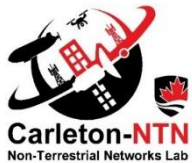


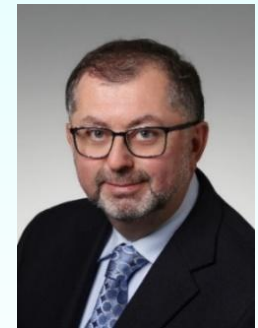


Telecom / Mobile Networks / 3GPP Ecosystems at Crossroads

The **NTN** Perspective



Halim Yanikomeroglu
Chancellor's Professor | Systems and Computer Engineering
Founding Director | **Carleton-NTN Lab**
Carleton University



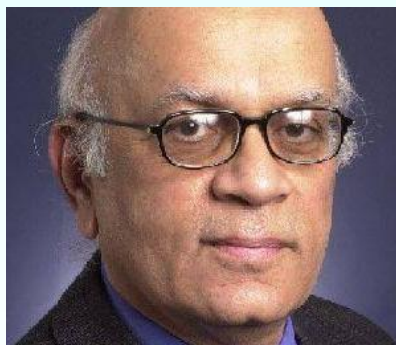


Heartfelt Thanks

- WWRF Fellows Nomination Committee
- WWRF Steering Board
- My nominator and endorsers



Mohamed-Slim Alouini
WWRF Fellow



Vino Vinodrai
WWRF Fellow



Veena Rawat
WWRF Fellow



Some Highlights from WWRF History

- Established in August 2001 → Silver Jubilee
- Carleton joined WWRF around 2002 (David Falconer, Halim Yanikomeroglu)

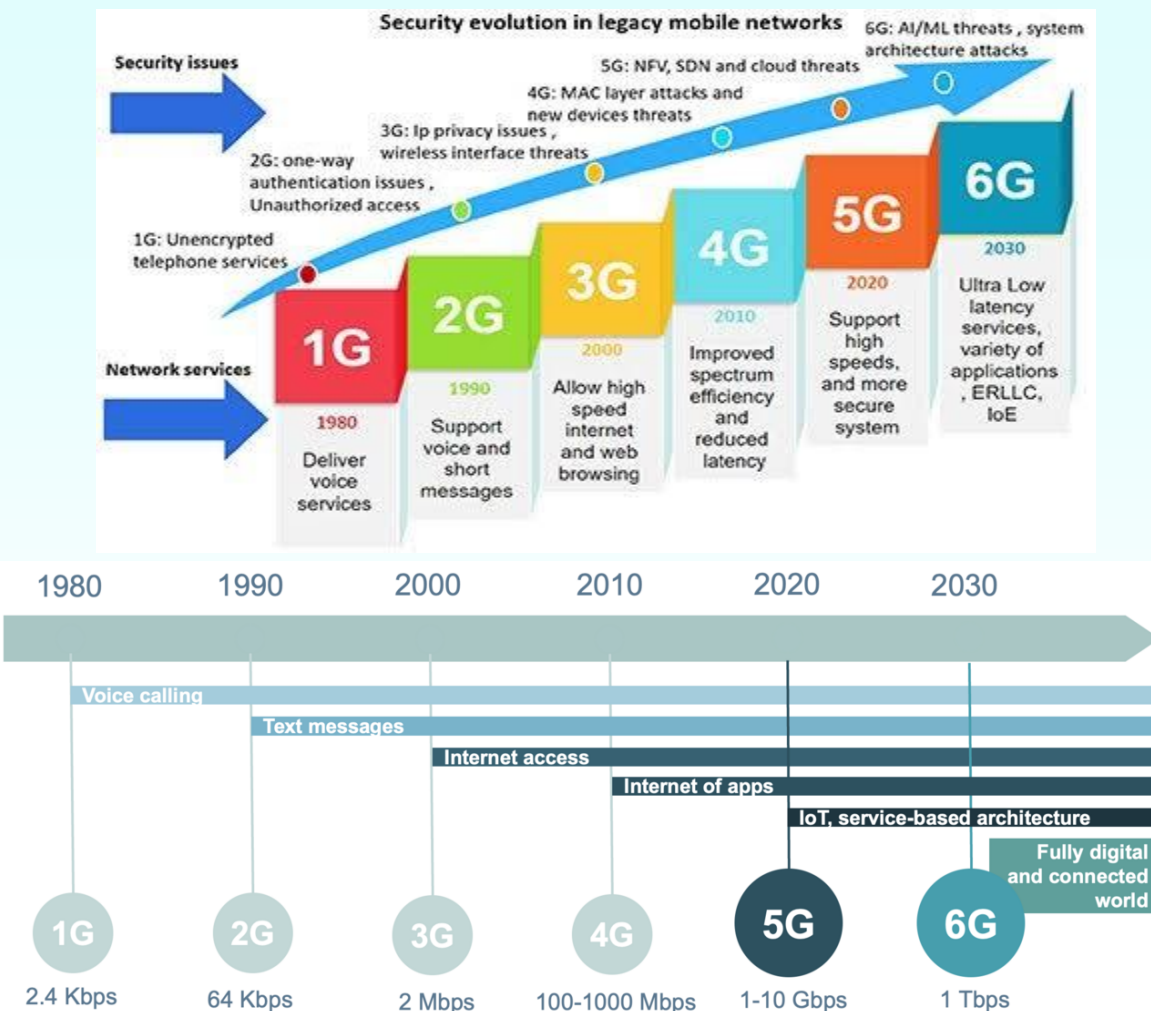


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- “Relay-based deployment concepts for wireless and mobile broadband radio”, *IEEE Communications Magazine*, September 2004
2,300+ citations including 128 in patents
- WWRF → FP6 WINNER Project → 4G LTE (Rel-8, -9, -10)



