

#### HAPS D2D SERVICE

- ✈ 20km Altitude
- 🕒 Persistent Coverage
- ⚡ High Throughput
- 📶 Low Latency
- 📱 Direct-to-Device

#### CONNECTING EVERYONE, EVERYWHERE

- 📶 4G / 5G Compatible
- 🏠 Works Indoors & Outdoors
- 📱 Standard Smartphones
- 🛡 Secure & Reliable

# Non-Terrestrial Networks and Small Cells: *Regenerative HAPS D2D constellations*

GLASGOW

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**SMALLCELLS**  
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# Non-Terrestrial Networks: HAPS and Small Cells

- Thesis: NTN Small Cells operating from HAPS can deliver “True” Mobile Broadband
- D2D LEO NTNs: Some facts and figures and reference points
- What is a High Altitude Platform Station and a HAPS NTN Constellation?
- HAPS Communication Payload Challenge
- Why are 3GPP Small Cells the answer?





# LEO NTN Constellations

- It's getting busy in space...
  - ~115k planned LEO SATs
- LEO NTN is delivering Four Service Models
  - Fixed broadband
  - Nomadic Broadband
  - 3GPP NTN
  - IoT and M2M
- A few LEOs are focused on 3GPP NTN = Mobile Broadband

Launches in 2016 = 221  
Launches in 2025 = ~4300  
Launches in last 30 days = ~300

 BROADBAND INTERNET  
High-capacity data

 3GPP NTN  
Direct-to-device / Cellular NTN

 IOT / M2M  
Low data rate connectivity

 GOVERNMENT / DEFENSE  
Secure & sovereign networks

 CONSTELLATIONS  
30+ announced

 SATELLITES  
~115,000+ planned

 OPERATORS  
20+ countries





























































 INVESTMENT  
>\$100B committed

 SERVICE STARTS  
2019-2026+ ongoing rollout

HOW TO READ

 **FIXED BROADBAND**  
High-throughput services using dedicated terminals (dish / antenna)

 **3GPP NTN**  
Uses 3GPP standards (LTE/5G NR) to connect to phones, vehicles, IoT

CONSTELLATION	OPERATOR / COUNTRY (OWNERSHIP HIGHLIGHT)	PRIMARY SERVICE MODEL (KEY)	SERVICE TYPE (FOCUS)	STATUS	SATELLITES		ORBIT		SPECTRUM (EXAMPLES)	PARTNERS / INVESTORS (SELECT)	TARGET SERVICES
					OPERATIONAL	PLANNED	ALTITUDE	INCLINATION			
 STARLINK	SpaceX  (Private – USA)	 FIXED BROADBAND  3GPP NTN (Direct-to-Cell)	 Broadband Internet  Direct-to-Device	OPERATIONAL Global	10,370	~42,000	550 km	53° / 70° / 97.6°	 + many	T-Mobile SpaceX	Broadband, Mobility, Direct-to-Cell, IoT
 OneWeb	Eutelsat Group (OneWeb) (Public/Private)  	 FIXED BROADBAND  3GPP NTN (Direct-to-Cell)	 Broadband Internet  Direct-to-Device	OPERATIONAL Global	648	648	1,200 km	87.9°	 = SoftBank	Eutelsat Group SoftBank	Broadband, Enterprise, Government, Backhaul
 amazon project kuiper	Amazon  (Private – USA)	 FIXED BROADBAND	 Broadband Internet	IN DEVELOPMENT Initial launches 2024	78	3,236	590 / 610 / 630 km	42° / 51.9° / 33°		Amazon	Broadband, Enterprise, Government
 TELESAT LIGHTSPEED	Telesat  (Public – Canada)	 FIXED BROADBAND	 Broadband Internet	IN DEVELOPMENT First launches 2026	–	198	1,015 km	35°	 MDA	Telesat MDA	Broadband, Mobility, Government
 IRIS <sup>2</sup>	EU Consortium  (EU Sovereign Programme)	 BROADBAND  IOT / M2M	 Broadband Internet  IoT / M2M	IN DEVELOPMENT First launches 2025	–	290+	~750 km	Ka-band	 eesa	EU / ESA	Secure Connectivity, Government, Enterprise
 中国星网 CHINA SATNET GW	China SatNet (GW) (State – China) 	 FIXED BROADBAND  IOT / M2M	 Broadband Internet  IoT / M2M	IN DEVELOPMENT First launches 2024	–	12,992+	1,100 km	Ku / Ka / Q/V		China SatNet	Broadband, Mobility, Government, IoT
 上海星座 SPACESAIL	Shanghai SpaceSail (Private – China) 	 FIXED BROADBAND  IOT / M2M	 Broadband Internet  IoT / M2M	IN DEVELOPMENT First launches 2024	–	648	~600 km	Ku / Ka	 CICC CICC ALPHA	CICC	Broadband, Mobility, IoT, Maritime, Aviation
 O3b mPOWER	SES  (Public – Luxembourg)	 FIXED BROADBAND	 Broadband Internet	OPERATIONAL Global	17	17	~8,000 km	Ka-band		SES	Enterprise, Maritime, Aviation, Government
 LYNK GLOBAL	Lynk Global  (Private – USA)	 3GPP NTN	 Direct-to-Device Messaging, Voice, IoT	BETA / EARLY SERVICE Selective coverage	7	100+	500 km	GSM / LTE (Licensed)	+ mobile operators	Lynk Global	Direct-to-Device Messaging, Voice, IoT
 AST SpaceMobile	AST SpaceMobile  (Private – USA)	 3GPP NTN	 Direct-to-Device Broadband (5G)	BETA / EARLY SERVICE Selective coverage	5	~168	~700 km	Licensed (AT&T, Others)		AT&T	Direct-to-Device Broadband (5G)




KEY TAKEAWAYS

- LEO NTN is expanding rapidly across broadband, D2D and IoT.
- 3GPP NTN enables connectivity to everyday devices.
- Fixed broadband constellations deliver high-capacity services using dedicated terminals.
- Partnerships with telcos, governments and cloud providers are accelerating adoption.

NOTES

- Numbers reflect public information as of May 2025 and are subject to change.
- Many constellations are in phased deployment.
- Additional smaller IoT constellations not listed.
- Orbits vary within constellations; values show typical ranges.



OTHER ANNOUNCED / EMERGING CONSTELLATIONS (SELECT)

 Swarm

 HawkEye 360

 Satellot

 Unseenlabs

 Kepler

 Plan-S

 Yaliny

 BharatNet (IN-SPACE)

