

# *INTUITION*

The Path to a Unified  
5G Ecosystem with  
5G NTN

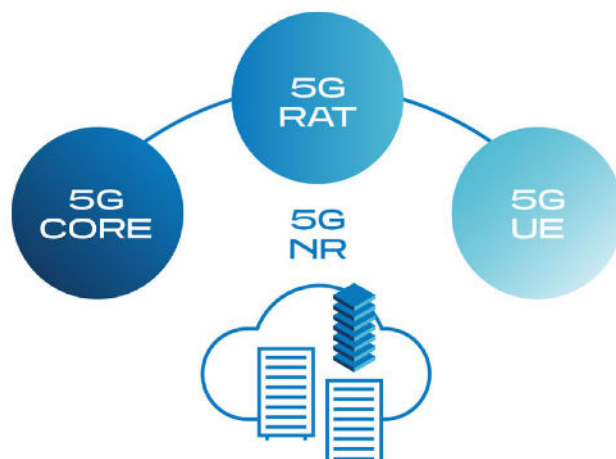
5G Non-Terrestrial Networks (NTN) represent a revolutionary step forward in global telecommunications, unlocking the ability to deliver seamless, high-performance connectivity worldwide. By bridging terrestrial and satellite networks, 5G NTN establishes a unified communication layer that extends the reach of 5G beyond conventional infrastructures. This transformation goes beyond merely expanding coverage; it redefines connectivity to support global mobility, strengthen national resilience, and drive innovation across industries and communities that have faced technological limitations. Anchored by 3GPP standards, 5G NTN integrates satellite reach with terrestrial systems, creating a scalable and standardized foundation for ubiquitous connectivity, unlocking exceptional opportunities for satellite operators and telcos.

Cloud-native, multi-orbit Satellite Ground Systems are positioned to incorporate 5G NTN and 5G New Radio (NR) enabling 5G user terminals (UE) to move between terrestrial and multi-orbit satellite networks across different Radio Access Technologies (RAT) and waveforms incl. 5G NR and DVB-S2X. Those ground systems that will enable 5G NTN, while also maximizing the value of the satellite operators' current network investments will lead the way in unifying ecosystem collaboration and set the path to 6G NTN.

This whitepaper explores the benefits of 5G NTN within satcom architectures, focusing on 5G Core, 5G RAT, 5G NR, and hybrid 5G UEs, while showcasing iDirect's strategic approach to enabling 5G NTN and unifying diverse networks through multi-waveform/ multi-radio access enabling hybrid roaming. It examines advancements in 3GPP standards, highlights iDirect's role and developments, and outlines the significant benefits and market growth opportunities for satellite operators and telcos - from addressing underserved markets and supporting emerging enterprise applications to enhancing critical communication systems.

## UNLOCKING THE FULL POTENTIAL OF 5G NTN

With the growing demand for more dependable, scalable, and widespread connectivity in the 5G era, the Third Generation Partnership Program (3GPP) introduced NTN into its 5G framework through 3GPP Release 17 and subsequent Release 18. The 5G NTN standards enable the adaptation of technologies such as **5G Core**, **5G RAT**, **5G NR**, and **5G UE** to satellite networks, all underpinned by the flexibility and scalability of a **cloud-native ground system** architecture. Together, these elements form the foundation for seamless connectivity, advanced services, and new business opportunities across satellite and terrestrial networks.



## 5G Core in a Satcom Architecture

The 5G Core serves as the central intelligence of 5G networks, managing critical functions like connectivity, mobility, authentication, and data handling. Built on cloud-native architecture, it enables dynamic **scalability** along with rapid service setup and orchestration.

The 5G Core **centralizes the management of networks**, significantly simplifying operations such as the challenges of fragmented protocols while reducing the complexity of overseeing disparate systems. Furthermore, advanced capabilities such as network **slicing** allow operators to deploy dedicated virtual networks for **tailored QoS services** optimized for specific applications like IoT, enterprise broadband, or mission-critical public safety systems.