Evolution of Mobile Networks: Linear and Predictable Progress



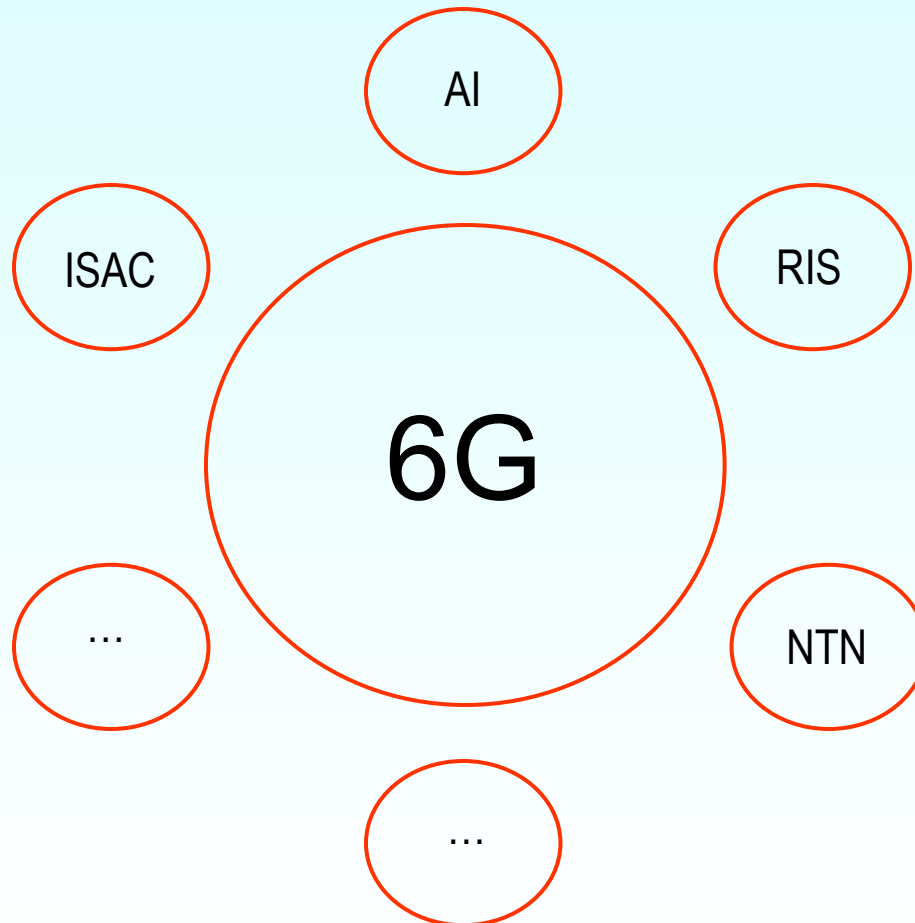


Emerging Transformative and Disruptive Paradigms

- AI & **NTN**
- Good news or bad news?
- How to position wrt transformative and disruptive paradigms?



Positioning 6G wrt AI and NTN | yesterday





Positioning 6G wrt AI and NTN | today

AI

The diagram consists of three large, overlapping circles arranged horizontally. Each circle has a red outline and a light blue fill. The left circle is labeled "AI", the middle circle is labeled "6G", and the right circle is labeled "NTN". The circles overlap in the center, creating a common intersection area for all three.

6G

NTN



No.	Symbol	Company Name	Market Cap ∨	Stock Price	% Change	Revenue
1	NVDA	NVIDIA Corporation	5.09T	210.96	-3.36%	302.97B
2	AAPL	Apple Inc.	4.86T	333.08	0.24%	466.82B
3	GOOGL	Alphabet Inc.	4.27T	349.39	3.22%	445.87B
4	MSFT	Microsoft Corporation	3.75T	505.41	1.97%	331.84B
5	AMZN	Amazon.com, Inc.	2.73T	253.54	-1.26%	775.68B
6	SPCX	Space Exploration Technologies ...	2.01T	148.15	-2.02%	23.04B
7	TSM	Taiwan Semiconductor Manufact...	1.94T	418.01	-3.52%	139.57B
8	META	Meta Platforms, Inc.	1.70T	665.60	2.71%	228.25B
9	AVGO	Broadcom Inc.	1.65T	344.72	-4.77%	89.10B
10	TSLA	Tesla, Inc.	1.42T	358.97	-1.77%	103.62B

Market Cap Chart

\$

%

Chart →



Range

1M

6M

YTD

1Y

3Y

5Y

10Y

Max

11 Jun 2026 → 13 Sep 2026



Since the IPO on June 12, 2026, SpaceX's market cap has increased from \$1.77T to \$2.01T, an increase of 13.91%. That is a compound annual growth rate of 65.83%.