 NileSat

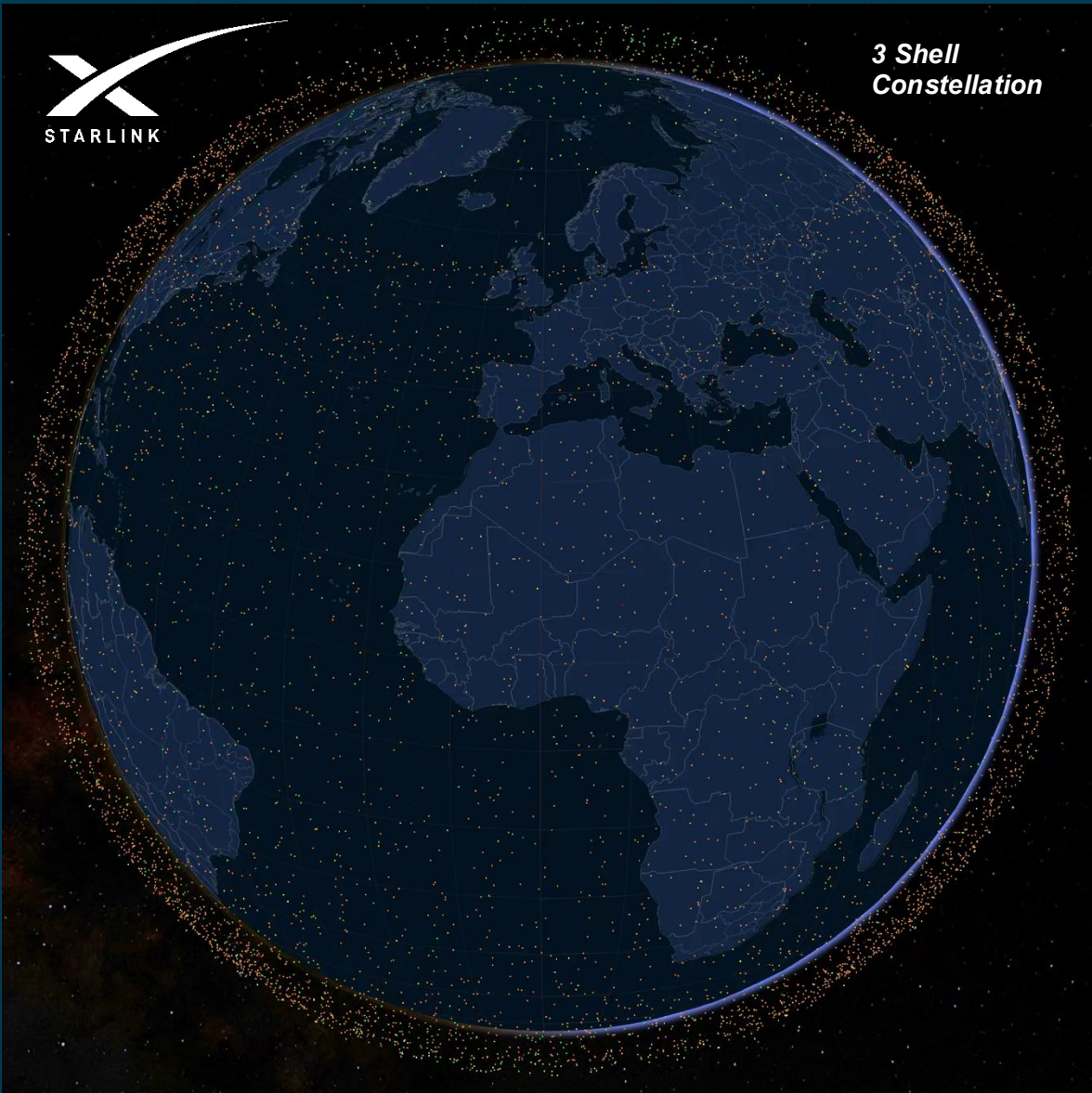
...and more

KEY:  FIXED BROADBAND =   
 3GPP NTN = 



Current Status

First Launched	May 24, 2019
Planned Size	42,000
Total Launched	11935
Active Satellites	10370
Decayed	1565
Hardware Types	v2 mini, v2 mini d2c, v1.5
Last Launch	May 20, 2026





- US Coverage: 2.3% = ~220-300
- **UK Coverage: 0.09% = ~12-20**
- India Coverage: 0.55% = ~75-120

## Limited Coverage Footprint

- Depending on generation and sharing across all customers

- Gateways provide backhaul connection to internet
- GW capacity is shared across LEO Sats
- Starlink has 7 Gateway sites
  - Ka, E, and Q/V Bands
  - Higher frequency bands are impacted by the weather
  - and tracking angles to Horizon

## Limited Delivery Capacity



# Direct to Device (D2D / Direct to Cell)

3GPP NTN Direct-to-Device service much is more challenging...

Currently Starlink has ~660 DTC Satellites in service.

- Example: This means 1-2 over UK at any time
- Typically operating with narrow 5MHz FDD channels
- Large channel sizes are almost impossible

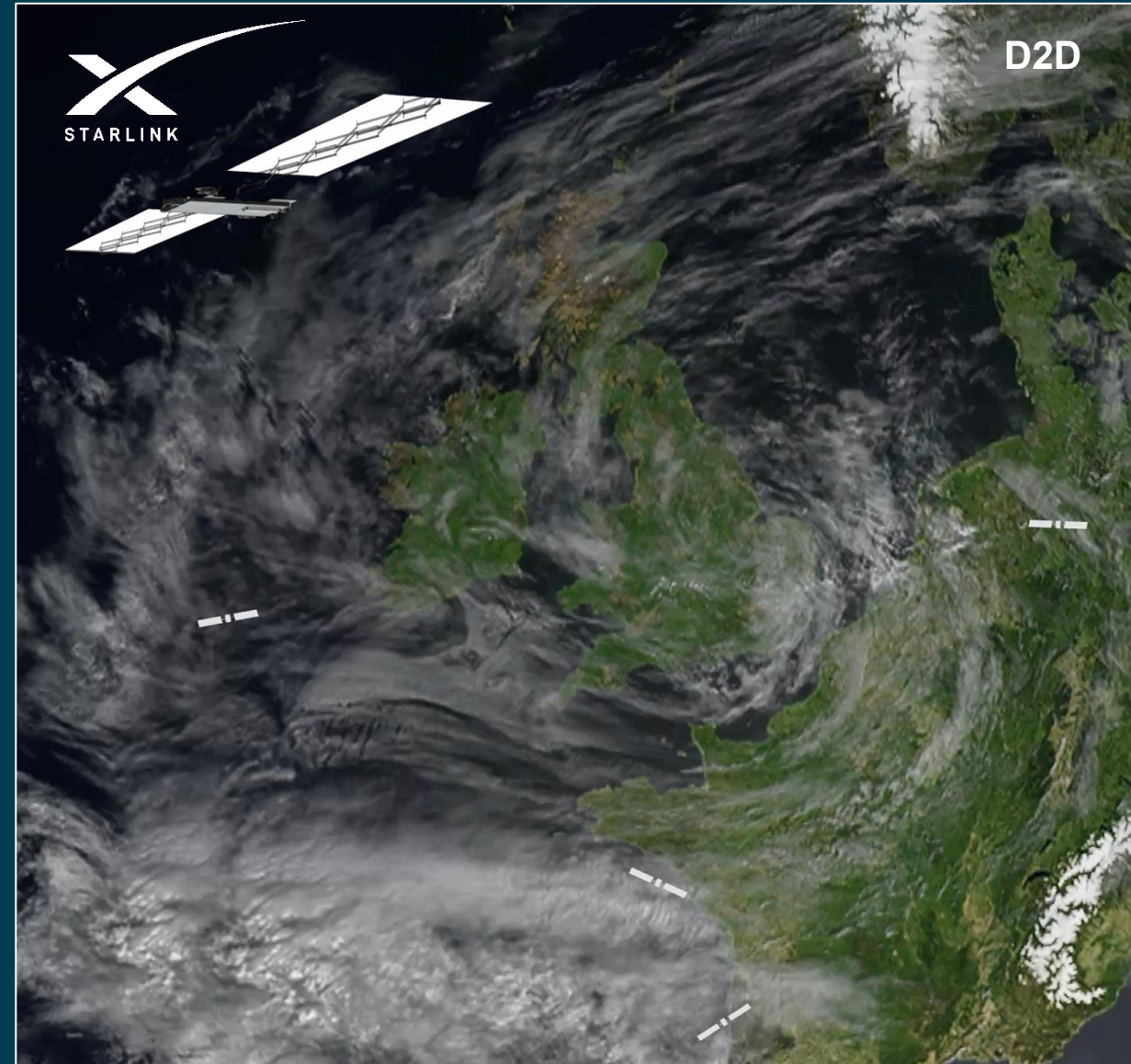
## Capacity per LEO Sat is limited

- 48 beams per Sat = ~200 Mbit/s
- Uplink capacity is extremely limited
- Very poor link budget = Messaging only!
  - From 0dBi gain antenna and ~23dBm Tx Power



