Technology Management Wireless

LET'S FLY WITH 5G NR NTN

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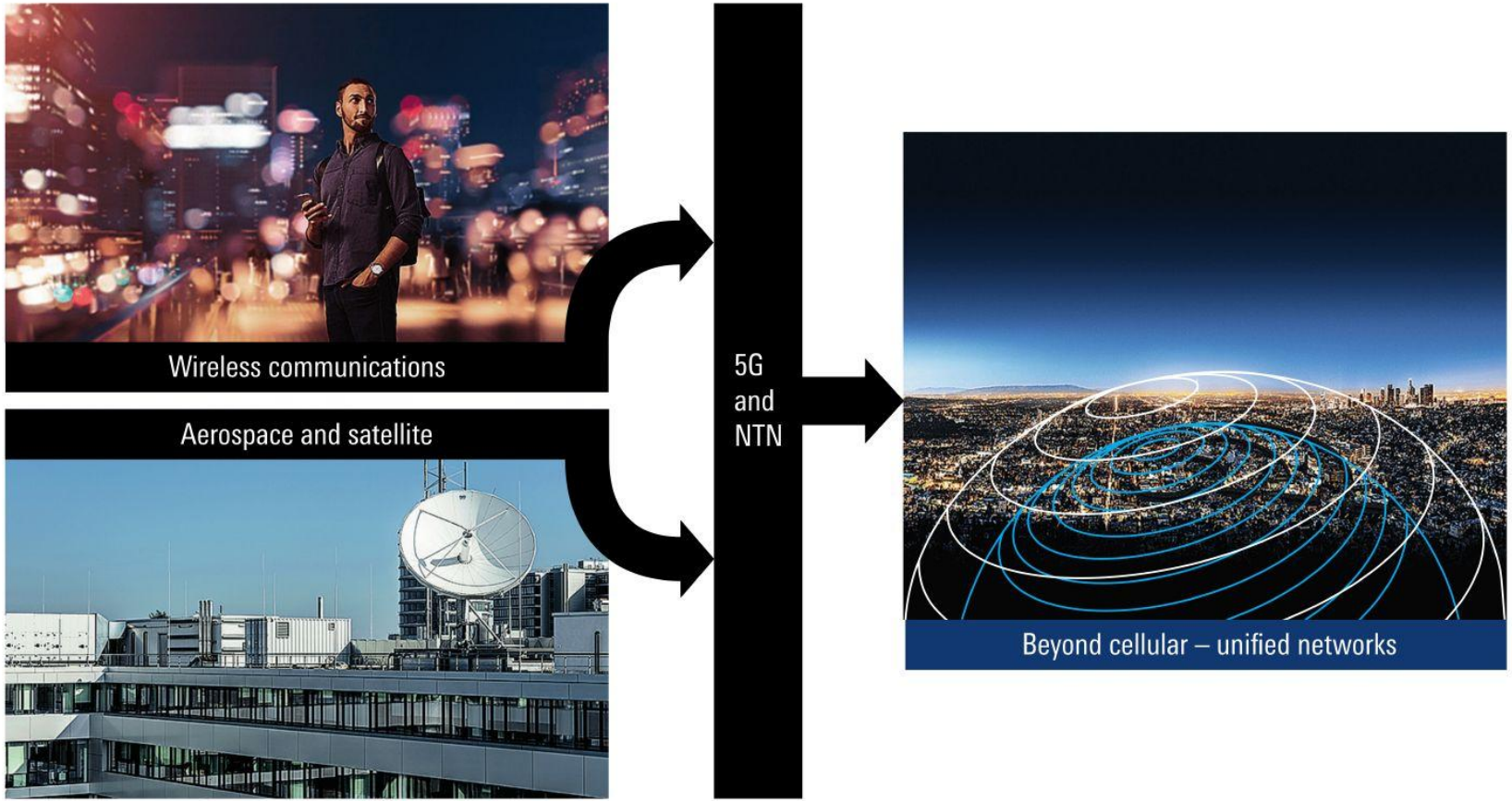
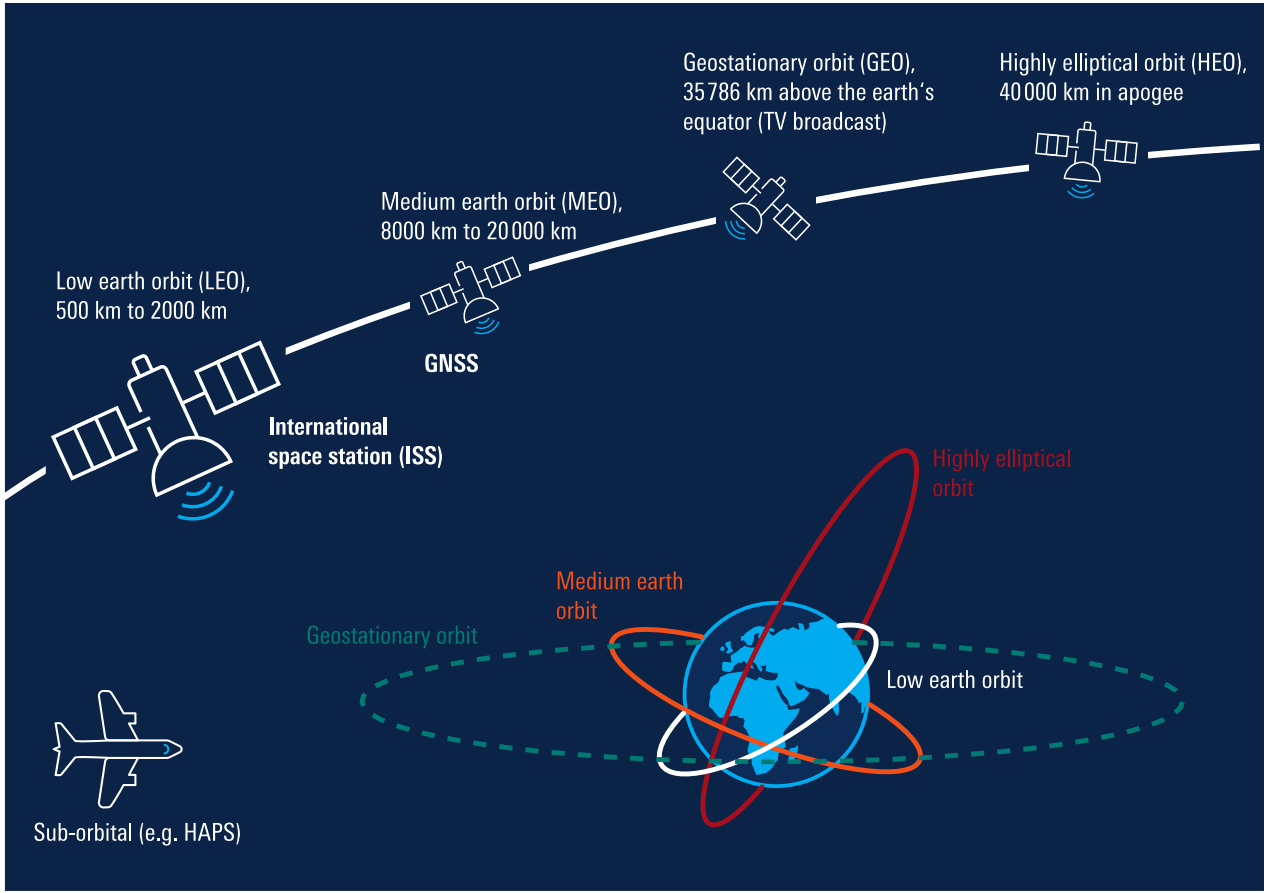
ROHDE&SCHWARZ
Make ideas real

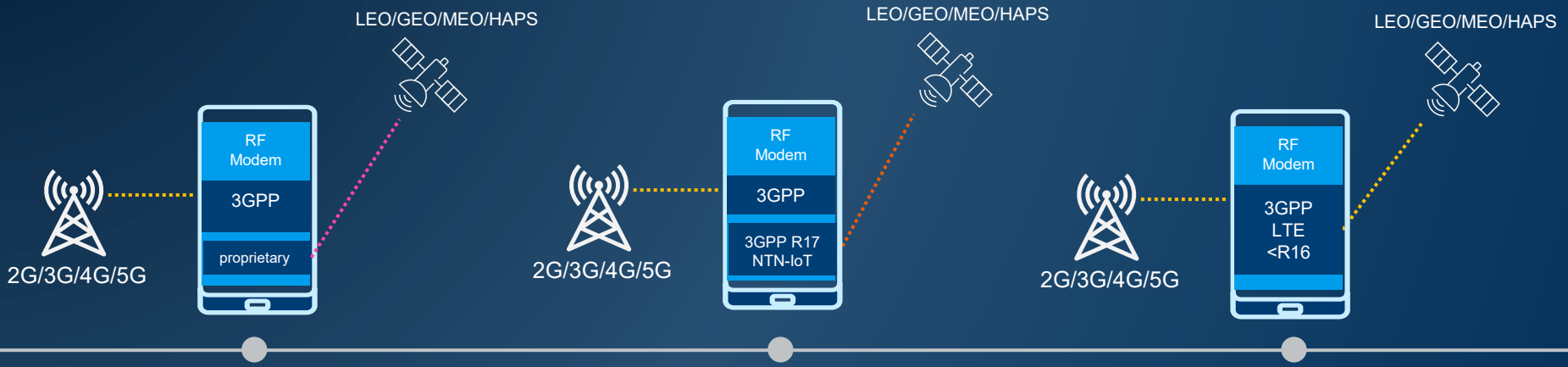
CONVERGENCE BETWEEN AEROSPACE AND WIRELESS ECOSYSTEMS



5G NTN: CONSTELLATIONS



THE DIFFERENT NTN TECHNOLOGIES
Proprietary, 3GPP & D2D



PROPRIETARY

SMS / SOS messaging with iPhone 14 using Globalstar (used NOW)

3GPP R17+ NTN-IoT

NB-NTN for SMS / SOS messaging and support for IoT ecosystem. Skylo is the 1st commercial NB-NTN operator and uses a GSO constellation. Commercial agreement with VzW.