Market Cap Chart

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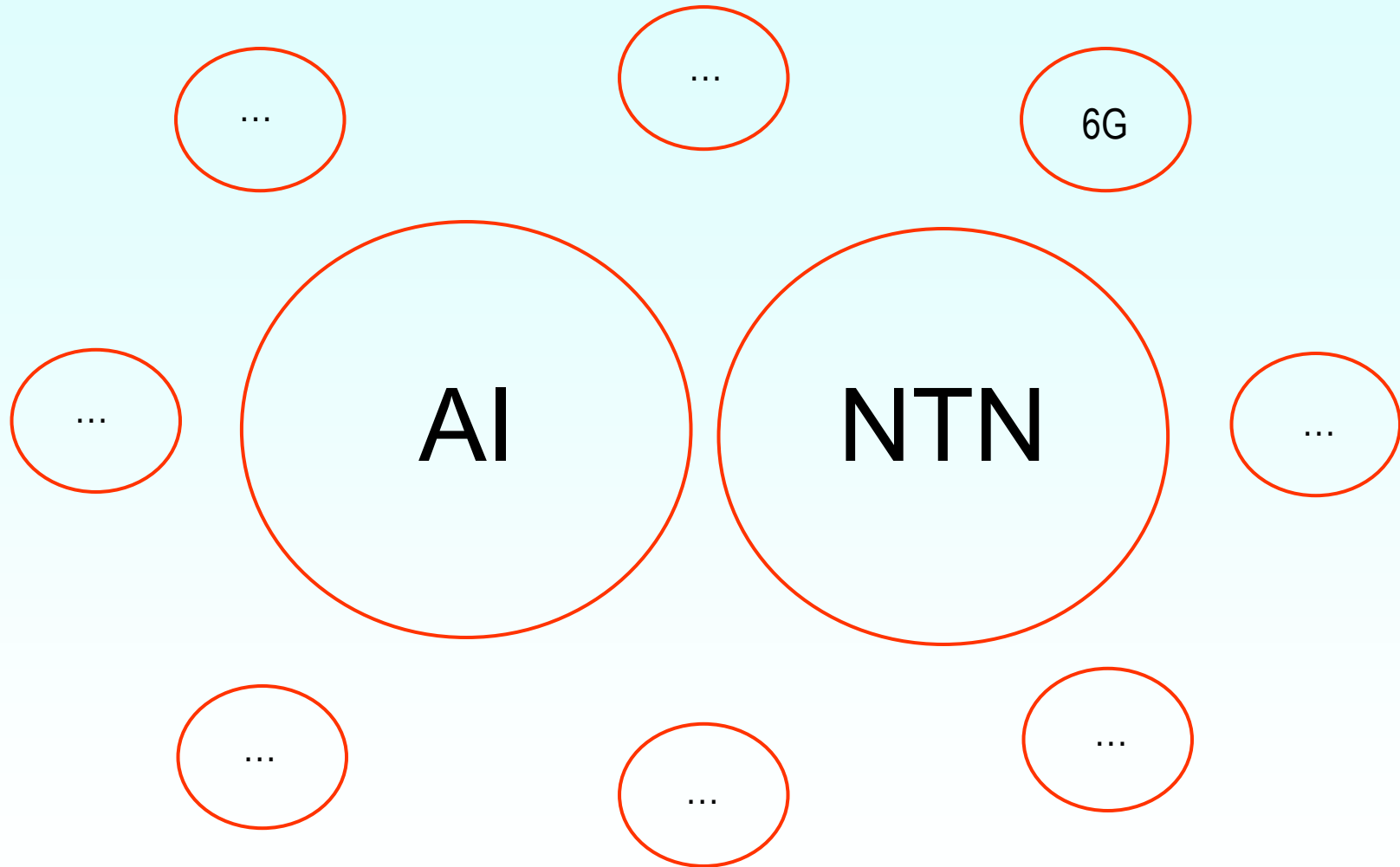
13 Sep 2023 → 13 Sep 2026



Since September 11, 2019, AST SpaceMobile's market cap has increased from \$251.00M to \$23.35B, an increase of 9,202.81%. That is a compound annual growth rate of 90.85%.

