster is considered.

The GSMA forecasts market opportunity for Satellite D2D with new revenue for telcos worth over 30 billion USD by 2035. This includes Consumer D2D market as well as Enterprise and Government and Institution (G&I) market estimates. Reference is [14] and [8].

There are 5.2 billion mobile phones addressable in this market for the World population. A proportion of 51% of the World population lacks access to broadband. A lack of terrestrial connectivity exists for over **2.7 billion individuals**. This represents an addressable market for the D2D products.

Furthermore, this is complemented with the mobility of individuals to remote locations, where access is required for private and business connectivity.

The total market of the Consumer D2D market is estimated to 19.9 billion USD by 2035 by the GSMA study [14].

3.3.2 Identification of market drivers and trends

For the 6G joint terrestrial satellite integrated services, we can recognize a need for truly ubiquitous service provisioning for different user segments, handhelds, vehicles, maritime applications, emergency services.

The main market drivers are the need to connect devices everywhere, which is related to the user requirements for use cases for which ubiquitous connectivity is expected.

There is an additional requirement to address emergency services communication and public warning, even in remote locations.

3.3.3 Market evolution scenario towards 2030/2035

There is an increased momentum around the Satellite D2D opportunity, especially from satellite network connectivity and an interest of terrestrial wireless operators in complementary satellite network connectivity as complementary service.

This strong momentum for all major stakeholders of cellular and satellite industry driving the 5G Non-Terrestrial-Networks (NTN) for Satellite D2D is reflected in the requirements proposed for the Release 20 for 6G and it responds to the IMT-2030 expectation for ubiquitous connectivity needs.

Many announcements are made in the current ecosystem related to this opportunity of D2D services.

Several announcements are made by blue-chip and satellite players with different strategies (using existing or new capabilities in space).

In particular, there is an emerging start-up (mostly US-based) still at experimental stage and with financial viability remaining as their biggest challenge.

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We also note the trend of large mobile network operators (MNOs) and car manufacturers' investments being deployed in Satellite D2D start-ups.

Furthermore there is also a strong interest expressed by the European Commission in satellite D2D to address governmental, business and social imperatives in Europe and other regions of interests.

In total, the GSMA Intelligence [14] has evaluated the D2D market opportunity towards 2035 as follows:

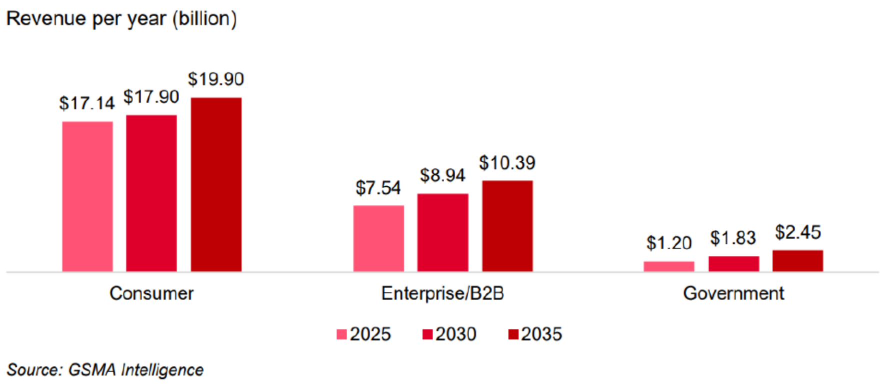

FIGURE 4: GSMA INTELLIGENCE PREDICTS, D2D SATELLITE OFFERS ACCESS TO NEW REVENUE FOR TELCOS,WHICH WILL BE WORTH OVER 30 BILLION BY 2035.

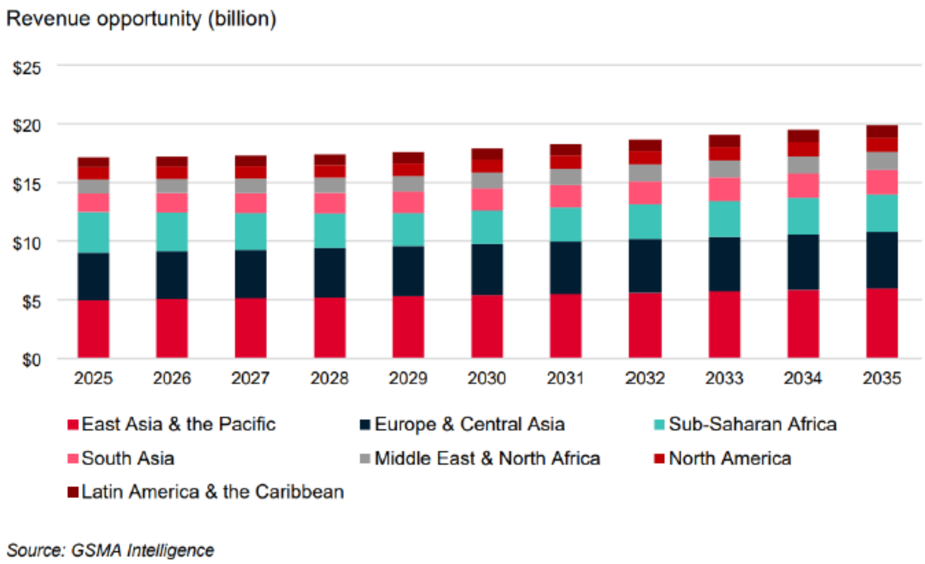

FIGURE 5: GSMA INTELLIGENCE PREDICTS D2D CONSUMER REVENUE OPPORTUNITY TO REACH 20 BILLION PER YEAR (2% OF THE TOTAL TELCO TOPLINE) BY 2035

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4 AUTOMOTIVE MARKET ANALYSIS

4.1 MARKET DESCRIPTION AND SEGMENTATION

4.1.1 Automotive segmentation and market according to ACEA

The Automotive Market consists of different types of vehicles like passenger cars, light commercial vehicles / vans, trucks and buses.

Communication can be line fitted in the factory or served by the aftermarket and installed out of the factory.

TABLE 3 - VEHICLE TYPE SPLIT ON THE ROAD IN THE EUROPEAN UNION BY THE ACEA [15]

	2018	2019	2020	2021	2022	Change
Cars	239,047,934	243,579,963	246,488,324	249,634,819	252,237,775	+1%
Vans	27,906,239	28,523,130	29,049,728	29,744,175	30,191,188	+1.5%
Trucks	6,089,675	6,179,290	6,220,478	6,328,424	6,451,695	+1.9%
Buses	708,581	720,421	703,803	713,483	720,783	+1%

Advanced services are mainly driven by evolved vehicles with increased driver services and autonomy as well as navigation and tracking needs.

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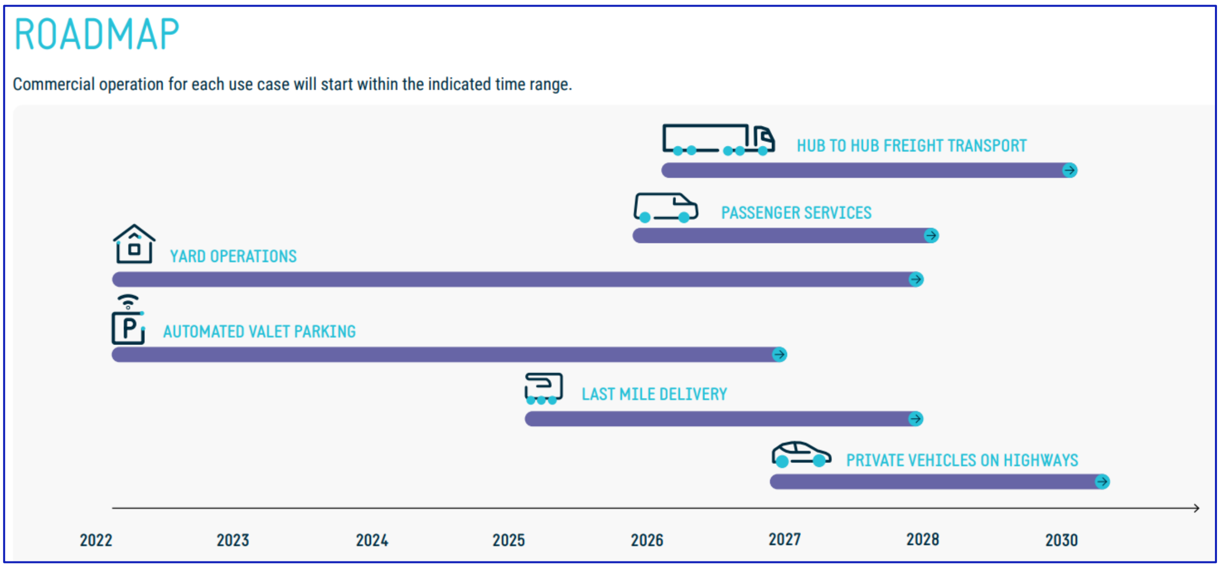

FIGURE 6 - AUTOMATED AND AUTONOMOUS DRIVING ROADMAP BY THE ACEA [16]

The commercial operation for automated and autonomous vehicles is expected to start in 2026/2027 according to the ACEA.

4.1.2 5GAA position on NTN

The 5G Automotive Association (5GAA) has developed a roadmap of automotive services that could benefit from NTN. It should be noted that 5GAA has not identified any NTN-exclusive use cases. NTN is seen as a complement to terrestrial networks, which can provide coverage in areas not served by terrestrial networks. Providing ubiquitous coverage with NTN thus allows to offer the same services everywhere, regardless of terrestrial network build-out.

The roadmap (Figure 7) is structured in phases which are linked to throughput performance. In phase 1, a broad base of initial narrowband services is established using NB-IoT (as standardized in 3GPP Rel-17) in L- and S-band via existing GEO satellites. First market offerings are already available for smartphones and IoT. Mass deployment of these services in new vehicles is expected already in 2027/2028. Examples for such services include emergency calls, local hazard and traffic information and vehicle/fleet management, which require data rates of less than 400 kbps.

This is followed by a second phase of wideband services, e.g. tele operated driving or data collection and sharing for HD maps. These services demand significantly higher data rates of up to 10 Mbps, which in turn requires new constellations of LEO satellites which support NR NTN. Therefore, mass deployment is expected not before 2029/2030.

Finally, in phase 3, more advanced use cases are served which demand broadband data rates above 10 Mbps, e.g. for video streaming. Such high data rates would likely require not only new satellite constellations, but also more spectrum than what is currently available for NTN in FR1. Larger bandwidths are available for example in Ka or Ku-band. However, 5GAA has identified that a critical implementation aspect for these bands are antenna designs for implementation in automotive use cases. In particular, phased array antennas that are small enough to be integrated e.g. into the roof of a vehicle and at the same time sufficiently energy- and cost-efficient, are yet to be developed.

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Currently many use cases do only need narrowband or wideband data rates. The small number of wideband use cases is expected to grow in the future and depend on optimized terminal parameters and cost.

The 3 phases are outlined in the graphic below by 5GAA.

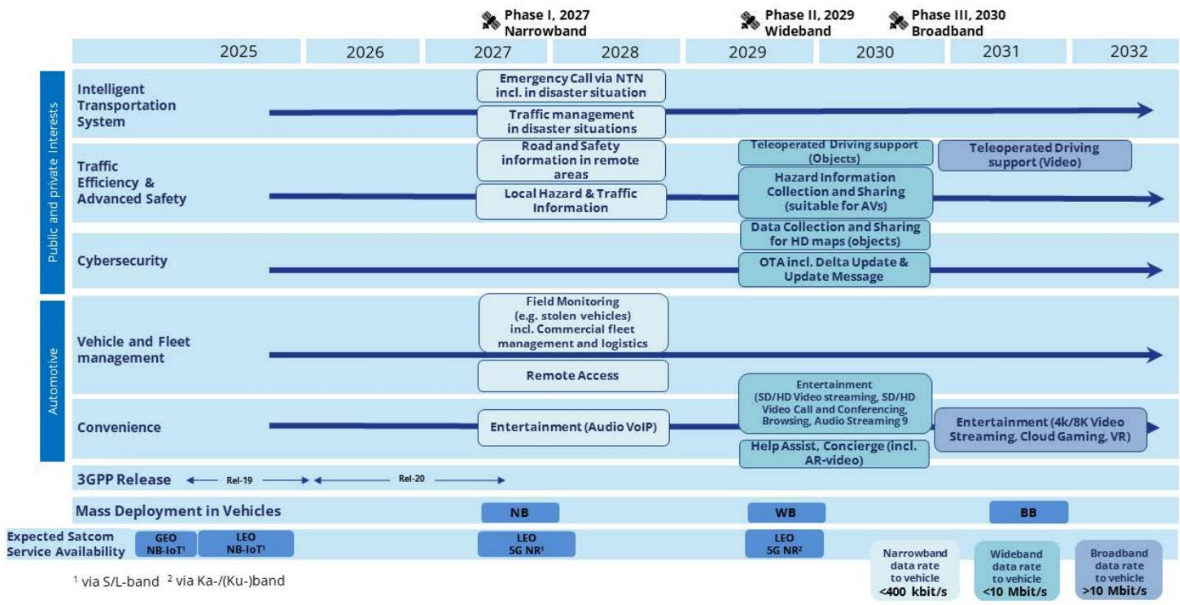

FIGURE 7 – UPDATED NTN ROADMAP BY THE 5GAA [17]

Finally, aside from throughput, 5GAA has identified mobility and TN/NTN interworking as another performance driver, as service continuity, even when changing between TN and NTN, is a fundamental customer expectation.

4.2 ROLE MODEL & VALUE CHAINS

4.2.1 Current or near term analysis (y2020-2025)

Current connectivity usage for automotive includes:

- Infotainment (media, telephony, navigation)
- Tracking and tracing
- Shared Mobility
- Connected machinery (construction, farming, etc.)
- Mandated emergency services
- Roadside assistance
- Mandated connected toll systems
- Remote maintenance, access and status for e-vehicles
- Driver assistance and supervision (commercial, insurance)

Overview Communication usage

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TABLE 4 - COMMUNICATION USAGE

	Communication Need	Current TN Technology	Deployment Driver
Infotainment	• Broadband • Continuous data stream	• LTE MBB • 5G eMBB	• Car OEMs • Services & differentiation
Tracking and tracing	• Narrowband • Data packets	• LTE MBB • LTE MTC	• Logistics, Fleet Mgmt.
Shared mobility	• Narrowband • Data packets	• LTE MBB • LTE MTC	• Mobility services provider
Connected machinery	• Narrowband, broadband • Data packets	• LTE MBB, MTC • 5G eMBB	• Logistics, Fleet Mgmt. • Remote maintenance
Mandated emergency services	• Narrowband voice & data • Continuous voice	• 2G	• Regulation • Mandated service
Roadside assistance	• Narrowband voice & data • Continuous voice	• LTE MBB • 5G eMBB	• Car OEMs, Fleet operator • Services & differentiation
Toll systems	• Broadband • Continuous data stream	• LTE MBB • 5G eMBB	• Regulation • Mandated service
e-vehicles remote maintenance & service	• Broadband • Continuous data stream	• LTE MBB • 5G eMBB	• Car OEMs • Remote maintenance • Configuration & analytics
Driver assistance and supervision	• Broadband • Continuous data stream	• LTE MBB • 5G eMBB	• Car OEMs • Services & differentiation

Stakeholders and roles are:

- Vehicle OEM, defining and integrating factory side communication integration and connectivity based services
- Aftermarket vendors, for additional communication functionalities and services such as theft protection or remote status for rental cars and commercial vehicles and others
- MNOs, often in partnership with car OEMs providing connectivity
- Remote management platform providers for connected passenger cars, commercial vehicles and fleets
- Digital services providers for entertainment and car related services

4.2.2 Evolution trends and drivers towards 6G (y2030-2035)

Trends towards 6G include emphasis of existing usages as well as new usages and business models.

Existing use cases with increased emphasis, transition, extended usage:

Broadband for infotainment

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Large segment and strong driver, especially in the premium and electric vehicle market.