3GPP R17+ NTN-NR

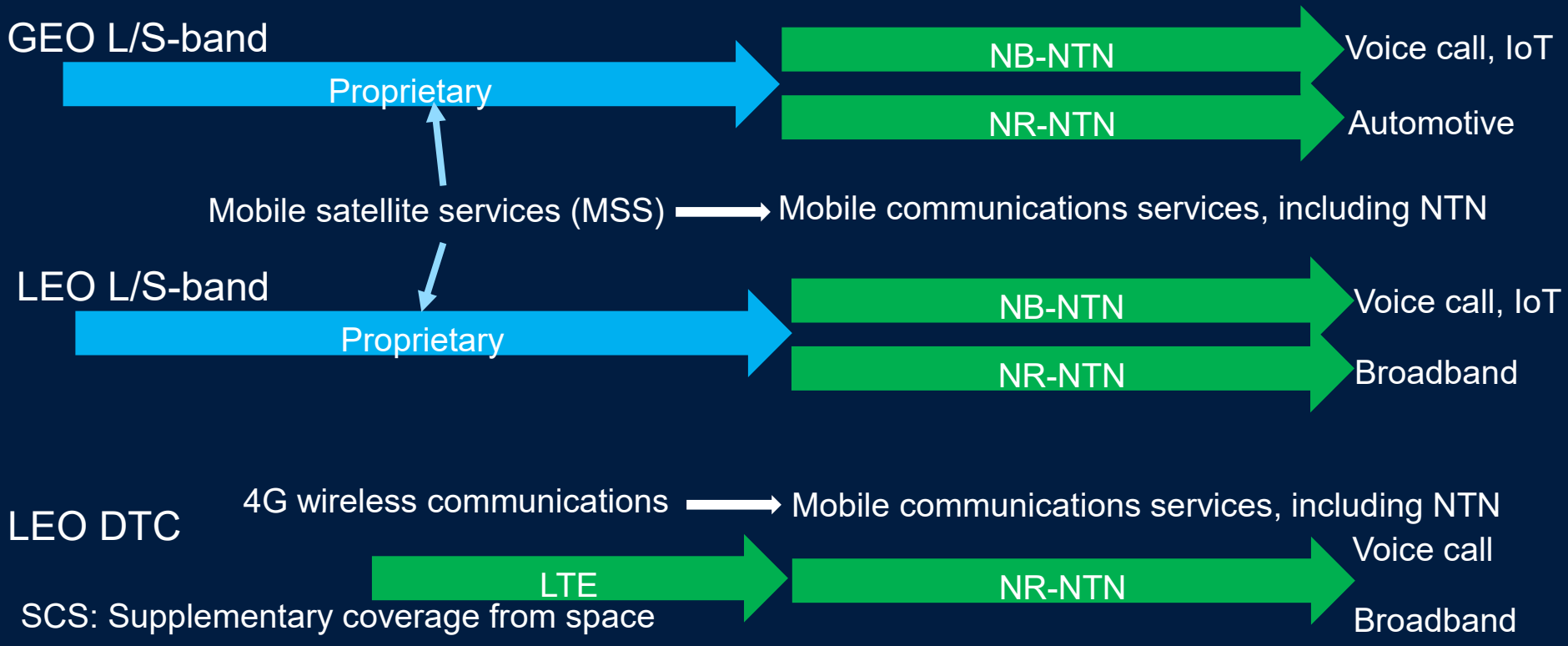
Technology that will allow for voice, messaging and low/mid-speed data at L/S-band and high-speed data at Ku & Ka bands.

Direct-to-Device (D2D: LTE NTN)

Unmodified LTE (from the perspective of the UE) for voice, messaging and low/mid-speed data.

- AT&T & VzW with AST Space Mobile LEO constellation
- T-Mobile with Starlink LEO constellation

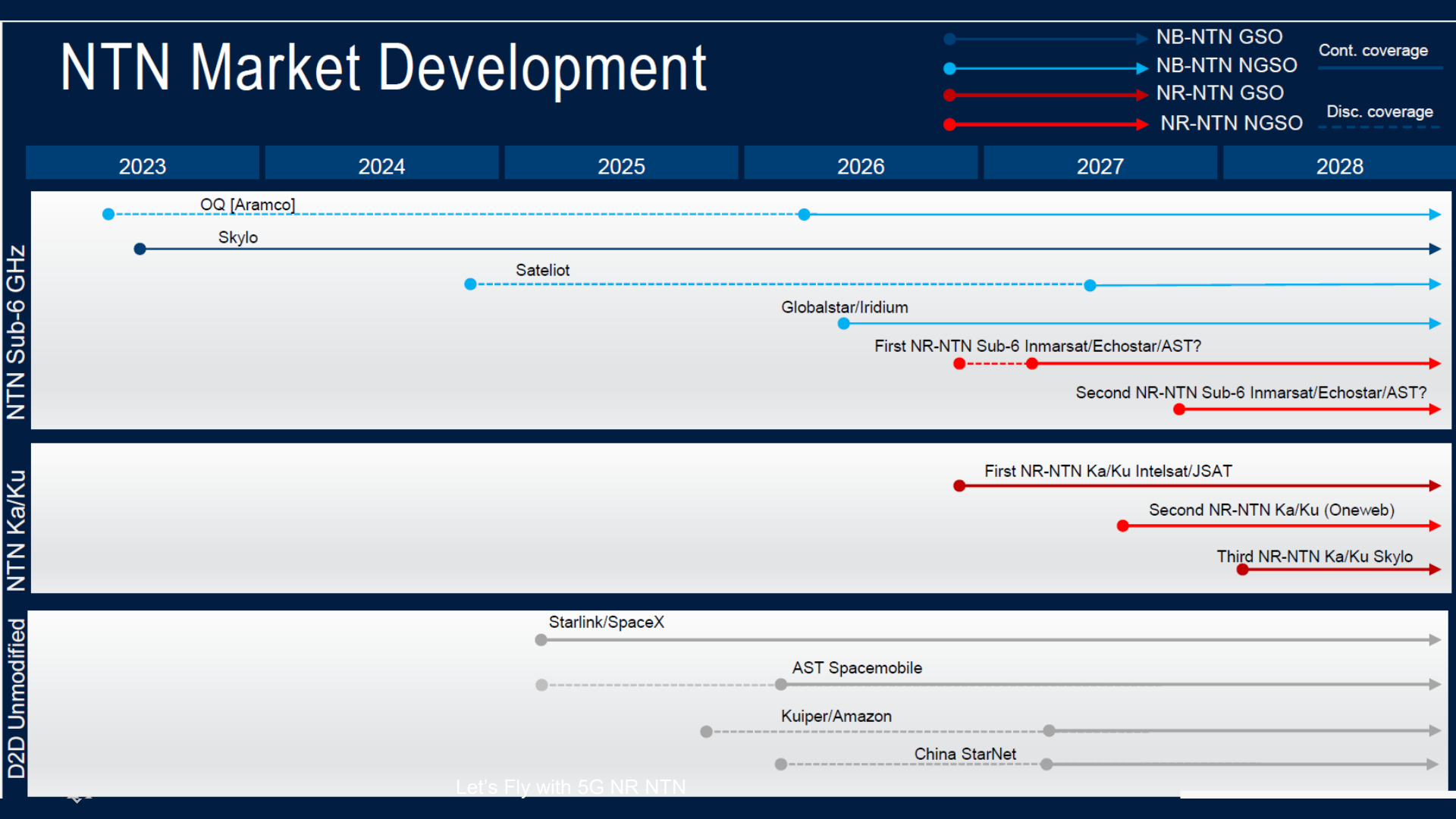
Satellite communication framework + evolution



Excursion: Difference between LTE DTC and NTN

- LTE DTC – works with many devices today!
  - **enodeB**
    - performs doppler compensation
    - takes over part of the timing advance
  - UE should implement some tweaks – not in the specs
  - Narrow sat beams mandatory
- NR and NB-NTN – requires new devices
  - **UE**
    - performs doppler compensation
    - does full timing advance
  - Handover optimizations available
  - Dedicated L/S satellite bands

NTN Market Development



5G NTN SPECTRUM OVERVIEW & UE ASPECTS

FR1: NTN bands

Band	Region	Related bands	Band type	UL low MHz	UL high MHz	DL low MHz	DL high MHz
n253	EU	L-ext	FDD	1668.0	1675.0	1518.0	1525.0
n254	EU	L+53	FDD	1610.0	1626.5	2483.5	2500.0
n255	EU	n65	FDD	1626.5	1660.5	1525.0	1559.0
n256	NA	n24	FDD	1980.0	2010.0	2170.0	2200.0

FR2-1N: new NTN bands (R18). FR2-1N range 17.3 – 52.6GHz

Band	Region	Band type	UL low MHz	UL high MHz	DL low MHz	DL high MHz
n510	US	FDD	27500	28350	17300	20200
n511	US	FDD	28350	30000	17300	20200
n512	EU	FDD	27500	30000	17300	20200

„FR3“ bands Ku: requested in R19

Band	Region	Band type	UL (Earth to space) GHz	DL (Space to Earth) GHz
Ku	Region 1	FDD	12.75 – 13.25 & 13.75 – 14.5	10.7 – 12.75
Ku	Region 2	FDD	12.75 – 13.25 & 13.75 – 14.5	10.7 – 12.7

UE aspects for NTN

Link level assumptions	FR1 NTN-UE or IoT-UE	FR2-1N VSAT UE
TX power	23dBm ± 2dB (200mW) (note: more likely 23 dBm + 2dB)	33 dBm (2W)
Antenna type	Omnidirectional	60cm aperture diameter
Antenna gain	TX/RX 0dBi	TX: 43.2 dBi / RX: 39.7 dBi
Noise figure	9 dB	1.2 dB
Polarization	Linear (dual polarized possible)	Circular polarized phased array antenna