From an operational perspective, the 5G Core unlocks significant **cost efficiencies**. Shared resources across integrated networks reduce the need for redundant infrastructure, while dynamic resource allocation optimizes network performance and scales services according to demand. Additionally, the 5G Core's adherence to global 3GPP standards ensures interoperability, scalability, and future innovations, allowing operators to confidently align their operations with industry advancements and taking advantage of cost optimization through a mature and well-established supply chain.

**Security** remains another key advantage of the 5G Core. By implementing mutual authentication protocols, zero-trust architectures, and robust encryption measures, the 5G Core strengthens the network against evolving cybersecurity threats, making it an ideal solution for applications in defense, healthcare, and other sensitive industries.

Built-in **Quality of Service (QoS)** mechanisms of the 5G Core ensure reliable, low-latency performance for critical systems such as real-time analytics and emergency communications.

5G Core also plays a pivotal role for **seamless operations in inter-provider roaming**: The 5G Core's centralized user management enhances operational simplicity by consolidating user data and profiles into a unified system, enabling seamless service delivery. Consolidated billing further streamlines operations, providing integrated, transparent invoicing for users across varied services. Unified policy management ensures consistent application of service rules and quality standards, enhancing user experience and network reliability.

## 5G RAT in a Satcom Architecture

Radio Access Technology (RAT) serves as the comprehensive framework for **managing radio access** in 5G NTN satcom architectures, encompassing both high-level controls and the air interface, 5G NR, which handles signal transmission and reception. The 5G RAT facilitates critical functions like signal modulation, demodulation, and error correction while integrating GNSS for **precise synchronization** between satellites and terrestrial networks, essential for maintaining robust, low-latency communication. A key component of RAT is the gNodeB, the base station that implements the functionality of 5G NR, acting as the intermediary between user equipment and the 5G Core. Through dynamic spectrum allocation and adaptive power control, RAT optimizes bandwidth and power efficiency over multi-orbit constellations. Its support for network slicing and QoS enforcement is further enhanced by the 5G Core's centralized management, which streamlines the deployment of virtualized network partitions tailored to applications such as IoT, enterprise broadband, and public safety. Additionally, RAT's integration with the 5G Core enables **advanced handover mechanisms**, ensuring uninterrupted connectivity and robust performance for diverse global use cases, reinforcing the scalability and reliability of the entire ecosystem.

## 5G NR in a Satcom Architecture

5G NR, as the air interface of the broader 5G RAT framework, enables operators to adopt multi-vendor ecosystems by adhering to standardized radio waveforms and protocols. This **standardization** reduces vendor lock-in, allowing greater flexibility in deployment options. For users, 5G NR provides a seamless and consistent connectivity experience across networks, while integration with the 5G Core ensures a unified framework for applications, security, and billing.

When operating within the 5G RAT, 5G NR powers **advanced capabilities** such as network slicing, enabling the creation of dedicated, virtualized network partitions optimized for specific use cases like eMBB, IoT, enterprise systems, or public safety. The 5G RAT framework extends these capabilities by managing resource allocation and integrating QoS mechanisms, ensuring reliable, latency-sensitive performance for critical applications.

The **scalability** and **flexibility** of 5G NR make it suitable for deployment across diverse non-terrestrial environments,

including LEO, MEO, GEO, and HEO satellite constellations, as well as transparent and regenerative satellites. Its foundation within the evolving 3GPP standards ensures the 5G RAT remains a future-proof solution, adaptable to emerging technological demands and capable of supporting complex, high-performance global networks.