Evolved service needs include:

- Higher service reliability
- Positioning service
- Data throughput

Tracking and tracing

Smaller segment, buses, commercial vehicles, vans and trucks. Only some critical and demanding sub-use cases.

Evolved service needs include:

- Higher service reliability
- Positioning service

Shared mobility

Focus on shared mobility for vehicles lies in the location of vehicles and the transaction related to contractual elements of the sharing agreement. In addition, telemetry about the vehicle status is transmitted.

Current services are well served with existing 5G technology. Evolved services may have additional requirements due to the extension of shared mobility to rural areas and higher service levels.

- Positioning
- Extended services
- Higher service reliability

Connected Machinery, Construction Vehicles

Smaller segment, high value professional vehicles or fleets. Larger share of usage expected due to high machinery cost and high failure cost.

Evolved service needs include:

- Higher service reliability
- Positioning service
- Broadband for updates

Mandated Emergency Services – see also “Warning System and Traffic Safety”

Future evolutions of the mandated pan-European eCall emergency call system can benefit from extended reach and coverage as well as the seamless interworking allowing critical service continuity.

May get an additional component related to warning services possibly in the context of V2X communication.

Evolved service needs include:

- Reliability
- Positioning
- Updates for critical components, keys and certificates

Roadside Assistance for Passenger Cars

Will be combined with general connectivity (infotainment) for passenger cars.

Evolved service needs include:

- Higher service reliability

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- Positioning service
- Remote maintenance and diagnostics

Toll systems

Extension of toll areas, enabling a more dynamic toll system.

Evolved service needs include:

- Higher service reliability
- Positioning service

e-Vehicles remote maintenance, access & service

Higher needs in terms of software updates, remote configuration and predictive maintenance

Evolved service needs include:

- Higher service reliability
- Positioning service
- Remote maintenance and diagnostics

Advanced driving assistance and supervision

Advanced driving assistance systems are already well established, reliability, functionalities, and services are evolving fast.

Evolved service needs include:

- Reliability
- Positioning
- Broadband
- Updates for critical components, telemetry, keys and certificates

New use cases or use cases which may be transformed

Mainly driven by evolved vehicles with increased driver services and autonomy.

Autonomous Car

The different degrees of autonomy have in common that they need a reliable system for maintenance, remote telemetry and status inquiries. Some active functions may be supported in parallel for better redundancy.

Service needs include:

- Reliability
- Positioning
- Broadband
- Updates for critical components, keys and certificates

Tele Driving

Tele driving services for parking, vehicle logistics and shared mobility are currently in trial phase. Higher reliability and redundancy can be key drivers for adoption.

Service needs include:

- Reliability
- Positioning
- Broadband
- Updates for critical components, keys and certificates

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Warning System and Traffic Safety – see also "Mandated Emergency Services"

May get an additional component related to warning services possibly in the context of V2X communication.

Service needs include:

- Reliability
- Positioning
- Updates for critical components, keys and certificates

4.2.3 6G role models by y2030-2040

The following table intends to summarize the previous sub section analysis.

TABLE 5 - 6G ROLE MODEL BY Y2030-2040

	Area	(Evolved) Service Needs	6G NTN Adoption
Existing	Infotainment	• Reliability • Positioning • Data throughput	• Initial adoption by premium cars • Part of combined car communication system
	Tracking and tracing	• Reliability • Positioning	• Reliable goods tracking use cases will adopt initially
	Shared Mobility	• Positioning • Extended services • Higher Service reliability	• Potentially within the extension of services to rural areas
	Connected machinery, Construction Vehicles	• Reliability • Positioning • Broadband for updates	• Reliable tracking, connected machinery, smart farming
	Mandated emergency services	• Reliability • Positioning • Updates for critical components, keys and certificates	• Evolution in warning systems
	Roadside assistance for Passenger Cars	• Reliability • Positioning • Remote maintenance and diagnostics	• Reliable fleets • Cars will combine with infotainment

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	Toll systems	• No 6G NTN evolution foreseen	• No 6G NTN evolution foreseen
	e-vehicles remote maintenance & service	• Reliability • Higher throughput for larger software updates • Positioning	• Increasing need for remote updates and configuration, especially for critical systems
	Advanced driving assistance	• Reliability • Positioning • Broadband	• Mainly as a backup • Telemetry & maintenance
	Driver supervision	• No 6G NTN evolution foreseen	• No 6G NTN evolution foreseen
New	Autonomous Car	• Reliability • Positioning • Broadband • Updates for critical components, keys and certificates	• Mainly as a backup • Telemetry & maintenance
	Tele Driving	• Reliability • Positioning • Broadband	• Mainly as a backup • Telemetry & maintenance
	Warning Systems, traffic safety	• Reliability • Positioning • Narrowband	• Mainly as a backup • Telemetry & maintenance

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5 PUBLIC SAFETY MARKET ANALYSIS

5.1 MARKET DESCRIPTION AND SEGMENTATION

5.1.1 Market description

What should be understood by « Public Safety market »? Here are two examples that can help us to introduce this market segment.

The first one is a segmentation of the overall “Mission Critical communication networks” that is provided by Omdia consultants. Six sub-markets are shown that are grouped in 2 categories: Public Protection and Disaster Relief (PPDR) and Enterprise Critical Processes. We can identify here that PPDR seems to be equivalent to Public Safety, whereas Enterprise Critical Processes could be understood as a sub-category of the more general category such as B2B or a specific group of critical communications within an Energy and Oil business category and the same for transport and logistics and manufacturing.

FIGURE 8 - MISSION CRITICAL COMMUNICATION NETWORKS MARKET SEGMENTATION [18]

The second example that we consider is one provided by European Union Agency for the Space Programme (EUSPA) in its Secure SATCOM Market and User Technology Report. This segmentation is use case oriented and focused on domains where SATCOM are used. We can observe in this overall “secure SATCOM” market some other categories that can be more linked to Governmental activities that are not part of public safety, for instance the “surveillance” activities such as land border surveillance and maritime surveillance. The communication services for embassies or the connectivity in polar regions can also be identified as not being part of public safety. Conversely the “civil protection” and “law enforcement interventions” categories can be more understood as clearly linked with “public safety”.

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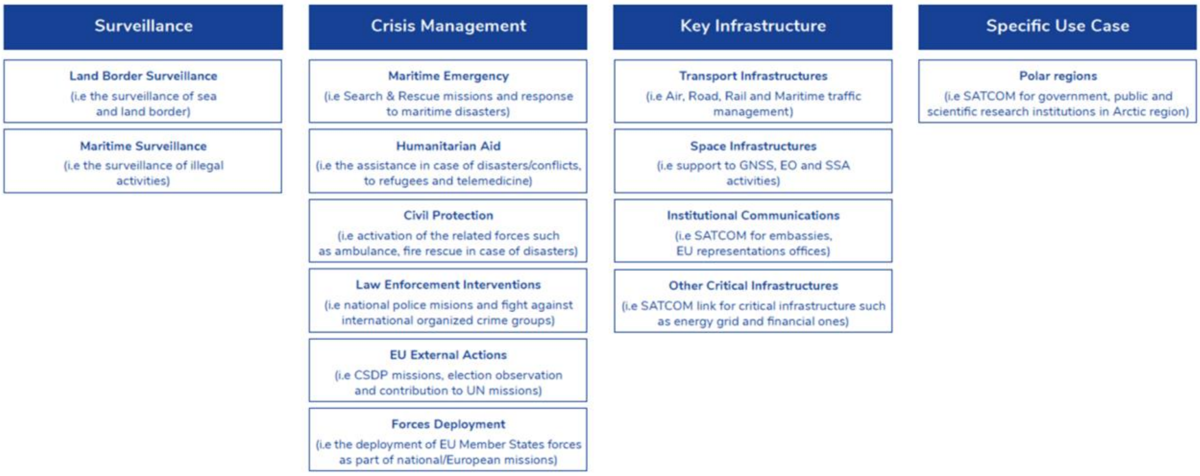

FIGURE 9 - SECURE SATCOM MARKET SEGMENTATION, [19]

These two examples are given in order to show that the "public safety" market is not identified clearly or named the same way in different analyses that adopt multiple viewing angles.

5.1.2 Terminology & Definitions

This section provides definitions and terminologies from several sources in order to show the variety of concepts that are linked to "Public Safety" and can vary across the countries or the organisations that use and analyse them.

Public safety = PPDR (Public Protection & Disaster Recovery)

- Public safety or PPDR Organisation : **Also called Emergency Services or First Responders**, which employ staff that are working in very dangerous situations where lack of communications is considered to be life threatening, such as **Police, Fire, Rescue, Health, Ambulance and Civil Protection services**. In some jurisdictions PPDR organisations are mandated by law to deliver a certain level of service to society. They undertake operations that require a highly-available capability for communications, which have typically used voice but are increasingly using data to deliver faster access to more diversified Mission Critical services that end users require today. Source [20]
- **First Responders**: a first responder is a person responsible for going immediately to the scene of an accident or emergency to provide assistance. Therefore, the first responder market is defined to include both full-time and volunteer personnel in **law enforcement, fire services and emergency medical services (EMS**). Source [21]

Mission Critical communication, Source [22]

- Critical communications are communications services that are critical for the successful delivery and completion of the missions, tasks and operations of professional users who rely on being in contact when it counts.
    - Examples of mission critical and business critical users include the following: Public Safety/PPDR, Government entities, Utilities (Electricity, Gas, Water), Power Generation, Petrochemical/Extraction, Transport (International and Metropolitan Rail, Metro, Ports, Airports, Buses, Trams and Taxis), Military/Paramilitary, Security, Telcos, Sporting and leisure complexes

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- PMR: private/professional mobile radio. PMR refers to networks and radio equipment used for Mission Critical Communication. Historically, it was used by opposition to public network which are opened to general public whereas PMR are available only to a closed user group.

Secure Satcom, source [19]:

- Secure SATCOM is defined as a satellite-based, one or two-way communication capacity/service that is able to provide **reliable, accessible and guaranteed satellite capacity/service for communications**. Secure SATCOM can be provided with any type of frequency band by GOVSATCOM, COMSATCOM, MILSATCOM
- **COMSATCOM** refers to SATCOM capacity and service provided on the global open market, generally with a degree of 'on-demand' access. These services encompass a wide range of sectors, including telecommunications, broadcasting, internet access, maritime communication, aviation, and more. COMSATCOM systems contribute to global connectivity and information dissemination.
- **GOVSATCOM** encompasses the communication services specifically tailored to meet the needs of governmental entities, as defined in the Working document of the European External Action Service of 15/03/2017 (Council of the European Union. 2017). This involves the deployment of **satellite communication systems to ensure reliable, secure, and resilient communication for government operations, including defence, emergency response, public safety, and diplomatic communication**.
- **MILSATCOM** is a highly protected and guaranteed SATCOM, generally provided by military systems, offering highly assured and protected satellite communication capacity both in terms of nuclear hardening, anti-jamming/dazzle capacity and highly secure Telemetry, Tracking, and Command (TT&C), supplemented by an equally robust and resilient ground segment. The security and technology are highly specific and largely sovereign in nature. Those MILSATCOM systems are primarily designed for military purposes and are under national control.

5.1.3 Market segmentation synthesis

Based on the segmentation examples and the definitions and terminology described in previous sections we try to synthesize our understanding in the following block diagram.

This diagram outlines the components of **critical communications** and their applications, categorized into three main sectors, all linked to **Secure Satcom** (secure satellite communication). Here is a description of the sectors:

- **Public Safety (PPDR - Public Protection and Disaster Relief) / First Responders** (purple box on the left):
    - **Fire Services, Firefighters & Associated Organizations**: Communication systems used for firefighting and related rescue operations.
    - **Law Enforcement**: Communications for police and security agencies to maintain law and order.
    - **Emergency Medical Services**: Communication for ambulances, paramedics, and hospitals during emergencies.
- **Other Governmental Critical Communication** (blue box in the centre):

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  - **Diplomatic Communications**: Secure communications for diplomatic missions and government officials.
  - **Military/Paramilitary**: Communications for armed forces and paramilitary organizations.
  - **Humanitarian Aid**: Communication support for disaster relief and aid distribution efforts.

- **Enterprise Critical Communications** (pink box on the right):

  - **Utilities & Energy (Oil & Gas)**: Communication systems for energy production and distribution industries.
  - **Transport (Ports, Airports, Railways, etc.)**: Communications for transportation infrastructure and logistics management.
  - **Financial Services Infrastructure**: Secure communication networks for banking and financial institutions.

These three categories collectively fall under the broader umbrella of **critical communications**, with **Secure Satcom** playing a pivotal role in enabling reliable and secure connectivity across all these sectors.

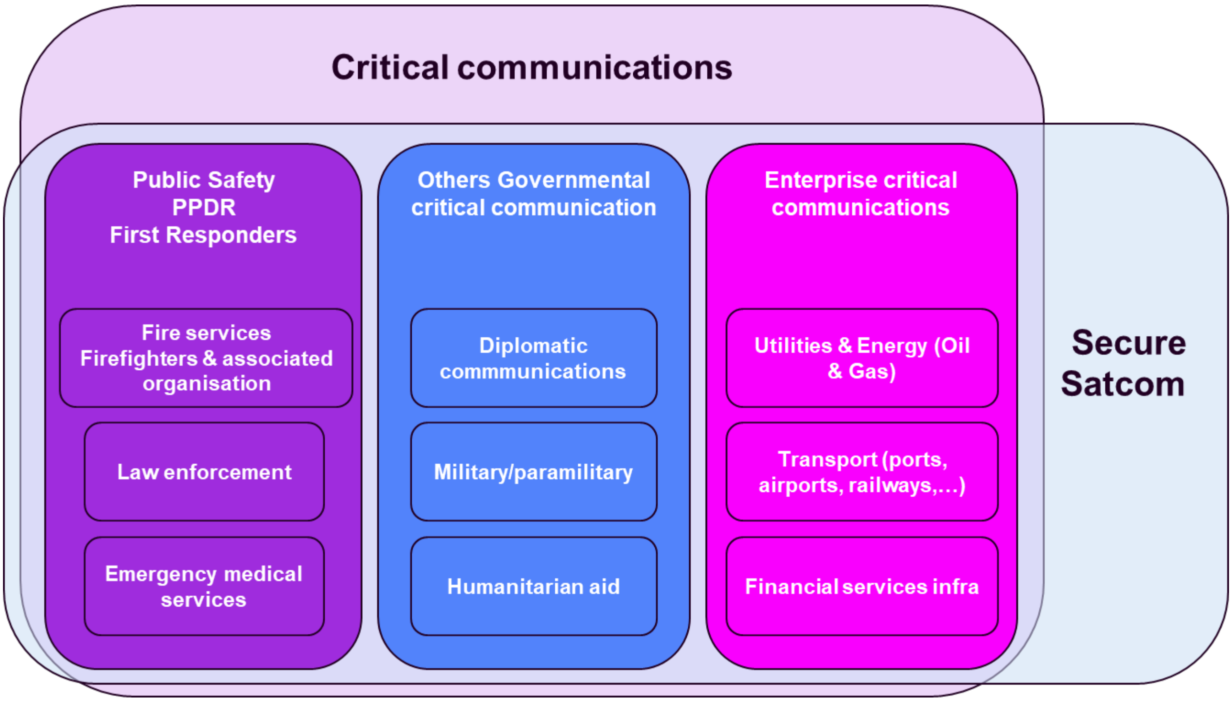

FIGURE 10 - MARKET SEGMENTATION SYNTHESIS (SOURCE: PROJECT INTERNAL ANALYSIS)

In the next sections of this public safety market analysis, we will focus only on the Public Safety category without considering the other governmental critical communications or the Enterprise critical communications.

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5.1.4 Market, evolution and links with Satcom

Public safety organizations currently utilize Professional Mobile Radio (PMR) networks under their own control as the primary solution, with PMR networks fragmented between and within countries. These PMR networks are still based on 2G technology (TETRA, TETRAPOL) and support voice services (including group-based push-to-talk) and low bandwidth data services.