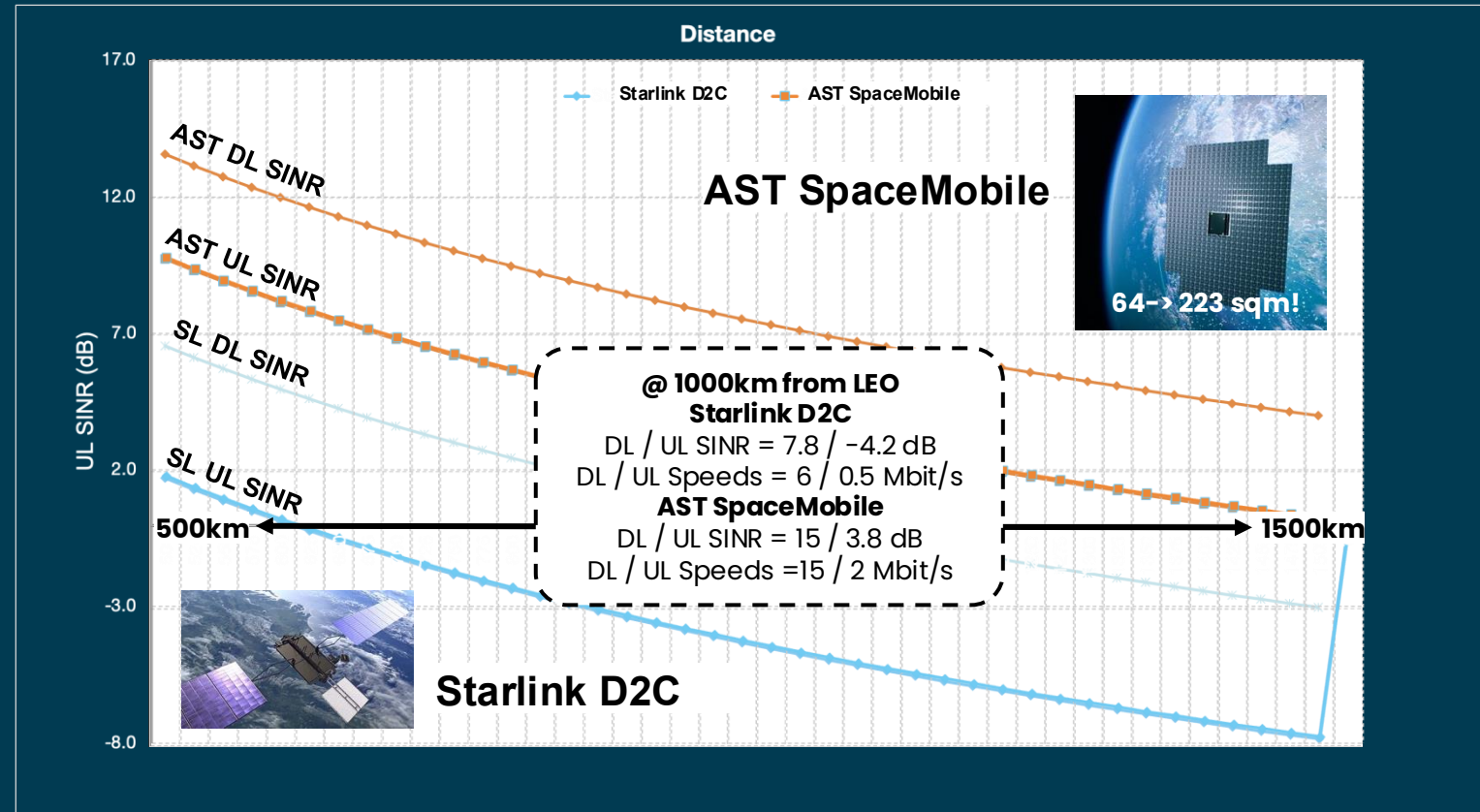
Service?

## Why is the Capacity limited?



# LEO D2D: What can it deliver?

- **Some simple Link Budgets....**
  - 500km to 1500km
  - 5 MHz FDD at 1.8 GHz
  - Standard UEs
  - for LOS Outdoor Coverage
    - Starlink D2D
    - AST SpaceMobile
  - Basically Noise Limited
    - limited “rural” terrestrial interference
- **Typical SINR Plots show the limited service both LEO solution provide**
  - UL SINR is the key challenge



**Does deliver simple messaging/text and voice, and some limited data services**  
**LEO D2D providers will improve link budget but always challenged by >500km distances**



# What is a High-Altitude Platform Station (HAPS)

- Also called “Stratospheric pseudo-satellites”
  - or a giant solar powered Drone!
- In an NTN D2D context a HAPS is a mobile phone “Tower-in-the-sky”
- 15+ companies actively developing platforms that can permanently fly in the stratosphere

## Growing Eco-system of HAPS Both Lighter-than-Air and Heavier-than-Air





# HAPS NTN – Can it do better?

## EARTH CURVATURE & ALTITUDE COMPARISON

### LEO SATELLITE (500 km) vs FIXED-WING HAPS (20 km)

Centered over the UK

#### LEO SATELLITE (500 km)

- Altitude: 500 km
- Horizon range: ~2,500 km
- One-way signal delay: ~2.5 ms
- Coverage footprint: Very wide area (thousands of km radius)