### 5G UE in a Satcom Architecture

Complementing the infrastructural strengths of 5G NR is the evolution of 5G UE. These user devices will be designed for integrating seamlessly with terrestrial and satellite systems while maintaining compliance with globally recognized 3GPP standards. This multi-network compatibility minimizes the need for specialized purpose-built devices, leveraging the 5G chipset availability in the ecosystem. Affordability will drive 5G UEs' widespread adoption. Standardized hardware designs will be able to **leverage economies of scale**, significantly lowering costs for both manufacturers and users. In industries such as aviation, logistics, and automotive, interoperability and widespread availability of chipsets and devices will enable uninterrupted service across complex, multi-network environments become a reality.

**Security** features embedded in 5G UE elevate its applicability across sectors where data protection is a critical priority. Its encryption-based architecture ensures that sensitive information remains secure even across complex hybrid networks. The user experience is further refined by the capabilities of 5G UE, ensuring uninterrupted and consistent connectivity across **hybrid networks**. Devices using 5G UE will be able to seamlessly switch between GEO, NGSO satellite and terrestrial systems, maintaining high levels of operational reliability particularly interesting for services, where connectivity resilience impacts everything from supply chain monitoring to mobility all the way to autonomous vehicle operations.

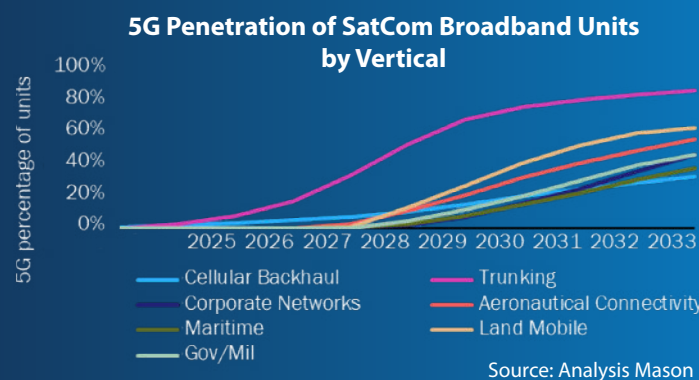
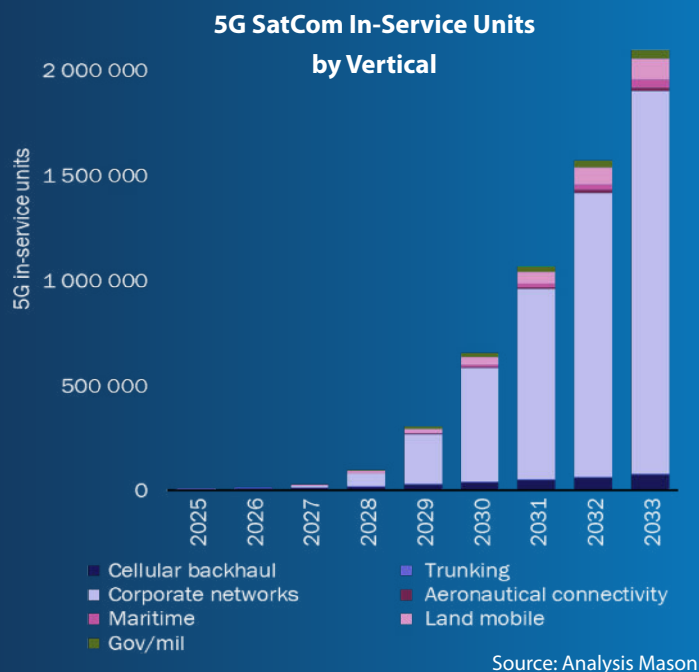
Together, 5G Core, 5G RAT, 5G NR and 5G UE form the backbone of a dynamic and highly interoperable telecommunications ecosystem. While 5G Core, 5G RAT and 5G NR set the stage for unified, efficient, and scalable network operations, 5G UE ensures that end devices can fully leverage the infrastructure's advances. By integrating these capabilities into overarching 5G NTN frameworks, operators can deliver reliable, efficient, and forward-looking solutions to meet the demands of an increasingly connected world.