A transition to dedicated PMR networks based on 3G technology was bypassed mainly due to the high investment costs of establishing a new PMR network and purchasing new dedicated terminals (typically costing 1,200-1,500 Euros, associated with a relatively small PPDR user market).

Satellite communication (SatCom) solutions are used, for instance, to create a mobile cell "on wheels" (a vehicle equipped with a mobile cell tower with satellite backhaul) for remote areas or disaster relief.

Currently, public safety organizations utilize national PMR networks (owned and operated by governments or companies). Several countries have started to adopt mission-critical communication services via mobile network operators (with national coverage). In most countries, there is a national government entity (e.g., ASTRID in Belgium, RRF in France, ESN in the UK) that manages elements in private PPDR networks and acts as the contractor for these new Mission Critical (MC) services from Mobile Network Operators (MNOs) or for national public safety organizations. SatCom may also be used in regions with no mobile coverage. The benefits of these existing solutions include geographical coverage and high availability, and that the solutions are fully under the own control of the national government.

Some public safety organizations also utilize 4G mobile networks for voice and data services, either through a dedicated Mobile Virtual Network Operator (MVNO) or via a contracted MNO. Specific features may be implemented to enhance reliability, availability, coverage, and security. These additional functions include support for national roaming, dedicated SIMs (within a separate security domain), and priority and pre-emption on the Radio Access Network (RAN) and core network. With these enhancements, commercial mobile networks could be extensively used for mission-critical communication. Furthermore, support for Mission Critical group-based communication services (such as group-based push-to-talk, data, and video services) is required on top of mobile RAN and core networks.

In the following table, we try to give a synthesis of the evolution in time of the network used in public safety.

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TABLE 6 SYNTHESIS OF THE EVOLUTION IN TIME OF THE NETWORK USED IN PUBLIC SAFETY.

	Past until nowadays	Nowadays & Near future	Mid-term (2027 - 2035)	Long term (2035 onwards)
Network type	PMR network	4G/5G public networks (+ private networks)	4G/5G TN + 5G NTN	6G (TN&NTN)
Network ownership	government	MNO & Government	MNO & Government	
Network operation	by government or contracted company	By gov own MVNO and/or by contracted MNO*	By gov own MVNO and/or by contracted MNO	By gov own MVNO and/or by contracted MNO
Technology	2G (TETRA, TETRAPOL)	4G/5G	4G/5G TN + 5G NTN	6G (TN&NTN)
Services	• voice (including group-based push-to-talk services) • Low bandwidth data	Mission Critical (MC) Voice / Data / Video **	MC services over SatCom access, seamless integration and continuity of voice and data services during hand-over between SatCom and 5G access networks.	• Same services with performance improvement • Positioning service
Satcom use	• Backhauling e.g. for a mobile cell “on wheels” • Satphones	No evolution	Smartphone or pedestrian terminal direct connectivity to satellite Vehicle terminal connectivity to satellite	All terminals are NTN enabled => Highly resilient network
Pains/Constraints	• Network fragmentation between countries and within countries • Terminal cost (typically 1,200-1,500 Euro, related to a relatively small market of PPDR users) & proprietary technologies (no scale effect)	• Coverage gaps/holes • Public network availability during crisis	• Seamless roaming or integration with terrestrial networks is needed • Satellite networks also need to be connected to several 5G networks from different mobile network operators	
Benefits	• geographical coverage • high-availability • under own-control	Using 3GPP technology brings: • Terminal costs decrease • Network evolutivity with backward compatibility • Interworking across frontiers	• Coverage outside terrestrial networks footprint • Improved overall network availability	Coverage Resiliency Performance

* In most countries there is already a national (government) organisation (e.g. ASTRID in Belgium, RRF in France, ESN in UK, …) that contracts and operates elements in the private PPDR networks and will act as the contractor of these new Mission Critical (MC) services from Mobile Network Operators (MNOs) or for national public safety organisations
** Specific features may be implemented to increase reliability, availability, coverage and security. Additional functions are e.g., support of national roaming, dedicated SIM (within a separate security domain) and priority and pre-emption on the RAN (and core) network. With the support of these additional functions commercial mobile networks could be used for mission critical communication to a large extent. Also, the support of Mission Critical group-based communication services (like group-based push-to-talk, data and video services) are needed on top of mobile RAN and core networks.

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The PPDR (Public Protection and Disaster Relief) market is evolving significantly across various dimensions:

- Technologically, there is a shift from proprietary systems to standardized ones, transitioning from TETRA to 4G LTE and now 5G.
- In terms of spectrum usage, the market is moving from dedicated spectrum allocations to a hybrid approach that combines dedicated and shared spectrum, focusing on terrestrial networks (TN) only.
- Ownership and operations are also transforming, with a move away from fully dedicated infrastructure towards a hybrid model that integrates both private and public infrastructure.
- Service offerings have expanded from narrowband voice communications to mission-critical broadband services, encompassing data, voice, and video.
- Finally, there is a trend towards greater integration, moving from isolated, dedicated systems to seamless integration of non-terrestrial networks (NTN) and terrestrial networks (TN).

These trends reflect a broader push towards more versatile, efficient, and comprehensive communication solutions in the PPDR sector.

The following table outlines the potential impact of various 6G NTN features on the Public Safety market compared to 5G NTN. For vehicle-mounted terminals, 5G NTNs are limited to FR1 with wideband data rates and cumbersome FR2 terminals, resulting in limited vehicle deployment. In contrast, 6G NTNs may offer improved FR1 wideband data rates and compact FR2 terminals (typically 20x20cm), enabling more use cases and a strong adoption for vehicles and drones. Light indoor and in-car coverage, unavailable in 5G, may become accessible in 6G, enhancing service without significantly affecting adoption rates. Multi-connectivity in 6G may allow uninterrupted service and seamless TN to NTN handovers, enabling more use cases and improving service reliability without substantially increasing adoption rates. Additionally, 6G may bring resilient positioning during GNSS outages and GNSS-free operation, boosting service independence and reliability without significant market adoption shifts. Overall, these 6G features may substantially enhance service capabilities and use case scenarios in the Public Safety market.

TABLE 7 - 6G NTN KEY FEATURES' IMPACT ON PUBLIC SAFETY MARKET WRT 5G NTN

6G NTN possible feature	5G NTN restriction	6G NTN enhancement	Possible Impact on market
Vehicle mounted terminal	FR1 only with wideband data rate FR2 terminal too big => limited number of vehicles equipped	FR1 wideband data rate improved FR2 compact terminal (typically 20x20cm) use with high improvement of data rate	More use cases enabled Virtually 100% of adoption rate for vehicles Virtually 100% of adoption rate for drones
Light indoor/in car coverage	Not available	Available	Service improvement but no expected impact on adoption rate

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Multi connectivity	Not available	Available. Full seamless integration and no service interruption when TN to NTN handover	More use cases enabled Service improvement but no expected impact on adoption rate
Positioning service	Not available	Available	Resilience of positioning in case of GNSS outage. Service improvement but no expected impact on adoption rate
GNSS free operation	Not available	Available	Independence from GNSS availability Service improvement but no expected impact on adoption rate

5.2 ROLE MODEL & VALUE CHAINS:

The organization and roles within the public safety sector's Terrestrial Networks (TN) vary by country, including government ministries and responder organizations like police and fire services. This section outlines the key actors and roles involved in providing connectivity services, such as TN Network Operators, Public Safety Network Operators, and various vendors. It also discusses emergent roles and the potential shifts in connectivity with the introduction of 5G and 5G NTN, highlighting possible future configurations and value chains without anticipating significant evolution with 6G NTN.

Established roles on Terrestrial Networks (TN)

- The organization of the public safety sector and the specific roles of public safety organizations differ for each country and even for each member state within EU. In general, the following roles can be distinguished in the public safety domain:
  - Governments: Ministries responsible for public safety: e.g., **Ministry of Interior**;
  - **Public Safety** (also referred to as Public Protection and Disaster Relief (PPDR)) **responder organizations**: e.g., police, civil protection, fire and rescue services and ambulance services;
- With respect to the provision of connectivity services to the PPDR responder organizations as Communications Service Customers, the following roles can be distinguished:
  - Governments: ministries responsible for telecommunications policy making and telecommunications **regulators** responsible for regulation of the telecommunications field, including spectrum allocation and licensing.
  - **TN Network Operators**: provide radio access and services over mobile networks;
  - **Public Safety Network Operators**: provide connectivity services to PPDR responder organizations via private (e.g., TETRA or TETRAPOL) or public networks (e.g., 4G, 5G);
  - **TN Infrastructure & Network Vendors**: network equipment providers supplying network infrastructure to network operators;
  - **Device Vendors**: supply devices to PPDR responder organizations;
  - **Application Providers**: supply applications to PPDR responder organizations.

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Emergent roles

- Regarding the role of the public safety actors themselves, there are no major evolutions foreseen in near to midterm.
- For connectivity services a shift from usage of dedicated private PPDR networks to public (5G) networks is an option.
- Regarding the role of actors providing network and connectivity services the following evolutions can be expected:
    - 5G Mobile Network Operators can provide new PPDR communication services with enhanced geographical coverage, national roaming and PPDR-grade services with guaranteed priority and availability (for mission critical voice, data and video).
        - A new role of Network Slice Provider enables the MNO with shared use of the network (this role could be performed by the MNO itself).
        - Furthermore, MNOs can facilitate integration with complimentary alternative radio networks such as satellite, Wi-Fi, etc.
    - Dedicated Public Safety Mission Critical Mobile Network Operators
        - can make use of their own infrastructure or make use of shared PPDR-grade 5G networks.
        - can also act as MVNO i.e. a 'slice aggregator' that assembles slices from different MNOs and SNOs.

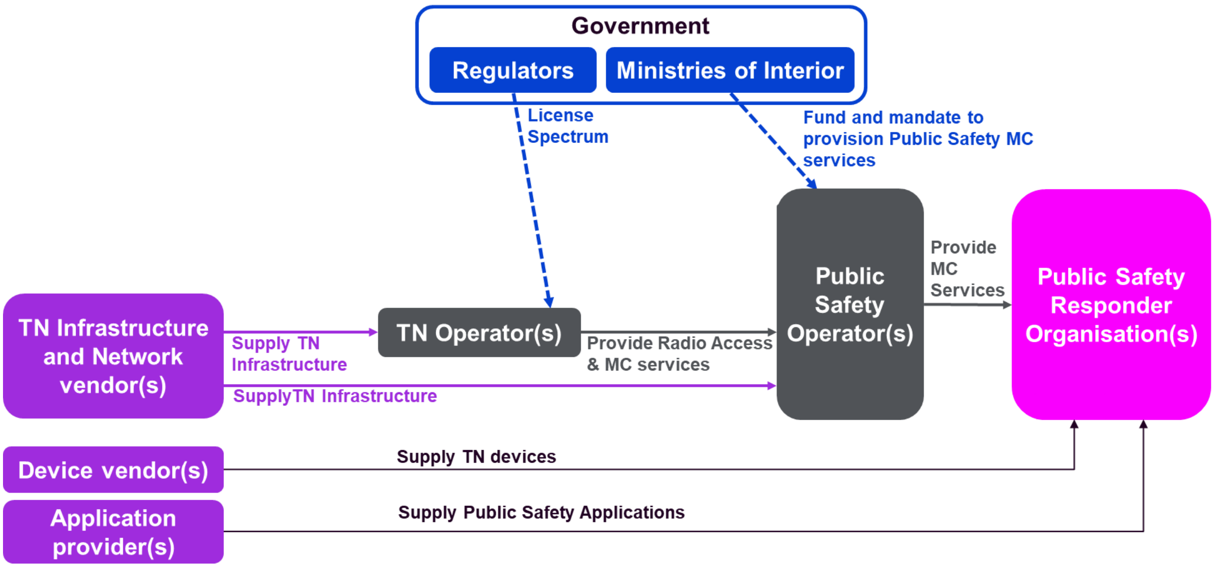

FIGURE 11 - CURRENT/NEAR TERM PUBLIC SAFETY VALUE CHAIN WITHOUT NTN

Role models with NTN

We anticipate two roles to appear in the role model with NTN:

- the NTN Infrastructure and Network vendors: this role could be performed by specific NTN actors, especially for infrastructure, but could also be partially performed by more TN oriented actors, especially for Network equipment, that would extend their activities towards NTN.

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- The NTN operators: here again this role can be shared across several actors being more or less active specifically on the NTN and TN domain.

We note that the Device Vendor role is now slightly modified because it now integrates the NTN capability in the devices that are supplied to users.

Two possible options of the role model are shown with NTN operators offering:

- NTN radio access or Mission Critical (MC) Services to either TN Network Operators
- or directly to Public Safety Operators.

Both the TN Operators and the Public Safety Operators can offer services across multiple EU member states and have (national) roaming agreements on PPDR TN radio access.

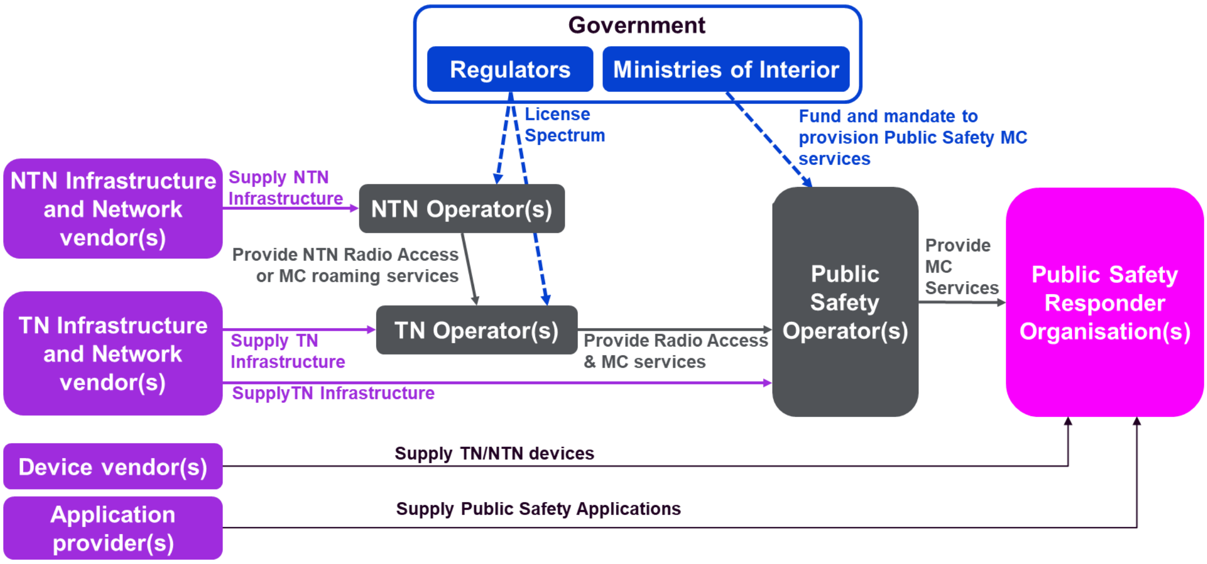

FIGURE 12 - PUBLIC SAFETY ROLE MODEL WITH NTN INTEGRATION BY TN OPERATORS

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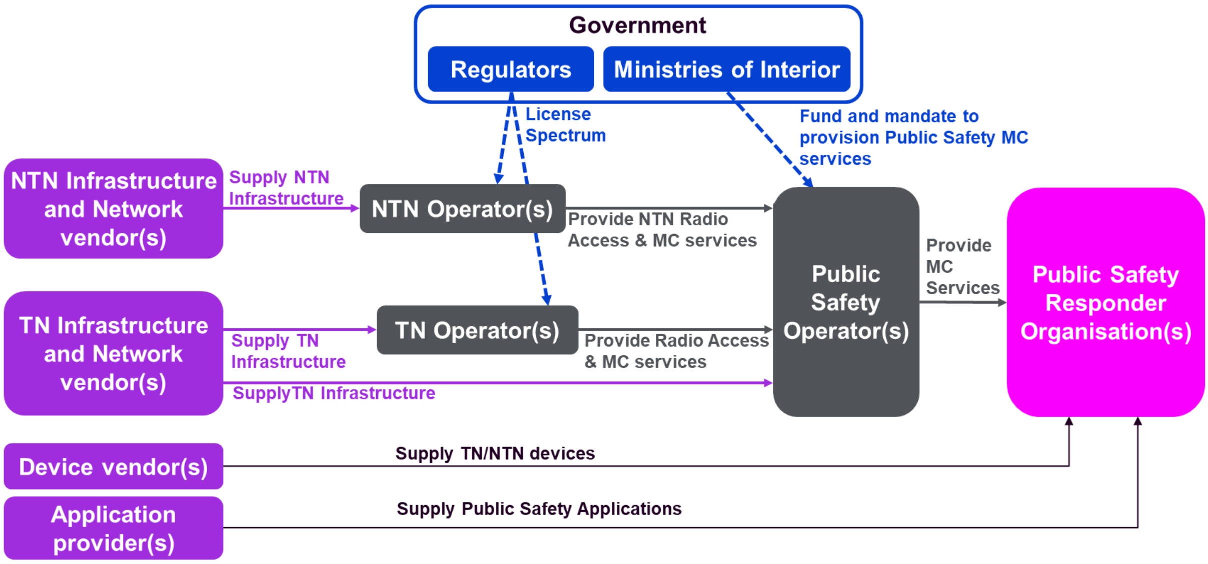

FIGURE 13 - PUBLIC SAFETY ROLE MODEL NTN INTEGRATION BY PUBLIC SAFETY OPERATORS

Complementary considerations on role models

Following the roles as given in 3GPP TS 28.530 [9], the role of the 5G Enabled Mobile Network Operator can be further broken down into the following roles that can be played by one or more organizations simultaneously:

- Communication Service Provider (CSP): it provides communication services. Designs, builds and operates its communication services. The CSP provided communication service can be built with or without network slice.
- Network Slice Provider (NSP): it provides network slice as a service.
- Network Operator (NOP): it provides network services. Designs, builds and operates its networks to offer such services.