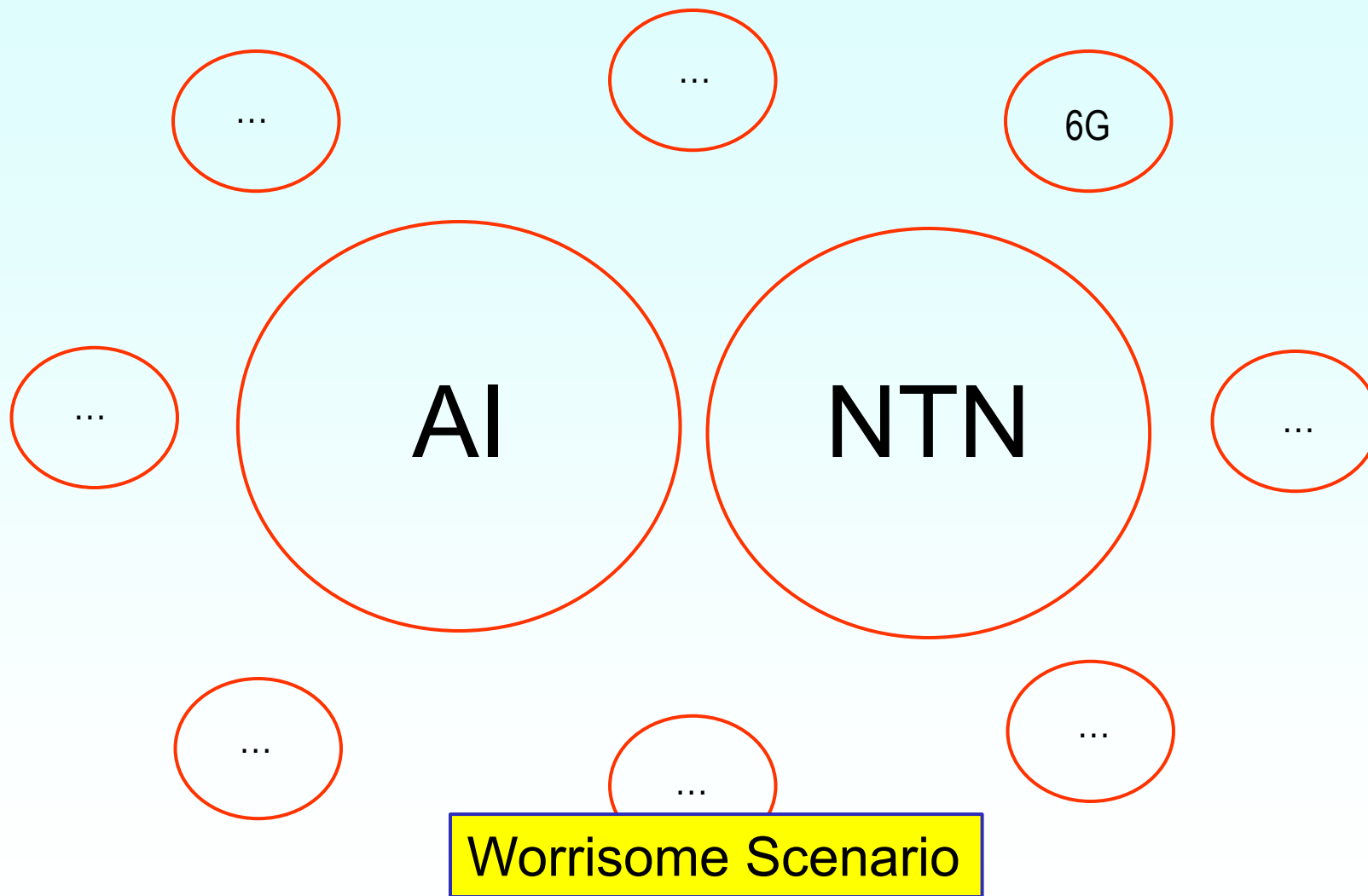


Positioning 6G wrt AI and NTN | tomorrow (?)





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Misleading and Overlooked Facts

- **Misleading Fact**

16 Sep 2026 | urban / suburban regions:

Performance (typical terrestrial link) >> Performance (typical satellite link)

→ urban / suburban: terrestrial network
rural / remote: satellite network

supplementary coverage



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1) The closest link is not necessarily the strongest link

PathLoss (1000 km @ $n=2$) $\sim$ PathLoss (1 km @ $n=4$)



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Satellite-direct-to-smartphone || 2019: 0 bps → 2026: **Mbps**



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3) New **mega-players**: deep pockets + access to enablers & infrastructure



Amazon Cash on Hand 2012-2026 | AMZN

Prices Financials Revenue & Profit Assets & Liabilities Margins Price Ratios Other Ratios Other Metrics

Total Assets Cash on Hand Long Term Debt Total Liabilities Share Holder Equity