## 5G NTN MARKET GROWTH OPPORTUNITY

The integration of satellite and terrestrial networks with 5G NTN is projected to generate USD57 billion in capacity and equipment revenue between 2023 and 2033. 5G NTN service revenue is expected to reach USD 30.2 billion by 2032, serving over 2.1 million 5G UEs, excluding direct-to-device (D2D).

### The key 5G NTN markets are:

- **Mobility:** Seamless connectivity for the aero and maritime sectors with a 32% of cumulative market opportunity
- **Enterprise Services:** Extending corporate networks for energy, banking, and social inclusion- representing 80%
- **Rural Broadband:** Closing the digital divide by providing connectivity to rural areas
- **Government and Military Applications:** Enhancing coverage, resiliency, and security



## BENEFITS OF 5G NTN



## RECOMMENDATIONS

Preparing for 5G NTN is a critical step for satellite operators and telcos. [These guidelines](#) can assist in preparation for this transition.

### For **satellite operators**:

- ☒ Choose a flexible ground system built on a cloud-native, multi-orbit foundation that incorporates non-3GPP 5G Interworking Functions, 5G Core, 5G RAT and 5G NR for both transparent and regenerative satellites. This ensures the use of more efficient satellite specific waveforms (S2X/MRC) for 5G Core powered networks until 5G NR's efficiency is fully optimized.
- ☒ Ensure the ground system enables seamless mobility and roaming between non-3GPP/ S2X and 5G NTN/ 5G NR networks to extract maximum value from your existing networks and extend coverage through partnerships.
- ☒ Explore cloud-based deployment models, automation, and AI-driven orchestration to continuously improve network efficiency, scalability, and service offerings managed by a comprehensive NMS allowing to ensure unity of operations across your networks

### For **telcos**:

- ☒ Engage in collaborative discussions with satellite ecosystem partners to develop your hybrid connectivity strategy. Choose a partner that allows 5G NTN adaptation as technologies evolve.
- ☒ Choose a satellite ground system that enables seamless mobility and roaming between non-3GPP and 5G NTN networks delivering 3GPP-compliant QoS and QoE and back-end interoperability.
- ☒ Select satellite partners that adhere to 3GPP, TM Forum, MEF standards and API architectures to ensure simplified integration and reduced deployment costs.
- ☒ Evaluate your go-to-market strategy and service differentiation and choose a partner offering highly flexible go-to-market models that can evolve over time.

## STRATEGIC PATHWAYS TO 5G NTN INTEGRATION WITH INTUITION

To adapt to a 5G NTN architecture, satcom ground systems must be 5G NTN-ready. The foundational layer is a secure, **cloud-native architecture** that forms the backbone for addressing the unique challenges of non-terrestrial networks. A scalable and **unified NMS** is a critical component, ensuring seamless and efficient operation in a 5G NTN environment. The ground system also needs to support a **hybrid approach**, recognizing that 5G NR may initially be less efficient than satellite-specific waveforms until this is addressed in future 3GPP releases. By integrating both waveform types, the ground system can maximize flexibility and interoperability while providing a clear path for transitioning to 5G NR as it matures.

iDirect's cloud-native, multi-orbit ground system, **Intuition**, incorporates all these foundational layers. Intuition is powered by advanced technologies such as virtualization and end-to-end orchestration providing the performance, efficiency, and scalability required to harness the potential of software-defined satellites, high-performance networks, and multi-orbit constellations. Built on industry standards and designed with intelligent bandwidth allocation, Intuition ensures robust performance, superior QoS, and seamless mobility across global markets.

To optimize this robust foundation, iDirect introduces three architectural pillars that underpin seamless 5G NTN integration.



### 1. Non 3GPP access to 5G Core- A step towards 5G NTN

iDirect is integrating its cloud-native, multi-orbit ground system Intuition with the 5G Core via an **Interworking Gateway Function (IGW)**, creating a unified, standards-compliant access architecture that seamlessly connects non-3GPP access satellite systems with next-generation 5G services.