The Network Slice Provider (NSP) can possibly be a new role within the value chain, in case a third party acquires this service and on top of that provides a service as a Communication Service Provider (CSP). This model is then a form of a Mobile Virtual Network Operator (MVNO).

Within the value chain different options exist for providing PPDR connectivity services:

- a dedicated 5G PPDR network
- a shared commercial 5G mobile network with different levels of outsourcing between government and service providers
- a hybrid network (using both dedicated and commercial spectrum) combining above options.

For a dedicated PPDR network (using dedicated PPDR spectrum) the following options exist:

- Government Owned, Government Operated (GOGO);
- Government Owned, Company Operated (GOCO);
- Outsourced Service Provision (OSP).

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For a commercial 5G network (using spectrum allocated to commercial operators) the following options exist:

- Managed Virtual Network Operator (MVNO) for PPDR users only;
- Shared mobile radio access network with dedicated or shared spectrum;
- Shared or dedicated mobile core for PPDR;
- Shared or dedicated Mission Critical Services platform for PPDR (for mission critical push-to-talk, etc.)

In the long term with 6G NTN introduction, we have not identified any necessary or possible evolution in the value chain or in the role model for public safety segment.

5.3 ADDRESSABLE MARKET:

We have not identified public publications that focus on the public safety addressable market for 5G/6G NTN, nevertheless we propose in this section an estimate and some evolution trends related to the underlying elements of the addressable markets which are the population of public safety agents, i.e. the number of people and the counts of vehicles used by these agents.

We assume that in the end, the addressable market is the sum of both 100% of people and 100% of vehicles.

We observe that the number of first responders such as police officers, firefighters, and emergency medical personnel can vary widely around the world due to several factors including government budgets, population size, geographic area, and local policies. Here are some trends.

Trends in North America:

In USA the number of police officers has generally been stable, though there can be regional variations due to local budgets and crime rates. Firefighters in the U.S. are often either career professionals or volunteers. Urban areas tend to have more career firefighters while rural areas rely more on volunteers. Emergency medical services (EMS) staff numbers can vary, with urban areas typically having more resources and specialized services compared to rural areas.

In Canada: Similar to the U.S., Canada has a mix of career and volunteer firefighters. Major cities have professional firefighting services whereas smaller towns often depend on volunteers. Police services in Canada are provided by various agencies including the Royal Canadian Mounted Police (RCMP), regional, and municipal police forces. The overall numbers are generally proportionate to population size and crime rate.

Trends in Europe:

United Kingdom: The number of police officers has seen changes in recent years due to budget cuts and policy reforms. There have been concerns over the impact of reduced numbers on public safety. Fire and rescue services have also seen budget cuts, though the UK maintains a professional firefighting service. Emergency medical services are provided by the National Health Service (NHS) and there has been an increasing demand for paramedics and other EMS personnel.

Germany: Germany has a mix of professional and volunteer firefighters, with a larger reliance on volunteers in rural areas. The police force in Germany is well-resourced, with the numbers

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typically determined at the state level (Länder). EMS in Germany is highly developed, with a strong infrastructure supporting both urban and rural areas.

France: France has both professional and volunteer firefighters, with the Service Départemental d'Incendie et de Secours (SDIS) being the main organizational structure. The French police force, including the National Police (Police Nationale) and the Gendarmerie, is sizeable and well-distributed. EMS in France is provided mainly by the public sector through the SAMU (Service d'Aide Médicale Urgente) and SMUR (Service Mobile d'Urgence et de Réanimation) units.

General Trends:

- Urban areas tend to have higher numbers of first responders per capita compared to rural areas due to denser populations and greater resource availability.
- Economic factors and government budgets can greatly influence the numbers and availability of first responders. Economic downturns tend to lead to budget cuts which can reduce the number of first responders.
- Technological advances and changing policies also influence the trends, with some regions investing in new technologies to improve efficiency and response times.
- It's important to note that these trends are subject to change and influenced by a multitude of local factors, including political decisions, funding allocations, and societal needs.

We tried to identify below some estimated figures for the number of first responders in specific countries. Please note that these figures can vary over time based on government budgets, policies, and other factors, and might not be up-to-date but should provide a general sense of the numbers involved. The figures were extracted from a variety of public source of information such as ministries or agencies website and various public reports.

TABLE 8 - PUBLIC SAFETY HEADCOUNT ESTIMATES FOR NORTH AMERICA AND 3 COUNTRIES IN EUROPE.

	Police	**Firefighters**	**Emergency Medical Services (EMS)**
USA	~700,000-800,000	~1.1 million total (about 370,000 career firefighters and 745,000 volunteers)	~250,000-300,000 certified paramedics plus additional emergency medical technicians (EMTs)
Canada	~70,000	~126,000 (about 21,000 career and 85,000 volunteers)	~40,000-45,000 (including paramedics and EMTs)
UK	~150,000 (including civilian staff)	~35,000-40,000 (career firefighters)	~30,000-40,000 paramedics and support staff

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Germany	~250,000	~1.3 million (about 30,000 career and 1.27 million volunteers)	~50,000-60,000
France	~240,000 (combined National Police and Gendarmerie)	~250,000 (about 40,000 career and 210,000 volunteers)	Not specified, but the public SAMU and SMUR units are well-staffed across urban centres

These figures provide a general overview and can fluctuate based on local and national changes in policy, funding, and societal needs. The reliance on volunteer firefighters, especially in rural areas, plays a significant role in the total numbers you see, particularly for countries like Germany and France.

Similarly to the headcount, we tried to identify order of magnitude for the count of vehicles. The table below shows these estimates. Again, please note that these figures can vary over time based on budgets, policy changes, and other factors. They provide a broad overview based on historical data and practices.

TABLE 9 - PUBLIC SAFETY VEHICLES COUNT ESTIMATES FOR NORTH AMERICA AND 3 COUNTRIES IN EUROPE

	Police Vehicles	**Firefighters trucks and engines**	**Emergency Medical Services (EMS) ambulances**
USA	250,000-300,000 patrol cars	75,000-100,000 (including pumper engines, ladder trucks, rescue vehicles, and others)	50,000-60,000
Canada	25,000-30,000 patrol cars	8,000-10,000	5,000-7,000
UK	40,000-50,000 patrol cars	3,500-4,500	5,000-6,000
Germany	40,000-45,000 patrol cars	25,000-30,000	15,000-20,000
France	50,000 patrol cars (including both National Police and Gendarmerie vehicles)	20,000-25,000	8,000-10,000 (including SAMU units and private ambulances)

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These numbers provide a rough picture and can be influenced by several factors such as replacement cycles, regional allocations, and evolving needs of the public safety organizations. Rural areas might see a higher reliance on multi-purpose vehicles, while urban centers typically have a more specialized fleet.

Conclusion:

Assuming that per capita the number of public safety agents and vehicles are equivalent in most of the developed countries, we can speculate that the addressable market in terms of addressable units is of a few tens of millions and that it is relatively stable in the future.

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6 IOT MARKET ANALYSIS

6.1 MARKET DESCRIPTION AND SEGMENTATION

Space-based Internet of Things (IoT) is based on the principles of using satellite technology to serve terrestrial IoT devices. Satellites orbiting at different altitudes (e.g., from LEO, MEO and GEO operational orbits) may support such IoT communications, either directly or through the use of ground IoT gateways, in charge of relaying the terrestrial IoT devices messages from and to the Internet, via the satellite communications links. All forms of satellite-based IoT communications put together, this market represents a dynamic and growing segment of the overall NTN market, as will be outlined in the rest of this section.

In effect, the combination of multiple technological drivers related to the new-space industry supported the uptake of a diverse space-based IoT ecosystem, partly made up of legacy players, and partly composed of new entrants, as can be seen in Figure 14.

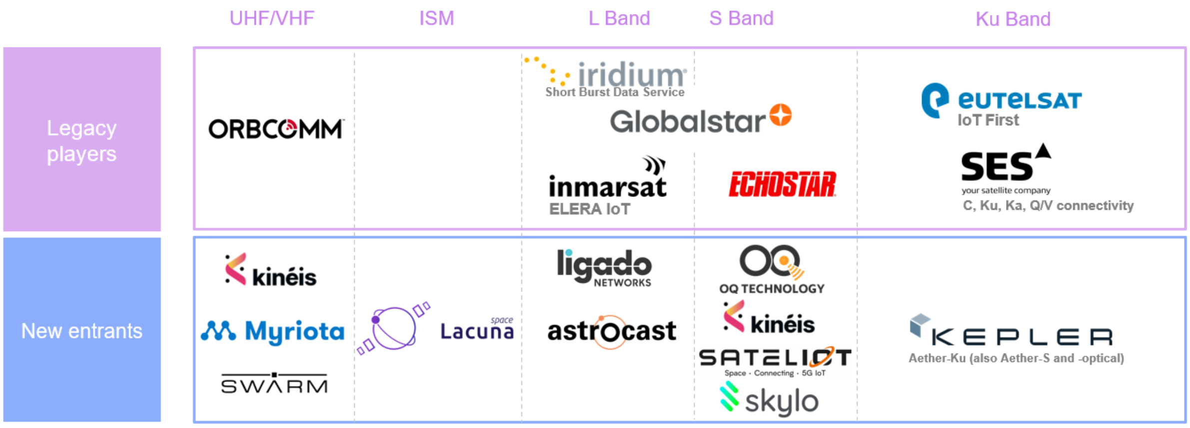

FIGURE 14 - A DIVERSE SATELLITE IOT ECOSYSTEM, MADE UP OF LEGACY PLAYERS AND NEW ENTRANTS

As Figure 14 illustrates in a non-exhaustive way, typical legacy actors of this ecosystem are traditional satellite operators such as Orbcomm, Iridium, Globalstar, Inmarsat, Echostar, Eutelsat and SES, to name a few. Over the years, they have developed satellite fleets or constellations targeting multiple uses, including that of IoT. One important aspect of these actors relates to the financial and operational stage of their satellite fleets: these are generally already deployed, and their funding is already covered for (or at least partly). Regarding the spectrum targeted for their own IoT services, Figure 14 illustrates a noticeable diversity of operational frequencies, from the UHF/VHF band (Orbcomm mainly operates its service links in the 137-138 MHz for the downlink and 148-150.05 MHz for the uplink [37]) to the Ku band and beyond (e.g., Eutelsat 'IoT first' GEO-based service targets compact and low-power Ku-band terminals). Regarding mid-band, many legacy actors like Iridium, Globalstar, Inmarsat (acquired by Viasat in 2022) and Echostar rely on L-band and S-band spectrum. As an example, Iridium, as part of its Iridium Next Certus service, is focusing its IoT offer around the development of modules, such as the Certus 9770 operating in the L-band (1616 - 1626.5 MHz), to be integrated in portable satellite terminals and devices [38]. In general, these legacy actors are well-established operators, with years of experience regarding the design, development, launch and operation of their respective GEO or NGSO fleets and constellations.

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In addition, dozens of new entrants have been seeking to build disrupting fleets and constellations of cost-efficient satellite, with IoT as the main target market and the main objective to find viable business models by offering affordable IoT connectivity, either globally or in complementary fashion with terrestrial IoT. As depicted in Figure 14, examples include Kineis, Myriota, Swarm (acquired by SpaceX in 2021), Lacuna Space, Ligado Networks, Astrocast, OQ Technology, Sateliot, Skylo and Kepler, to name a few. Furthermore, this same Figure 14 also hints at the wide range of operating frequencies targeted by these new entrants, from VHF band up to Ku band and beyond: actors like Astrocast and Swarm target operating frequencies in the sub-GHz bands, while Ligado Networks, Astrocast and OQ Technology, for instance, target spectrum in the mid-bands, in the L and S bands.

Regarding satellite IoT connectivity usage, several prominent use cases generally highlight the needs from diverse industry verticals, spanning domains such as transportation & logistics, energy and utilities, industry, automotive, as well as governmental and military communications. A brief outline of each use case is given in the rest of the subsection.

Transportation & logistics

Maintaining a reliable connectivity with IoT sensors in remote areas is increasingly important for transportation and logistics, notably regarding the topics of fleet management, vehicle tracking / geo-fencing and mobility prediction. Those algorithms are becoming more efficient and at the same time more bandwidth and latency-demanding due to the large amounts of dynamic data that need to be collected and processed in the context of these deployment cases. In addition, they are supported by positioning solutions which need to be as efficient as possible in most contexts, including underground and remote deployments. Speed and other specific features of varied vehicles such as cars, trucks, buses, drones, trains and maritime vessels must also be considered for the efficient design of these IoT solutions. On this basis, ubiquitous coverage, latency requirements and the expected volume of messages per time unit are structuring the transportation cases, and satellite operators are addressing this use case.

Regarding logistics, the container business allows illustration of this specific use case. By principle, clients wish to know, at regular times, where their containers are, along with data about e.g., integrity and various environmental parameters such as temperature and hygrometry. Therefore, requirements also relate to expected data volumes and latencies: a few messages per day are often sufficient to meet this vertical’s requirements. Therefore, LEO-based satellite access with low-cost tariff plan may provide an adapted solution in this context, which explains why many space-based IoT actors consider this market segment.

Energy & utilities

Energy and Utility companies often need to operate large-scale (or even global) infrastructures, which are often located in remote areas, with no available terrestrial network coverage. For such infrastructures, automation is often a primary enabler to reach efficient and affordable production, transmission, and distribution. In that regard, the ability for satellite-based IoT to complement and extend terrestrial-only connectivity is key to support full scale operations. Examples can be found in the fossil and renewable energy sectors, for which remote and automated monitoring is highly needed:

- For fossil energy, it is worth highlighting that the worldwide transmission pipeline network is estimated to be over millions of kilometres (e.g., the U.S. natural gas transmission and distribution network alone amounts to nearly 2 million km of

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gathering, transmission, and distribution pipelines [39]) and the geographical extent of this network explains why a global IoT connectivity would be particularly suited.
- Likewise, many needs expressed by the renewable energy sector highlight the relevance of that kind of connectivity. An example use case is the automated and remote monitoring of wind turbine structural integrity.

