

Qualcomm

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5G from space: The final frontier for global connectivity

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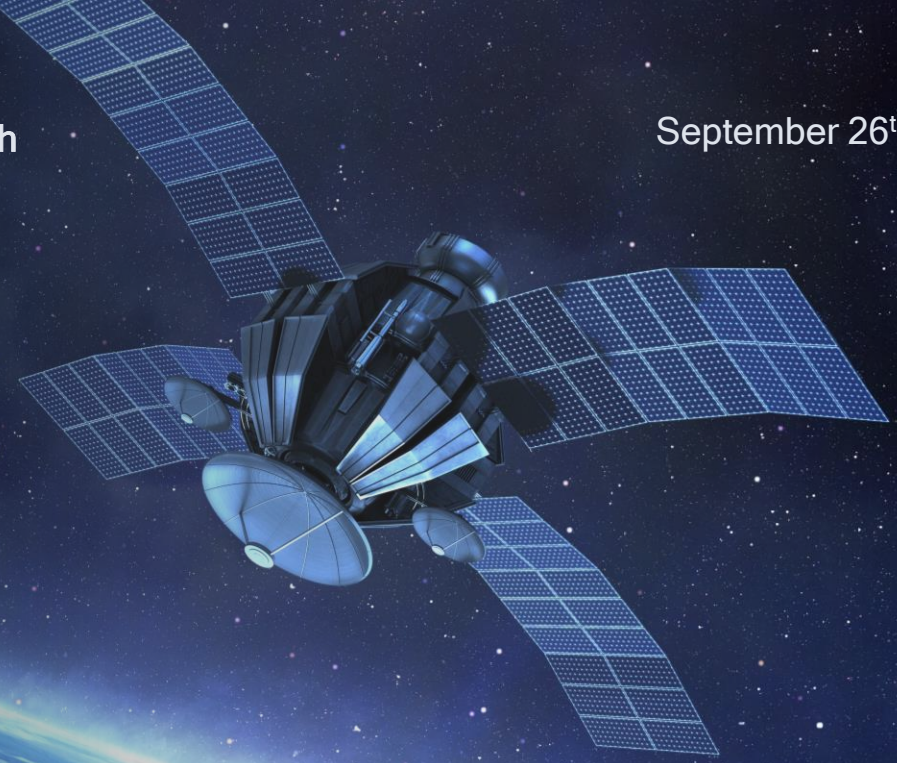
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Today's Agenda

The 3GPP standards roadmap
and ubiquitous connectivity for people and things

Solutions, capabilities, spectrum support, and
use cases for 5G non-terrestrial networking (NTN)

Proving readiness for 5G from space with
leaders in satellite technology and 5G infrastructure

5G IoT-NTN solutions and management platform
from Qualcomm Technologies

Questions?

OUR PRESENTERS



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Mobile has made a leap every ~10 years

Mobile voice communication

Efficient voice to reach billions

Focus shifts to mobile data

Mobile broadband and emerging expansion

A unified connectivity platform

The next innovation platform

1G

2G

3G

4G

5G

6G

1980s

Analog voice

AMPS, NMT,
TACS

1990s

Digital voice

D-AMPS, GSM,
IS-95 (CDMA)

2000s

Wireless Internet

CDMA2000/EV-DO
WCDMA/HSPA+,

2010s

Mobile broadband

LTE, LTE Advanced,
Gigabit LTE

2020s

Connected intelligent edge

5G New Radio

2030s

Next-gen wireless

AI-native, new spectrum, RF
sensing, and many more...

Leading wireless innovation for more than 35 years

Satellite communications



Two-way data

Digitized mobile communications



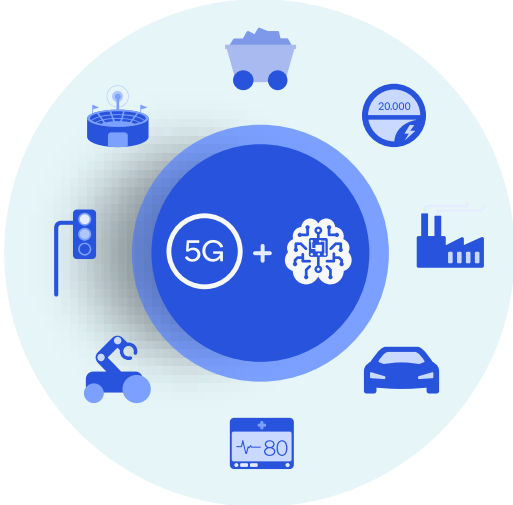
Analog to digital

Redefined computing



Desktop to smartphones

Transforming industries



Connecting virtually everything

A long history of innovation in satellite communication



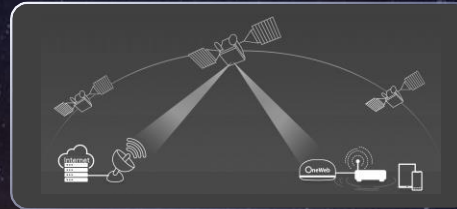
1988 OmniTRACS

Two-way data communication with OmniTRACS and Qualcomm two-satellite positioning for pre-GPS fleet management



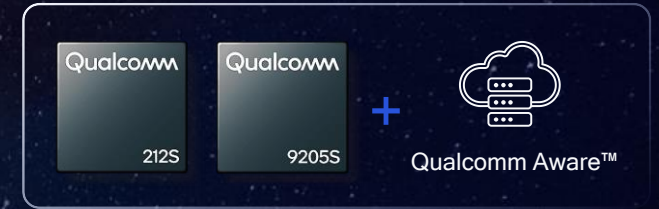
1991 Globalstar

Globalstar joint venture with Loral Space & Communications formed in 1991. First public satellite call in 1998.