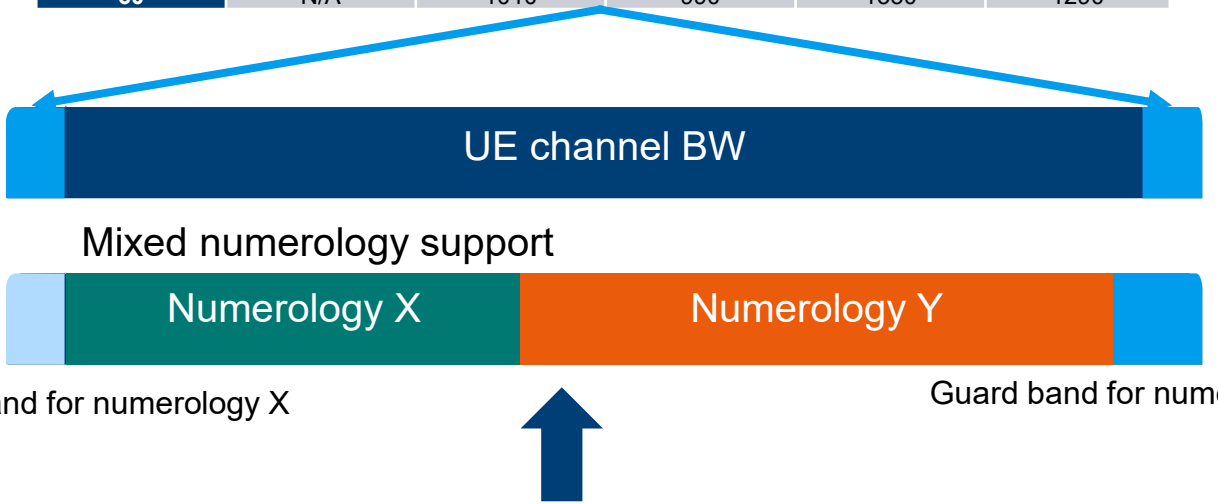
Upper C-band study in R20

Band	Region	Frequency MHz
Upper C	Region 1, 2 & 3	3800 - 4200

NTN – SPECTRUM IN 5G FR1

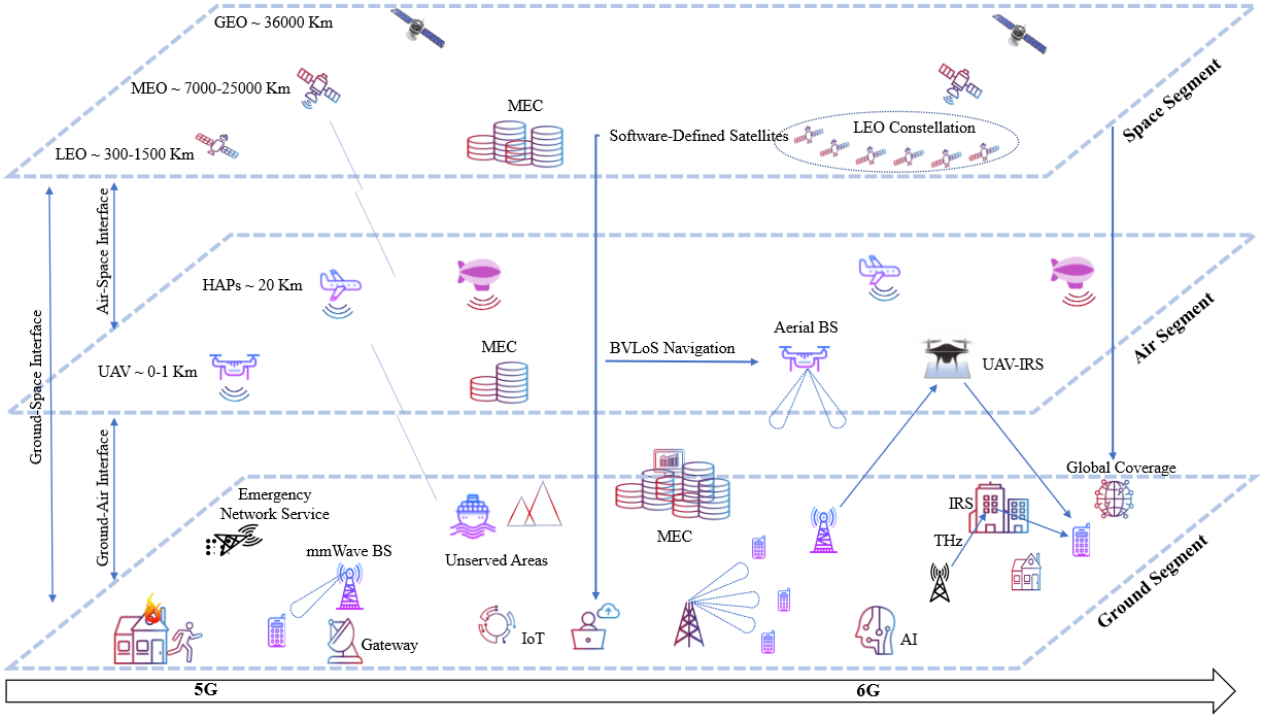
Minimum guard band (kHz)

SCS (kHz)	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz
15	242.5	312.5	382.5	452.5	592.5
30	505	665	645	805	945
60	N/A	1010	990	1330	1290

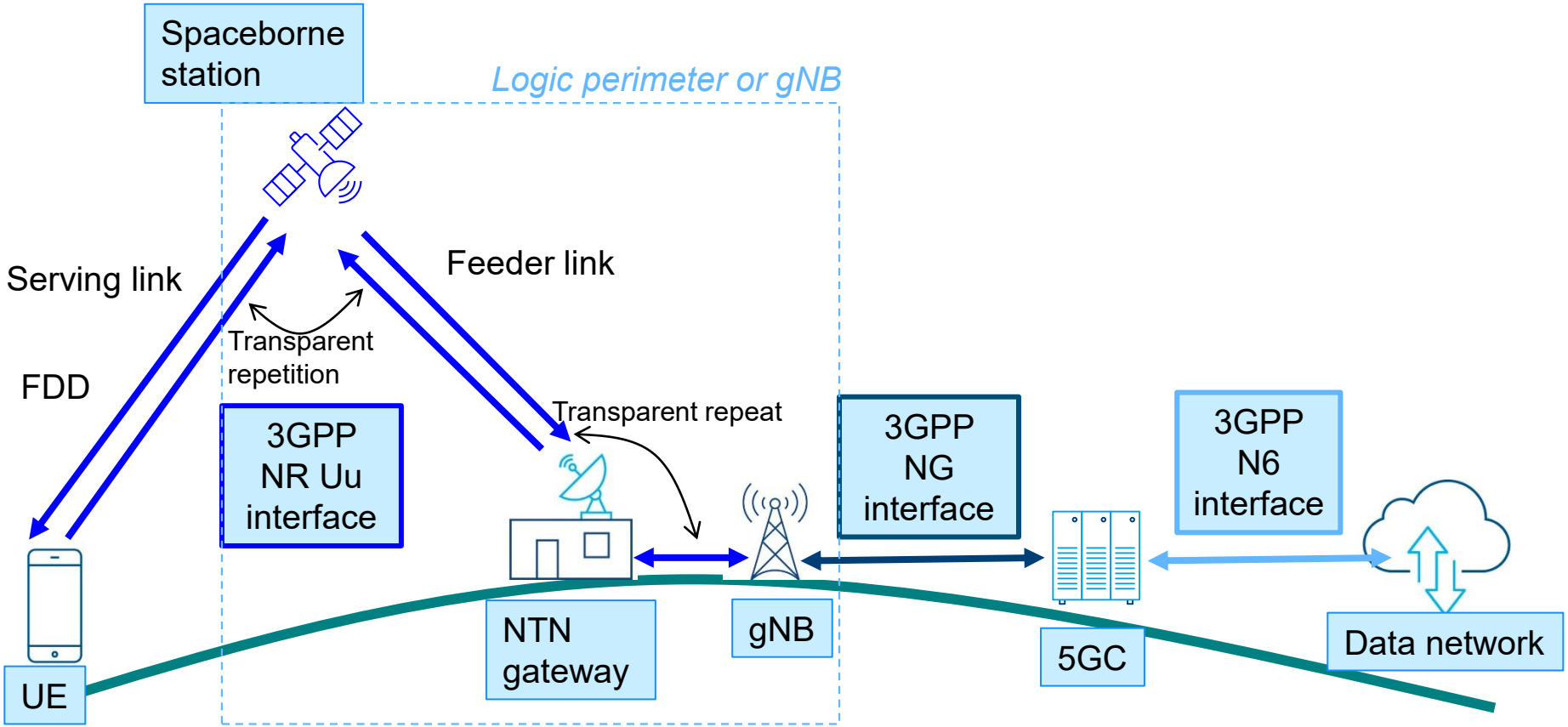


NTN satellite operating band	ΔF_{Raster} (kHz)	Uplink Range of N_{REF} (First – <Step size> – Last)	Downlink Range of N_{REF} (First – <Step size> – Last)	TX-RX frequency separation
n256	100	396000 – <20> – 402000	434000 – <20> – 440000	190 MHz
n255	100	325300 – <20> – 332100	305000 – <20> – 311800	-101.5 MHz