In that regard, space-based IoT is considered as a suitable complement to terrestrial IoT to assist/automate energy generation, distribution & consumption (e.g., for smart metering).

Industry (IIoT)

To materialize the concept brought with the so-called Industry 4.0, a key requirement is the increased automation and productivity of factories, which can be supported by an optimal information flow between supply chain, engineering, sales, and operations [40]. In turn, this optimal information flow will require an appropriate connectivity, able to increase the reliability and flexibility of automation systems and processes.

As illustrated by Figure 15, many relevant industrial use cases would benefit from space-based IoT connectivity, including the following aspects:

- Monitor and optimize the production process for smart manufacturing,
- Support predictive maintenance, remote operations, critical control, …
- Improve factory safety and energy efficiency.

To become a reality however, the issue of supporting challenging environments (both communication- and performance-wise [53]) for satellite connectivity shall be thoroughly addressed.

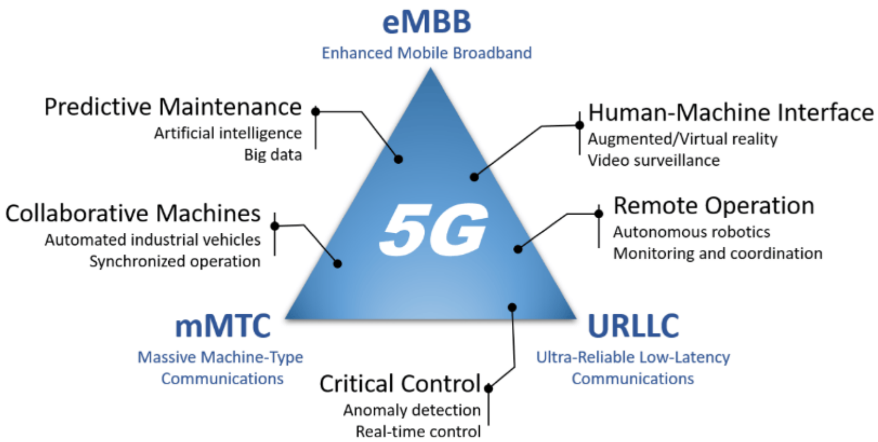

FIGURE 15 - REPRESENTATIVE INDUSTRIAL USE CASES SORTED ALONG THE THREE 5G SERVICES [40]

Automotive

As a complement to the larger automotive business segment investigated in Section 4, it is worth considering the needs of this vertical under the perspectives offered by space-based IoT. As previously mentioned, many use cases from the automotive market generally require reliable, low-latency and possibly high-capacity connectivity, with added needs such as accurate positioning. Some of these use cases, however, may be supported by IoT connectivity, regarding innovations such as tire monitoring sensors, intelligent predictive maintenance, vehicle sensor network, IoT vehicle doors, sensor-integrated seat belts, continuous position tracking, automated shipment tracking, on-board diagnostics, to name a few. In that regard, Figure 16 provides a classification of these innovations that can be

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supported by IoT connectivity, sorted by three stages of technological maturity, from emerging to maturing. It is worth noting that other innovations reported in this same Figure 16 would need to rely on low-latency and high-capacity connectivity, as previously described in Section 4.

Figure 16

	Emerging	Accelerating	Maturing
1	LiDAR scanners	Vehicle sensor network	Remote trip monitoring
2	Smart automotive lighting	AV tyre health monitoring	Smart speed governors
3	Autonomous steering	Collision avoidance systems	
4	Acoustic signalling devices	Sensor-integrated mirrors	
5	Satellite-based positioning	Accident detection telematics	
6	Object sensing radars	Smart de-icing windows	
7	Intelligent in-vehicle displays	Smart street lighting	
8	LiDAR object detection	FoV enhancement sensors	
9	Sensor controlled CVT gearing	Smart batteries	
10	Tyre monitoring sensors	Smart dimming headlights	
11	Intelligent predictive maintenance	IoT vehicle doors	
12	LiDAR sensor fusion	Automatic parking assist	
13		Smart suspension	
14		Sensor-integrated seat belts	
15		Continuous position tracking	
16		Vehicle dashboard cameras	
17		Automated shipment tracking	
18		On-board diagnostics	
19		Driver fatigue monitoring	
20		Smart car seats	
21		Vehicle anti-collision radars	

FIGURE 16 - INNOVATION ENABLERS FOR THE AUTOMOTIVE SEGMENT SORTED BY MATURITY [41]

On this basis, few enablers have already reached technical maturity, and as Figure 17 illustrates, the corresponding innovation S-curve is still concentrated on the emerging enablers. As a result, in particular from an IoT perspective, it is likely that the corresponding use cases may fully develop beyond the closest forecasts of 2027 considered in the rest of this section, and more specifically in the satellite IoT connectivity revenue forecast outlined in §6.2.2, in which this use case is not (yet) visible. Other reasons for that lack of visibility in the considered timeline include a relatively small starting base, compared to other IoT verticals, as well as specific regulation that is not likely to be addressed in the considered 2027-2030 timeframe. On the topic of regulatory framework for IoT automotive, there is a need to safeguard end users, as well as addressing cybersecurity challenges, which are particularly critical in the context of automotive. Consequently, the relevant regulatory framework is steadily evolving, for instance with the enforcement of Europe’s Cyber Resilience Act [54]. Applied to IoT automotive, such regulations highlight potential responsibilities for manufacturers and vendors that will progressively need to be understood and integrated in the regulations, probably beyond the timeline set in this section. For these reasons, the market of IoT for automotive is therefore more difficult to analyse over this timeline.

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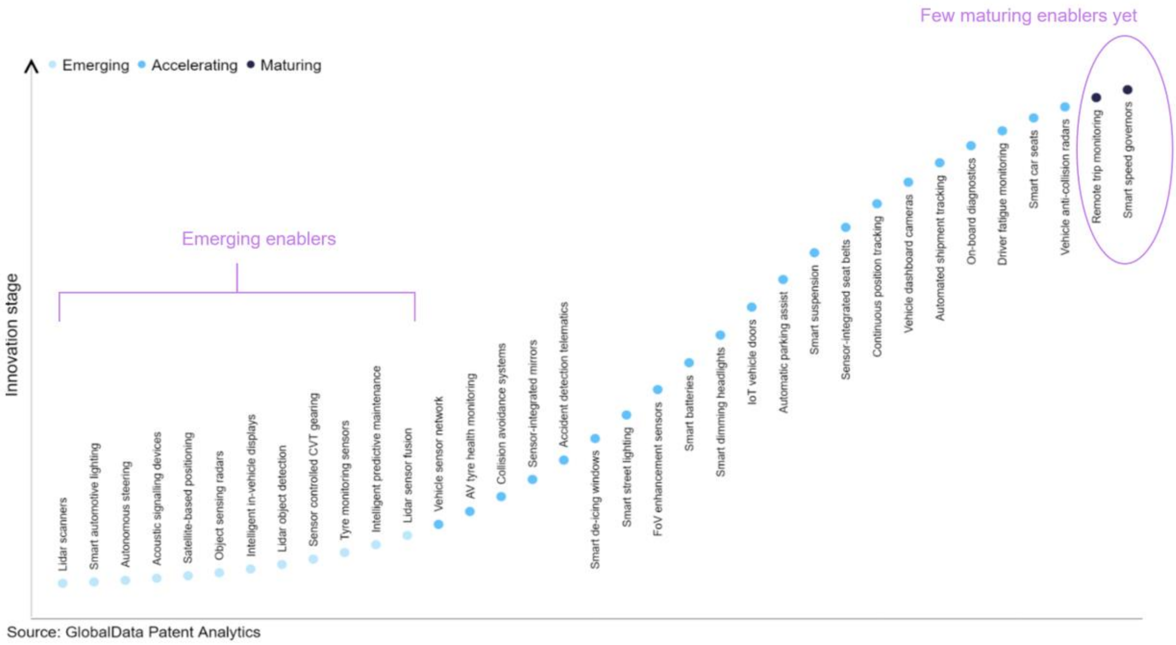

FIGURE 17 - INNOVATION S-CURVE FOR THE AUTOMOTIVE SEGMENT, BASED ON THE TABULAR DATA OF FIGURE 16

GovMil

Governmental and Military (also usually referred to as GovMil) examples include government asset tracking, real-time military personnel tracking, sensor networks for battlefield situational awareness, and so on. IoT GovMil is a part of GOVSATCOM and MILSATCOM as previously seen in subsection 5.1.2. As in the previous use cases, the extent of the required coverage, whether it refers to surveillance areas, battlefields or any other theatre of operation, advocates in many cases for the use of space-based IoT to support many GovMil deployment scenarios [42] [43]:

- One of the salient reasons is that these mission-critical scenarios, as in the previously described IoT use cases, require network coverage which is likely to extend well beyond terrestrial network footprint.
- Moreover, the IoT market traditionally fosters affordable and robust technology, which are key enablers to complement and extend the sensing and computation capabilities provided by military grade equipment.
- Other IoT enablers, such as the ability to target small form factor designs and energy-efficient sensors, should prove particularly relevant for the GovMil deployment cases. In that regard, capillary and high density personal and environmental sensors systems will allow supporting and extending advanced GovMil applicative scenarios.

Space-based IoT is therefore expected to leverage the emergence of advanced cyber-physical features such as soldier and specialized staff biometry support, gesture enhanced communications, collaborative and crowd sensing, smart information provisioning through augmented reality, and logistics and supply chain automation. In that regard, it is worth highlighting that several key challenges will need to be addressed, and notably the need to ensure coexistence and co-deployment of commercial IoT with as GovMil-specific equipment, which raises prominent cybersecurity and information assurance concerns [43]

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6.2 ROLE MODEL & VALUE CHAINS:

6.2.1 Current or near term (y2020-2025) analysis:

To give an overview of how the space-based IoT role models are currently evolving, Figure 18 illustrates recent illustrative (albeit representative) business relations among four classes of actors: Satellite Network Operators (SNOs), Vendors, Mobile Network Operators (MNOs) and IoT Solution Providers. On that basis, the rest of this subsection gives a brief description of these partnerships, with the objective of perceiving and analysing structured trends for the current or near term.

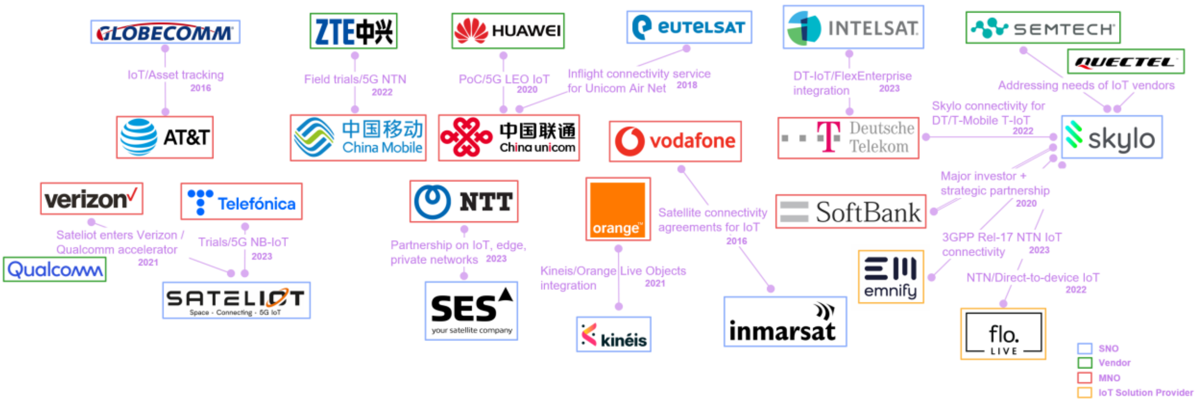

FIGURE 18 - OUTLINE OF RECENT BUSINESS PARTNERSHIPS IN THE DOMAIN OF SPACE-BASED IOT

SNO/MNO partnerships

The first type of business relationship entails partnerships between MNOs seeking to extend their IoT offers (generally, coverage-wise), and SNOs. In that context, as previously described in §6.1, satellite actors can be established players, already operating space-based IoT constellations like Globecomm, Eutelsat, Intelsat, Inmarsat, SES. They also can be relatively new entrants, like Sateliot, Kineis or Skylo.

- The first exemplary business relation is between **AT&T** and **Globecomm** [23]. While a relatively older announcement (dating back to 2016), it is interesting to note that even at that time, complementarity was already a major objective, since through this partnership, the goal was to allow AT&T's clients to operate their IoT devices on cellular connectivity when available, and on satellite-based IoT connectivity otherwise.
- In 2020, China Unicom (through its subsidiary **Unicom Air Net**) and **Eutelsat** presented their joint approach regarding in-flight connectivity, whereby the targeted clients connect to China Unicom's terrestrial network when available and can also benefit from Eutelsat 172B satellite connectivity. Although primarily focused on broadband connectivity, this example also illustrates the strong need for complementary connectivity, which requires to investigate how role models need to evolve regarding the tight partnerships required to ensure joint or consistent network operation and seamless connectivity [26].
- The following partnerships exemplify similar types of synergies whereby MNOs seek to extend their IoT footprint by leveraging on the SNO's ability to complement this footprint. That's for instance the case of the **Deutsche Telekom IoT GmbH** /

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Intelsat, the **Vodafone** / **Inmarsat** and the **NTT / SES** agreements [27], [36], [33] for which the objective (or a part of it in the case of [33]) is to prepare commercial offers based on a global cellular and satellite IoT-managed connectivity service.

Other public announcements illustrate how MNOs and equipment/chipset manufacturers can cooperate, such as China Mobile / ZTE [24], China Unicom / Huawei [25] and Verizon / Qualcomm [35] partnerships. In that kind of agreement, fast track developments and deployment can be expected, which is relevant to shorten the different stages of maturity of key technological NTN IoT enablers, for instance at normative, experimental, or operational stage. As an example, [24] illustrates the experiment of an early 5G NTN Rel.17 field trial using a transparent satellite operating in L-band, in which several D2D narrowband communication cases (e.g., synchronization, broadcasting, accessing and data transmission) were tested.

Finally, it is worth highlighting that an increasing number of partnerships in the context of space-based IoT involves new entrants [28] - [32], [34] - [36]. Among those, the business views of Skylo are worth highlighting, since unless most new entrants, Skylo does not seek to design, deploy and operate its own IoT satellite constellation. Instead, this actor leases geostationary satellite capacity, band 23 in the US and L/S bands (currently band 255 globally and band 256 in Europe) from other companies (e.g., Viasat and its subsidiary Inmarsat, Ligado Networks, EchoStar, TerraStar Networks, …). As a result, Skylo does not focus on building its own satellites, but rather on fostering diverse partnerships to enforce its objective to operate a large NTN network, targeting both NTN and IoT communications. In that regard, Skylo considers two types of clients:

- MNOs (e.g., Deutsche Telekom [28], Softbank [29], Verizon, Telefonica, Flo.Live [31], …) who, as in the aforementioned partnership, seek to extend their own IoT coverage. However, unlike other new entrants in the space-based IoT ecosystem, Skylo focuses more on the global operation of a TN/NTN network, rather than purely seeking to complement/extend MNO's footprint. The simplified Skylo target architecture, which encompasses partnering MNO's own connectivity, is illustrated in Figure 19.