2015 OneWeb

Co-developed technologies for the OneWeb satellite constellation, including a new, high-performance wireless air interface, hardware and software reference designs, and end-to-end system analysis and optimization

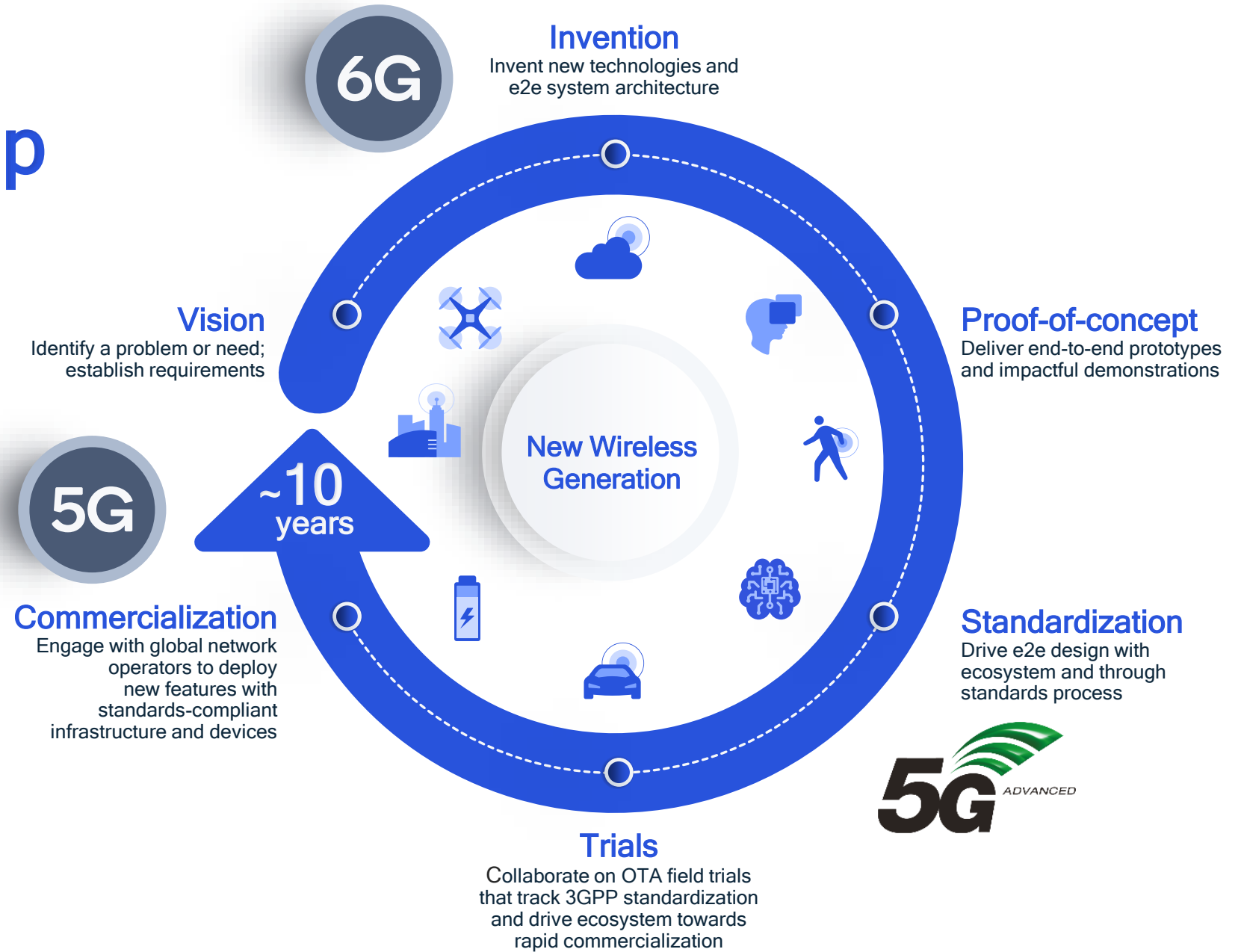


2023 5G IoT-NTN

Launched new 5G IoT-NTN satellite solutions in collaboration with Skylo to provide uninterrupted remote monitoring and asset tracking. Seamlessly integrates with Qualcomm Aware™ Platform for device management and more accurate tracking.

Foundation to “G” leadership is technology leadership

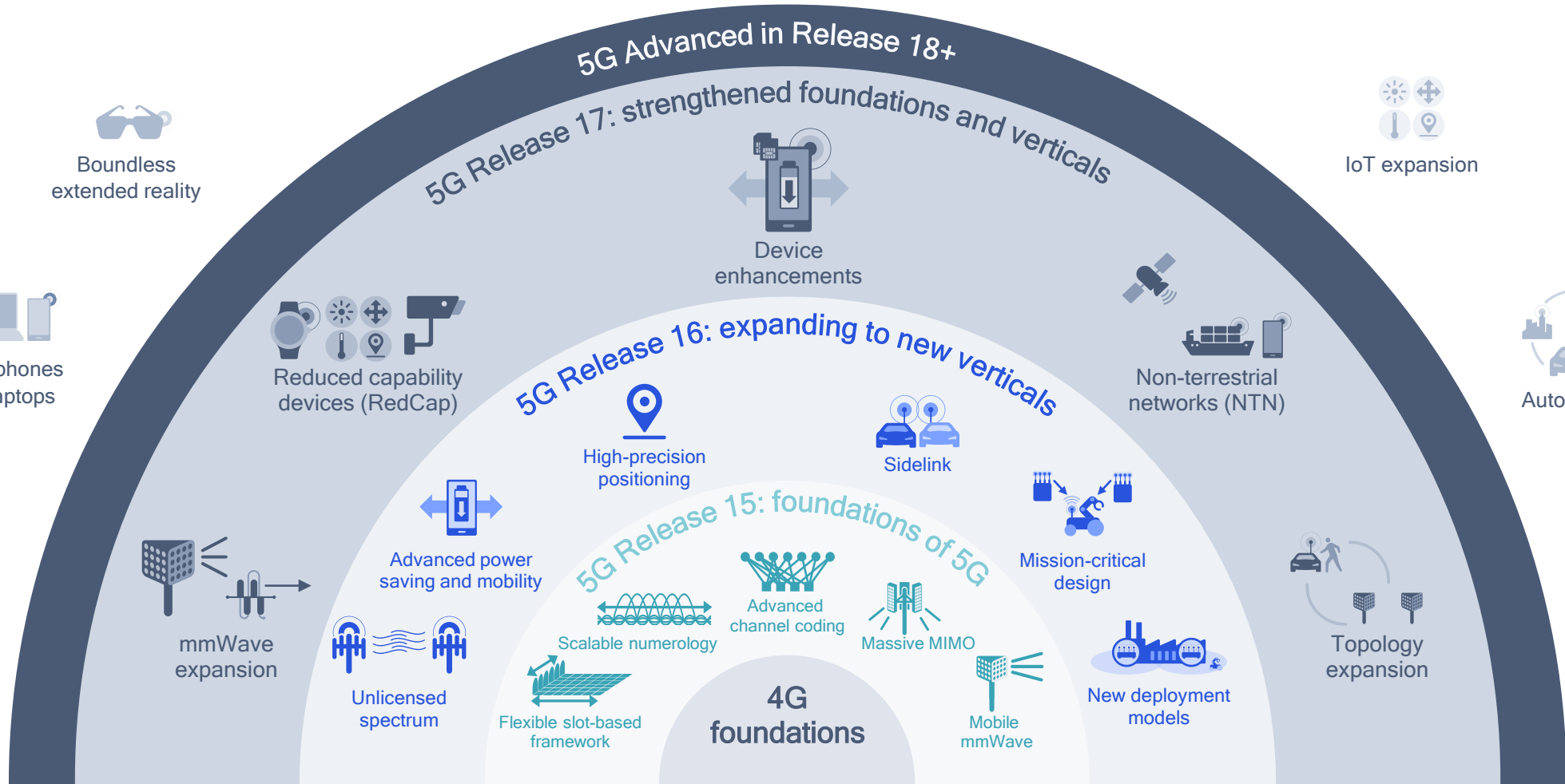
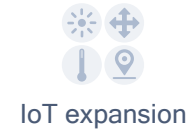
Early R&D and technology inventions essential to leading ecosystem forward