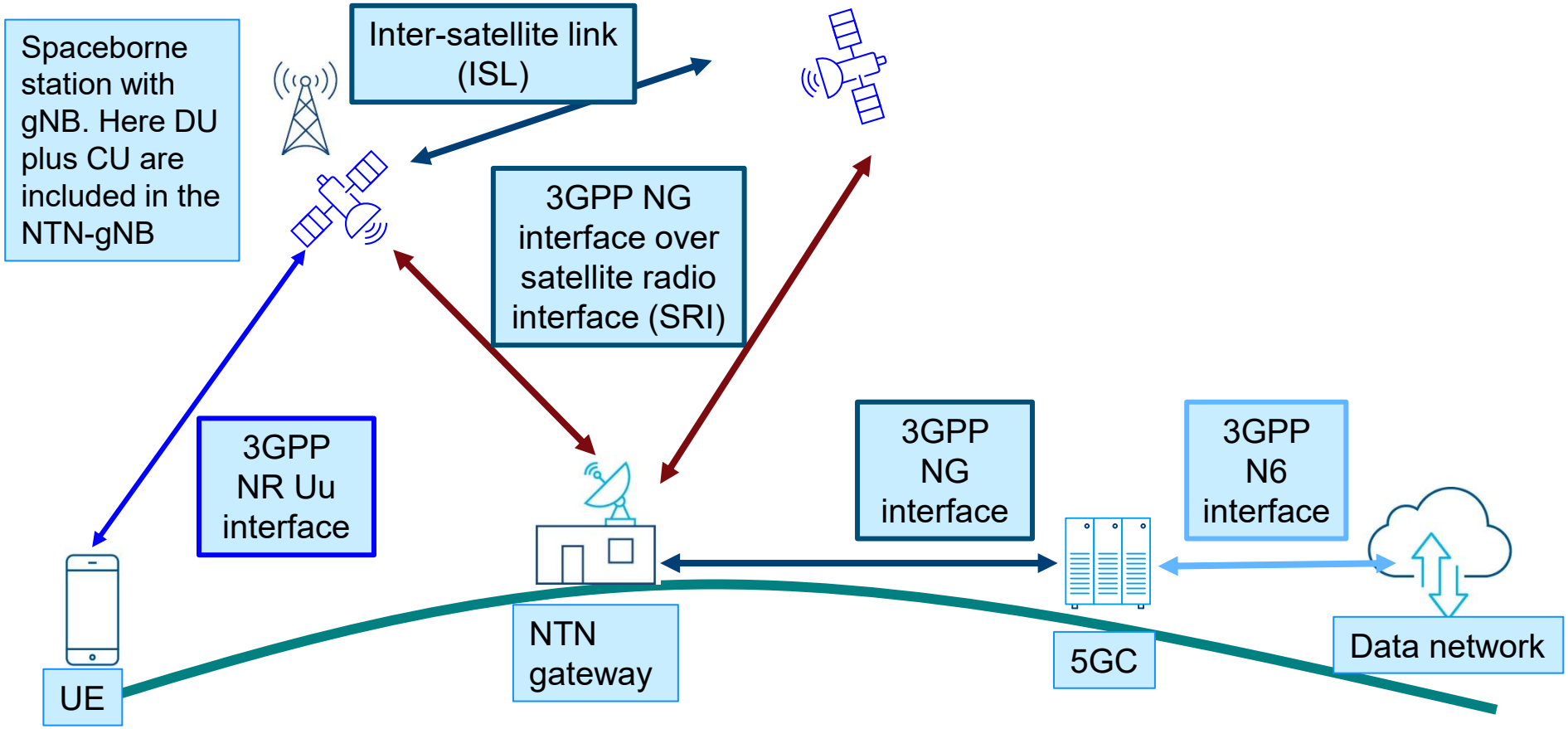
DIFFERENCES 5G NTN AND 6G NTN ARCHITECTURE



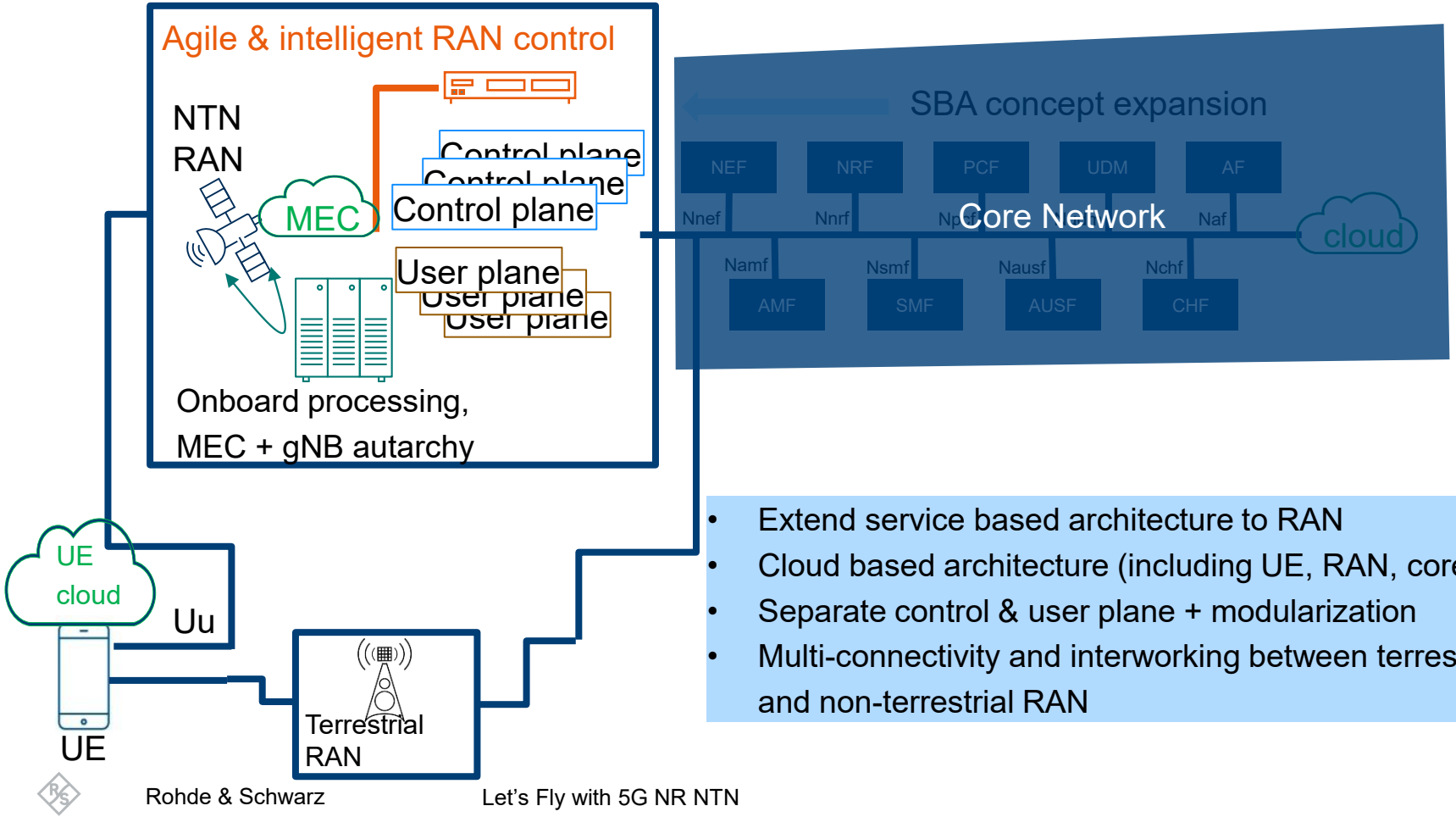
NTN: TRANSPARENT PAYLOAD ARCHITECTURE



NTN: REGENERATIVE PAYLOAD ARCHITECTURE

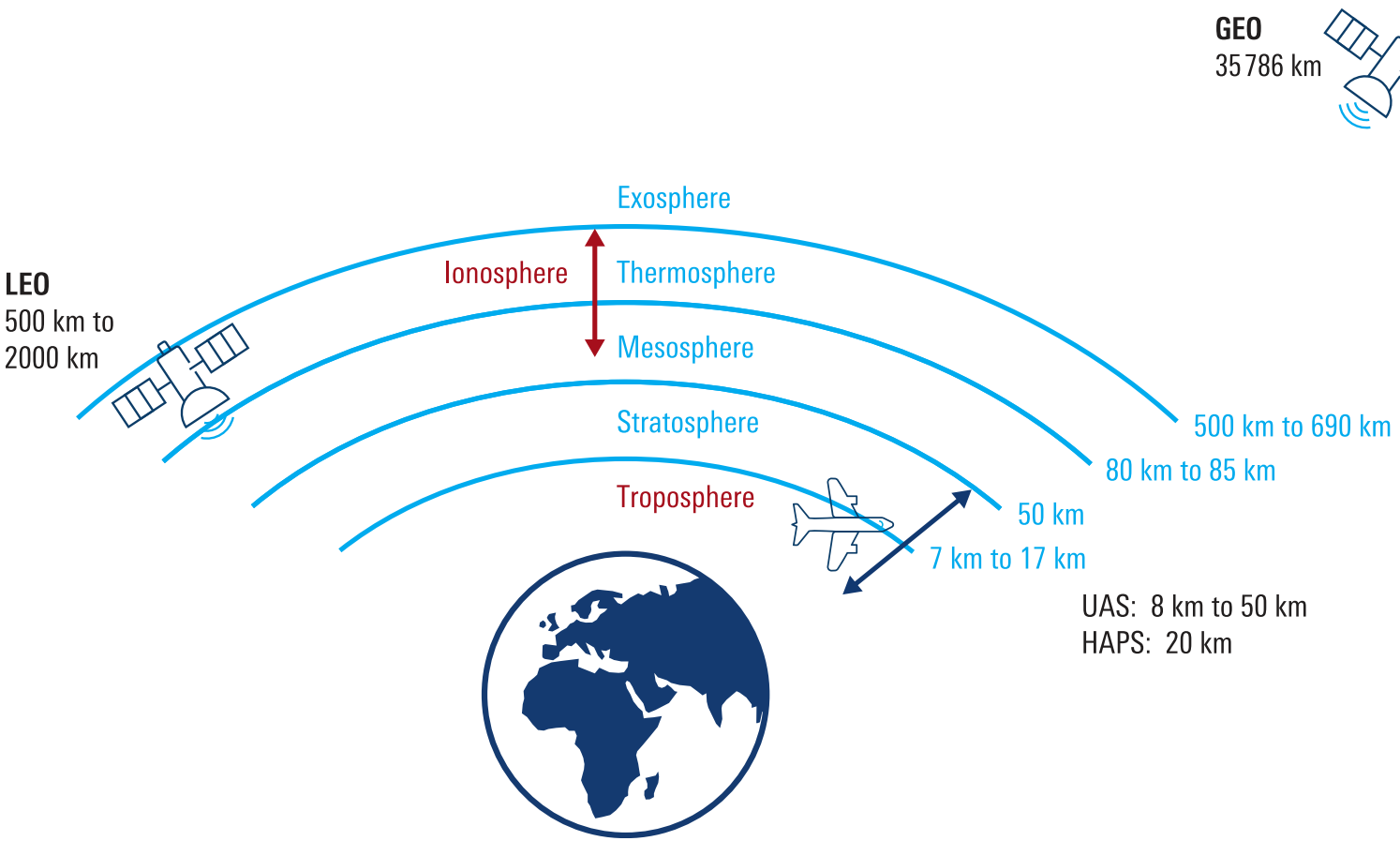


5G NTN ARCHITECTURE TOWARDS 6G

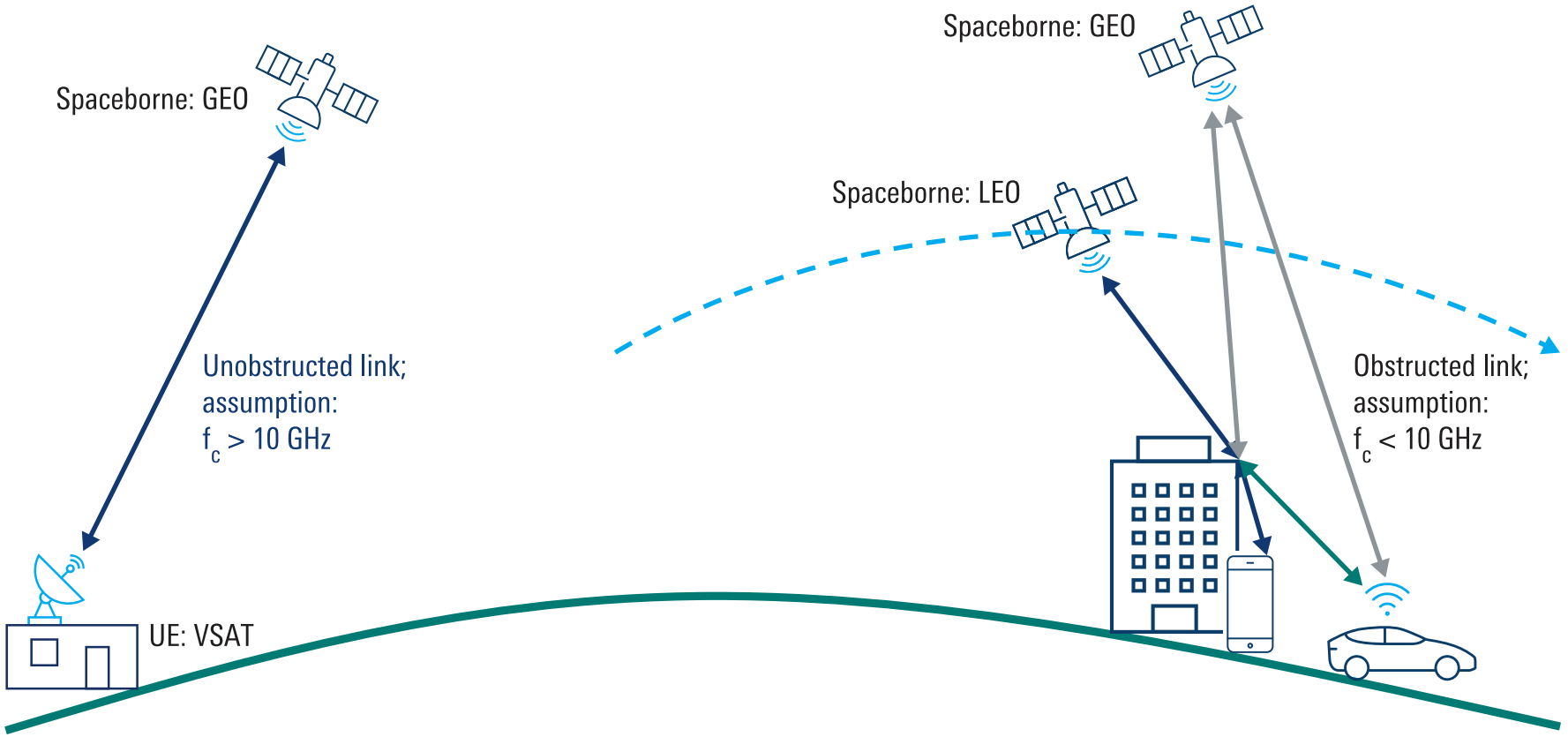


- Extend service based architecture to RAN
- Cloud based architecture (including UE, RAN, core, …)
- Separate control & user plane + modularization
- Multi-connectivity and interworking between terrestrial and non-terrestrial RAN

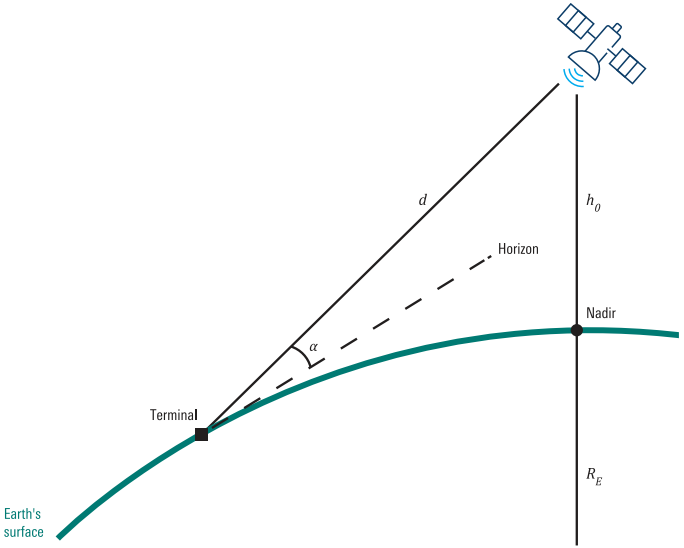
NTN: REMINDER: PROPAGATION ASPECTS



NTN: FADING ASPECTS



NTN: FADING ASPECTS, PATHLOSS



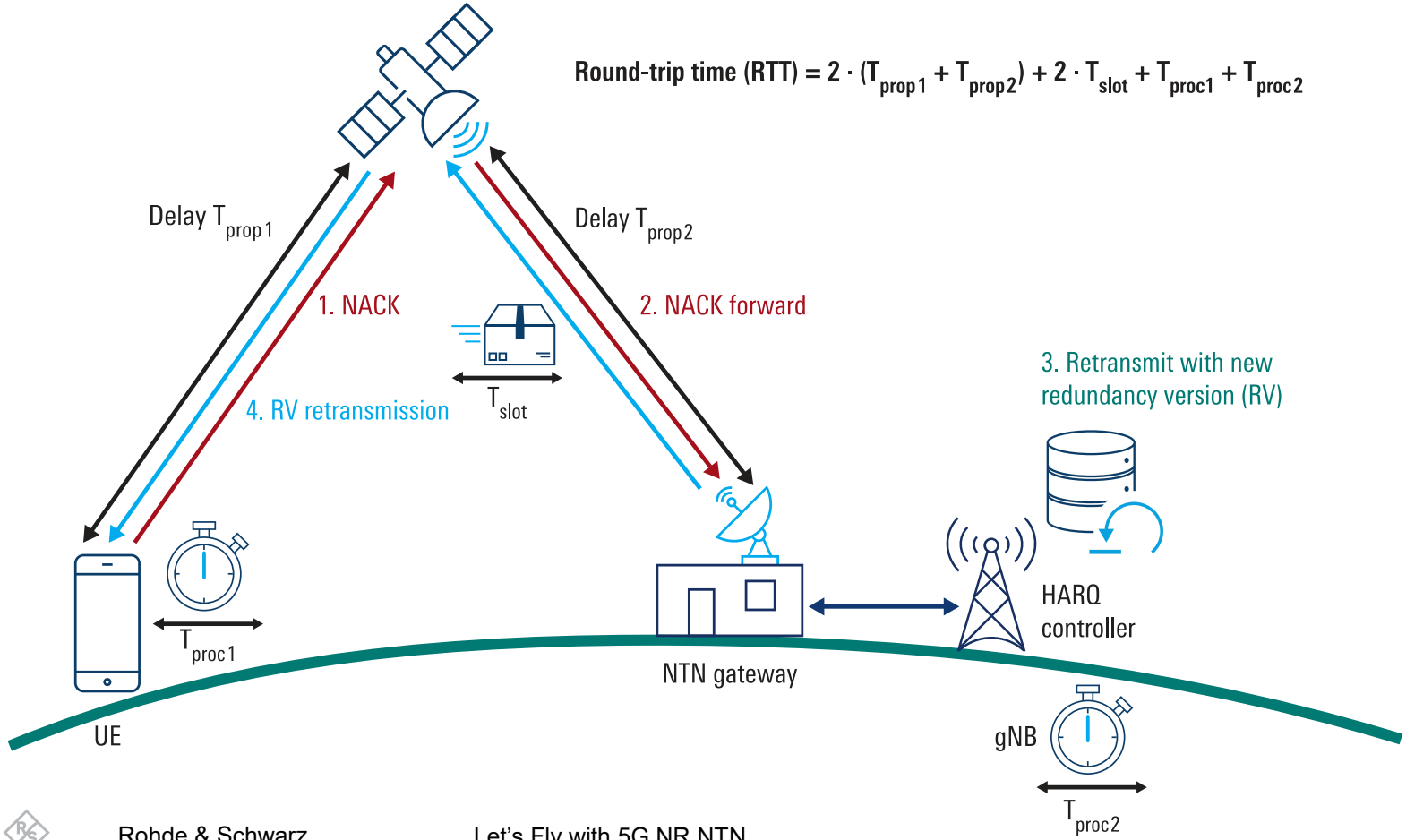
$$d = \sqrt{R_E^2 \sin^2 \alpha + h_0^2 + 2h_0 R_E} - R_E \sin \alpha$$

α: elevation angle (angle at which the UE sees the satellite, e.g. minimum elevation, approx. 10°)
R_E: earth's radius = 6371 km
h_0: satellite altitude

$$CNR = EIRP + G/T - k - FSPL - PL_g - PL_s - PL_e - PL_{AD} - B$$

Transmission mode	DL	UL