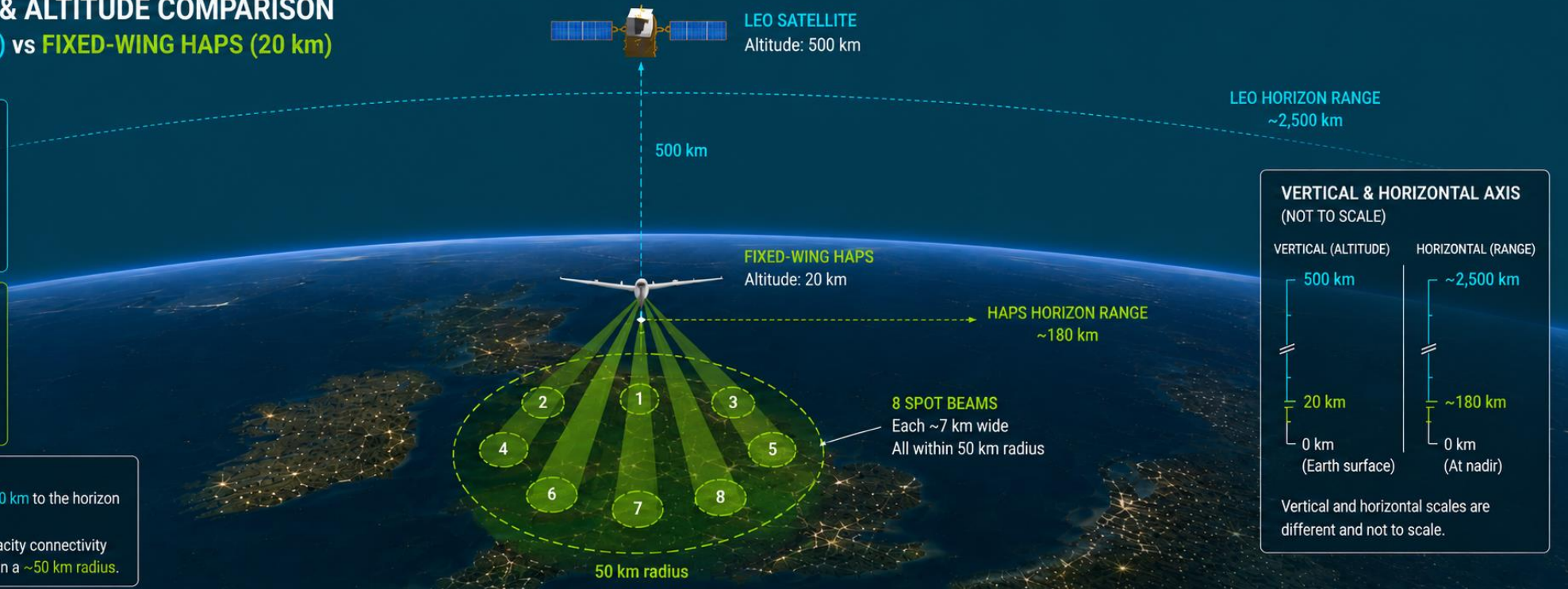
#### FIXED-WING HAPS (20 km)

- Altitude: 20 km
- Horizon range: ~180 km
- One-way signal delay: ~0.1 ms
- Coverage footprint: ~50 km radius (per spot beam)

#### KEY TAKEAWAY

The LEO satellite at 500 km sees ~2,500 km to the horizon and covers a very wide area.

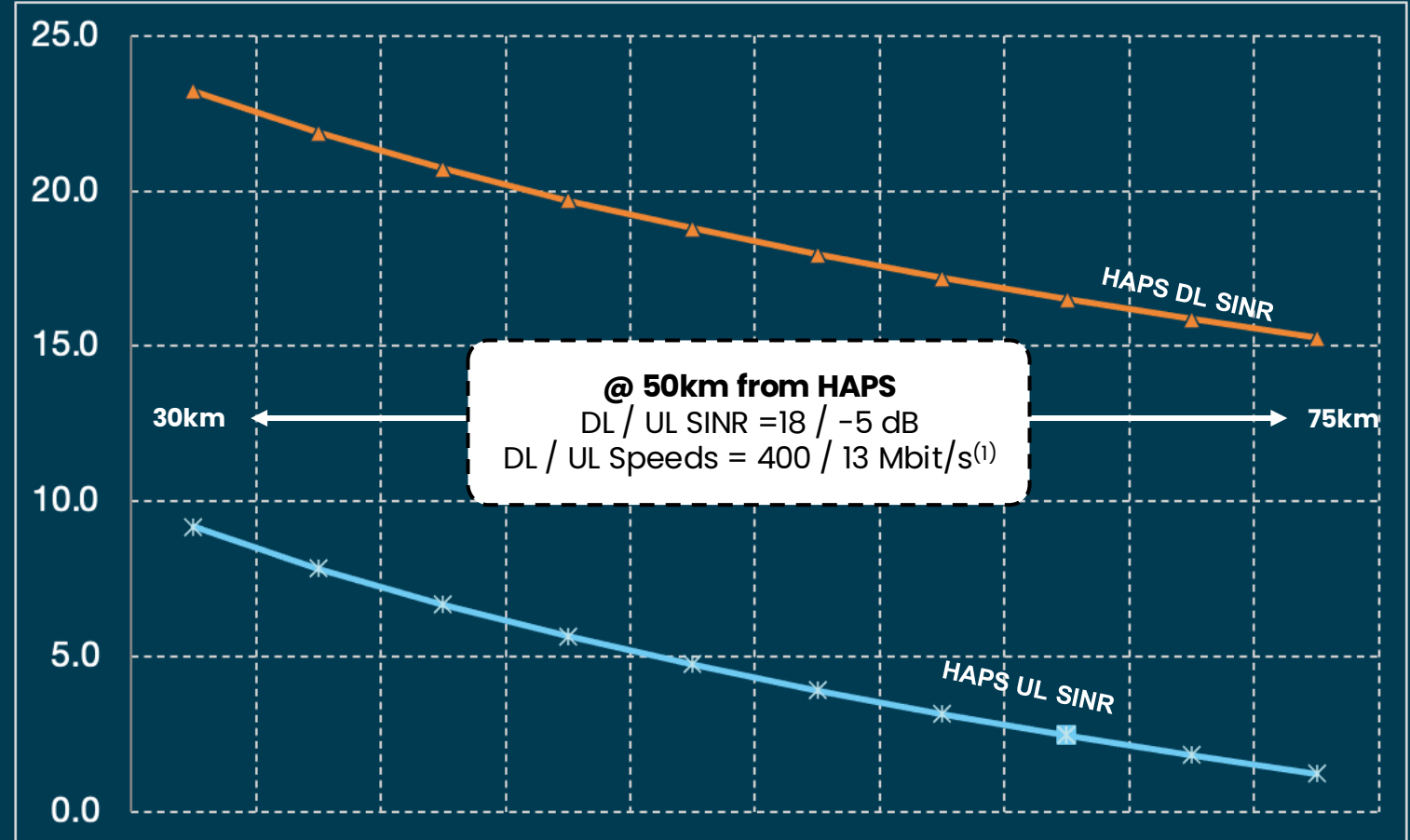
The HAPS at 20 km provides high-capacity connectivity using 8 spot beams (~7 km wide) within a ~50 km radius.



- Concept is a fleet of HAPS Aircraft, just like LEO Satellite Constellations – But at 20km not 500km+
- HAPS has the potential deliver a “true” mobile Broadband Service... Why?

# HAPS D2D: What can it deliver?

- **Again, a simple Link Budget....**
  - Distances from 30km to 75km
  - using 100 MHz 5G NR in n77 in DL
    - Using 10 MHz in Uplink
  - to regular handsets (UEs)
  - for LOS Outdoor Coverage
  - Noise Limited
- **Typical SINR Plots show the service a HAPS solution could potentially provide**
  - SINRs are better (both DL and UL)
  - UL from regular handsets is still challenging
  - Much higher uplink performance possible with FWA style CPEs