Amazon cash on hand from 2012 to 2026. Cash on hand can be defined as cash deposits at financial institutions that can immediately be withdrawn at any time, and investments maturing in one year or less that are highly liquid and therefore regarded as cash equivalents and reported with or near cash line items.

- Amazon cash on hand for the quarter ending March 31, 2026 was **\$123.029B**, a **21.57% increase** year-over-year.
- Amazon cash on hand for 2025 was **\$123.029B**, a **21.57% increase** from 2024.
- Amazon cash on hand for 2024 was **\$101.202B**, a **16.62% increase** from 2023.
- Amazon cash on hand for 2023 was **\$86.78B**, a **23.93% increase** from 2022.



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4) Geopolitics → not only a business case discussion anymore



Overlooked Facts

- “impossible to put up 7,200 LEOs” (Feb 2019) X
- “impossible to deliver video from LEO direct-to-smartphone” X
- “impossible to have indoor coverage from way up” ?



Overlooked Facts

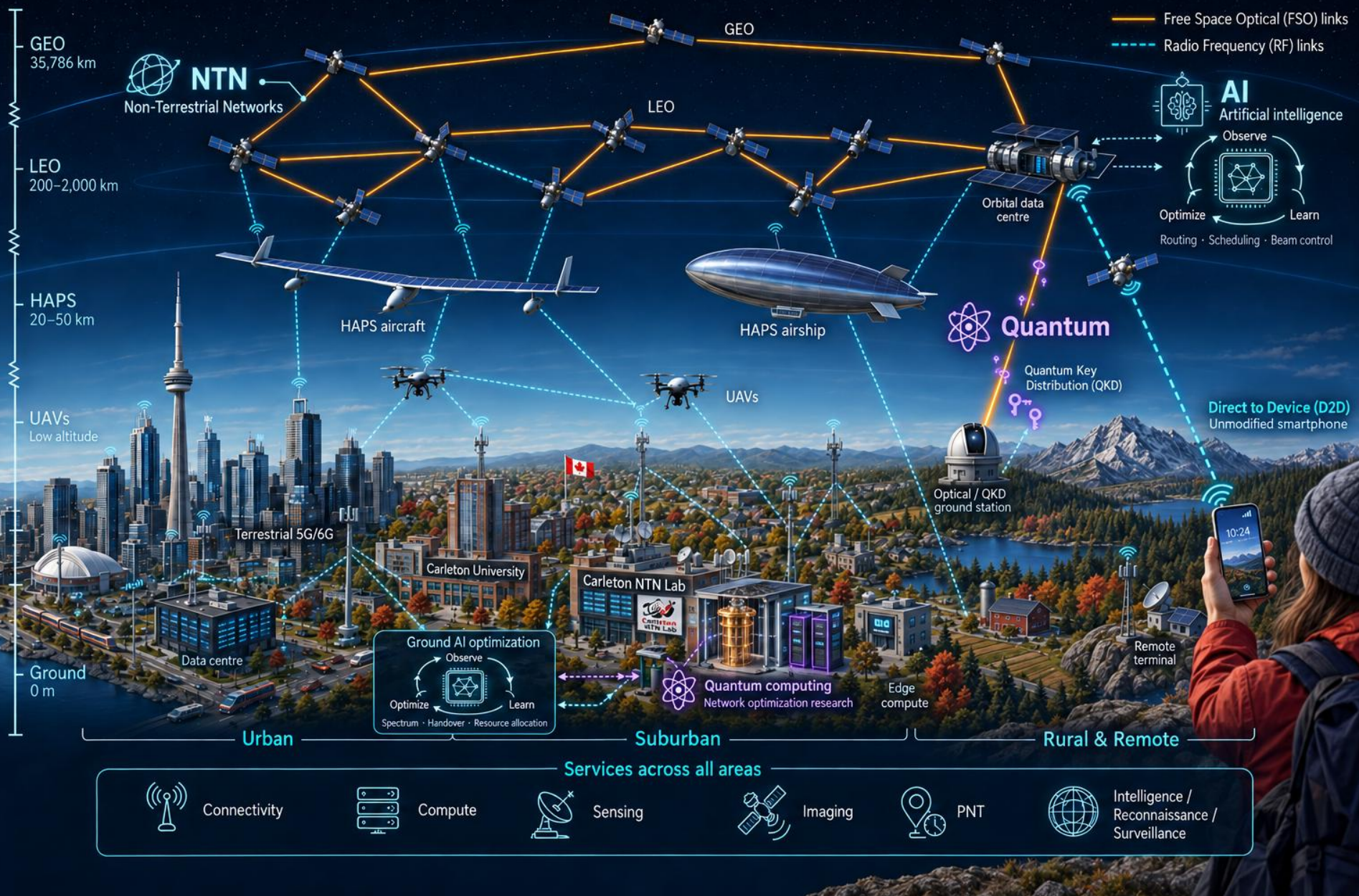
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What could/should be done?