Frequency	2 GHz	2 GHz
TX: EIRP	78.8 dBm	23 dBm
RX: G/T	–31.6 dB·K^{-1}	1.1 dB·K^{-1}
Bandwidth	30 MHz	0.4 MHz
Free space path loss	159.1 dB	159.1 dB
Atmospheric loss	0.1 dB	0.1 dB
Shadow fading margin	3 dB	3 dB
Scintillation loss	2.2 dB	2.2 dB
Polarization loss	0 dB	0 dB
Additional losses	0 dB	0 dB
CNR	**6.6 dB**	**2.8 dB**

NTN: PATH DELAY, ROUND-TRIP TIME RTT

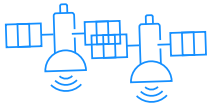


NTN: RTT AND NTN NETWORK TYPES

RTT = 600ms
Orbit = 35786km

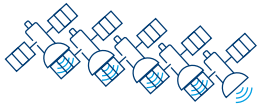
Geostationary earth orbit (GEO)

RTT = 150ms (@8500km)
Orbit = 500 -2000 km



Medium earth orbit (MEO)

RTT = 30ms (@500km)
Orbit = 500 -2000 km



(Very) Low earth orbit ((V)LEO)

RTT = 1-2ms
Orbit = 10 -50 km

High altitude platform systems (HAPS)

RTT = <1ms
Orbit = 1-5 km

Low altitude platform systems (LAPS)
Uncrewed aerial vehicals/systems (UAV/AUS)

RTT based on transparent payload & speed of light, no additional delay due to signaling included [source 5G Americas]

NTN: SATELLITE DISTANCE CALCULATION FOR PL, RTT, ETC.