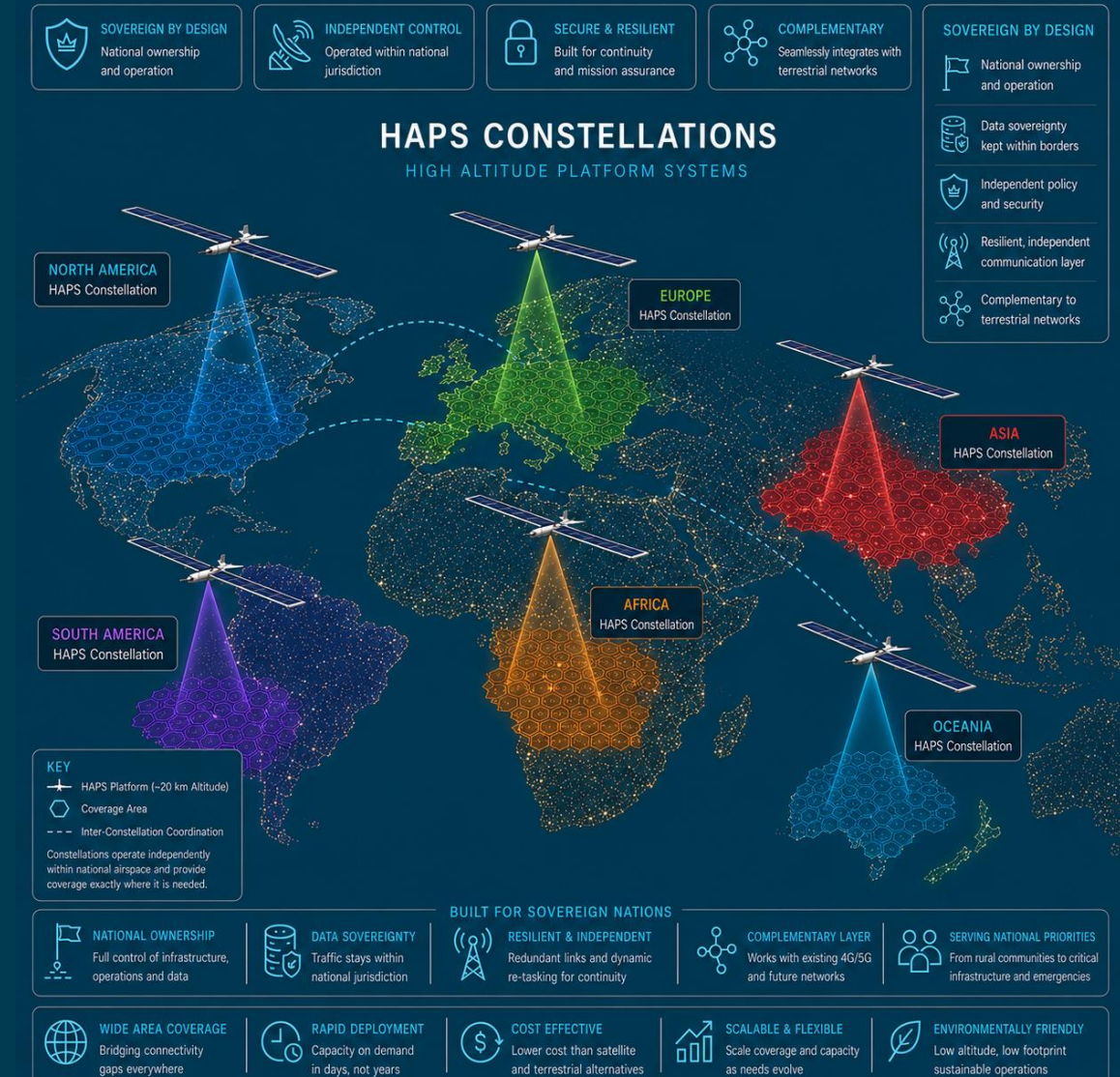
**HAPS D2D link significantly better - delivers “True” Mobile Broadband**

(1) – Scheduled over 10 MHz, rather than full 100 MHz



# HAPS NTN – Sovereign Networks

- The **KEY** advantage of HAPS over LEO is that it is possible to build Sovereign Networks
  - Per Country / Region basis
  - Per Use Case basis
  - Per Mobile Operator / Neutral Host basis
- **Geo-Political, Data sovereignty and Security issues can often make the use of LEO D2D problematic**
  - Often requires special Backhaul / Ground Station arrangements
- **MNOs are increasingly skeptical about the intentions of Starlink, as it acquires spectrum assets globally**
- **Regional HAPS networks allow Airborne Regulation (FAA, CAA, EASA...) to move at different pace**
  - enabling earlier deployment





# HAPS NTN – Different Use Cases

## HAPS CONSTELLATION PROVIDING TARGETED SERVICES TO THE UK

FLEXIBLE • RESPONSIVE • COST-EFFECTIVE

A constellation of High Altitude Platform Stations delivering capacity exactly where and when it's needed.

HAPS Constellation  
~20 km Altitude



### RURAL IN-FILL COVERAGE

Bringing reliable 4G/5G connectivity to hard-to-reach rural and remote communities.

- Agriculture
- Remote workers
- Public safety
- Education & healthcare



### SPECIAL EVENTS

On-demand high capacity for temporary events.

- Sports & entertainment
- Festivals
- Major gatherings
- Emergency response



### MARITIME COVERAGE

Seamless connectivity over UK waters and beyond.

- Commercial shipping
- Fishing fleets
- Offshore energy
- Search & rescue
- Leisure & yachting



### PRIVATE NETWORKS

Secure, dedicated connectivity for business and critical operations.

- Industrial sites
- Energy & utilities
- Mining & construction
- Secure communications

### CAPACITY / SERVICE LEVEL

- Very High Capacity
- High Capacity
- Medium Capacity
- Rural / Wide Area
- Private / Dedicated
- Maritime Coverage

### KEY CHARACTERISTICS

- Persistent High Altitude Coverage
- Rapid Re-Tasking & Dynamic Steering
- Targeted Capacity Where Needed
- Direct to Device (D2D) & 3GPP Small Cell Compatible
- Integrates with Existing 4G/5G Networks & Core



### DEPLOY RAPIDLY

Days to activate capacity



### TARGET PRECISELY

Capacity where it's needed



### COST-EFFECTIVE

Lower cost per bit



### RESILIENT & RELIABLE

Built for mission-critical use



### SUSTAINABLE

Low environmental impact

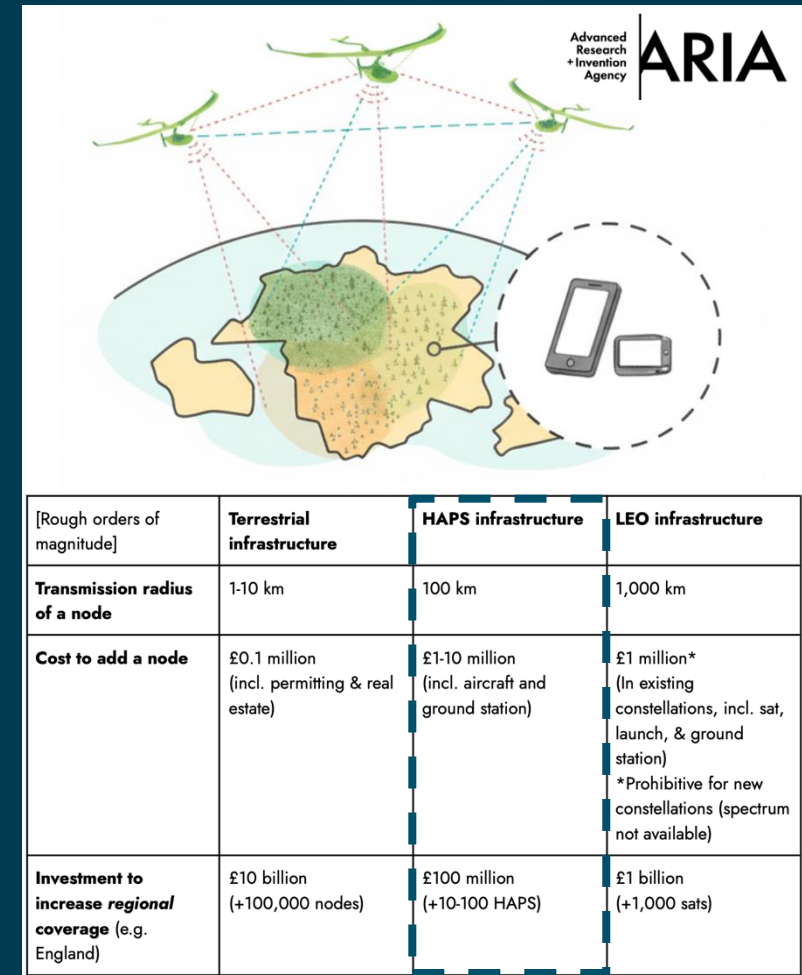
**HAPS D2D NTN can support a range of use cases and is a “Steerable” capability**