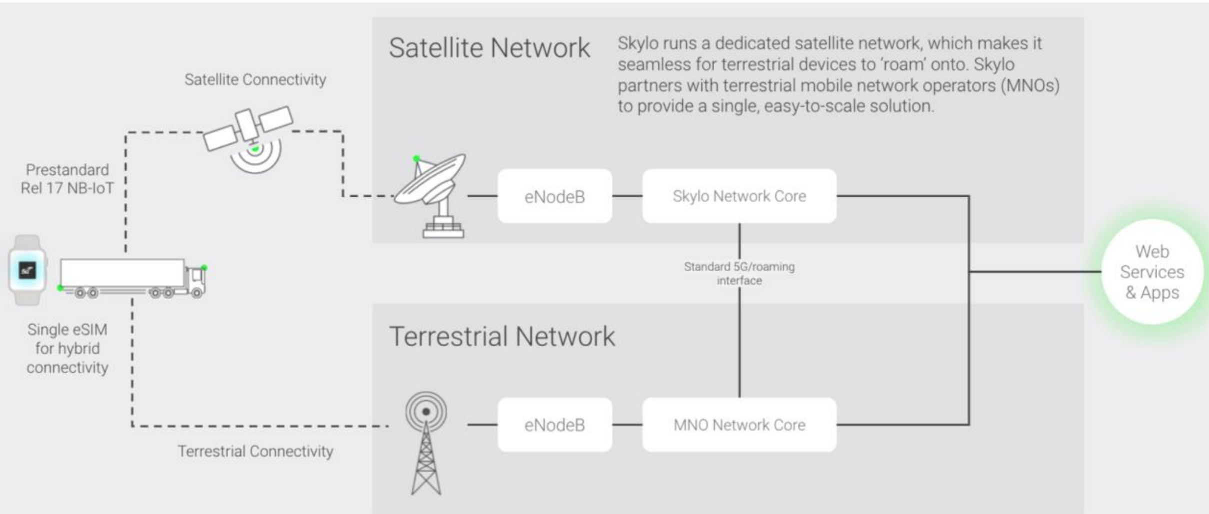

FIGURE 19 - SKYLO TARGET NETWORK ARCHITECTURE [44]

- In addition, Skylo also seek to address needs of IoT device manufacturers (e.g., Semtech, Quectel, …), who often seek to bundle their products with a connectivity plan.

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6.2.2 Evolution trends and drivers towards 6G (y2030-2035):

The current landscape of satellite IoT per regions:

The regional landscape of satellite-based IoT connectivity is led by North America as of 2022, with an approximative market share of 40% [45], followed by Asia-Pacific and Europe (with respective shares of around 25% and 20%), then South America (with a market share below 10%) and finally Middle East-Africa, with a market share around 5%.

- The current weight of North America regarding market shares can notably be explained by the large adoption of space-based IoT by many verticals. This includes the energy and utilities sector, which is increasingly seeking support of satellite IoT connectivity to e.g., monitor the US transmission pipeline network, which as previously mentioned in §6.1, amounts to nearly 2 million km of gathering, transmission, and distribution pipelines. More generally, many verticals in North America widely use this type of connectivity to perform remote networking, management, or operations.
- Another explanation for the large current share of the North American space-based IoT market is the relative concentration of major space-based IoT players in the region, as well as the presence of a high level of investment in high technologies [45].

It is also worth highlighting that various factors explain the uptake of space-based IoT in other regions.

- For the European market, sustainability and environmental regulation are strong factors that drive the growth of satellite-based IoT. In addition, IoT for sustainable industrial, agricultural, and urban development are domains where satellite IoT connectivity can efficiently complement terrestrial technologies [46].
- Governments in the Asia-Pacific region, such as China, Japan and India, are actively seeking to use satellite connectivity to complement terrestrial infrastructure in key deployment cases related to public protection and disaster relief and to address the Digital Divide gap in remote and rural areas.

Evolution trends per regions:

All considered regions are expected to expand, in terms of space-based IoT market size. The main driver for this continued growth will be the ability of satellite IoT connectivity to suitably complement terrestrial IoT to allow advanced service perspectives in all considered target use cases, as previously described in Section 6.1.

However, it is also expected that the Asia-Pacific region will witness the strongest growth. By 2030-2033, satellite IoT market shares per regions should follow the observed trend in the general IoT market, for which the Chinese market is expected to become the largest region in terms of IoT connections, as illustrated by Figure 20.

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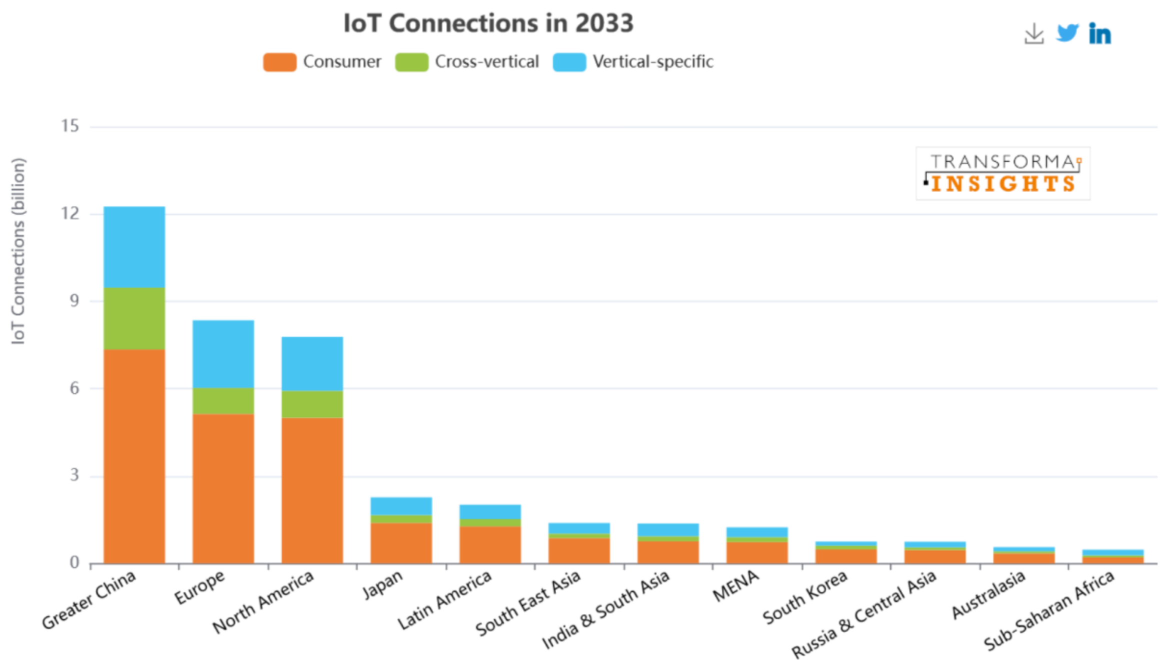

FIGURE 20 - FORECAST OF GLOBAL IOT CONNECTIONS PER REGION BY 2033 [47]

Evolution trends per use cases:

Figure 21 illustrates the trend of different sectors regarding global IoT connectivity, by 2033, in terms of revenue (by 2022) and revenue compound aggregate growth rate (CAGR) over 2022-2033. As can be seen, the governmental, transportation & storage, retail & wholesale and utilities were the four dominating sectors by 2022, with similar estimated CAGR around 10%. For global IoT connectivity, it is therefore expected that those sectors will still be prominent by 2030-2033.

For the more specific case of satellite IoT connectivity, the steepest growth will be observed in use cases where the benefits of satellite are expected, in particular regarding ubiquity (and IoT coverage extension). In particular, three use cases that were previously described in §6.1 (transportation & logistics, energy & utilities, and industry) will strongly grow during the considered timeline. Globally, estimations (in terms of CAGR evolution, both with respect to satellite IoT connections and market revenue) given by different market intelligence companies vary significantly due to different hypotheses and forecast periods taken, but for the sake of illustration, it is worth mentioning that conservative estimations such as [48] foresee connection CAGR increase of 12.7% and revenue CAGR increase of 16.6% over the 2022-2030 period. In slightly different conditions or forecast periods, other revenue CAGR forecasts vary between 10% and more than 30%, e.g., as estimated by [45] – [50].

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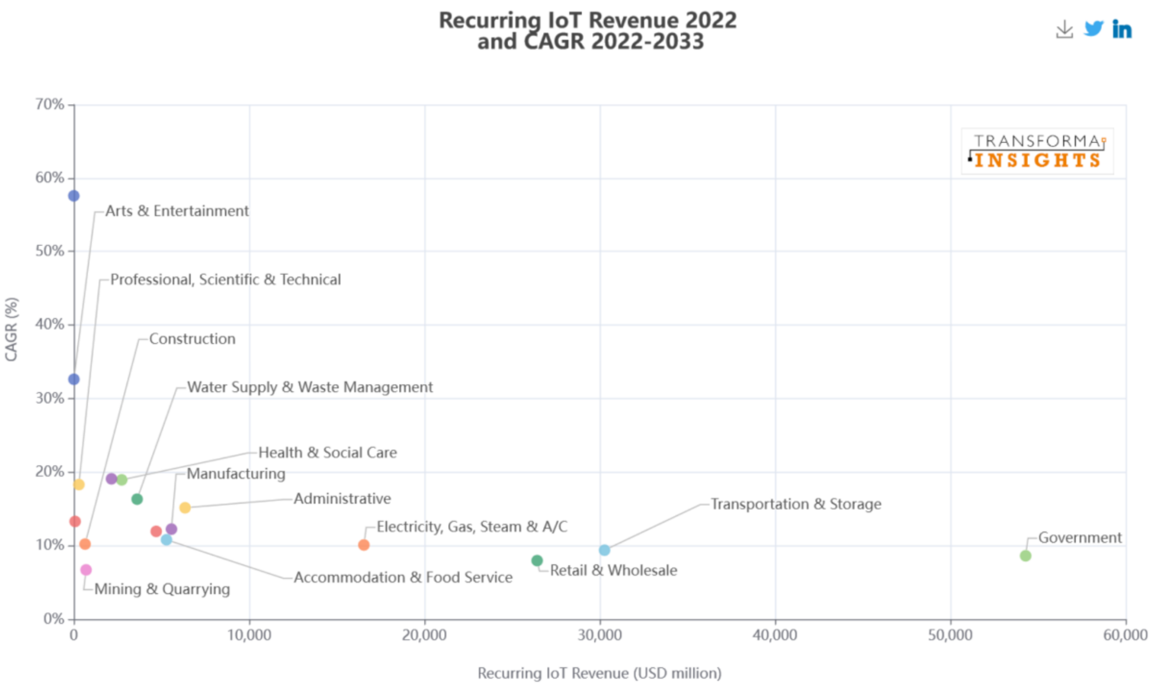

FIGURE 21 - FORECAST OF GLOBAL IOT REVENUE PER USE CASE, BY 2033 [47]

6.3 ADDRESSABLE MARKET:

As could be seen in previous sections, the strong uptake of the satellite IoT connectivity is supported by a solid set of technical and economic drivers. One important driver is naturally the unique proposal of this form of connectivity, able to fully meet ubiquity and complementarity user perspectives. In that regard, all use cases regarding transportation & logistics, energy and utilities, industry, automotive, as well as governmental and military communications, will increasingly need to rely, where and when necessary, on space-based IoT.

This driver is further consolidated by the enablers and cost reduction perspectives offered by the environment of the New Space, applied to cost efficient deployment such as IoT satellite fleets or constellations. For instance, more optimized satellite design, manufacturing, launch and operations processes shall support more cost-efficient satellite services, which is particularly impactful for the context of satellite-based IoT connectivity.

That being said, it is also important to consider the fact that due to lower entry costs for new entrants and the multiplication, in the New Space era, of potential sources of funding, this ecosystem of space-based IoT has seen the development of a large number of small structures, all aiming for profitable commercial openings. However, due to this typology of small competitors, a continued process of market consolidation is to be expected over the next years. This observation should be supported by the recent observations regarding fluctuations in terms of capital investment at certain times. For instance, as can be seen in Figure 22, a steep drop in Venture Capital IoT investment could be observed in 2022. While temporary and specific to some aspects of venture capital (Figure 22 also highlighting that early-stage ventures were unaffected by this downwards trend observed in 2022), this type of investment fluctuation can be a strong driver for financial defaulting, bankruptcies, or simply market consolidations. While targeted to the general sector of IoT, terrestrial and satellite alike, this

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figure can be further confirmed by Figure 23, which focuses on the number of yearly deals and amount invested in the space technological sector.

As a result, the space-based IoT market is likely to further expand with the emergence of stronger, consolidated actors at the centre of a larger system of smaller entrants, in a continued competitive landscape that should continue to drive satellite IoT pricings down. This later pricing decrease represents a critical enabler for this type of connectivity to secure a solid market share alongside terrestrial IoT connectivity.

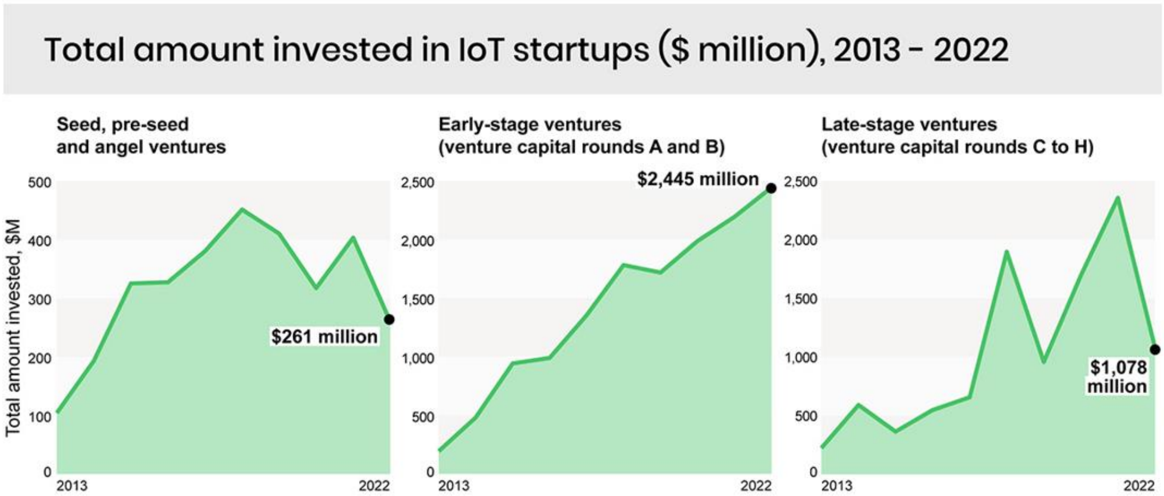

FIGURE 22 - TOTAL YEARLY AMOUNT INVESTED IN IOT STARTUPS (IN US$M) OVER 2013-2022 [51]

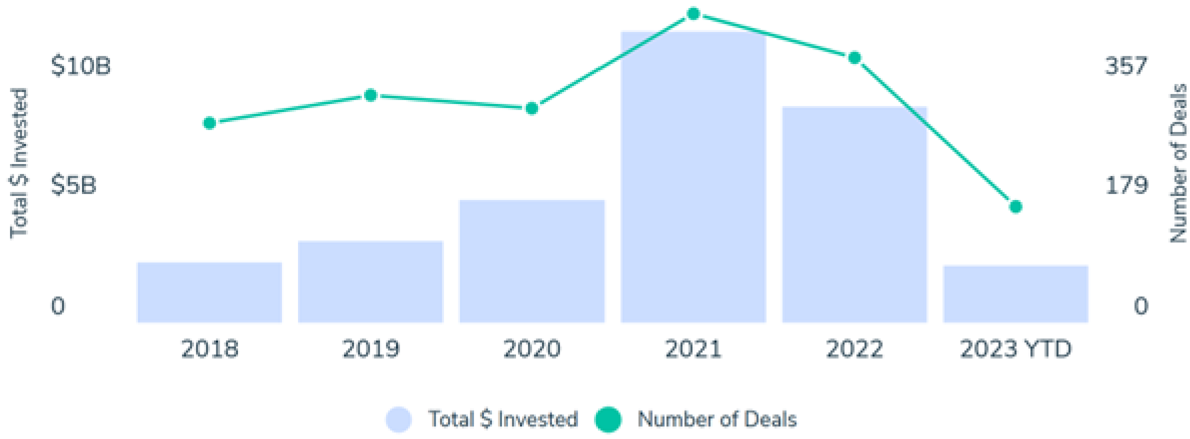

FIGURE 23 - VENTURE FUNDING IN THE CATEGORIES OF SPACE TRAVEL, SATELLITE COMMUNICATION AND AEROSPACE OVER 2018-2023 [52]

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7 DRONE MARKET ANALYSIS

Important remark: In this section, we do not consider 6G aerial base stations, as they are part of the targeted 3D non-terrestrial system. We only discuss aerial UEs, i.e. drones that consume network resources, used for civilian operations. In D2.2 [2], we have distinguished Light and Heavy drones. Light drones correspond to widespread all-purposed drones, such as multi-rotors aircrafts embedding cameras (e.g. for infrastructure monitoring) with more limited battery and operating over bounded areas. Heavy drones relate to drones larger than 3m, which are often more specialized and dedicated to long-range operations, e.g. flying wings.