Enhancing mobile broadband



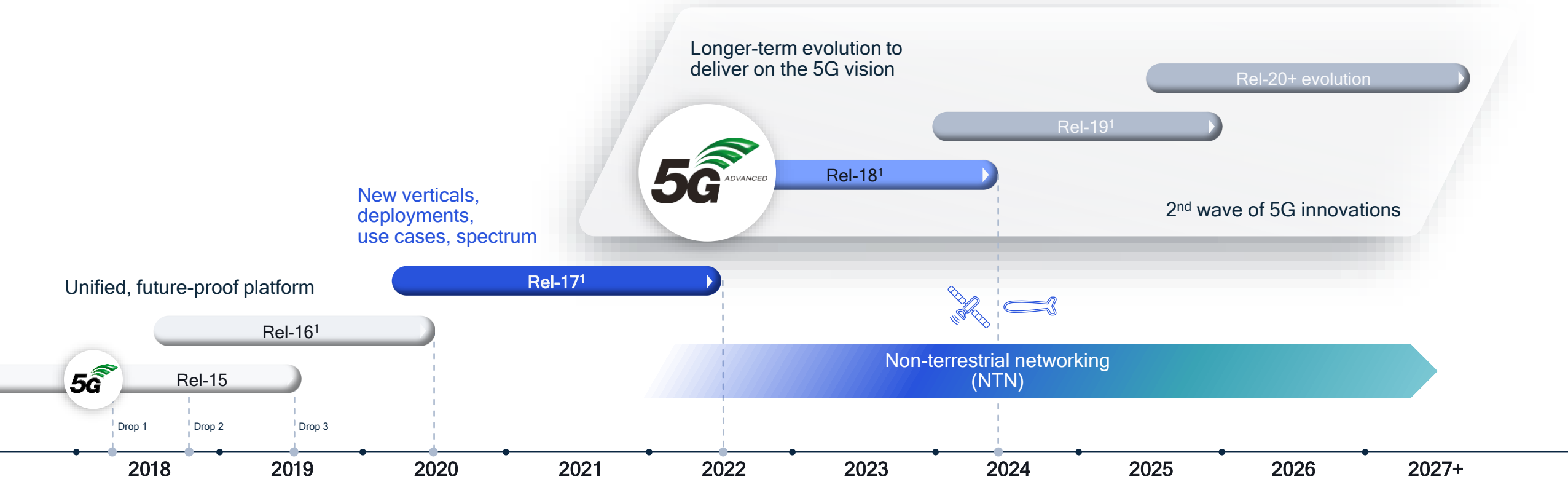
Enabling new verticals



Our innovations expand the foundation of 5G

Foundational Qualcomm innovations lead 3GPP Releases 15,16 and 17

3GPP Release 17 and 5G Advanced expand 5G for non-terrestrial networking



Rel-15 eMBB focus

- 5G NR foundation
- Sub-7 and mmWave
- Scalable & forward compatible
- Basic URLLC support
- mMTC via eMTC & NB-IoT

Rel-16 industry expansion

- Unlicensed spectrum (NR-U)
- Enhanced URLLC
- New functionalities: Sidelink (NR V2X), Positioning
- 5G broadcast
- eMTC/NB-IoT with 5G core
- Topology: IAB
- eMBB enh: MIMO, device power, CA/DC, mobility

Rel-17 continued expansion

- mmWave extended to 71GHz
- Lower complexity "NR-Light" (RedCap)
- **Non-terrestrial communication: NR NTN and IoT NTN with satellites and HAPS²**
- Improved IIoT, positioning, V2X
- Enhanced IAB, RF repeaters

Rel-18+ 5G-Advanced

- Next set of 5G releases (i.e., 18, 19, 20, ...)
- Rel-18 scope decided in Dec '21
- Rel-18 study/work to start in Q2-2022
- **Enhancements for IoT-NTN and NR-NTN**

1. 3GPP start date indicates approval of study package (study item->work item->specifications), previous release continues beyond start of next release with functional freezes and ASN.1

2. HAPS: High altitude platform systems



Release 18+



Mobile broadband evolution and further vertical expansion

Deliver enhanced mobile broadband experiences and extend 5G's reach into new use cases



Immediate commercial needs and longer-term 5G vision

Drive new value in commercialization efforts and fully realize 5G's potential with future deployments

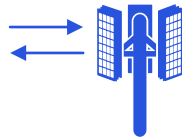


New and enhanced devices and network evolution

Focus on the end-to-end technology evolution of the 5G system to bring new levels of performance

Driving the 5G Advanced evolution

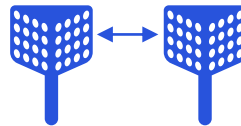
Strengthen the end-to-end 5G system foundation



Advanced DL/UL MIMO



Enhanced mobility



Mobile IAB, smart repeater



Evolved duplexing



AI/ML data-driven designs



Green networks

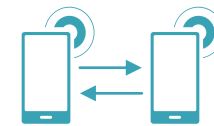
Proliferate 5G to virtually all devices and use cases



Boundless extended reality



RedCap evolution



Expanded sidelink



Expanded positioning



Drones & expanded satellites comm.