# UK: Aria “Enduring Atmospheric Platforms”

- UK Government is investing £50m to accelerate HAPS ecosystem development over the next 2–3 years.
  - R&D Funding Competition
    - TA1: Breakthrough technologies for persistent atmospheric platforms
    - TA2: Integrated HAPS system development and demonstration
    - TA3: Communications architecture and Deployment planning (Digital Twin)
- The Aria Thesis is:
  - A HAPS D2D network reduces path loss roughly 600× versus LEO D2D, enabling efficient “true” direct-to-device connectivity.
  - HAPS delivers multi-Mbps broadband directly to standard 4G/5G smartphones, including some indoor coverage.
  - Persistent regional coverage enables terrestrial-like connectivity
  - Regional HAPS costs are 10–100× lower terrestrial or LEO infrastructure.
  - HAPS constellations could cost <£100m for nation-scale deployment.



**Aria will announce their awards in a few weeks!**













**Aria “HAPS” Thesis...**



# Japan: Sovereign HAPS



- SoftBank and Space Compass are leading commercial deployment.
- Japan sees HAPS as core 6G infrastructure, not an experiment.
  - MIC, NICT and NEDO are heavily funding HAPS R&D.
- Target HAPS use cases are to support rural coverage, disaster recovery and maritime connectivity.
- HAPS will also provide a D2D Service for SoftBank and NTT DoCoMo
- Solar power, lightweight airframes and energy storage are key challenges.

GOVERNMENT FUNDING & R&D PROGRAMS SUPPORTING HAPS				
MIC	NICT	NEDO	Beyond 5G / 6G Promotion Strategy	Other Partners & Ecosystem
<p>Ministry of Internal Affairs and Communications</p>  <p>Leads national policy, spectrum allocation, and supports R&amp;D for NTN (satellite, HAPS, UAV). HAPS is a strategic part of Japan's Beyond 5G/6G and resilience policy.</p> 	<p>National Institute of Information and Communications Technology</p>  <p>Japan's ICT R&amp;D agency and manager of the "Innovative ICT Fund Projects for Beyond 5G/6G". Provides grants for research, prototypes and trials.</p> 	<p>New Energy and Industrial Technology Development Org.</p>  <p>Funds HAPS-related technologies to improve endurance, energy efficiency and reduce weight – critical for practical deployment.</p> 	<p>Beyond 5G/6G</p>  <p>Cabinet-level strategy positioning NTN (satellites, HAPS, UAVs) as essential infrastructure for Japan's digital future and global competitiveness.</p> 	 <p>Wide ecosystem of Japanese companies, universities and research institutes working together on HAPS.</p> 
KEY ACTIVITIES	KEY HAPS PROJECTS (Examples)	HAPS-FUNDED PROJECTS (Examples)	KEY GOALS	PARTICIPANTS INCLUDE
<ul style="list-style-type: none"><li>✓ Spectrum studies &amp; regulatory frameworks for HAPS</li><li>✓ Disaster-resilient connectivity policy</li><li>✓ International coordination (ITU)</li></ul>	<ul style="list-style-type: none"><li>✓ HAPS payload technology (trials using SoftBank platforms)</li><li>✓ NTN radio &amp; network technologies</li><li>✓ Interference &amp; coexistence studies</li><li>✓ 6G system integration research</li></ul>	<ul style="list-style-type: none"><li>✓ High energy density battery packs</li><li>✓ High-efficiency solar cells for HAPS</li><li>✓ Lightweight structures &amp; materials</li><li>✓ Power management systems</li></ul> <p>(4-year program from FY2025)</p>	<ul style="list-style-type: none"><li>✓ Global leadership in 6G standards &amp; IP</li><li>✓ Strong domestic industry &amp; supply chain</li><li>✓ Social implementation &amp; global contribution</li></ul>	<ul style="list-style-type: none"><li>✓ Aerospace: IHI, Mitsubishi Heavy Industries, Kawasaki Heavy Industries</li><li>✓ Telecoms: SoftBank, NTT</li><li>✓ Universities &amp; research labs</li><li>✓ Component &amp; materials suppliers</li></ul>
 <p>Coordinated government–industry funding builds Japan's capability in HAPS, driving 6G/NTN innovation, resilience and global leadership.</p> 				

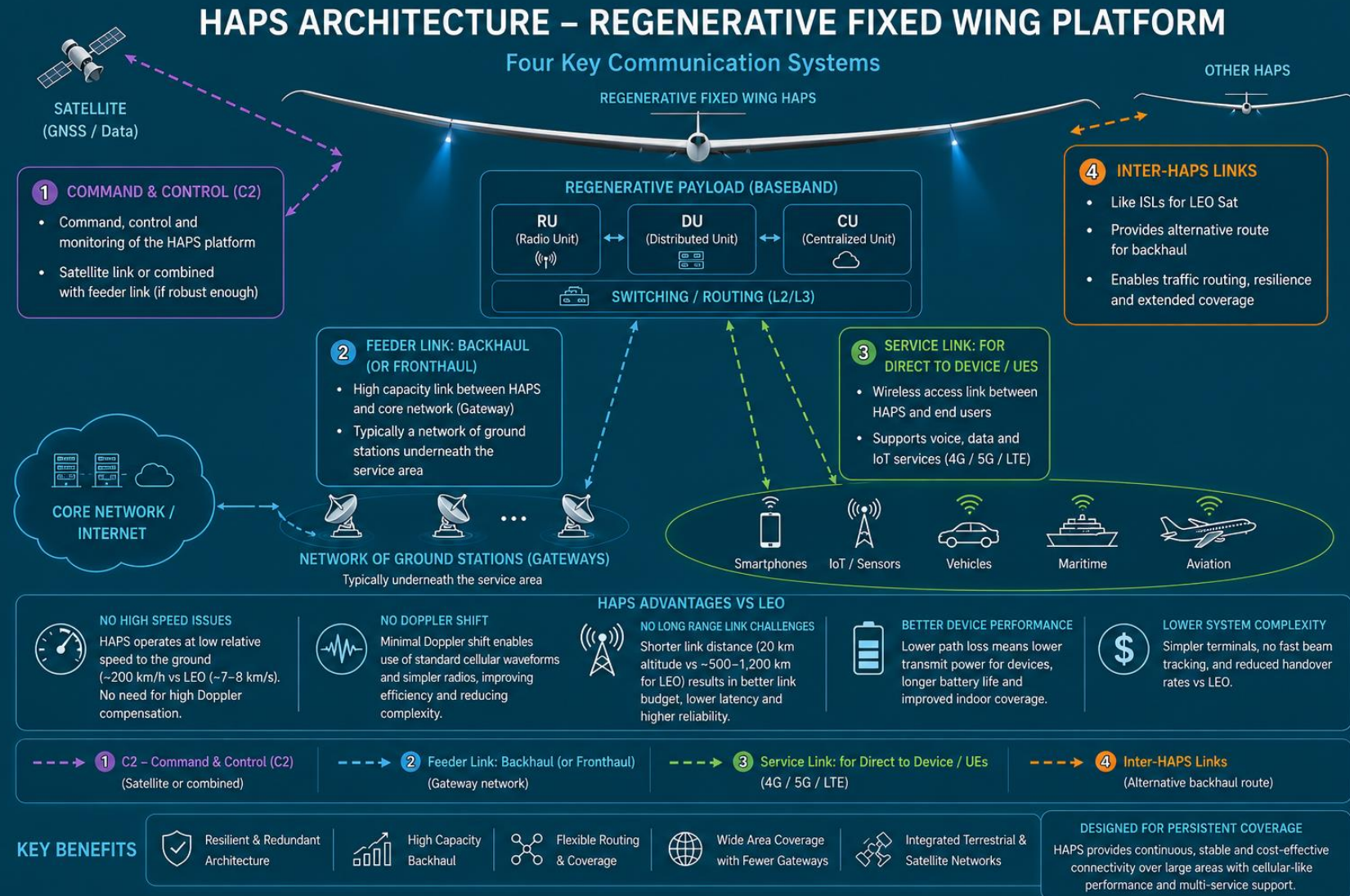
Japan aims to build a sovereign nationwide “Sky Network” for NTN and 6G.