HAPS: High Altitude Platform Stations in Near-Space

HAPS: “A station on an object at an altitude of 20 to 50 km and at a specified, nominal, **fixed point relative to the Earth**” (ITU Radio Regulations, Article 1.66A).

HIBS: HAPS as an IMT (International Mobile Telecommunications) Base Station
HIBS altitude: 18-25 km (WRC-23)





HAPS: High Altitude Platform Station - Urban/Suburban Regions



D2D: no problem
Latency: no problem

$$(\sqrt{2} \times 100)^4 = (20,000)^2$$

Pathloss @ 140 m (w/ PL exp = 4)
= Pathloss @ 20 km (w/ PL exp = 2)

HAPS: Super Macro Base Station in Stratosphere (20 km)

M. Alzenad, M.Z. Shakir, H. Yanikomeroglu, M.-S. Alouini, “FSO-based vertical backhaul/fronthaul framework for 5G+ wireless networks”, *IEEE Communications Magazine*, Jan 2018.

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HAPS: High Altitude Platform Station - Urban/Suburban Regions

non-orbiting

- Easy tracking
- No handover
- Easy deployment
- Scalable deployment
- Maintenance / upgrade
- Relay in LEO-to-smartphone
- Data security and sovereignty
- Easy integration with TN

close to Earth

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much more than
connectivity



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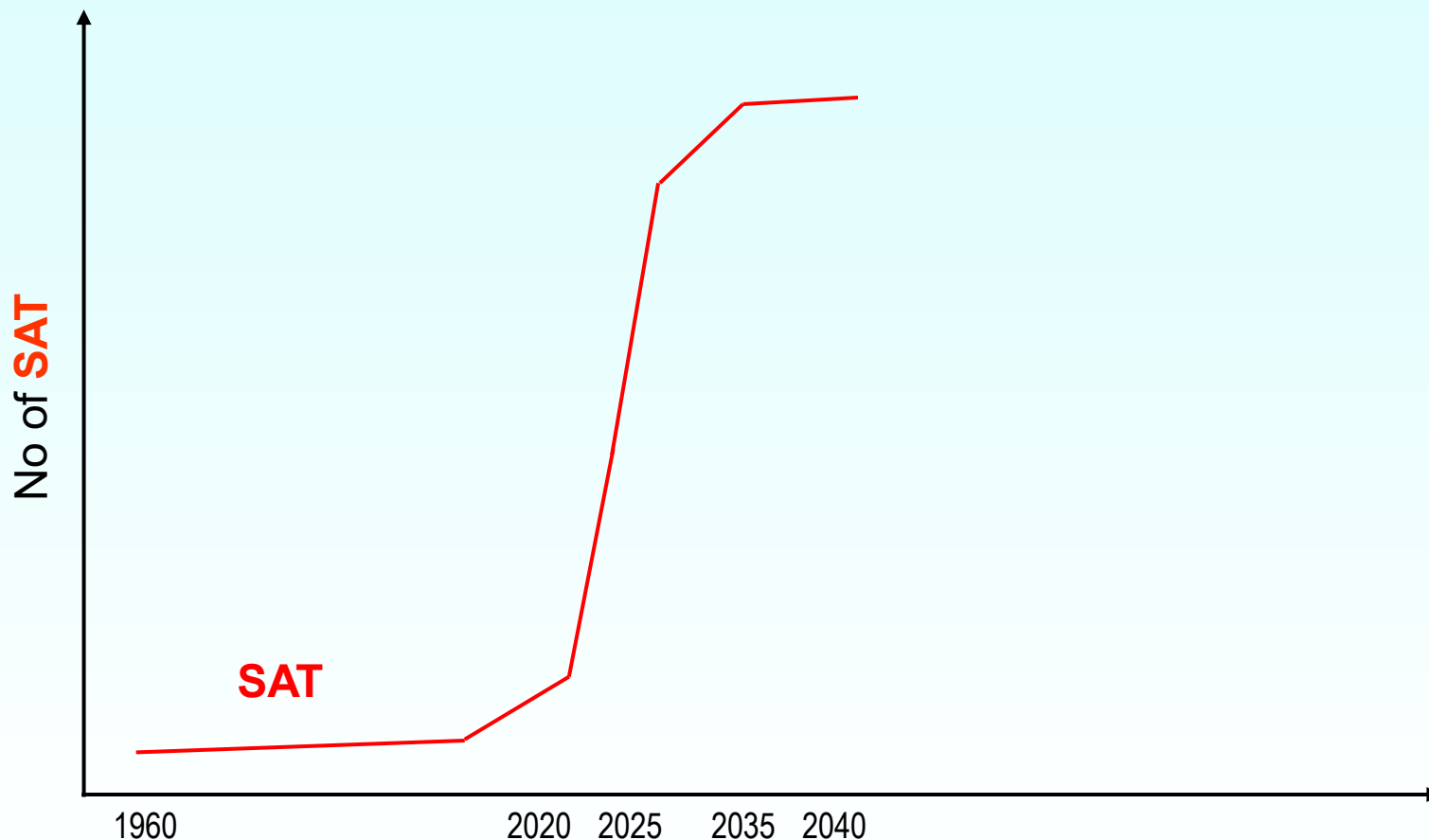
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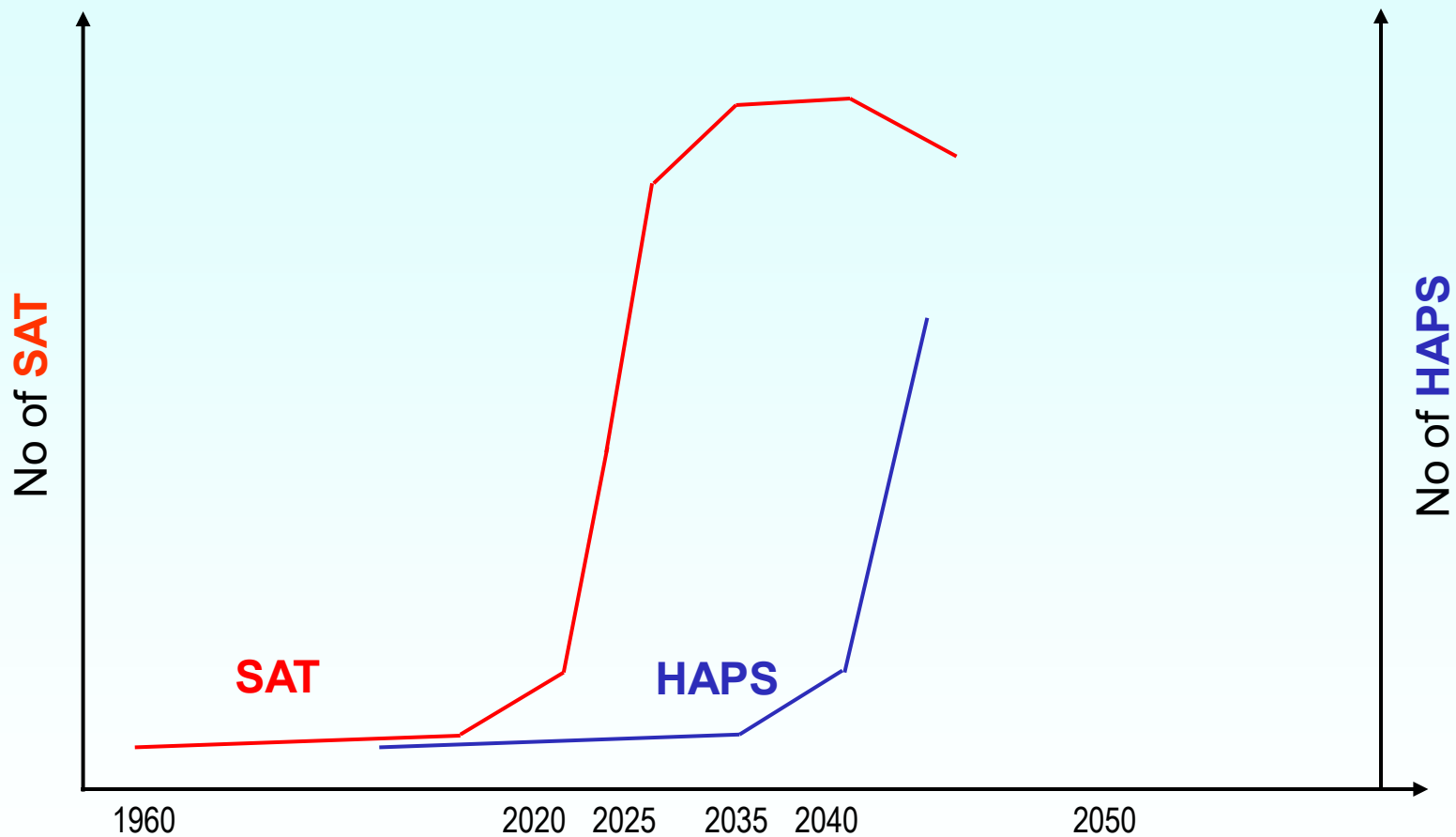


Number of SAT and Number of HAPS (1960–2050)