Multicast & other enhancements

5G NTN

IMT-2020-Sat
candidate
technologies

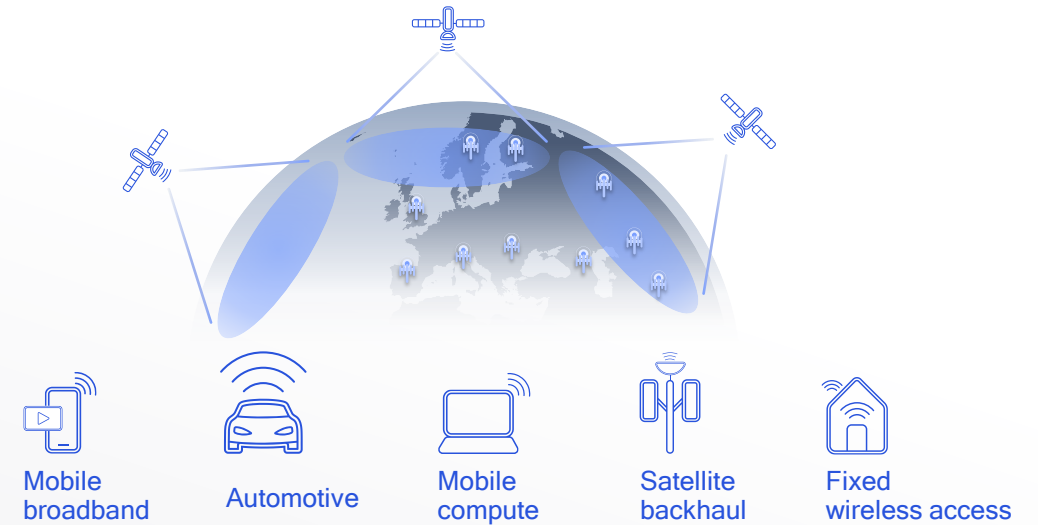
Support a broad range
of use cases with 5G
non-terrestrial
networking

5G Advanced will
further enhance the
non-terrestrial networks
(NTN) foundation

5G NR-NTN

Complementing terrestrial
networks in underserved areas

Rel-17+ NR-NTN
GEO / MEO / LEO



5G IoT-NTN

Expanding addressable
market for the 5G massive IoT

Rel-17+ NB-IoT
GEO / MEO / LEO



Leveraging cellular for non-terrestrial communication

5G Rel-15

Study focused on deployment scenarios and channel models

5G Rel-17

Projects focused on satellites for eMBB & IoT¹ and HAPS/UAV

6G

Continued evolution of 5G NTN & NTN IOT into the 6G era, depending on ecosystem status at that time