# Regenerative Direct-to-Device HAPS Architecture

## Four Communication Systems

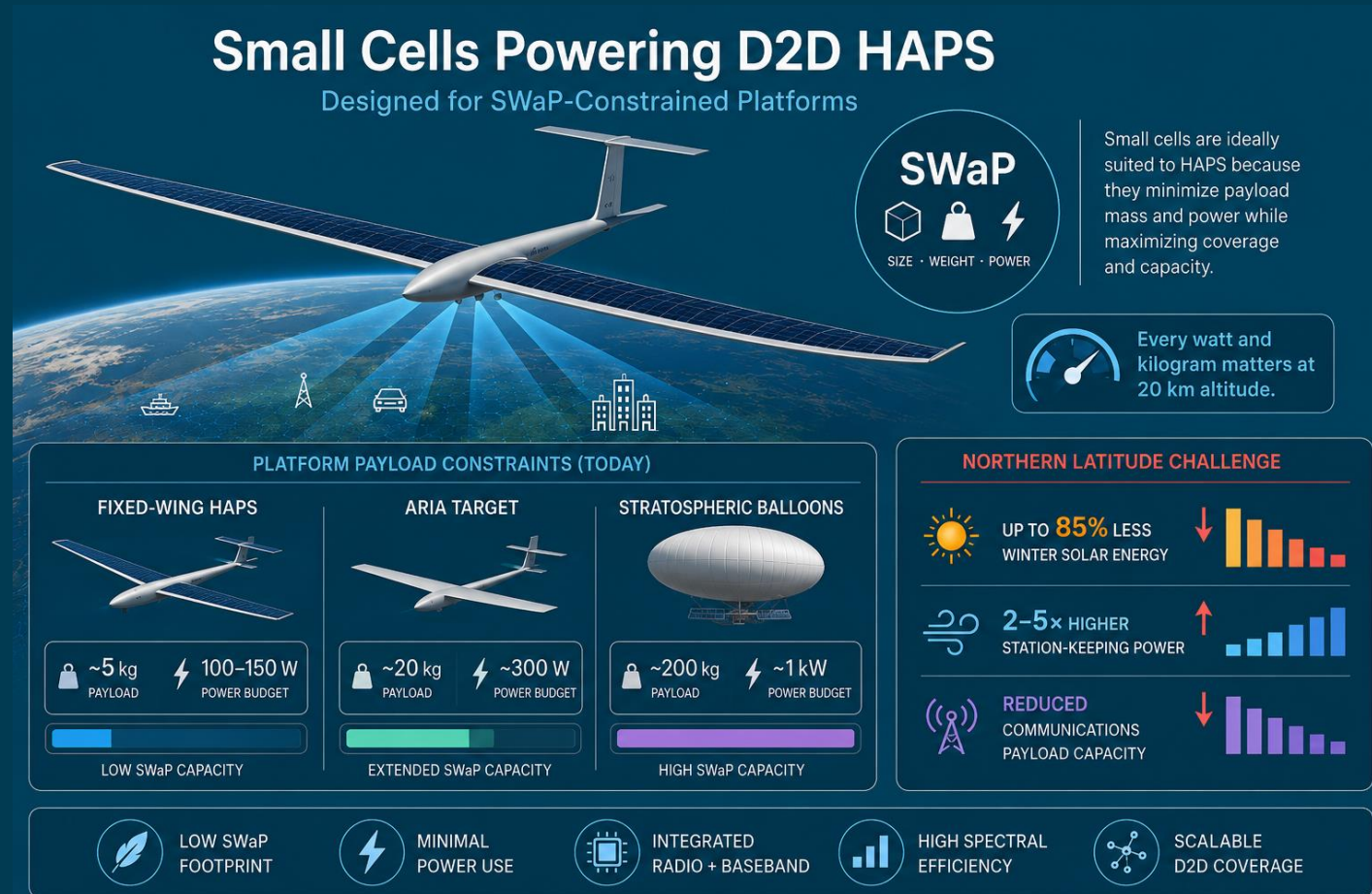
- **Command & Control (C2)**
  - Controls and monitors the HAPS platform.
  - Via satellite link or integrated feeder link.
- **Feeder Link (Backhaul/Fronthaul)**
  - Connects HAPS to the core network.
  - Typically uses a network of ground gateway stations.
- **Service Link**
  - Provides 3GPP direct connectivity to user devices (UEs).
  - Supports smartphones, IoT, fixed wireless, maritime and aviation users.
- **Inter-HAPS Links**
  - Connect HAPS platforms together, like LEO ISLs.
  - Enable traffic routing, resilience, and alternative backhaul paths.



# Small Cells and HAPS: The Payload Challenge

All good so far.... now comes the catch!

- **Flights at Northern Latitudes (>50°) very challenging (aka UK / Japan)**
  - less winter solar energy
  - higher station-keeping power requirements
  - Longer nights, colder temperatures, stronger winds
- **Solar powered HAPS aircraft already have limited communication payload capabilities (the SWaP)**
  - **Fixed Wing:** 5kg and 100-150W
  - Aria Target: extend to 20kg and 300w
  - **Balloons:** 200kg and 1kW
  - But at Northern Latitudes the capability rapidly reduces