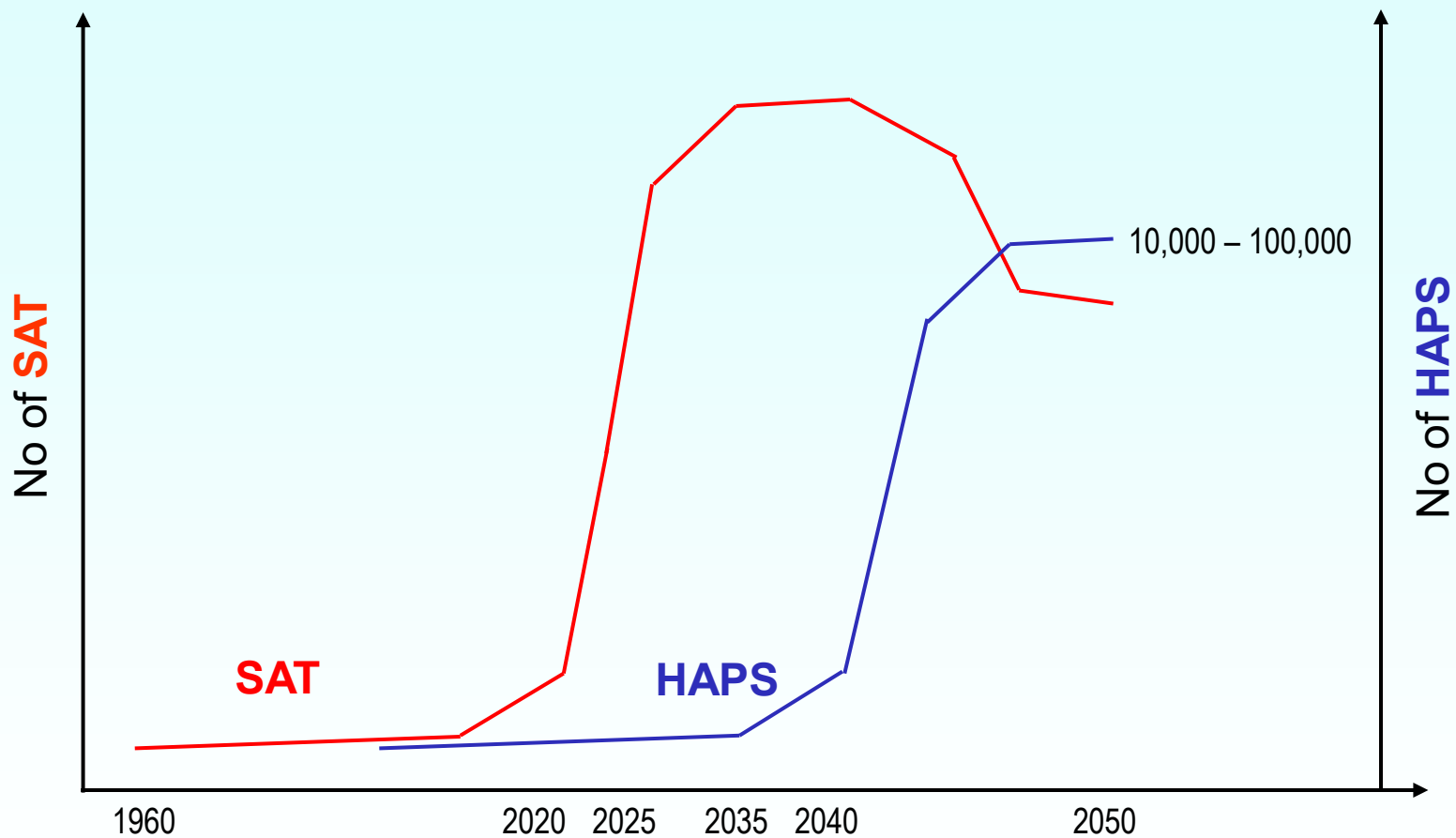


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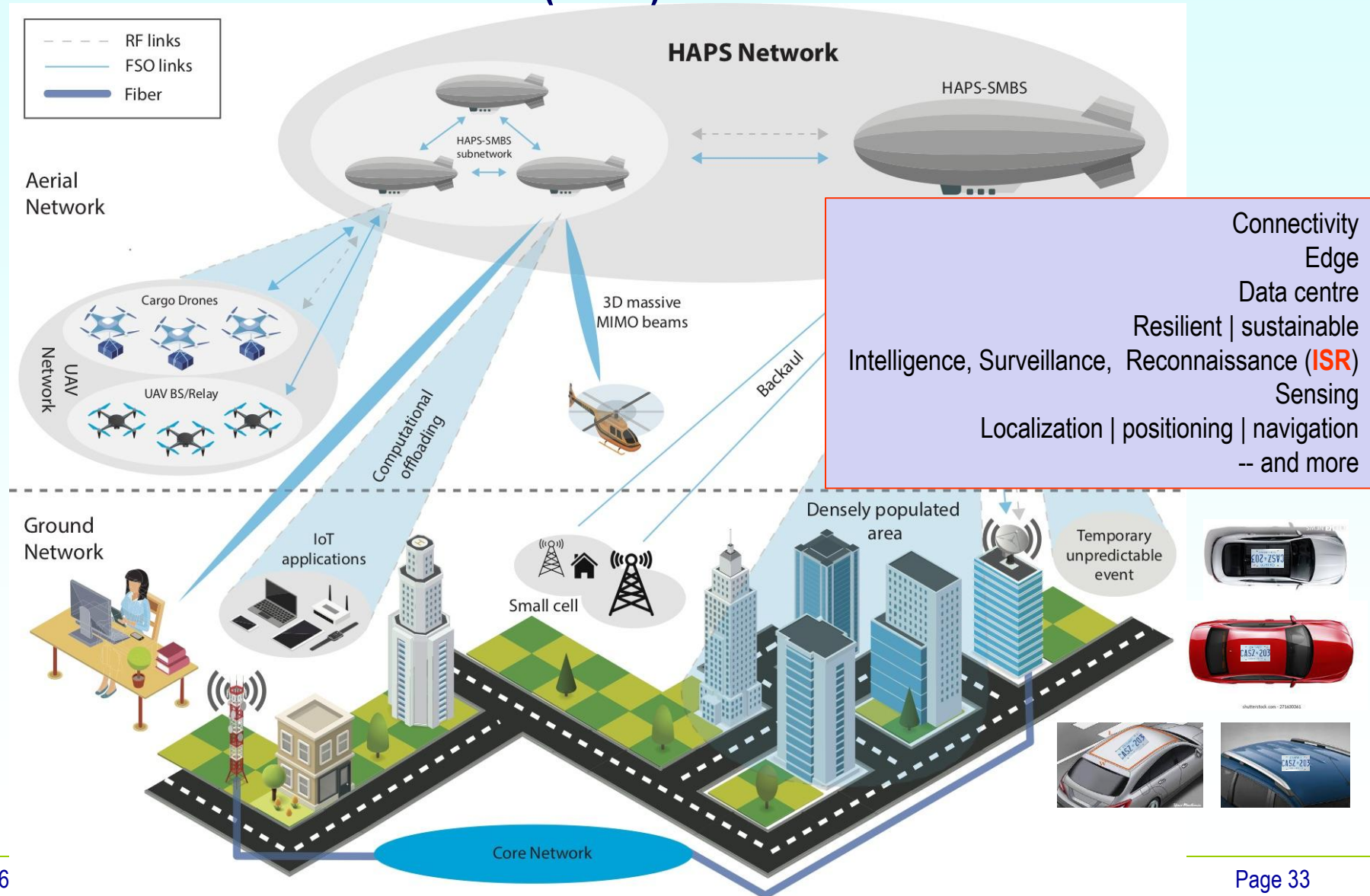