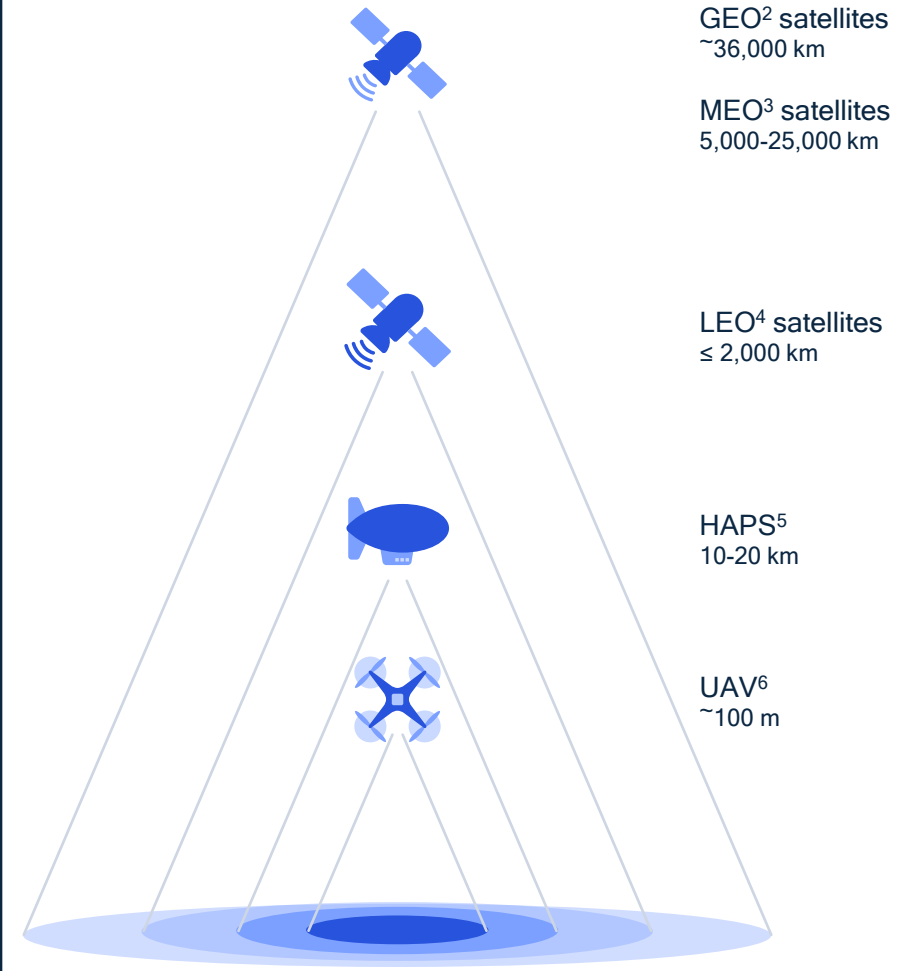
5G Rel-16

Study focused on adapting 5G NR to support NTN

5G Rel-18+

Further enhancements for UAV, HAPS, and satellites

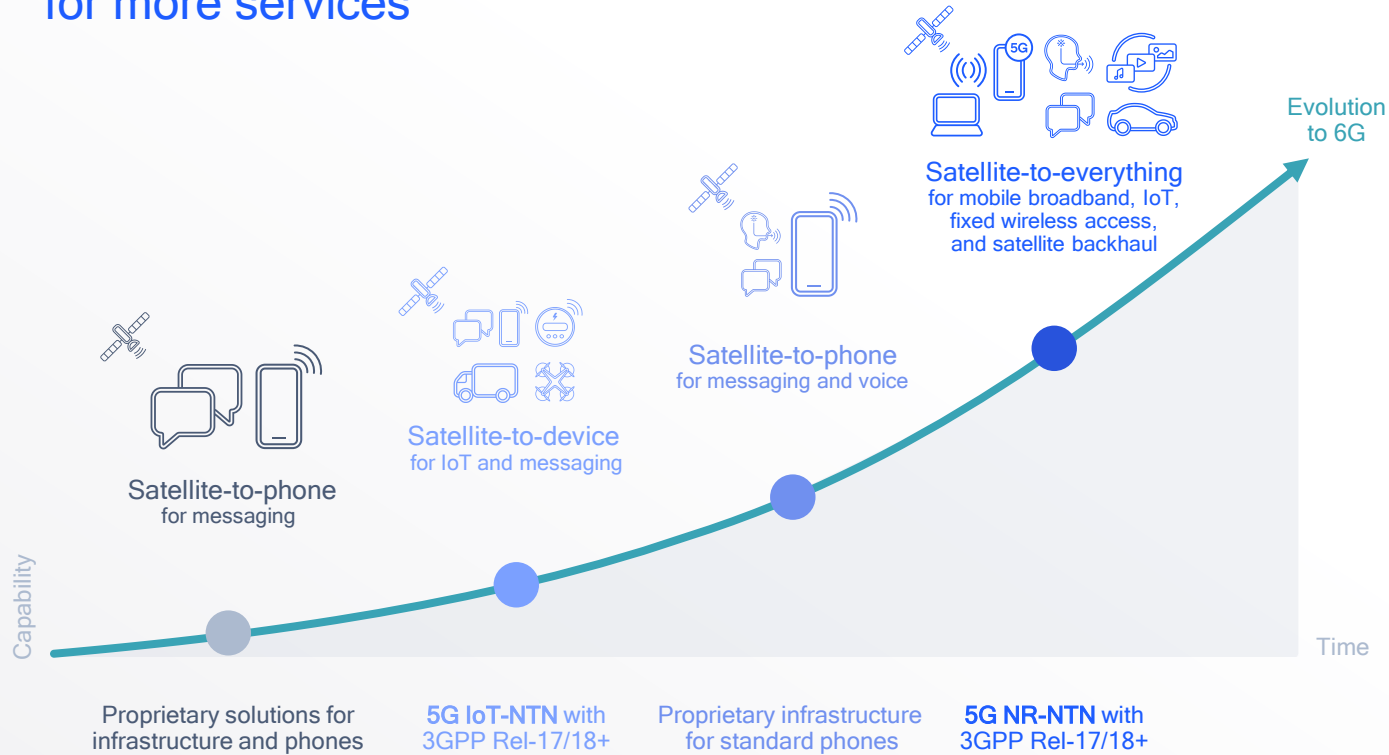
1 eMTC and NB-IoT; 2 Geostationary; 3 Medium Earth Orbit; 4 Low Earth Orbit; 5 Unmanned Aerial Vehicles; 6 High Altitude Platform Station;



5G NTN satellite services bring new efficiencies for a broad range of use cases

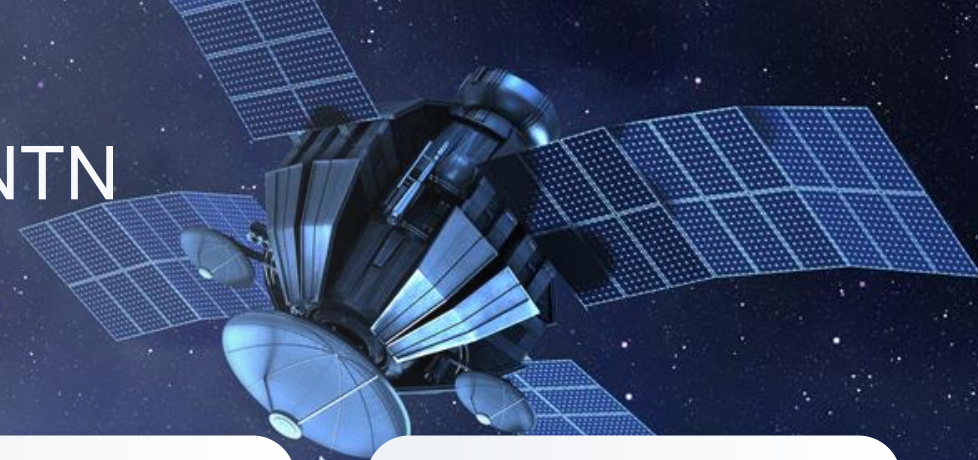
Complementing terrestrial networks with coverage from space

Provide ubiquitous connectivity for more services



Satellite services can evolve to include 5G NTN

Device upgrade cycles could promote convergence to 5G solutions



Satellite-to-phone
for messaging

Proprietary solutions for
infrastructure and phones

New smartphones with additional
modem and RF front end
Dedicated satellite spectrum
Existing satellite constellations
Limited capacity per satellite
Limited use cases
(e.g., text messaging)



Satellite-to-device
for IoT and messaging

5G IoT-NTN with
3GPP Rel-17/18+

New devices with Rel-17+ NB-IoT
Dedicated satellite spectrum
Additional NB-IoT channel to existing
bent-pipe satellites, or new satellites
Limited capacity per satellite
(200 kHz BW)
Limited use cases
(low bit-rate data)



Satellite-to-phone
for messaging and voice

Proprietary infrastructure
for standard phones

Existing 4G/5G devices
Terrestrial spectrum via satellite
Proprietary satellite architectures
Limited capacity
(Poor performance without device
modification)
More use cases
(e.g., voice, text messaging)



Satellite-to-everything
for mobile broadband, IoT, fixed wireless
access, and satellite backhaul

5G NR-NTN with
3GPP Rel-17/18+

New 5G devices
Dedicated satellite spectrum
5G-compatible satellite architectures
Higher capacity
(Wider bandwidths and better link budgets)
Broadest range of use cases

3GPP Release 17 solves the key challenges for 5G satellite connectivity

Release 17

Long propagation delay

Moving cells

Large Doppler shift

RAN1 Working Group

Uplink time and frequency pre-compensation
Using broadcasted ephemeris and UE geolocation