UE support of GNSS is mandatory in NTN

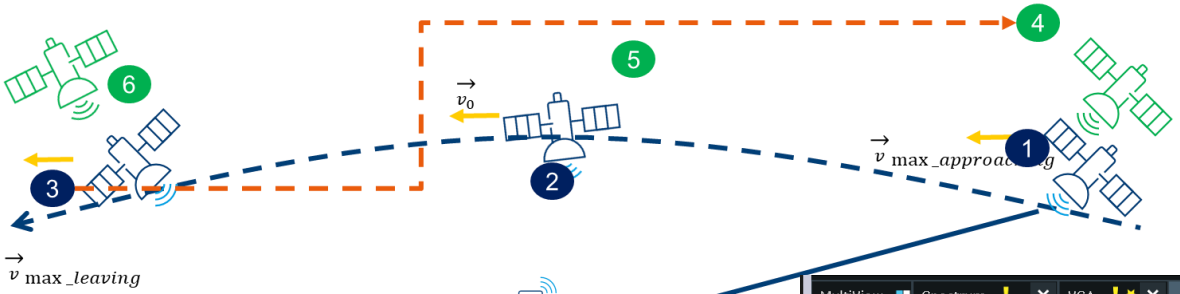
UE position via GNSS as X_{UE}, Y_{UE}, Z_{UE}

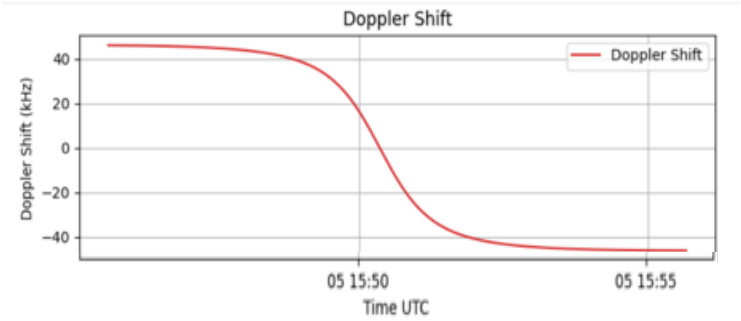
Satellit position via SIB19 as X_{SAT}, Y_{SAT}, Z_{SAT}

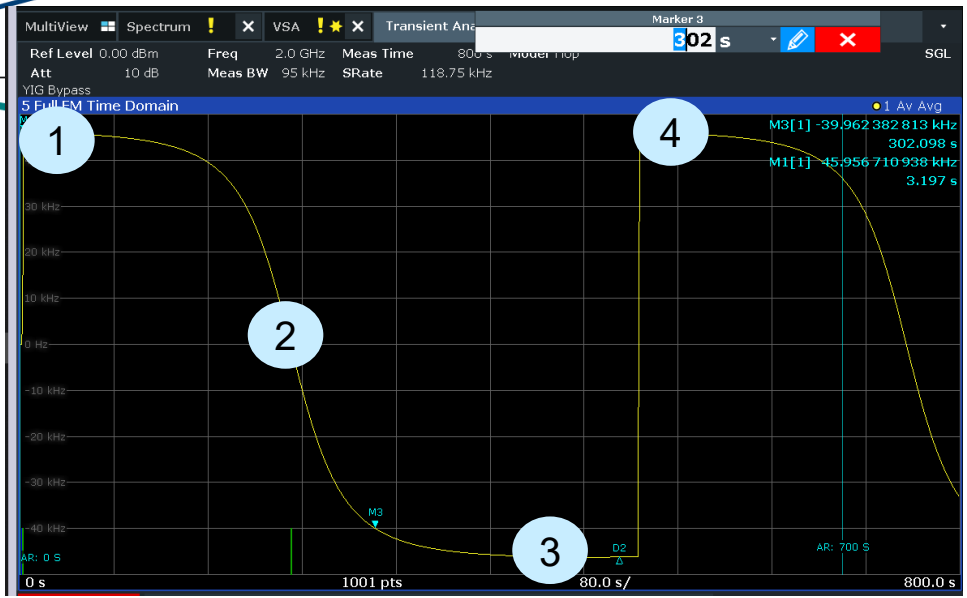
Distance calculation for pathloss, latency, RTT estimation

$$d = \sqrt{(x_{UE} - x_{SAT})^2 + (y_{UE} - y_{SAT})^2 + (z_{UE} - z_{SAT})^2}$$

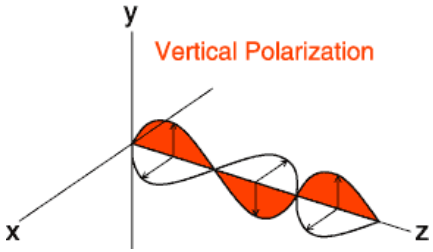
DOPPLER SHIFT SCENARIO DURING HANDOVER

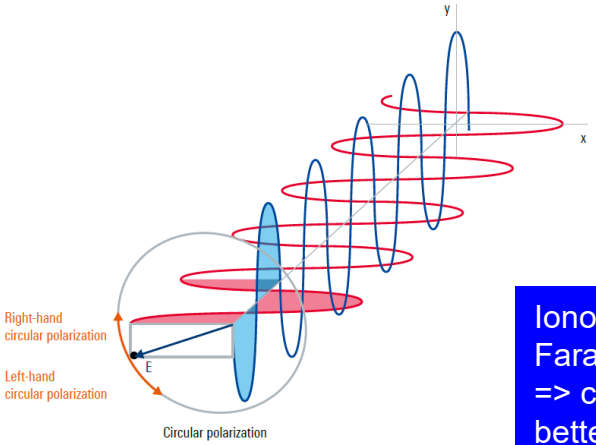


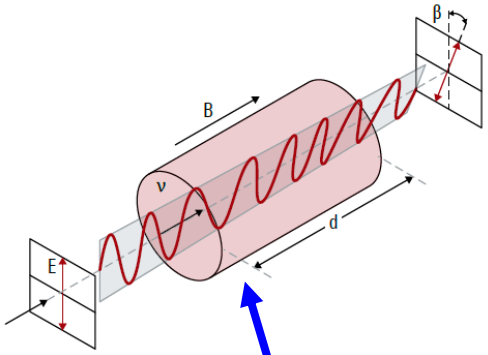




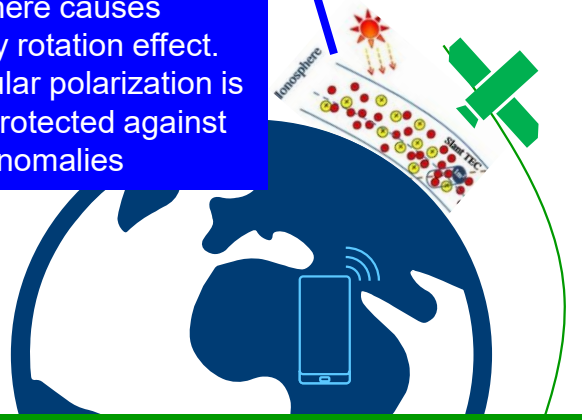
REMINDER: ANTENNA POLARIZATION







Ionosphere causes Faraday rotation effect.
=> circular polarization is better protected against those anomalies

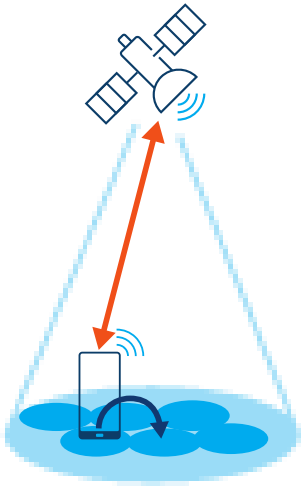


Terrestrial communications often use vertical polarization.
Geometry of antennas is quasi-static

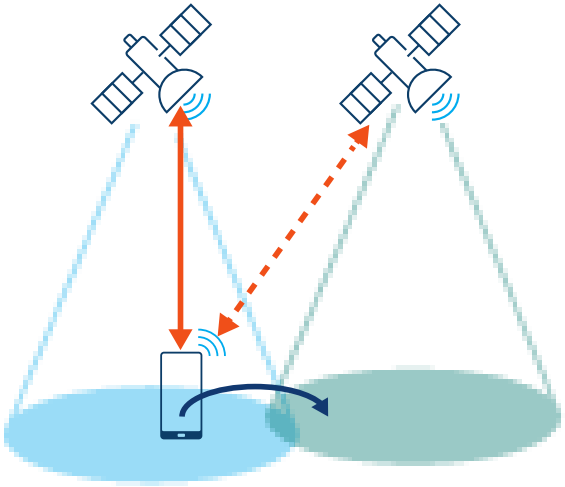
Geometric differences if satellite moves with respect to the fixed Earth-bound station => linear polarization may lose alignment

5G NTN MOBILITY SCENARIOS - EXAMPLES

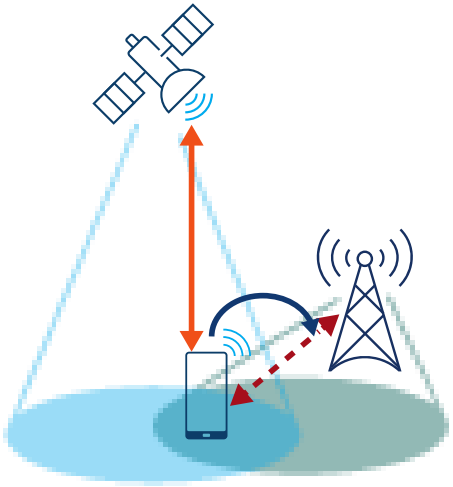
Cell selection/
cell reselection



Intra-satellite/
inter-beam handover



Inter-satellite handover/
inter-satellite dual connectivity (DC)