This approach enables seamless interoperability between iDirect's Intuition S2X/MRC Access and 5G applications without requiring significant hardware changes. By streamlining network control, fostering compatibility, and adhering to 3GPP NTN standards, it establishes the first cornerstone for delivering reliable, high-performance connectivity while streamlining operations, maximizing the value of operators' infrastructure, and setting the path to full 5G NTN adoption all while maintaining a focus on performance and reliability.

### 2. Full 3GPP access enabled by 5G infrastructure (RAT)

Intuition will be equipped with advanced Radio Access Technologies (**RAT**), including a satellite-adapted **gNodeB**, as a key enabler for seamless integration of 5G NR NTN capabilities over both transparent and regenerative satellite links. To achieve this, iDirect will optimize gNodeB functionalities, particularly Distributed Unit (DU), Central Unit (CU) and Radio Unit (RU), to perform efficiently within the complexities of satcom networks.

In parallel, hybrid 5G UE modems will support both non-3GPP access networks with S2X waveforms and 5G NTN networks with 5G NR. This ensures maximum operational flexibility, enabling seamless fixed and mobility services across non-3GPP satcom networks, 5G NTN networks and terrestrial networks. For operators it will mean connecting their existing multi-orbit non-3GPP networks to 5G NTN and TN in order to move between terrestrial and multi orbit satellite networks across different waveform technologies.

### 3. Hybrid Roaming

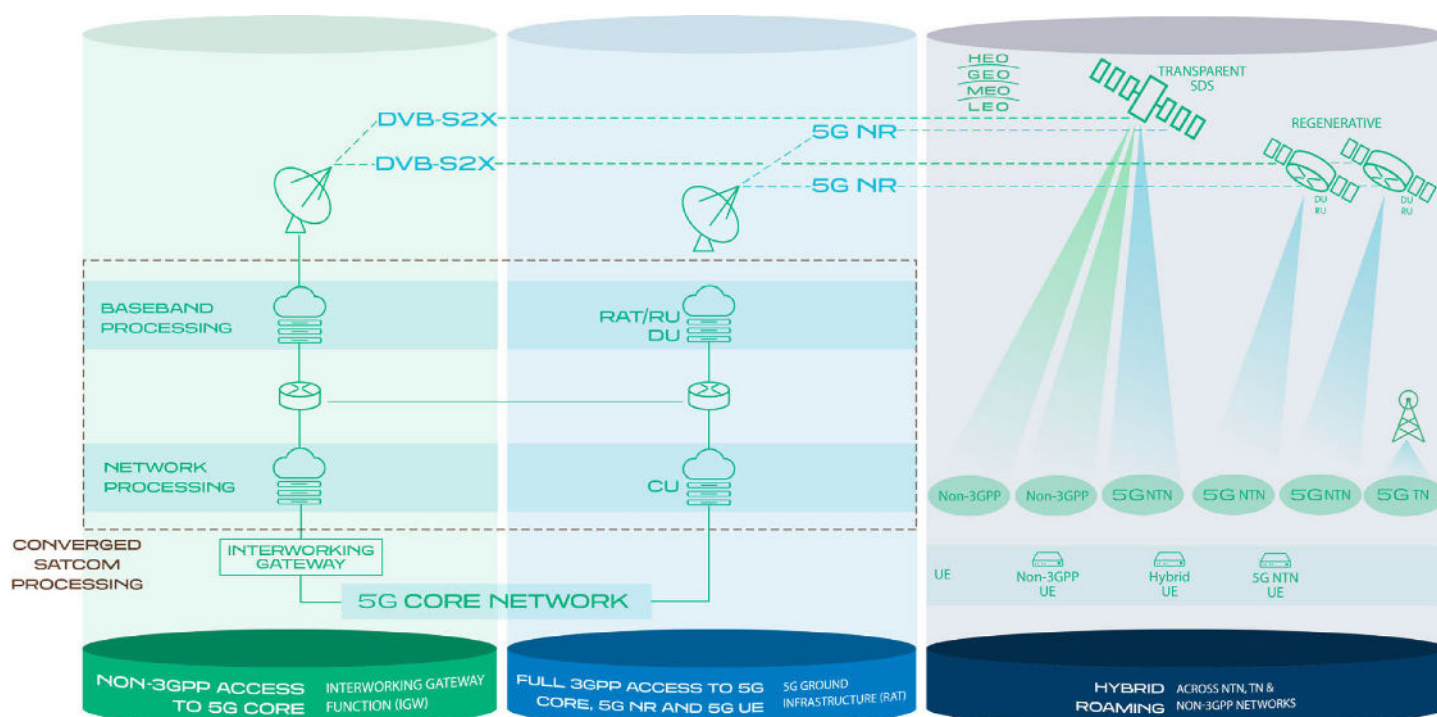
By introducing a 5G NR enabled Hybrid UE, iDirect is providing three roaming options to offer maximum roaming flexibility. These hybrid roaming options ensure uninterrupted transitions for terminals operating across terrestrial and satellite networks, leveraging support for multi-orbit, multi-waveform, and partner ecosystem configurations.