Enhancements to timing relationships

HARQ enhancements
Up to 32 HARQ processes

Beam management
Satellite beam switch

Bandwidth part (BWP) operation

RAN2 Working Group

Idle mode enhancements
SIB, cell selection / reselection, tracking area update

Connected mode enhancements
Measurements and handover

Timer extensions

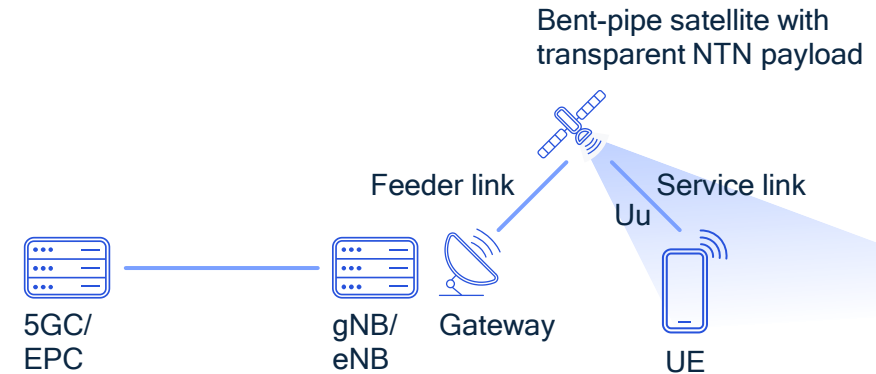
Uplink scheduling latency reduction

Service continuity between terrestrial and non-terrestrial systems

SA2 Working Group

Regulatory services

QoS for satellite backhaul, satellite access, and feeder link switch



Transparent NTN payload for bent-pipe satellites

Facilitates rapid service deployment through existing satellites

Broad coverage options

Earth-fixed beam and
Earth-moving beam

Broad platform support

GEO/GSO, MEO and LEO
satellites, HAPS, and UAV

Spectrum

FR1 FDD: L- and S-bands (n255 and n256)

Device support

NB-IoT and eMTC (Cat-M) devices,
including smartphones

Smartphones, automotive,
embedded devices

Throughput

1 to 100 kbps

1-10 Mbps

Core network support

EPC

5GC

3GPP Release 18 enhances 5G NTN applications and performance

Release 18

NTN coverage

NTN capacity

NTN/TN mobility

NR-NTN enhancements

Coverage enhancements
PUCCH repetition, DMRS bundling

Network-verified UE location
Multi-RTT positioning with a single satellite

Support for frequencies > 10 GHz
e.g., Ka band (UL: 27.0-30.0 GHz / DL: 17.7-20.2 GHz)

High-performance UEs
VSAT and Earth station in movement (ESIM)

Mobility and service continuity
enhancements
NTN-TN and NTN-NTN transitions

IoT-NTN enhancements

Performance enhancements
HARQ feedback, GNSS operations

Mobility enhancements
Measurements and handover, eMTC mobility

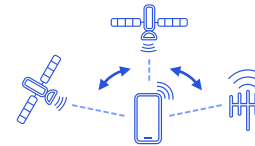
Discontinuous coverage enhancements
Discontinuous service link and feeder link,
e.g., Store-and-forward architecture



>10 GHz NR-NTN support
for high-performance UEs
e.g., VSAT / ESIM devices



Coverage enhancements



Mobility enhancements
e.g., NTN-TN and NTN-NTN
mobility



Network-verified UE location
e.g., with multi-RTT

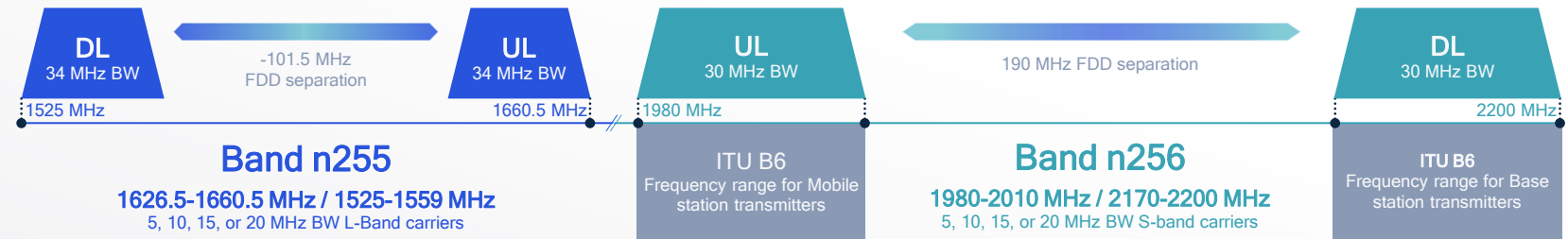


Reduced GNSS operations

Leverage a global NTN ecosystem

with 3GPP standardized frequency bands

FR1 FDD frequency bands for 5G NTN in 3GPP Release 17



FDD frequency band candidates > 10 GHz for 5G NTN in 3GPP Release 18*



* Reference: R4-2220239 WF for above 10GHz band definition and system parameters_v8