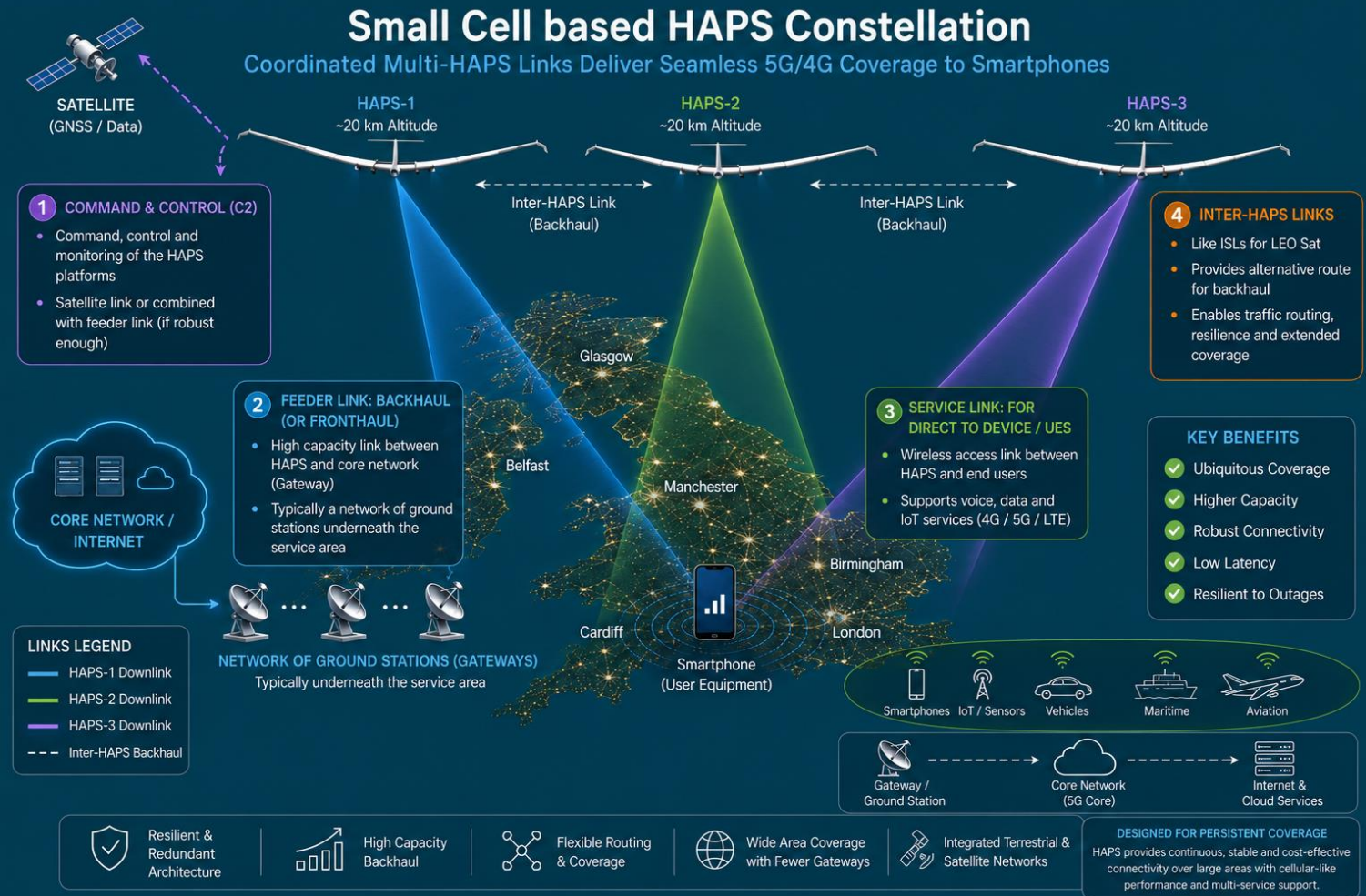


**Lightweight, Power Efficient**  
**Small Cell technologies are the key!**



# Small Cells: Key Requirements for HAPS D2D

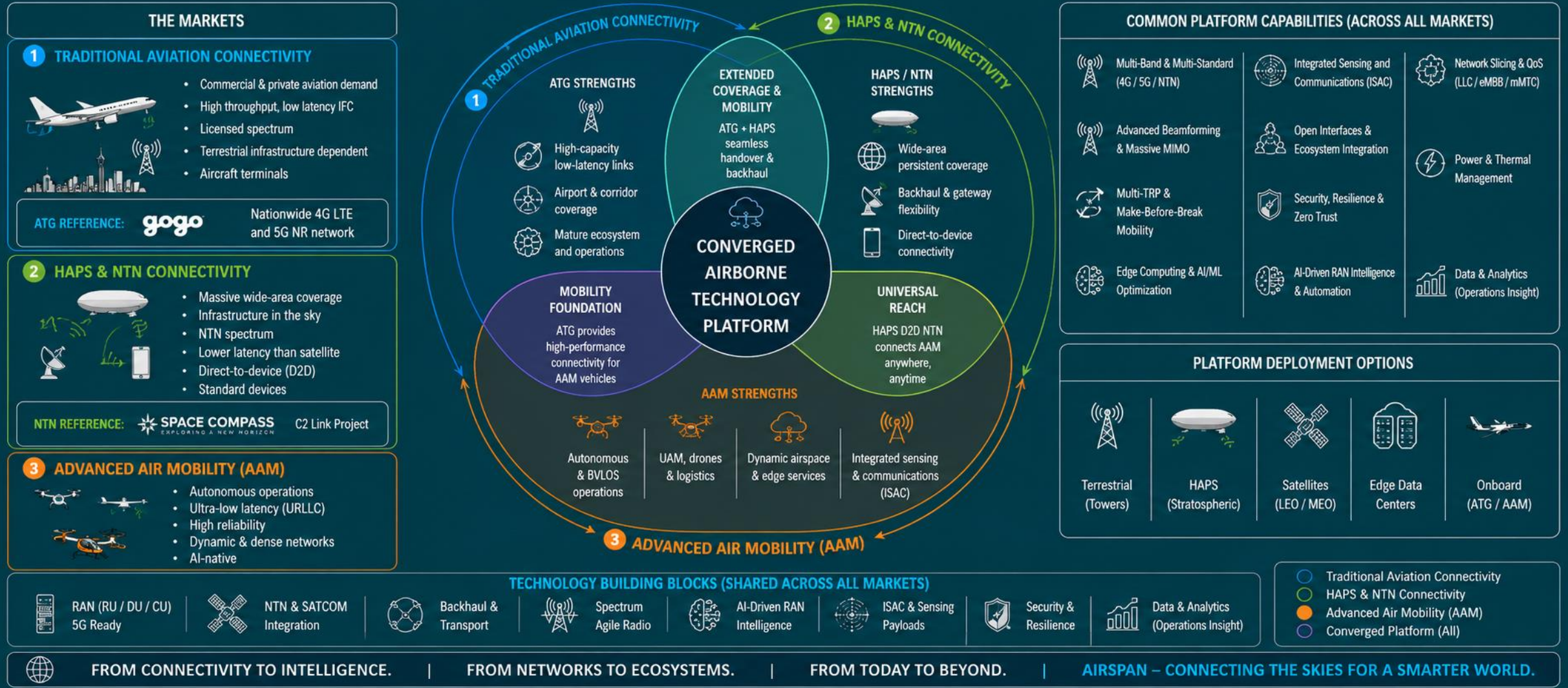
- **5G (and 6G) D2D Services from HAPS constellations are a compelling proposition**
- **The most likely requirements:**
  - Support LTE, 5G and 6G evolution
  - Ultra-low SWaP: < 20 kg, < 300 W
  - Direct-to-device connectivity using standard smartphones (incl. legacy)
  - Fully integrated radio and baseband
  - Advanced beamforming and Massive MIMO-Like capabilities (N x spot beams)
  - Neutral-host operation across multiple MNOs (UK JOTS option?)
  - Inter-HAPS links for resilience backhaul routing



**Small Cell technologies key to making this vision real**



# Airspan: Converged Airborne Connectivity Platform



Based on next generation small cell solutions