The first option is **inter-provider roaming between two non-3GPP networks** based on S2X enabled by a 5G Core and multi-orbit. The 5G Core acts as a unifying platform, simplifying operations, reducing costs, and ensuring a consistent user experience when roaming between two providers- from a home network to a visiting network. For visiting networks, it means expanded reach into new (or sometimes restricted) regions, even different orbits, unlocking new revenue opportunities while achieving savings with faster-time-to-coverage. Home network providers benefit from selling network capacity, leading to higher fill rates, greater ROI on network buildouts, and additional revenue from further service differentiation. End users enjoy a seamless network-switching experience with consistent applications, security, and billing, ensuring uninterrupted connectivity across networks.

The second option is **roaming between non-3GPP NTN (S2X) networks and 5G NTN (5G NR)** networks for hybrid UEs enabling unmatched global connectivity, increased network resilience and enriched user experience. For operators, it opens new revenue opportunities, lowers infrastructure costs, and ensures scalable, future-ready solutions. For users, it guarantees seamless, secure, and reliable connectivity across diverse environments, making it a cornerstone of the 5G NTN ecosystem. Managing both network types requires a single, complex NMS as it streamlines processes, reduces complexity, and boosts efficiency, ensuring seamless management of hybrid networks.

The third option is to **roam between 5G NTN networks** and seamlessly extending to **5G terrestrial networks (TN)** truly converging into a network of networks.

iDirect's Hybrid Roaming 5G NTN strategy embraces all three options, giving satellite operators and telcos maximum flexibility and interoperability for mobility and roaming.



Strategic Pathways to 5G NTN Integration with Intuition

## Advancing 5G NTN with Innovation and Proven Expertise

iDirect has supported the cellular industry for years by bridging the gap between satellite and wireless technologies, overcoming differences in architecture, standards, and service capabilities.

Its ongoing efforts in development, proof of concepts, and integration testing aim to optimize the interaction between 5G and satellite systems. Through ESA and EU-funded 5G projects such as SaT5G, Satis5, and OSMOSIS, iDirect has demonstrated live satellite integration into 5G networks, enabling advanced capabilities like network slicing, SDN/NFV orchestration, and edge computing. Further proof of concepts is being demonstrated on Intuition ground system, which lays the groundwork for fully integrating 5G NTN capabilities. Through active and sustained participation over the years in the ongoing 3GPP working groups across the multiple Releases, iDirect has played a pivotal role in shaping satellite specifications for 5G NTN. By leveraging its satcom and RF expertise iDirect is recommending adaptations to 5G NR to achieve efficiencies closer to satcom-specific waveforms, including GNSS-based enhancements. iDirect remains committed to driving innovation and optimizing satellite communication technologies for the 5G era.