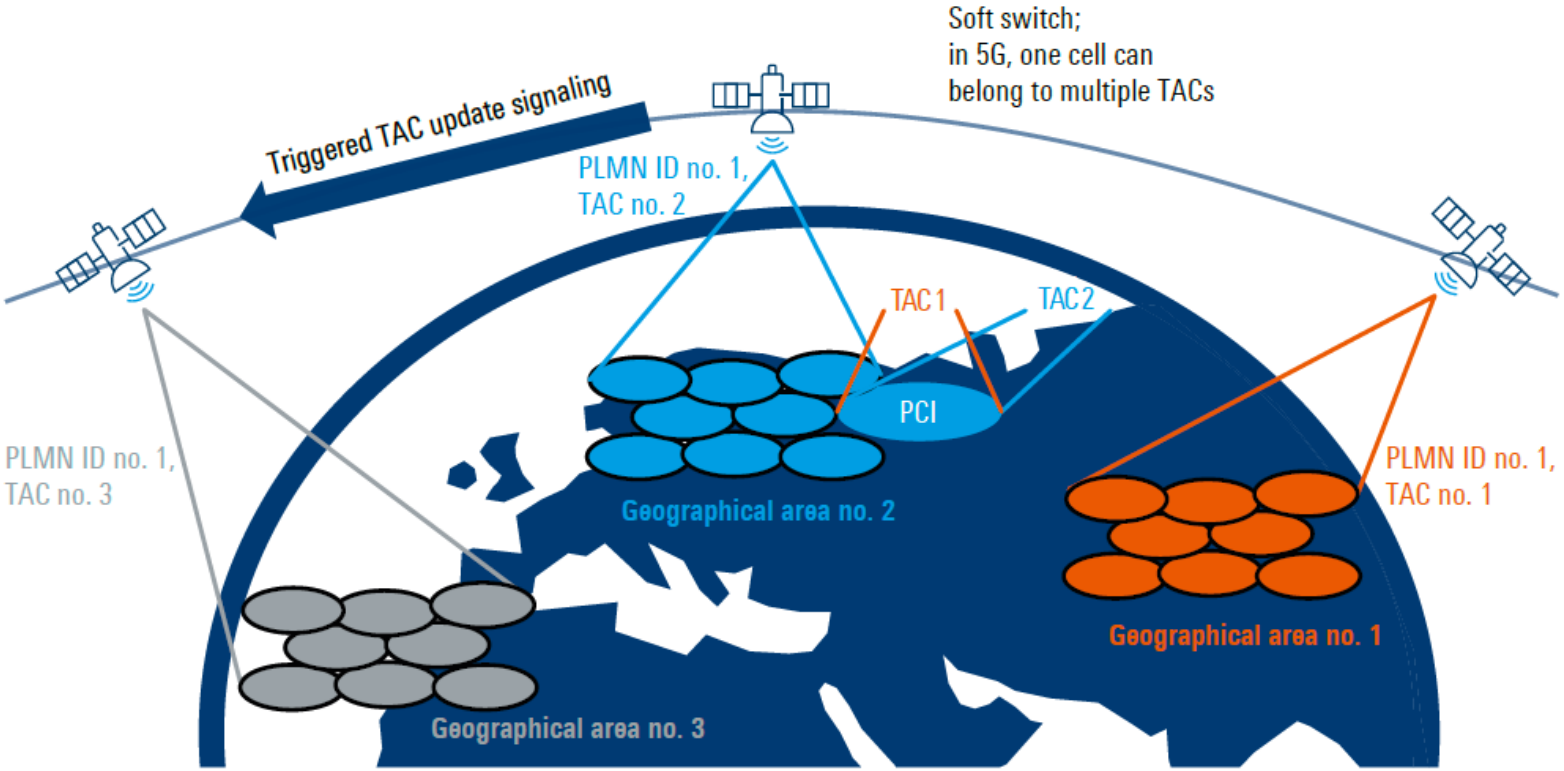
NTN – terrestrial
handover/DC

NR-NTN connection

Target or simultaneous dual connectivity NR-NTN connection

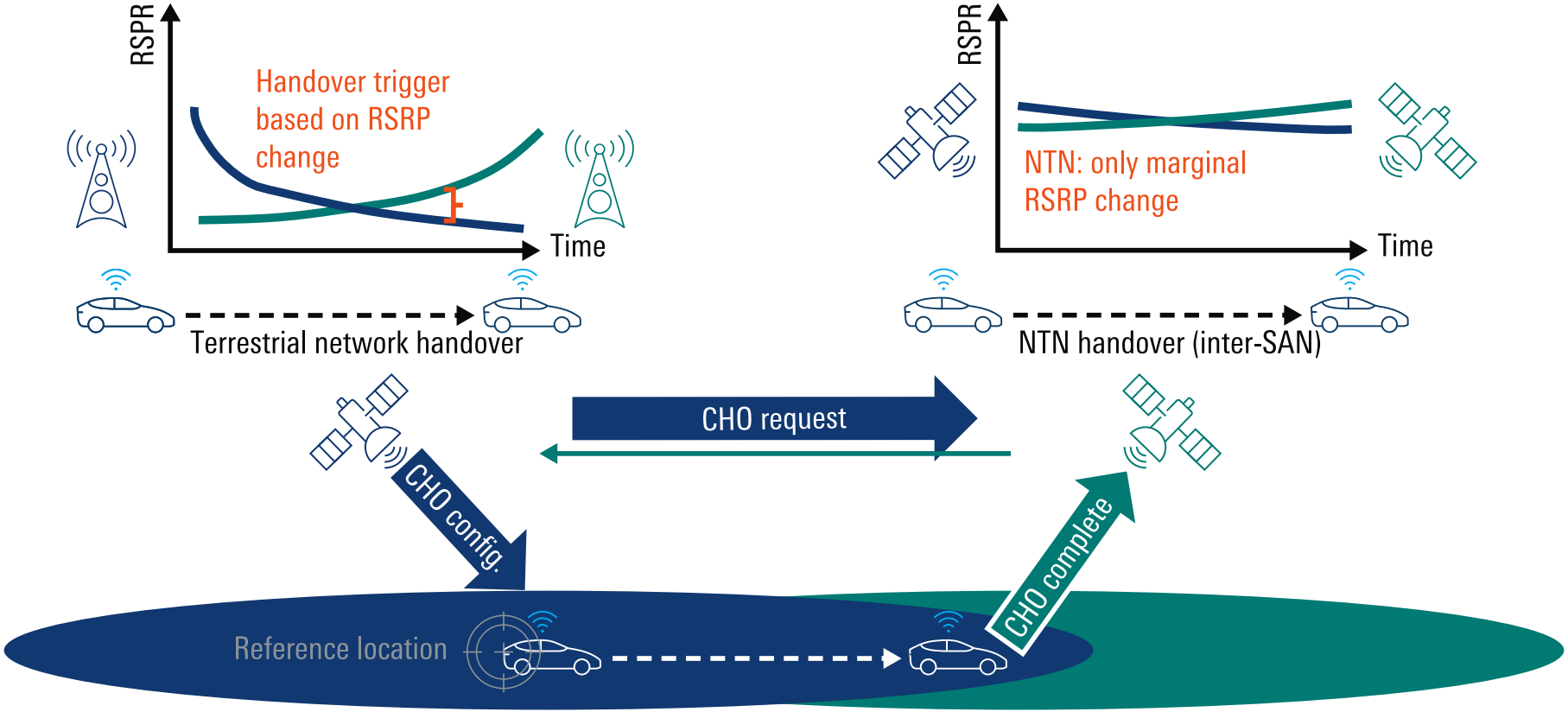
Target or simultaneous dual connectivity terrestrial connection

NTN: TRACKING AREA ASPECTS



5G NTN supports Earth-fixed tracking area codes (TAC) and multi-TAC signaling

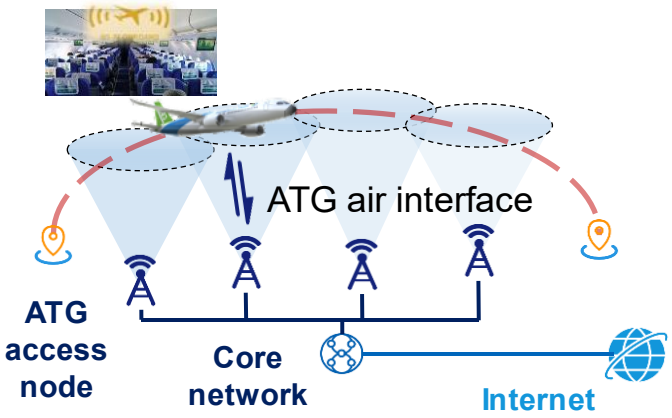
5G NTN HANDOVER EXAMPLE (CHO)



Conditional handover (CHO): network configures UE with triggering condition; e.g. distance between UE and reference location

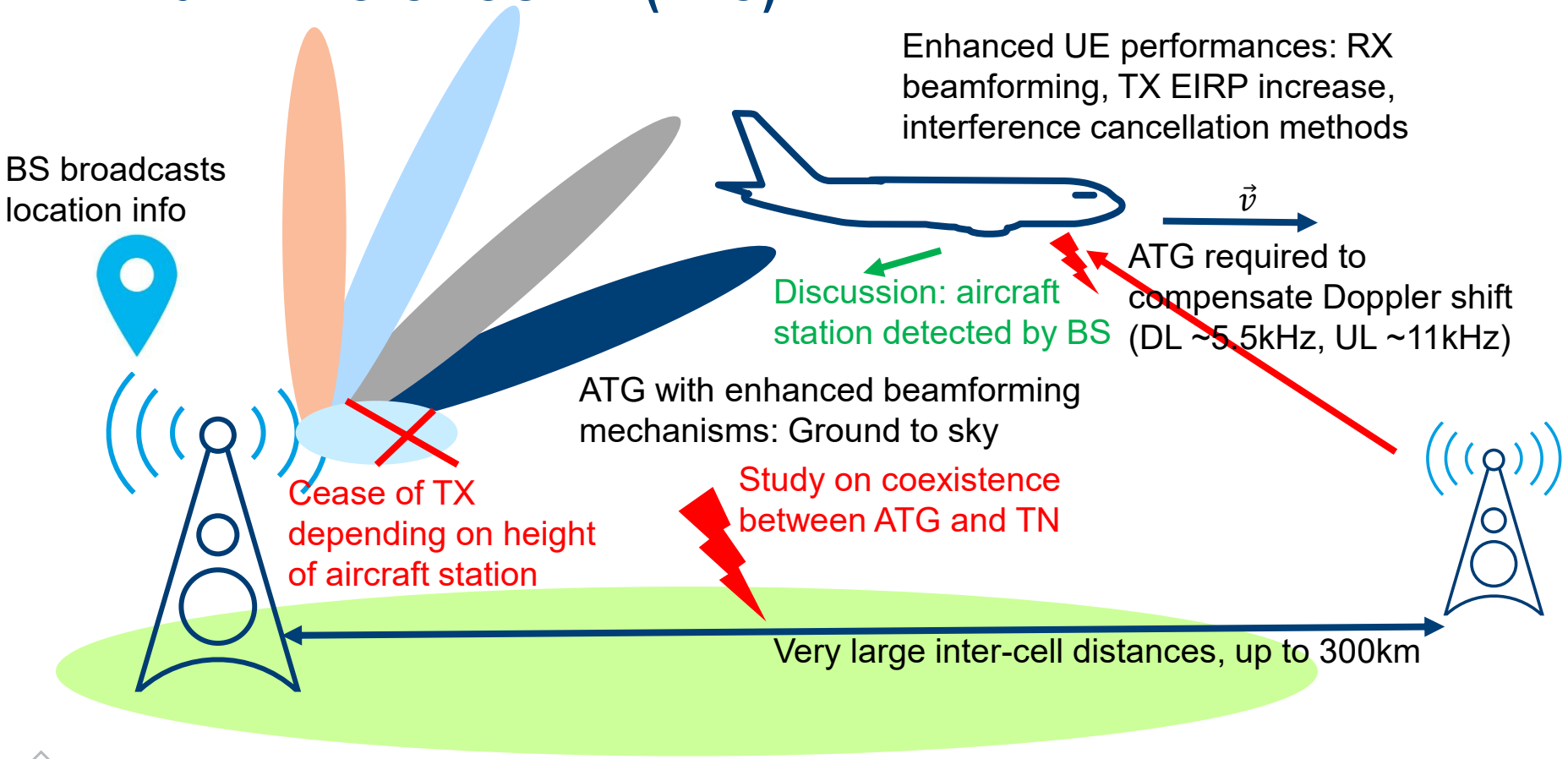
REL-18 AIR TO GROUND (ATG)