Bring global coverage to the IoT with 5G IoT-NTN

Utility grid monitoring



Agriculture



Industrial handhelds and point of sale devices



Shipping logistics



Early fire detection and reporting

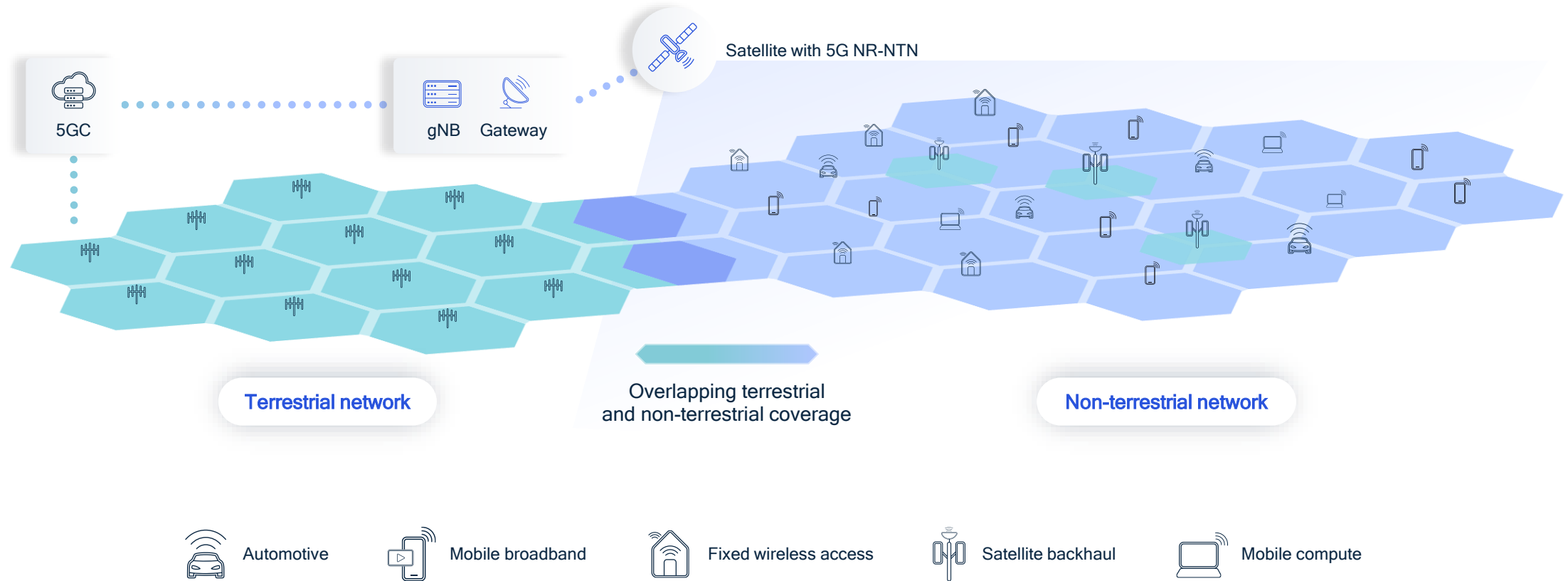


Mining off-shore and on-shore



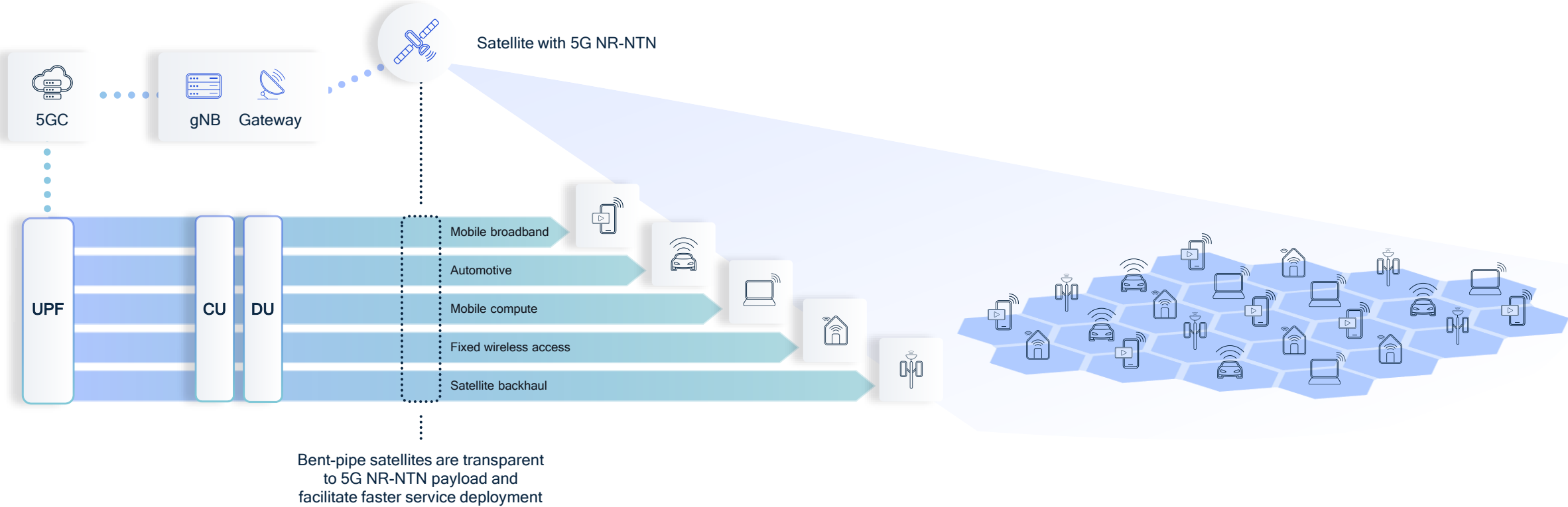
3GPP Rel-17+ NB-IoT brings a global ecosystem of devices and service providers for terrestrial and non-terrestrial IoT

Unlock new revenues in underserved areas with 5G NR-NTN



Improve customer experience with seamless 5G coverage across larger footprints by integrating terrestrial and non-terrestrial networks

Use network slicing for consistent user experiences with 5G NR-NTN



Leverage the network slicing feature in 5G standalone networks to manage valuable non-terrestrial radio access resources

The satellite communications industry supports 5G NTN

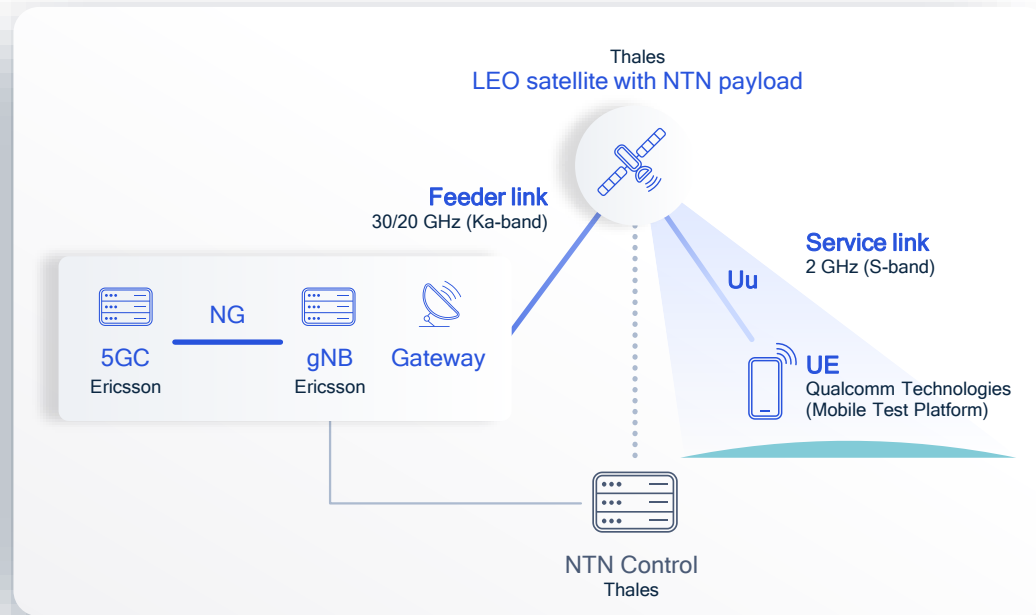
Airbus	EUTELSAT	Hughes	Leonardo SpA	Omnispace	ST Engineering iDirect
CITICSAT	Gilat	Inmarsat	Ligado	Panasonic Corporation	SyncTechno Inc.
DLR	Globalstar	Intelsat	Lockheed Martin	Sateliot	Thales
ESA	HISPASAT	KT SAT	Mitsubishi Electric	Siemens	TNO