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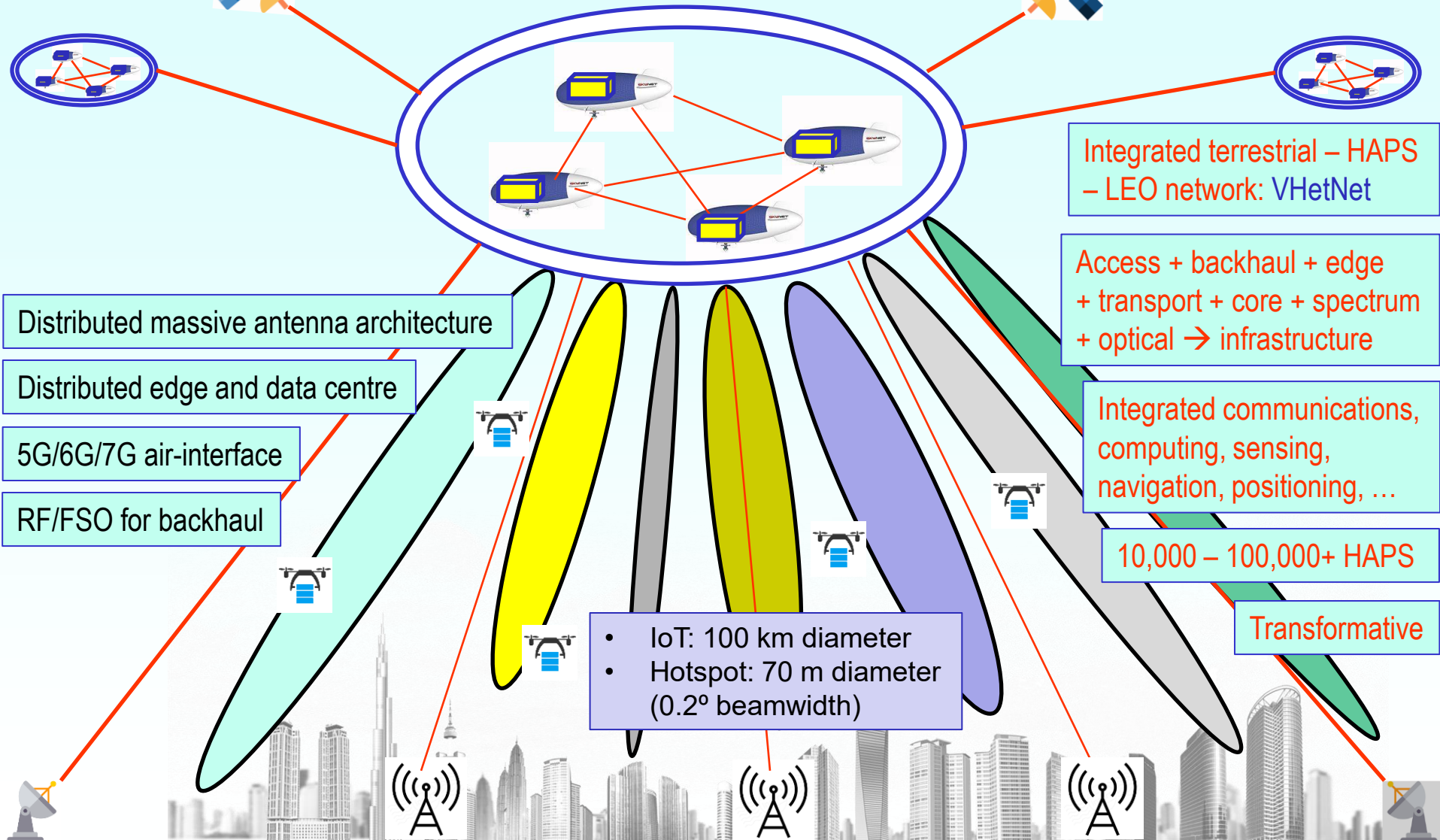


Terrestrial BSs + HAPS BSs (HIBS) in Urban/Suburban Areas





HAPS-enabled Wireless Infrastructure towards 2050





Do We Need 6G After 6G?

Legacy numerology

- nG: Not awfully exiting any more (“Fast & Furious 10”)
- 5G: A high number of optional features
→ MNO-A’s 5G $\neq$ MNO-B’s 5G
- 6G: Multiple paradigms (NTN, ISAC, AI, ...)
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Proposed numerology

- Eliminate Gs
- NTN-1 (Rel-17, -18, -19), NTN-2 (Rel-20, ...)
- ISAC-1 (Rel-19, ...), ISAC-2