7.1 MARKET DESCRIPTION AND SEGMENTATION

There is no longer any need to demonstrate the added value of drones, or UAV (Uncrewed Aerial Vehicles), for 5G verticals and industries. They have emerged as flexible and cost-effective tools to collect large amount of data, transport goods or people, and perform tasks which may be unsafe or costly for humans. But there is also no longer a need to demonstrate the added value of UAVs for network operators, despite the business uncertainties that remain in this very new and still immature ecosystem. Although not all operators may want to distribute drone hardware or operate them by themselves, the provisioning of communication services and enriched data services (including alternatives to GNSS, ID&Tracking, etc.) may become a non-negligible source of revenues.

While leisure drones have launched the market, followed by the media & entertainment sector (for aerial videos and pictures), drones have rapidly attracted the interest of other industries, in particular those operating over vast territories or in hazardous environments, such as the energy grid or oil & gas sectors. Figure 24 presents a general view on the revenue opportunity segmentation per vertical, taken from a GSMA Intelligence survey [55], [66].

One of the most important facts about the UAV market is that it is no more considered as a hype and has now reached a sufficient level of confidence and stability by industries [55]. Yet, this market remains a highly complex one when it comes to evaluate potential revenues. As highlighted in [56], a significant fall in the drone market growth estimates has been observed since the highly optimistic post-COVID expectations of 2022 (with an averaged CAGR estimation decreasing from 24% to 17,8%). Furthermore, the different forecasts for the next years show a wide variation in market values (ranging from 3,99$b to 54$b), with a CAGR between 3,24% and 50%, depending on studies [56]. Yet, overall growth is still there, and these uneven figures potentially reflect the better understanding of actual UAV capabilities and remaining challenges or limitations.

The drone market is still significantly driven by national airspace regulators and their progress in defining, testing and deploying the UTM / U-Space services, towards BVLoS (Beyond Visual Line of Sight) or other types of complex drone operations, largely awaited by industrials. In Europe, some countries are now way ahead, e.g. Belgium (with a first operational drone grid for emergency services, deployed by the telco operator CityMesh [57], and several other pilot projects in harbors, cities and airports), while some other countries are still struggling to translate international and European recommendations into their national regulations, regarding both airspace services [58] and cellular spectrum utilization for aerial vehicles [59]. A comparison of the overall drone “readiness index” in different European countries is presented in Figure 25, taken from a GSMA Intelligence study prepared for British Telecom [60]. This index, constructed by the GSMA for the purpose of the study, accounts for the regulatory status of the country, its economic strength, telecoms sector readiness and enterprise demand (i.e. drone end-users). We refer the interested reader to [60] for further details on how this metric is computed.

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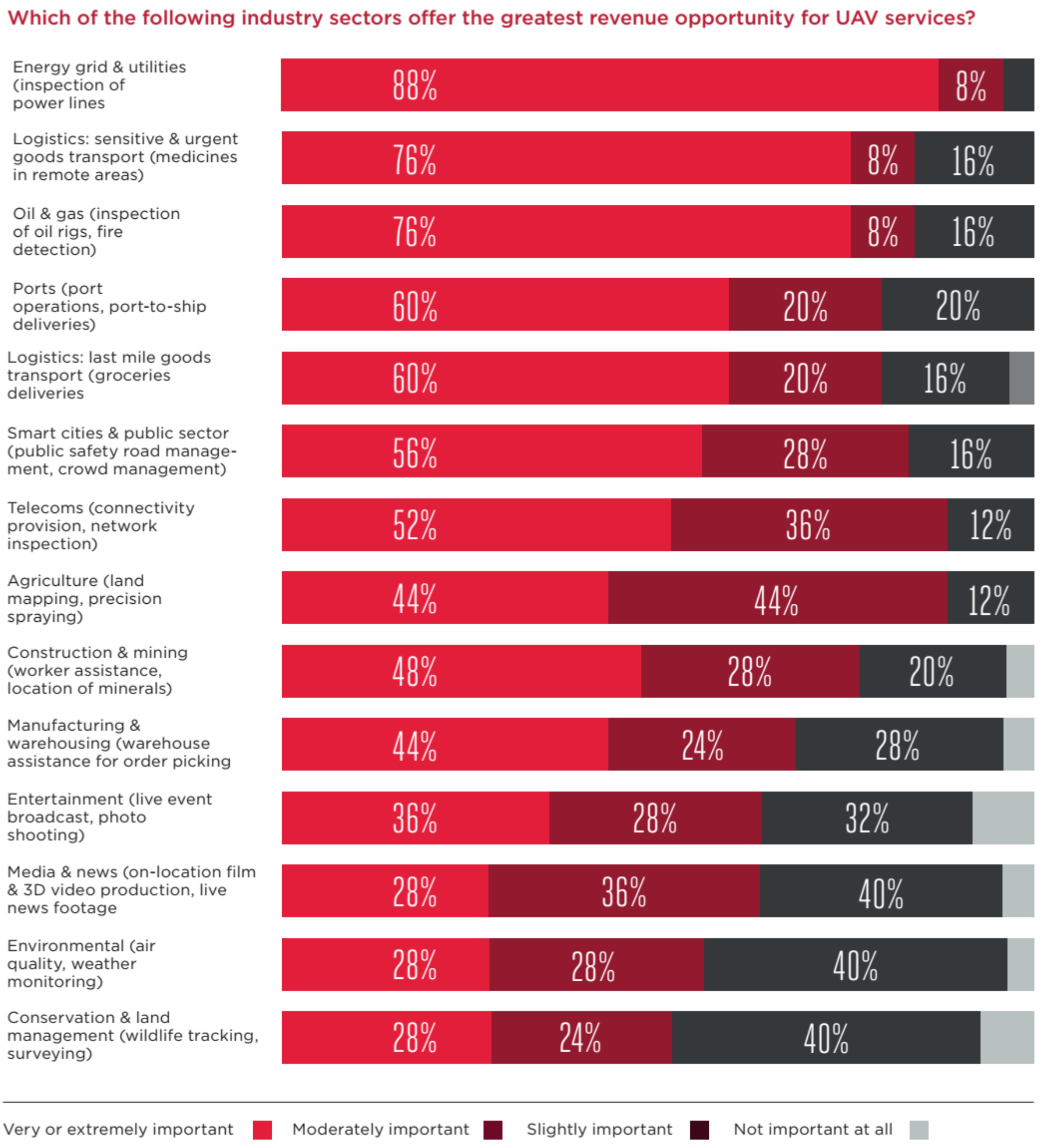

FIGURE 24 - GSMA INTELLIGENCE SURVEY RESULTS OF REVENUE OPPORTUNITIES FOR UAV SERVICES [66]

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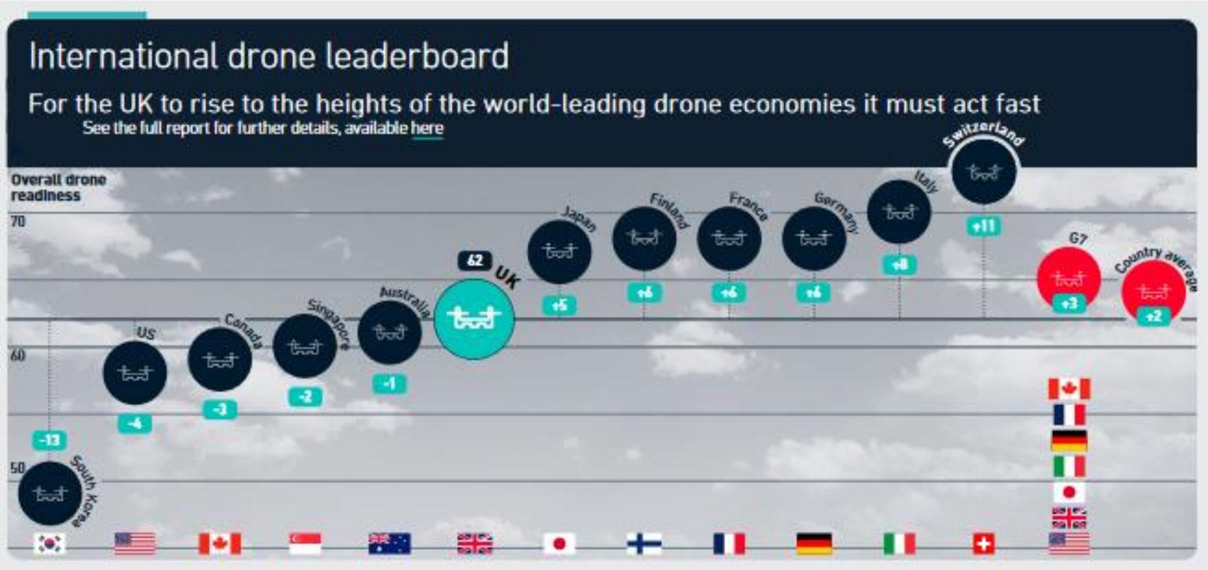

FIGURE 25 - A COMPARISON OF THE OVERALL DRONE READINESS IN DIFFERENT EUROPEAN COUNTRIES [60].

This index has been computed based on GSMA's own formula. Although arguable, this index allows a ranking of the different countries wrt the drone ecosystem.

Today, drone services are commonly based on short-range license-free transmissions, with a pilot in close vicinity. This mode of operation significantly limits the opportunities, and cellular connectivity is clearly perceived as pivotal to unlock the full potential of drones. Thus, aside airspace regulators, MNOs are considered as major drivers for this market. Some of them are already gearing up their networks to prepare drone-related data traffic. In terms of market, the connectivity ARPC (average revenue per customer) for cellular drones has been estimated to 5.4$ per month in 2030, almost 10 times higher than for a typical IoT device [61]. Even if potentially a bit overestimated, opportunities are numerous, as discussed in section 7.2, with the description of role models and value chains.

Now coming back to the context of the 6G-NTN project, satellite connectivity is today mainly used for large military drones, with a high level of autonomy. Although first antenna designs are emerging, especially for drone tracking, it is not yet widely considered for civil ones, due to several drawbacks:

- Satellite-enabled terminals able to offer high uplink throughput are generally too large and heavy for smaller UAVs, which can be limited to carrying only a few additional hundreds of grams (not accounting for nominal payload). Terminals of larger form factor can be however considered for cargo drones (able to carry some tens or hundreds of kilograms) or flying taxis.
- The terminals are also not designed to support the drone velocity and motion (e.g. beam tracking issues),
- As today's terrestrial and satellite networks are not integrated, service continuity, which is critical for remote piloting, shall be entirely managed by the drone itself, e.g. the drone should be provided with two always-on radio devices and with data processing capabilities to sense both radio channels, detect link losses and decide if data flows must be switched from one network to another one.

However, it is expected that the growth of the drone market, together with the technological progress, will accelerate the demand for satellite connectivity. Indeed, it can offer coverage where there is no TN, in the horizontal plane (i.e. "white zones") but also in the vertical plane (i.e. at high altitudes). This second aspect is particularly critical as future use cases shall operate in the so-called "non-segregated airspace", i.e. from ground level to airplane cruising

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altitude, mixing unmanned drones and manned aircrafts. That's also why airspace regulation is already willing to remain techno-agnostic and applicable to any type of connectivity. Integrated TN / NTN shall then become a key market-driver for drones.

7.2 ROLE MODEL & VALUE CHAINS:

7.2.1 Current or near term (y2020-2025) analysis:

As highlighted in WP2's deliverables ([1], [2] and [3] D2.1, D2.2 and D2.3), drone services can be roughly decomposed into three categories:

- **Drone operation services** related to the drone conception, selling and operations (e.g. aircraft & payload manufacturing & distribution, packaging of end-user services),
- **Payload data services** related to the mission of the drone. This data is collected by payload devices, on board the drone (e.g. videos for power line inspection),
- And **Non-Payload data services** related to drone traffic management and safe integration into the national airspace (e.g. identification & tracking, C2 - command & control, online flight authorization platform).

Corresponding role models are illustrated in Figure 26. Although simplified, this view allows a good understanding of the current drone ecosystem around connectivity and its potential evolution regarding TN / NTN integration. More complete role descriptions can be found in [55], [62].

In this deliverable, we have chosen to distinguish the two following roles:

- The **Vertical-specific drone management service provider**, which provides a platform to operate fleets of drones tailored to the considered use case. Indeed, delivery drones and inspection drones should obviously not be managed equally.
- The **USSP, for U-Space Service Provider**, which provides UAV Traffic Management (UTM in North America or U-Space in Europe) services, as regulated by airspace authorities, to support the safe integration of unmanned aircrafts, from different drone operators, into a given airspace volume (flight authorization, situational awareness, tracking, collision detection, etc.). This generally private, but certified, stakeholder can be compared to a digital air traffic controller.

In addition to these roles, the **SDSP (Supplemental Data Service Provider)** provides operational, and generally standardized, data to other stakeholders (including USSP, C2-CSP, drone operator, etc.) that helps mitigate air & ground risks, for example, weather forecast, aerial connectivity quality information, population density monitoring.

Then, with respect to connectivity, we define:

- The **Payload-CSP (Connectivity Service Provider)**, which provides connectivity services for mission-related data. It shall thus fulfil the end-user's requirements. For example, a drone used for power line inspection may require high uplink throughput and low latency, for AI-enabled autonomous anomaly detection. On the contrary, delivery drones only require very limited payload connectivity services, for example sending a digital proof that the parcel has been successfully delivered.