- Air-to-ground (ATG) network refers to in-flight connectivity technique, using ground-based cell towers that send signals up to an aircraft's antenna(s) of onboard ATG terminal. As a plane travels into different sections of airspace, the onboard ATG terminal automatically connects to the cell with strongest received signal power, just as a mobile phone does on the ground



- **Scenario**: to provide broadband access for civil aircrafts
  - ATG gNB deployed on the ground, with antennas pointing upward to form an aerial cell
  - Aircraft as a special UE
  - Aircraft to ATG gNB: 5G air interface
  - Aircraft to passengers: WiFi access

REL-18 AIR TO GROUND (ATG)



REL-18 UAV (UNCREWED AERIAL VEHICLE)

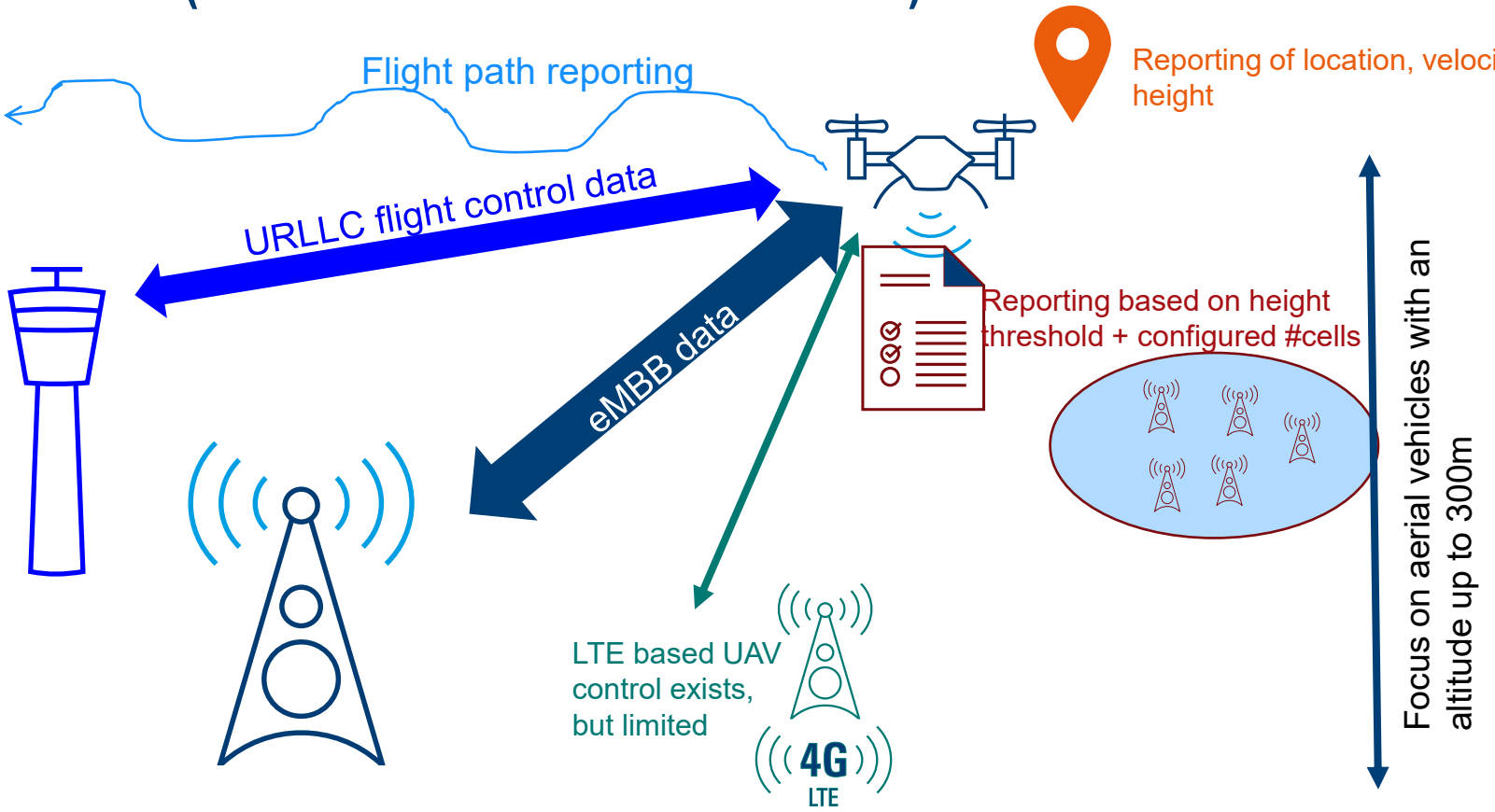
Justification

- uncrewed aerial vehicles based services increased,
- including e.g. for multiple drone operation, personal entertainment for flight experience, cargo delivery, etc.
- Need a capability for remote control / data transmission from operators and drone manufacturas
- Already studied in LTE , it shall be continued and need also low latency in NR
- Important aspect is potential interference with eNB/gNB operations

Objectives:

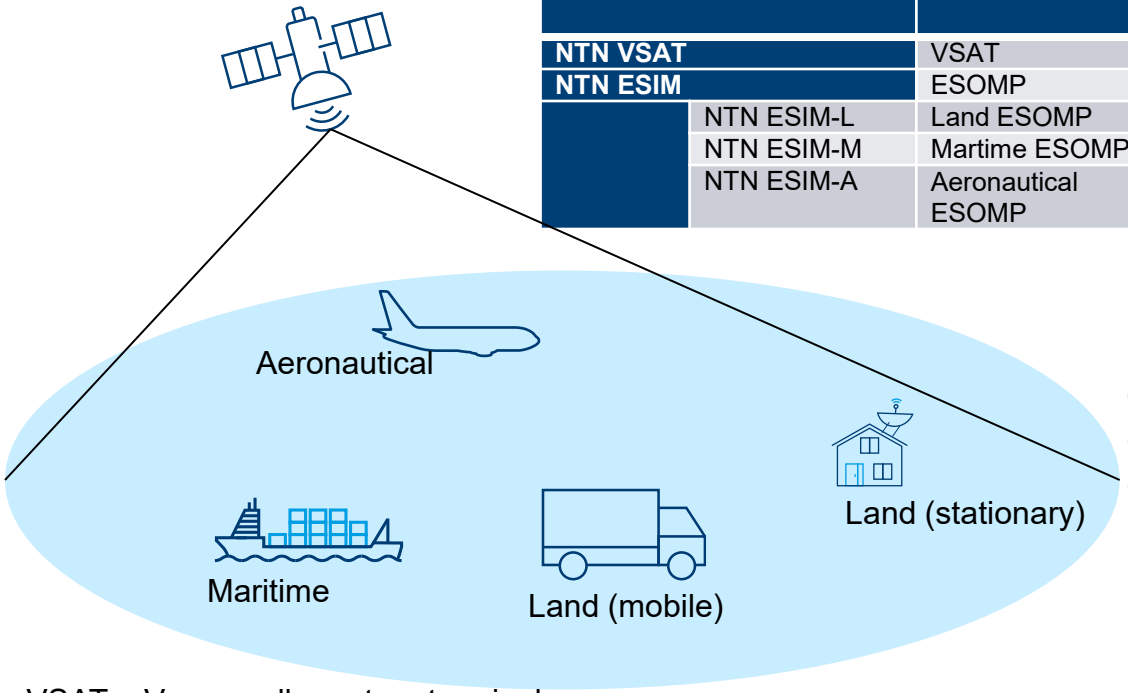
- Specify enhancements on measurement reports (i.e. reporting of height, location, speed in measurement report, flight path [RAN2]
- signaling to support subscription-based aerial-UE identification
- broadcast of UAV identification [RAN2, RAN1, SA2 interaction] for both LTE and NR

REL-18 UAV (UNCREWED AERIAL VEHICLE) – TOPICS TO BE DISCUSSED



NTN REL. 18 UE CATEGORY DISCUSSION (>10 GHZ)

Proposed naming in RAN4		CEPT	FCC	ACMA	Mobility	Satellite tracking feature
NTN VSAT		VSAT	Earth station	VSAT	No, fixed	No
NTN ESIM		ESOMP	ESIM	ESIM	Yes	Yes
	NTN ESIM-L	Land ESOMP	ESIM / VMES	ESIM-L		
	NTN ESIM-M	Martime ESOMP	ESIM / ESAA	ESIM-M		
	NTN ESIM-A	Aeronautical ESOMP	ESIM / ESV	ESIM-A		



RRM discussions:
Case-1: Stationary UE for GSO
Case-2: Stationary UE for LEO
Case-3: Mobile UE for GSO

UE architectures:
Fully electronically-steered beam UEs (Type 1)
Fully mechanically-steered beam UEs (Type 2)

VSAT = Very small aperture terminal
ESIM = Earth station in motion
ESOMP = Earth station on mobile platform

THANK YOU

Future networks: Fiber to the space (FTTS)