## BUILDING THE FOUNDATION FOR A UNIFIED 5G ECOSYSTEM

Achieving seamless global connectivity through 5G NTN unlocks exceptional opportunities for operators and telcos. iDirect is uniquely positioned to lead the way, providing a clear, strategic path to 5G NTN/NR adoption while maximizing the value of current network investments. By enabling inter-provider roaming, iDirect empowers operators to deliver seamless global connectivity and enhance user experiences across diverse networks.

With its advanced, cloud-native, multi-orbit, and 5G NTN-ready Intuition ground system, iDirect offers operators flexibility to evolve their networks at their own pace. Whether integrating 5G Core to enhance existing satellite networks or deploying 5G Core and 5G NR together with 5G UEs, iDirect ensures operators can capitalize on innovation while maintaining a focus on performance and reliability. These solutions deliver 3GPP-compliant QoS and QoE, elevating network efficiency and dependability.

iDirect's approach unifies diverse networks, optimizes operations, and maximizes infrastructure value. Hybrid roaming between 3GPP and non-3GPP networks creates seamless global coverage, bolsters network resilience, and unlocks new revenue streams while reducing operational costs. With future scalability built in, operators can confidently address today's complex connectivity challenges and prepare for the demands of tomorrow.

Having demonstrated leadership in 5G through pioneering demonstrations and contributions to 3GPP working groups, iDirect is a trusted partner for operators navigating the 5G NTN landscape. By building scalable, interoperable, and high-performance networks, iDirect is enabling operators and telcos to drive innovation, growth, and a new era of ubiquitous, reliable communication.

# THE EVOLUTION OF 5G NTN

5G has marked a significant leap forward in global telecommunications, not only enhancing terrestrial connectivity but also extending its reach beyond traditional infrastructure through NTN. NTNs encompass satellite and high-altitude platform systems (HAPS), offering connectivity to remote, rural, and underserved regions where terrestrial networks are impractical or economically not viable. The adoption of 3GPP standards in the satellite industry is expected to bring significant advancements in areas such as network architecture, protocols, security, and quality of service (QoS). It will also allow for greater flexibility, scalability, and improved interoperability, making it easier to adapt to changing market demands. The evolution of 5G NTN began with foundational study items introduced in 3GPP **Release 15** focusing on enhanced mobile broadband (eMBB), ultra-reliable low-latency communication (URLLC), and massive machine-type communication (mMTC).

Building on this, **Release 16** introduced initial studies into satellite communications and non-terrestrial networks, signaling the industry's growing ambition to unite terrestrial and satellite connectivity. **Release 17** marked a pivotal moment by formalizing NTN support in the 5G standard enabling satellite systems to work seamlessly alongside terrestrial networks. This release addressed critical challenges unique to satellite, including Doppler shifts and signal propagation delays, and introduced specifications for transparent and regenerative payloads. **Release 18** built on this progress by introducing enhancements such as improved mobility management, refined waveform designs, and detailed exploration of satellite use cases, all aimed at achieving scalability, operational efficiency, and seamless integration. Looking ahead, **Release 19** is set to refine satellite interoperability further, enhancing user experiences while addressing more complex coverage scenarios. It evolves the ecosystem toward fully integrated terrestrial satellite models, introducing regenerative payload capabilities, uplink capacity improvements, non-GNSS positioning, and better integration of simplified 5G devices with satellite networks. **Release 20** continues this evolution by enhancing NTN performance and expanding support for mission-critical services over satellite. It introduces improvements in satellite handover, low-rate voice and messaging over GEO and LEO systems, and deeper integration with public safety and IoT applications. These developments strengthen the foundation for resilient, ubiquitous connectivity and pave the way toward the 6G era.

Working on these standards for many years are key contributors from telcos, chip vendors, equipment vendors, system integrators, satellite operators, satellite manufacturers and satellite ground system providers such as ST Engineering iDirect