Source: RP-210908_WID NR-NTN_for Rel-17; RP-231407 Revised WID on IoT NTN enhancements

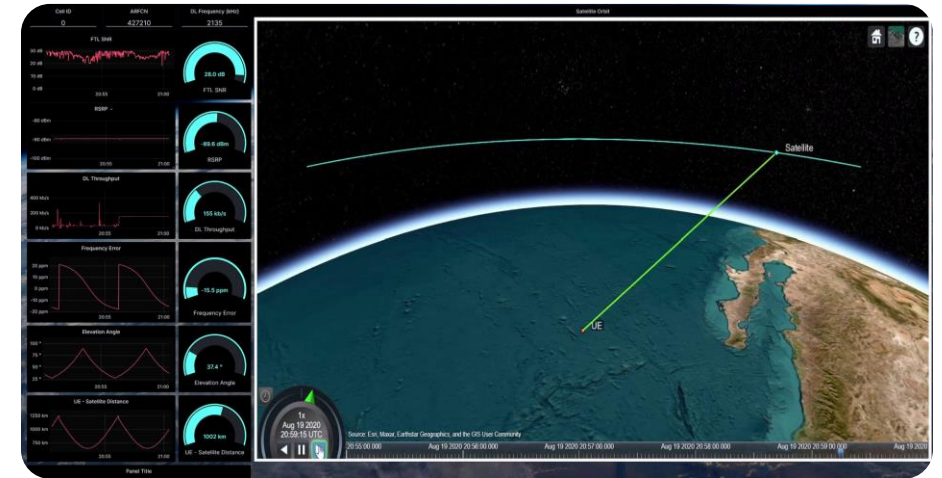
Satellite industry is working closely with the cellular ecosystem in 3GPP to evolve satcom with 5G

MWC-B 2023: Joint proof-of-concept demonstrating 5G NR-NTN end-to-end

On-the-ground testbed with prototype 5G NTN device and network, and an emulated NTN channel and delay



Qualcomm Technologies Mobile Test Platform

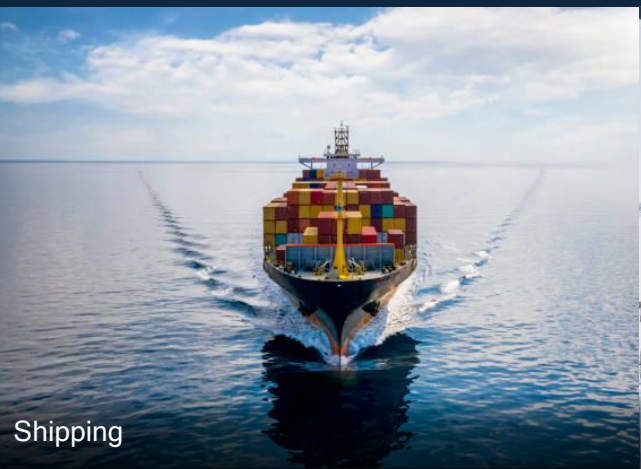


Qualcomm Technologies 5G NR-NTN demo interface

A key first step to commercializing 5G NR-NTN for broadband connectivity in underserved areas



Qualcomm® 212S and Qualcomm® 9205S modems are IoT-NTN solutions that easily establish off-grid connectivity for stationary and in-transit industrial uses cost-effectively at low power



Qualcomm Technologies products power ubiquitous IoT connectivity

5G IoT-NTN solutions based on 3GPP Release 17 (GEO/GSO only) for 3GPP NTN frequency bands



Qualcomm® 212S

- Ultra low-power consumption enabling multi-year operation in remote areas with the help of solar panels and super capacitors
- Can be attached to SOC or MCU host as a peripheral to provide satellite connectivity. Location provided by host
- No GNSS support necessary for standalone deployments, eliminating additional BOM costs
- Single mode NTN enables off-grid stationary or nomadic applications
- Module with NTN patch antenna to accelerate integration for variety of IoT use cases



Qualcomm® 9205S

- Low power wide area (CAT-M/NB-IoT) support with 2G for terrestrial network connectivity and superior mobility
- Highly capable applications processor and peripheral support to enable hub type of use cases
- Integrated GNSS to provide location for NTN connectivity
- Ideally suited for hybrid use case applications that require mobility between terrestrial and satellite networks
- Small 60mm x 60mm reference card provides flexibility to design form factors to address variety of IoT applications

Establish off-grid connectivity for stationary and in-transit industrial uses cost-effectively at low power with 5G IoT-NTN solutions

Qualcomm Aware Satellite Connectivity Highlights



3GPP Release 17 Standard-Based Solutions

Works with a variety of GEO and GSO constellations
Helps enable a more ubiquitous ecosystem



Easily Established Connectivity

Simplified device setup with an easy-to-connect NTN solution



Low Power Consumption

Enable multi-year device operation in remote areas with the help of solar panels & super capacitors



Cost-Effective Design

Use IoT-NTN solutions built specifically for off-grid, stationary devices that don't need GNSS



Ubiquitous Hybrid Connectivity

Use NTN connectivity, if needed, with terrestrial network handoffs including CAT-M/NB-IoT support and 2G fallback

Out-of-the-box connectivity with NTN capability for enhanced device management

Key longer-term research vectors

enabling the path towards 6G



AI-native E2E communications

Data-driven communication and network design, with joint training, model sharing and distributed inference across networks and devices



Scalable network architecture

Disaggregation and virtualization at the connected intelligent edge, use of advanced topologies to address growing demand



Expanding into new spectrum bands

Expanding to THz, wide-area expansion to higher bands, new spectrum sharing paradigm, dynamic coordination with environmental awareness



Air interface innovations

Evolution of duplexing schemes, Giga-MIMO, mmWave evolution, reconfigurable intelligent surfaces, waveform/coding for MHz to THz, system energy efficiency & **non-terrestrial communications**



Merging of worlds

Physical, digital, virtual, immersive interactions taking human augmentation to next level via ubiquitous, low-power joint communication and sensing



Communications resiliency

Multifaceted trust and configurable security, post quantum security, robust networks tolerant to failures and attacks



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