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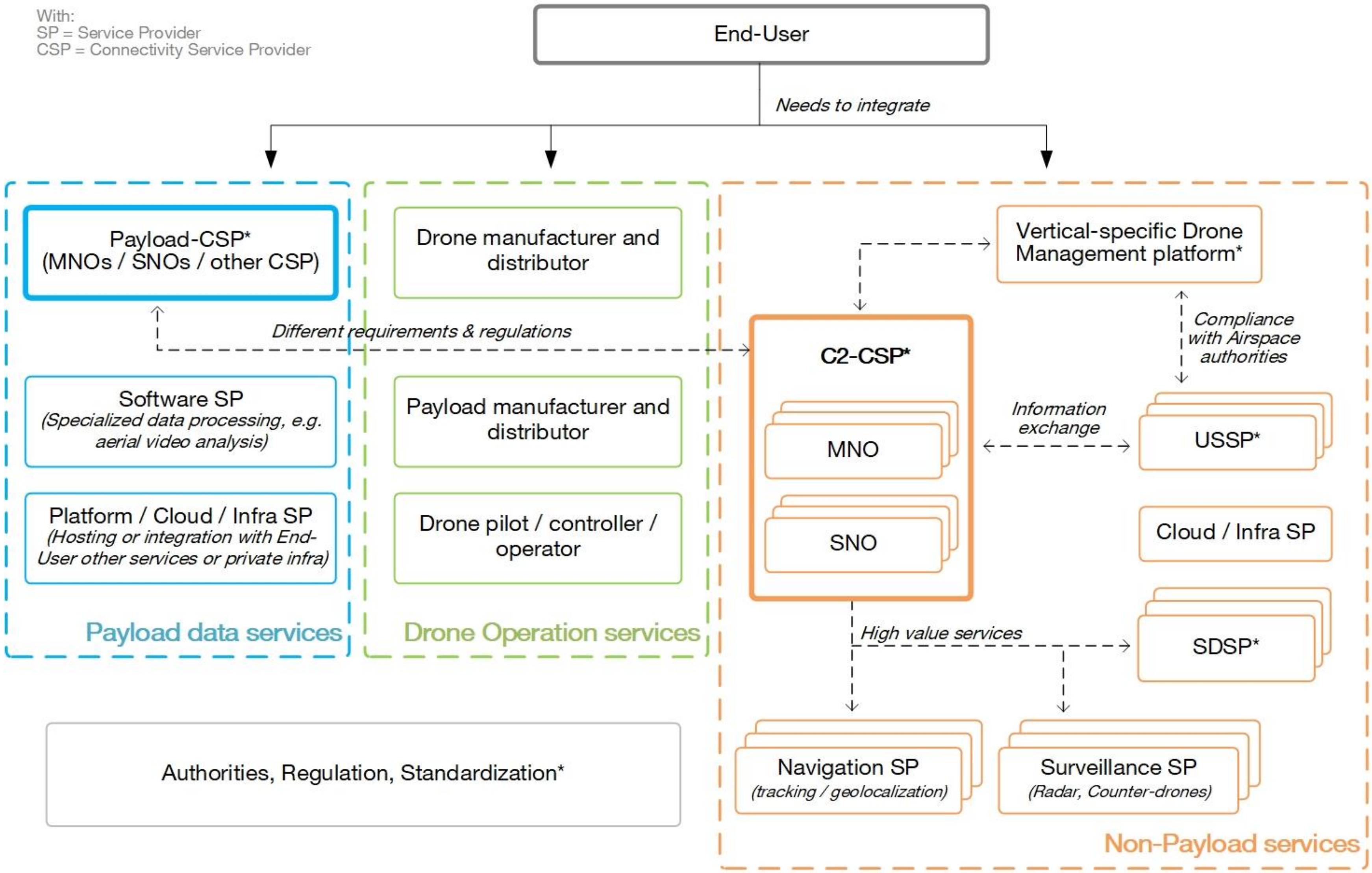

FIGURE 26 - AN OVERVIEW OF THE DRONE ECOSYSTEM (ROLES WITH AN ASTERISK ARE DETAILED IN THE TEXT)

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- The **C2-CSP (Command & Control link Communication Service Provider)**, which provides connectivity services for drone-control data, transmitted between the ground control station (potentially a remote centre) and the UAV. This role (including service level agreement - SLA, means of compliance and liabilities) is still under definition by airspace authorities, with the coordination of telecommunication standardization organizations, such as 3GPP. As for USSP, the stakeholder undertaking this role will probably require a certification.

Note that the SLA to be achieved by a C2-CSP is primarily about network availability, reliability and resilience. As shown in Figure 26, the C2-CSP may thus combine the coverage of several MNOs and SNOs, and sometimes the connectivity of other technologies. Due to size, weight and battery constraints, the embedded communication device would highly benefit from integrated TN / NTN, with uniform waveform and compact antenna design, for both the payload and the non-payload data.

Based on this ecosystem, several value chains can be considered (today or in the near term) to offer value-added drone services for end-customers, for example:

- The **Drone-as-a-Service provider**, where a third party integrates drone operation services and drone traffic management services, as well as the provisioning of the aircraft itself, connectivity modules (today, principally Wi-Fi) and payload equipment. Note that this type of stakeholder is often highly specialized in some missions (e.g. industrial inspection, media & entertainment, etc.) and has largely contributed to the emergence of the drone market, through customized turn-key solutions. Some aircrafts start to be provided with multi-connectivity, but it is so far generally managed by the drone itself (i.e. with two active radios and onboard sensing capabilities, to detect link failure). This remains a high-quality but niche and costly design. Nowadays, such stakeholders are now challenged by new regulation coming into force (regarding both airspace and connectivity / spectrum utilization) and the as yet undefined interactions with USSP.
- The **specialized USSP**, where full drone traffic management services are provided to drone operators (i.e. both U-Space and vertical-specific services). This could be, for example, a certified USSP offering complementary services, specialized in medical delivery. This model can allow a USSP to launch a business and obtain revenues without waiting for the drone market to reach a critical mass across all industries. Nevertheless, this business model is not foreseen to persist in the long term, principally due to the agnostic nature of a USSP as defined by airspace authorities, but it can support a USSP to demonstrate its capabilities.
- The **enhanced CSP**, where an MNO (or more generally, a CSP) partners with a USSP to offer aerial connectivity together with other data & cloud services that allow the drone to fly in full compliance with airspace authorities. This business model also generally includes a drone manufacturer which distributes, through the MNO, aircrafts provided with appropriate connectivity modules and SIM profiles.
- The **enhanced Private Network CSP or Integrator**, which relates to both the “Drone-as-a-Service Provider” and the “enhanced CSP” (but for private networks). It differs from the previous model in that it offers highly customized drone services as an add-on to a more global private network package (including for example, aircraft, fleet management software, payload data processing, cloud infrastructure, etc.), e.g. to build a drone-empowered digital twin for an industrial site. This type of stakeholder generally targets larger industries, with higher revenues, but will probably be challenged by future U-Space regulation, as there is no “private sky” (as opposed to land property).

Note that this list is not exhaustive.

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7.2.2 Evolution trends and drivers towards 6G (y2030-2035):

The characteristics of payload data, related to the mission to be fulfilled by the drone for the end-user, are somehow similar to those of a mobile IoT device, in particular used for video surveillance scenarios: machine-type communication, high throughput for video steaming, low latency for live AI processing, etc. The clearest evolution trend towards 6G is about the offloading of computational capabilities, from aircraft to edge servers, targeting for example drone-enabled digital twins. This allows to simplify and lighten the aircraft, as well as reduce its global manufacturing cost. With this perspective, the 6G Flagship program of the University of Oulu has demonstrated a “Lighter-than-air” drone [63]. One of the major challenges yet to be addressed concerns the drone mobility, potentially over long distances. Another driver lies in the outdoors / indoors service continuity, letting a drone fly under tunnels or move from a warehouse to open skies.

We now focus on non-payload data services, which are specific to the drone ecosystem. A few MNOs are getting closely involved in Drone Traffic Management, for both Vertical-specific and U-Space services, generally through mergers or acquisitions. However, most network operators today still prefer to concentrate on their core business, around connectivity, to provide value-added data services matching the C2-CSP and SDSP roles. Main value-added services have been identified in [55] and are illustrated in Figure 27.

The transition from 4G / 5G to 6G would represent new revenue opportunities, especially with respect to the integration of TN and NTN. Indeed, it represents a key enabler for beyond visual Line-of-Sight drone operations and allows to go much beyond current scenarios which mostly rely on short-range Wi-Fi communication services, between a drone and its pilot located in its close vicinity. Technical enablers have been described in D2.1 [1] and D2.2 [2]. They cover:

- Service ubiquity in 3D, ranging from ground level to manned aircraft cruising altitudes,
- Service continuity in mobility, through seamless and transparent TN / NTN switching,
- Unified network exposure for TN / NTN coverage predictability and monitoring (pre-flight and real-time 3D coverage maps),
- Interoperable services towards trusted identification & tracking, network agnostic data integrity, security and quality of service,
- Broadcast & Multicast communications, for drone notification or alerting service,
- Reduction of the NTN antenna form factor,
- And reliable 3D positioning without GNSS.

Beyond technology, it is expected that regulators (airspace authorities and spectrum agencies) will continue to play a pivotal role, as well as the general population. Indeed, with an ever-increasing number of flying drones, the societal acceptance will become critical. Urban Air Mobility (UAM) is expected to become a reality in 2030, offering safer, faster and cleaner mobility for both goods and people (taxi drones). The EU Aviation Safety Agency (EASA) has conducted a study across Europe to measure the global citizens’ acceptance and future UAM users’ confidence, accounting for safety, noise and environmental impacts, integration into legacy/local transport networks and affordability [64]. This study showed a better support of use cases benefiting the community (e.g. medical transport), over use cases designed for industrial or private needs. Other key market drivers are privacy, security and cybersecurity.

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	NORTH AMERICA		EUROPE				APAC		
	TELUS	VERIZON	SWISSCOM	DEUTSCHE TELEKOM	KPN	TELIA	CMCC	TELSTRA	KDDI
Aerial Connectivity for C2		1 to 3 years	1 to 3 years	Up to 1 year	1 to 3 years	Up to 1 year		3 years +	Up to 1 year
Aerial Connectivity for Payload		Up to 1 year	Up to 1 year	Up to 1 year	Up to 1 year	Up to 1 year		3 years +	Up to 1 year
QoS: Dedicated Vs Shared Resources/Best Effort			3 years +	1 to 3 years	1 to 3 years	1 to 3 years		3 years +	1 to 3 years
Network Remote ID & SIM-Based Identity		3 years +	1 to 3 years	1 to 3 years	1 to 3 years	1 to 3 years			Up to 1 year
Positioning Augmentation		1 to 3 years	3 years +	Up to 1 year	1 to 3 years	1 to 3 years		3 years +	Up to 1 year
Onboard UAV-Based and Edge-Based Computer Vision	Up to 1 year		3 years +	1 to 3 years	3 years +	1 to 3 years	1 to 3 years	1 to 3 years	1 to 3 years
High Resolution Topographical Information Service			1 to 3 years	Up to 1 year	3 years +	1 to 3 years		3 years +	Up to 1 year
Multi-Drone-Orchestration	1 to 3 years		1 to 3 years	1 to 3 years	1 to 3 years	1 to 3 years		3 years +	1 to 3 years
Hyper Localised Weather Services	1 to 3 years		1 to 3 years	1 to 3 years	1 to 3 years	1 to 3 years		3 years +	Up to 1 year
People Density Data			Up to 1 year	Up to 1 year	1 to 3 years	1 to 3 years		3 years +	1 to 3 years
3D Coverage Data			1 to 3 years	Up to 1 year	1 to 3 years	1 to 3 years		3 years +	1 to 3 years
Air Traffic Information Data			Up to 1 year	Up to 1 year	3 years +	1 to 3 years		3 years +	1 to 3 years
Airspace Surveillance	1 to 3 years		Up to 1 year	Up to 1 year	3 years +	1 to 3 years	1 to 3 years	3 years +	Up to 1 year
On-Demand Coverage - Cell on Wings			1 to 3 years	Up to 1 year	3 years +	3 years +		3 years +	3 years +
Logistics/Delivery Services			1 to 3 years	Up to 1 year	3 years +	3 years +		1 to 3 years	Up to 1 year
Automated Infrastructure Inspection and Critical Assets Monitoring			Up to 1 year	Up to 1 year	3 years +	3 years +	Up to 1 year	3 years +	Up to 1 year
Flight Management Systems			Up to 1 year	Up to 1 year	3 years +	3 years +		3 years +	Up to 1 year
U-Space Services Provider/UTM Services Supplier	3 years +		Up to 1 year	Up to 1 year	3 years +	3 years +	3 years +		1 to 3 years

KEY Up to 1 year (red) 1 to 3 years (grey) 3 years + (dark)

FIGURE 27 - VALUE-ADDED SERVICES THAT COULD BE OFFERED BY NETWORK OPERATORS [55]

7.2.3 6G role models by y2030-2040

The role model organization presented in Section 7.2.1 is still under construction and no major change is foreseen so far, although the role of C2-CSP is expected to largely benefit from seamless and transparent integration of TN / NTN services. Indeed, despite the willingness of airspace authorities to define techno-agnostic rulemaking, drone connectivity services could initially suffer from the performance gap that may exist between each layer of the TN / NTN system, and from the misalignment of KPIs or measurement methods, used to define and assess SLA. That's why, within the 6G TN / NTN framework, the business model of the "enhanced CSP", described earlier, is expected to play a pivotal role to offer adequate network services, that include native network resilience, seamless switching between the different radio accesses, as well as enhanced U-Space data services.

From another perspective, the current move to standardize telco APIs (in particular, through the CAMARA project and the GSMA Open Gateway initiative) may give in the future a new boost to the "Drone-as-a-Service provider" model, especially if this long-term trend reaches NTN. By letting developers have access to network APIs, new TN / NTN services can be easily built to fully address airspace authorities concerns, leveraging features like QoS on demand, low-latency connections, monitoring of population density, geofencing & geolocalization, or

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edge compute discovery. In this case, these standardized APIs would help both MNOs and SNOs monetize their assets for drones.

It must be also highlighted that drone service requirements show similarities with other verticals, which could lead to some convergence of role models in the long-term. In particular, the drone and the automotive sectors share a common basis of services about safety and security, involving identification and tracking, geo-localization and tracking, collision avoidance, coverage prediction and monitoring, etc. This is all the more true in the case of flying taxis for smart mobility. As stated in [65], “A drone is a robot, is a smart car, any type of vehicle that is mobile, operating in a dynamic situation, with complex situation.” It is thus more than likely that lessons learned from one ecosystem can help the other evolve, about technical enablers, business viability but also consolidated regulation.

Next, another type of convergence of ecosystems could be observed with the manned aviation sector. Today, the physical separation of two airspaces, one for uncrewed aircrafts (i.e. drones) and one for crewed aircrafts (i.e. planes), simplifies air traffic management. Tomorrow, the EASA is targeting a unified rulemaking for a continuous airspace, where drones could fly at plane cruising altitude. This could lead to a convergence of the roles between these two ecosystems. Given that manned aviation is still controlled by human controllers, we could say that the 6G TN / NTN role models that will gain maturity with drones will serve as a basis towards the digitalization of the whole airspace and will reshape this ecosystem as well.

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8 SYNTHESIS & CONCLUSION

The advent of 6G Non-Terrestrial Networks (NTN) will mark a transformative shift in telecommunications, integrating satellite and terrestrial systems to deliver fully seamless, global connectivity. This document presents a comprehensive analysis of the 6G NTN market, highlighting its unprecedented potential to address connectivity gaps, enhance user experiences, and enable innovative use cases across multiple sectors.

One of the key differentiators of 6G NTN is its ability to provide enhanced performance metrics over its predecessor, 5G NTN. These include faster data rates, reduced latency, improved location accuracy, and greater reliability. Furthermore, 6G NTN will incorporate advanced capabilities such as sensing, AI-driven network adaptability, and sustainability measures, setting new benchmarks in connectivity and operational efficiency.

The market segmentation reveals promising opportunities in consumer, enterprise, and vertical sectors. The consumer market benefits from ubiquitous access to communication and location services, particularly in underserved areas. Meanwhile, the enterprise sector, encompassing industries like logistics, mining, and energy, stands to gain significantly from enhanced connectivity. Vertical markets such as automotive, public safety, utilities, and transportation are poised to leverage 6G NTN for critical applications, including autonomous vehicle operation, disaster relief, and infrastructure monitoring.

The ecosystem surrounding 6G NTN is characterized by complex role models and collaborative frameworks. Service providers, network operators, and hardware suppliers must work together to ensure the seamless integration of terrestrial and non-terrestrial components. Unified terminals and interoperable systems will be pivotal in achieving this integration, allowing users to transition between network types effortlessly.

The adoption of 6G NTN depends on addressing key challenges, including regulatory hurdles, cost efficiency, and technological innovation. Policymakers and industry stakeholders must collaborate to establish frameworks that foster innovation while ensuring economic viability. Investment in R&D is essential to overcome technical barriers.

Looking ahead, 6G NTN holds immense potential to redefine connectivity paradigms. Its applications, ranging from immersive communication to autonomous systems and disaster recovery, promise to revolutionize industries and improve quality of life globally. By 2035, the market for satellite D2D services alone is projected to generate over $30 billion annually, underscoring the economic significance of this technology.

In conclusion, 6G NTN is an evolution of existing networks that brings a revolutionary approach to achieving a fully connected world. Its ability to bridge connectivity gaps, enhance resilience, and support advanced applications underscores its transformative impact on the telecommunications landscape. Success will depend on the collective efforts of stakeholders to align technology, economics, and policy, ensuring a future where connectivity is truly ubiquitous, and sustainable from an economic, an environmental and a social perspective.

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